



[KRM-90] MIDI-CV-Arpeggiator Retrofit

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Table of Contents

1 Quick Setup Instructions.....	1
1.1 MIDI Controllable Features.....	1
1.2 Arpeggiator, Mini Sequencer, and LFO MIDI Sync.....	3
1.3 LFO Waveshapes.....	3
1.4 Using The Arpeggiator.....	4
1.5 Recording With The Mini Sequencer.....	5
2 Overview Of the MIDI-CV-Arpeggiator Retrofit Board.....	6
3 Planning the Installation.....	7
3.1 On-board Connection Headers.....	7
3.2 DC Supply Voltage.....	8
3.3 Physical Mounting.....	8
3.4 CV and Gate Patch Points.....	9
3.5 Local Keyboard CV Considerations.....	9
3.6 Local Keyboard CV Routing.....	10
4 Important Notes About Tuning.....	11
4.1 Minimum and Maximum CV Range.....	11
5 Initial Configuration and Setup.....	12
5.1 Using the Learn Button.....	12
6 Resetting the Board to the Factory Defaults.....	15
Appendix A – Technical Specifications.....	16
Appendix B – Configuration Update Via SysEx.....	17
Appendix C – Custom LFO Waveshapes Via SysEx.....	30
Appendix D – Mini Sequencer Recording Via SysEx.....	32
Appendix E – Custom Tuning Table Via SysEx.....	33
Appendix F – MIDI Control Change Information.....	34
Appendix G – MIDI Implementation Chart.....	36

Thank You

Thank you for purchasing the [KRM-90] MIDI-CV-Arpeggiator retrofit board. It has been designed to be compatible with as many synthesizers as possible. I use it in my own studio, and have tested it extensively with a wide variety of equipment.

If you have any questions or comments, please visit my website for contact information.

www.krmmusicsystems.com

-Keith Robert Murray

1 Quick Setup Instructions

- Apply 10 V to 20 V DC power to the GND and V+ pads. Observe the correct polarity. The power LED (on the board) should light up. If it does not, disconnect the DC power. If a 10 V supply is used, see **Section 3.2 DC Supply Voltage** for more information.
- Connect pins 4 and 5 from the MIDI input jack (5-pin DIN, not included) to the MIDI IN pads. Optionally connect pins 4 and 5 from the MIDI output jack (5-pin DIN, not included) to the MIDI OUT pads. **Do not ground the MIDI input or output jacks.**
- The pitch CV appears on the CV pad (defaults to 1 V/octave).
- The gate signal appears on the GATE pad (defaults to 5 V V-trig).
- The aux CV (controlled by MIDI CC 74) appears on the AUX pad.

1.1 MIDI Controllable Features

The various features of the [KRM-90] are controlled with the following MIDI control messages (knobs and buttons):

Feature	MIDI Control	Notes
Arpeggiator On/Off	CC 85 (Toggle Button)	Start or stop the arpeggiator.
Arpeggiator Latch On/Off	CC 64 (Sustain Pedal)	Notes played while the sustain pedal is depressed will latch into the arpeggiator.
Arpeggiator Pattern	Program Change	Select Program Change (patch change) numbers to select the arpeggiator pattern.
Arpeggiator Clock Source (Internal / MIDI)	CC 83 (Toggle Button)	Choose internal clock, or MIDI sync.
Arpeggiator Speed / Quantization	CC 19 (Rotary)	Change the arpeggiator speed, or beat quantization for MIDI.
Arpeggiator Gate Width	CC 72 (Rotary)	Change the gate width (note length).
Mini Sequencer Record Start / Stop	CC 86 (Toggle Button)	Start or stop recording on the mini sequencer.

Aux CV	CC 74 (Rotary)	Adjust the aux CV output (typically the filter).
Pitch Wheel Range	CC 15 (Rotary)	Change the maximum range of the pitch wheel (1 to 12 semitones in both directions).
LFO Speed / Quantization	CC 16 (Rotary)	Change the speed of the built-in LFO, or beat quantization for MIDI sync.
LFO Waveshape	CC 17 (Rotary)	Change the waveshape of the built-in LFO.
LFO Phase	CC 18 (Rotary)	Change the phase (start point) of the built-in LFO.
LFO Key Sync On/Off	CC 81 (Toggle Button)	Restart the LFO waveshape on every key press.
LFO clock source (Internal / MIDI)	CC 83 (Toggle Button)	Select internal clock, or MIDI sync.
Mod Control	CC 1 (Modulation Wheel)	Modulation Wheel.
Mod Range	CC 15 (Rotary)	Change the maximum range of the modulation depth (1 to 12 semitones).
MOD Mapping (pitch, aux CV)	CC 80 (Toggle Button)	Select pitch modulation, or aux CV modulation (typically the filter).
Portamento Speed	CC 5 (Rotary)	Change the portamento speed.
Portamento Mode	CC 84 (Toggle Button)	Choose constant rate, or constant speed portamento.
Portamento On/Off	CC 65 or 5 (Toggle Button)	Turn portamento on or off.

1.2 Arpeggiator, Mini Sequencer, and LFO MIDI Sync

When synced to MIDI beat clock, the speed control for the arpeggiator and mini sequencer (MIDI CC 19), and LFO (MIDI CC 16), select from the following quantizations:

MIDI Beat Clock Sync	
4 Whole Notes	3 Whole Notes
2 Whole Notes	Whole Note
Half Note	Half Note Triplet
Quarter Note	Quarter Note Triplet
Eighth Note	Eighth Note Triplet
Sixteenth Note	Sixteenth Note Triplet
Thirty-second Note	Thirty-second Note Triplet

1.3 LFO Waveshapes

The LFO waveshape control (MIDI CC 17) selects from the following:

LFO Waveshapes	
Triangle	
Sawtooth	Inverted Sawtooth
Custom Programmable 1 (Smoothed)	Custom Programmable 2 (Stepped)
Square (50% Pulse)	40% Pulse
30% Pulse	20% Pulse
10% Pulse	Random

By default, the Custom Programmable LFO 1 is a sinewave shape, and Custom Programmable LFO 2 is a stepped pulse (major triad). See **Appendix C - Custom LFO Waveshapes Via SysEx** for more information.

1.4 Using The Arpeggiator

- Start the arpeggiator (MIDI toggle button CC 85).
- Play a chord, and keep the notes depressed.
- Change the arpeggiator pattern with MIDI Program Change messages (patch change messages).
- The sustain pedal (CC 64) will latch the notes into the arpeggiator, which will keep playing even if you release all notes on the keyboard.
- Stop the arpeggiator (MIDI toggle button CC 85) to return to normal playing.

The first number in the Program Change message selects the arpeggiator pattern from the following list:

Arpeggiator Patterns	
1. Up	2. Down
3. Up-Down	4. Down-Up
5. Up-Down with Repeated Note	6. Down-Up with Repeated Note
7. Random	8. Mini Sequencer (Custom Programmable Pattern)

The second number in the program change message selects the number of octaves to repeat with the pattern (from 1 to 5).

For example, sending program change **13** will select the **Up** pattern, repeated over **3 octaves**.

If you are using a Roland MIDI controller with '88' style number buttons, or an older MIDI controller that starts the program change numbering at 1 instead of 0 (some Yamaha keyboards), then see **Appendix B - Configuration Update Via SysEx** to modify the Program Change type.

1.5 Recording With The Mini Sequencer

There is a mini sequencer inside of the arpeggiator, that can store up to 32 notes or rests (including velocity or the Aux CC channel).

- Start the arpeggiator (MIDI toggle button CC 85).
- Enable mini sequencer recording (MIDI toggle button CC 86).
- Play notes one at a time, step-sequencer fashion. Press the sustain pedal to insert a rest.
- Disable mini sequencer recording (MIDI toggle button CC 86).
- Press a single note, and your sequence will play back. It will be transposed by the note you are playing, relative to middle C.
- Stop the arpeggiator (MIDI toggle button CC 85) to return to normal playing.

To play back a previously recorded sequence, select pattern 8 in the arpeggiator. It is also possible to repeat the sequence over multiple octaves, just like any other arpeggiator pattern.

The last sequence recorded is saved in non-volatile memory, and is retained when power to the [KRM-90] is removed.

2 Overview Of the MIDI-CV-Arpeggiator Retrofit Board

The installation of the [KRM-90] is straight forward, however it should be considered a moderate to advanced project. It is not recommended for a beginner, or as a first project. That being said, if you have enough patience, and plan ahead, any synth DIY enthusiast should have no problem retrofitting most synthesizers.

The [KRM-90] is designed to add MIDI functionality to a CV controlled monosynth or synth module. It requires 10 to 20 V DC power, and provides 3 output signals: pitch CV, auxiliary CV (typically filter cutoff), and gate.

The [KRM-90] supports all standard monosynth formats:

- 1 V/octave
- 1.2 V/octave (Buchla, EML)
- 0.32 V/octave (EMS)
- Hz/volt (early Korg and Yamaha)
- S-trig
- V-trig (5 V or higher voltage triggers)

The optional MIDI output port echoes (monophonically) the MIDI input, and the arpeggiator. This allows the MIDI-CV-Arpeggiator to drive an external MIDI module or keyboard, as well a CV monosynth, at the same time.

All real-time performance controls (arpeggiator, LFO, MIDI sync, etc.) can be change in real time with MIDI CC message. See section **1.1 MIDI Controllable Features** for full details.

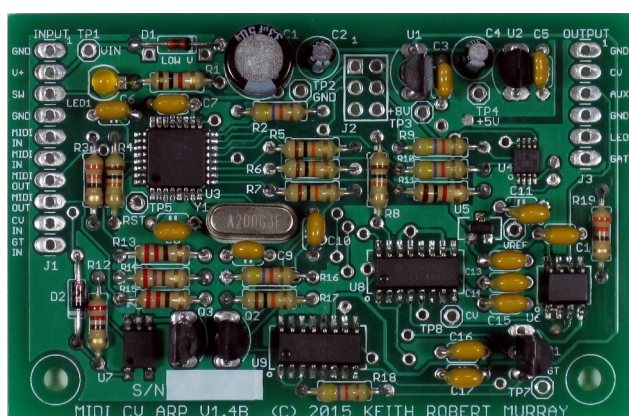
Configuration is done either through a hardware 'learn' button (see section **5.1 Using the Learn Button**), or through SysEx messages (see **Appendix B - Configuration Update Via SysEx**).

3 Planning the Installation

There are multiple ways to install the [KRM-90] into a synthesizer, depending on the synth architecture and what you want to control via MIDI. The following sections give an outline of the major items that should be considered.

3.1 On-board Connection Headers

There are two connections headers on the board. They use standard 0.1" or 2.54 mm pin spacing, and accept Molex KK headers or equivalent. You can also solder leads directly to the pads.



The **10-pin header on the left** (J1) contains MIDI, DC power, and CV inputs (optional, but recommended). Numbered from top to bottom...

1. GND, ground.
2. V+, DC Input 10 to 20 V.
3. SW, switch input for the learn button (not included). It should be momentarily grounded to enter the learn mode. This is an optional button, as all programming and operation of the [KRM-90] can also be done via MIDI CC messages or SysEx. It is highly suggested that this optional button be installed in a recessed position, to avoid being pushed accidentally.
4. GND, ground.
5. MIDI IN, connect to pin 4 of the MIDI input jack (5-pin DIN, not included).
6. MIDI IN, connect to pin 5 of the MIDI input jack (5-pin DIN, not included).
7. MIDI OUT, connect to pin 4 of the MIDI output jack (5-pin DIN, not included).
8. MIDI OUT, connect to pin 5 of the MIDI output jack (5-pin DIN, not included).
9. CV IN, loop through input of the local keyboard CV (optional, but recommended).
10. GT IN, loop through input of the local keyboard gate (optional, but recommended).

The **6-pin header on the right** (J3) contains all output CVs and gates, as well as the status LED (optional). Numbered from top to bottom...

1. GND, ground.
2. CV, main pitch CV output.
3. AUX, auxillary CV output (typicall the filter).
4. GND, ground.
5. LED, status LED output. Connect the cathode of a standard LED (not included) to this pin, and the anode to the GND pin. No current limiting resistor is required. The status LED will blink on MIDI activity, and also indicate learn mode messages. This LED is optional, unless the learn mode button is also installed.
6. GATE, gate output. This output can be programmed for V-trig or S-trig output, with either a 5 V or high V output. The high V output is equivalent to the V+ DC input voltage.

3.2 DC Supply Voltage

The DC supply voltage must be between 10 and 20 V, and should be regulated. An unregulated supply can be used, but there is a possibility of pitch instability.

The best place to tap into the voltage rails on the synthesizer is as close to the power supply as possible. There is usually a star ground and central routing point for all power rails.

When power is supplied to the board, the power status LED (on the board, near the V+ pad) should light up. If it does not, immediately remove power, and diagnose the issue.

If a 10 V supply is used, a jumper wire must be connected between the pads labeled LOW V, near diode D1. **This will also defeat the reverse polarity protection. Double check the voltage source before installing this jumper.**

The [KRM-90] will draw approximately 30 mA.

3.3 Physical Mounting

It is important to leave enough clearance for the [KRM-90] board, connectors and wiring, MIDI jack(s), and the optional button.

The board size is 75x48 mm (2 15/16" x 1 7/8"). The depth of the board is 12 mm (1/2"), without standoffs or other mounting hardware. There are two mounting holes, placed 63.5 mm (2.5") apart.

Ensure that nothing will come in contact with the board when the synth is closed.

3.4 CV and Gate Patch Points

The CV outputs of the [KRM-90] are designed to feed 100k impedance CV inputs.

The internal CV inputs on a synthesizer (for pitch or filter) are usually connected to an op-amp, configured as a summing node. Each of the CV sources is typically routed through a 100k resistor at the op-amp input. You may have to add additional resistors for the [KRM-90] CVs, depending on how you connect the board.

The gate output on the [KRM-90] can be configured for S-trig or V-trig, and can feed a wired-OR configuration. With some synthesizers, it may be necessary to add a diode to the gate out signal, to provide isolation.

The exact patch points for CVs and gates will vary from synth to synth, and there may be more than one option that will work. Some trial-and-error may be required to find the best patch points.

If schematics or a service manual for your synthesizer are not available, it may be helpful to trace backwards from the physical keyboard to find the pitch CV and gate busses.

3.5 Local Keyboard CV Considerations

When a key is depressed on a typical monosynth, the local pitch CV is latched into a sample-and-hold circuit, so that the pitch is stable for the duration of the keypress. When the key is lifted, the sample-and-hold circuit is no longer latched, and the pitch CV may drift over time. This is usually not an issue, as there is no output from the synth when there are no keys depressed.

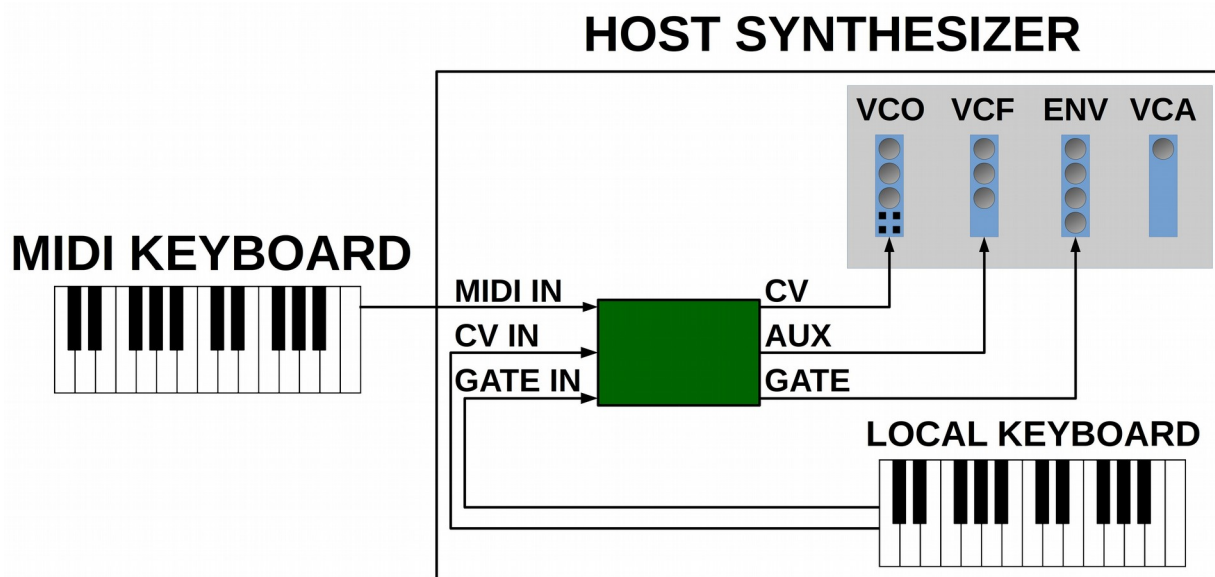
However, if you are feeding an additional gate and CV to the synth from an external source (such as the [KRM-90]), this drift in pitch may become audible as a 'drooping' sound.

To eliminate the drift in pitch, it is important to disconnect the local keyboard CV when the [KRM-90] is active. There is a loop-through switch built into the [KRM-90] that can do this automatically, described in the next section.

3.6 Local Keyboard CV Routing

The local keyboard CV can be routed in three different ways.

1. The simplest method is not to route the local keyboard CV at all. Just wire the direct CV output of the [KRM-90] to sum with the local pitch CV. This method is not recommended, however, as it may cause drooping pitches (as described previously).
2. The recommended method is to loop the local keyboard CV and gate through the inputs on the left-side header on the board (J1). Then take the CV and gate outputs from the right-side header (J3), and route them to the oscillators and envelope generators, as shown below.



If no MIDI data is received by the [KRM-90], then the local keyboard CV will loop through, and the synth will operate as normal. As soon as MIDI data is received, the local keyboard CV will be disconnected, and the CV output from the [KRM-90] will be sent to the synth.

To manually regain local synthesizer keyboard control, either power the synthesizer off and back on, or send a Local On message over MIDI (CC 122 with a value of 127).

3. A third method is to install a physical switch, instead of the CV loop-through switch on the board. This may be necessary for some monosynths that have non-standard CV input impedances, and are incompatible with the loop-through switches on the [KRM-90].

4 Important Notes About Tuning

The [KRM-90] has a built-in voltage reference, and is tuned digitally. There are no trimmers or potentiometers. The board is factory calibrated before being shipped, and is set up for the best possible tuning (for either V/octave or Hz/volt).

It is important to calibrate and tune the host synthesizer before installing the [KRM-90] board, so that it matches the V/octave or Hz/volt curve as closely as possible.

If the synthesizer is in tune, then no additional adjustment of the MIDI-CV-Arpeggiator should be required. However, this isn't always possible, especially with older equipment or DIY synthesizers.

The range and scale of the CV response can be adjusted using the learn button (as shown in section **5.1 Using the Learn Button**), or via SysEx messages (as shown in **Appendix B - Configuration Update Via SysEx**).

4.1 Minimum and Maximum CV Range

The CV output voltage range of the [KRM-90] is 0 to 5 volts. It is not possible to exceed this range.

For example, if the scale adjustment is set very wide, then the voltage corresponding to the highest key may represent more than 5 volts. Since this is not electrically possible, the highest key may seem flat, while the rest of the keyboard is in tune.

A full 5 octaves of range is possible with the 1 V/octave, 0.32 V/octave, and Hz/volt response curves. With the 1.2 V/octave response, just over 4 octaves of range (50 semitones) is possible.

5 Initial Configuration and Setup

The default configuration of the [KRM-90] assumes the most common setup:

- 1 V/octave response
- 5 Volt V-trig gate
- Lowest key on the (local) synthesizer keyboard corresponds to low C (MIDI note 36)
- Listen on MIDI channel 1
- No scale or range tuning compensation

There are two ways to change the default configuration: using the learn button, or with SysEx messages. The learn button is described below. See **Appendix B - Configuration Update Via SysEx** for more complete control over the configuration.

5.1 Using the Learn Button

Press the learn button 1 to 6 times, and then press keys or turn wheels/buttons on the MIDI controller, to change the configuration settings as shown below.

The LED will light up to indicate how many times the button has been pressed.

On the first press, the LED will light up solid. On each subsequent press, the LED will blink faster and faster.

After 6 button presses (or after one of the parameters has changed), the LED will go out, and the [KRM-90] will go back to 'play' mode.

Any configuration changes are immediately stored in memory, and are retained when the board is turned off.

1 Button Press - LED On

Lowest MIDI Note (Coarse Range Adjustment) - MIDI Channel

Press the lowest note on the MIDI keyboard, to correspond to the lowest note on the (local) synthesizer keyboard. This is usually low C, but may also be F, G or some other note. This will also set the MIDI listen channel to that of the MIDI keyboard.

2 Button Presses - LED Blink Slow

Aux CV MIDI Control

Turn any MIDI control knob or wheel to map it the the Aux CV value.
 To map the Aux CV to key velocity instead, press any MIDI key.
 To map the Aux CV to channel pressure or aftertouch, see **Appendix B - Configuration Update Via SysEx.**

3 Button Presses - LED Blink Medium

Voltage Response - Trigger Type - Trigger Voltage

To change the voltage response curve, trigger type, trigger voltage, aux CV response, or multi-trig setting, press the corresponding MIDI key. It is only possible to change one of these values at a time.

C = 1 V/octave

C# = 1.2 V/octave

D = 0.32 V/octave

D# = Hz/volt

E = Custom tuning table

F = V-trig

F# = S-trig

G = 5 volt gate

G# = High voltage gate (corresponding to the voltage supplied to the board)

A = Toggle the Aux CV response between normal/inverted

A# = Toggle Aux CV recording into the Mini Sequencer (enable/disable)

B = Toggle multi-trig on and off

4 Button Presses - LED Blink Fast

Fine Range Adjustment

Press any key above or below middle C (MIDI Note 60) to shift the fine range of the keyboard up or down. Each semitone above or below middle C corresponds to a shift of 2 cents. To reset the fine range adjustment (to 0 cents), press middle C. **You must set the Coarse Range Adjustment (the lowest MIDI note), before changing the Fine Range Adjustment.** To make extreme changes in range, see **Appendix B - Configuration Update Via SysEx.**

5 Button Presses - LED Blink Very Fast

Scale Tuning Adjustment

Press any key above or below middle C (MIDI Note 60) to change the scale tuning adjustment (V/octave or Hz/volt) up or down. Each semitone above or below middle C corresponds to a change of 2 cents. To reset the scale tuning, press middle C. To make extreme changes in scale tuning, see **Appendix B - Configuration Update Via SysEx**.

6 Button Presses - LED Blink Alternating

Define the Custom Tuning Table

After the custom tuning table has been enabled (see **3 Button Presses**), each note in the 5 octave range can be tuned using this procedure:

- Press any key, and keep it pressed.
- Adjust the coarse tuning by turning the MIDI knob associated with the arpeggiator speed (CC 19).
- Adjust the fine tuning by turning the MIDI knob associated with the LFO speed (CC 16).
- Continue for every key in the 5 octave range of the board.

Press the learn button to exit the custom tuning table mode, and write the changes to memory.

To make tuning easier, connect a MIDI synthesizer or sound module to the MIDI output jack. Monitor the output of the MIDI synthesizer, and use it as a pitch reference for each key.

6 Resetting the Board to the Factory Defaults

There are 2 ways to reset the board back to the factory defaults.

- Hold down the learn button (if it has been installed) and toggle the power off, and then back on, while keeping the button depressed.

Or

- Send the following SysEx message to the board. Most SysEx librarian software will automatically include the **F0** and **F7** bytes.

F0 00 02 0C 01 01 00 61 F7

The default configuration of the MIDI-CV-Arpeggiator assumes the most common setup:

- 1 V/octave response
- 5 Volt V-trig gate
- Lowest key on the (local) synthesizer keyboard corresponds to low C (MIDI note 36)
- Listen on MIDI channel 1
- No scale or range tuning compensation

For a complete list of all defaults, see the table of parameter descriptions in **Appendix B - Configuration Update Via SysEx**.

Appendix A – Technical Specifications

[KRM-90] MIDI-CV-Arpeggiator Retrofit

- 10 to 20 V DC regulated power source required.
- 30 mA current draw.
- Size 75x48 mm (2 15/16" x 1 7/8"). Approximately 12 mm deep (½"), without mounting hardware.
- 5-pin DIN MIDI input and output (MIDI jacks not included).
- 0 to 5 V output for pitch and aux CV.
- 16-bit DAC.
- 1 V/oct, 1.2 V/oct, 0.32 V/oct, or Hz/V pitch CV response.
- S-Trig or V-Trig gate.
- 5 V gate, or high voltage gate (equal to the DC source voltage).

Appendix B – Configuration Update Via SysEx

All configuration settings on the [KRM-90] can be changed by using SysEx messages. It is also possible to request a configuration dump over SysEx. This can be used to restore the [KRM-90] back to a known configuration state, or to clone one board from another.

Any changes made to the configuration are immediately stored in non-volatile memory, and are retained when the [KRM-90] is turned off.

The SysEx format for all configuration changes is shown below. The SysEx start and end bytes (**F0h** and **F7h**) are typically added in by SysEx librarian software, and do not need to be included.

F0 00 02 0C 01 01 <Device ID> <ACTION> <PARAMETER> <DATA> F7

If more than one [KRM-90] is used in a single chain of MIDI devices, each one should be given a unique **Device ID** (see parameter **3Eh** in the **Parameter Descriptions** table below). This will allow SysEx messages to be read by one [KRM-90], but ignored by others. By default, this ID is set to 00h. Sending an ID of 7Fh will be recognized by all boards, regardless of their actual Device ID.

The **ACTION** byte determines whether the SysEx message is a configuration update (writing to the [KRM-90]), a request for a configuration dump, or some other action. The ACTION byte must be one of the following:

- 01h** - Request a configuration dump.
- 41h** - Write a new configuration value to the board.
- 61h** - Factory reset.
- 62h** - Copy the current tuning table to the custom tuning table memory.

Some actions may also require a PARAMETER byte, and DATA bytes.

The **PARAMETER** byte determines which parameter settings will be updated, or returned in a configuration dump. A single parameter can be chosen (from the **Parameter Descriptions** table below), or a group of parameters can be selected from the following values:

- 40h** - The full main configuration, excluding the custom arpeggiator pattern, LFOs, and tuning table (64 bytes of data).
- 41h** - The custom arpeggiator pattern (64 bytes of data).
- 42h** - The custom LFO 1 wave shape (64 bytes of data).
- 43h** - The custom LFO 2 wave shape (64 bytes of data).

44h – The custom tuning table, MSB (61 bytes of data).

45h – The custom tuning table, LSB (61 bytes of data).

Each PARAMETER is associated with one or more **DATA** bytes. If a configuration dump is requested, then a single DATA byte is required, indicating the number of seconds to pause before sending the data dump. This will allow the SysEx librarian software enough time to get ready to capture the configuration dump.

When sending multiple SysEx configuration messages in a row, pause for a few seconds between them.

Example SysEx Messages

Factory Reset

F0 00 02 0C 01 01 00 61 F7

Update the MIDI Listen Channel to 0Fh (16)

F0 00 02 0C 01 01 00 41 00 0F F7

Update the Arpeggiator Start Button CC to 04h (4)

F0 00 02 0C 01 01 00 41 1E 04 F7

Update the Power-on Value for the Aux CV to 7Fh (127, fully on)

F0 00 02 0C 01 01 00 41 06 7F F7

Enable MIDI Active Sense

F0 00 02 0C 01 01 00 41 31 01 F7

Enable MIDI All Notes Off

F0 00 02 0C 01 01 00 41 33 01 F7

Disable Velocity on MIDI Out, and set the Default Velocity to 7Fh (127)

F0 00 02 0C 01 01 00 41 29 00 F7

F0 00 02 0C 01 01 00 41 2A 7F F7

Request the Full Main Configuration, Waiting For 5 Seconds Before the Dump

F0 00 02 0C 01 01 00 01 40 05 F7

The response from the above configuration request is this SysEx message:

F0 00 02 0C 01 01 00 41 40 00 24 0F 02 03 47 3F 03 10 32 03 11 00 12 00 01 03 0F 02 50 ... 00 00 00 00 00 00 00 00 00 00 F7

PARAMETER Descriptions

Parameter	MIDI Listen Channel	
00h	Default Value	00h (0, MIDI channel 1)
	MIDI listen channel. 00h represents MIDI channel 1. 0Fh represents MIDI channel 16.	

Parameter	Lowest MIDI Note	
01h	Default Value	24h (32, Low C on most keyboards)
	MIDI note value that represents the lowest key on the host synthesizer.	

Parameter	CC for Pitch Wheel Range	
02h	Default Value	0Fh (15)
	MIDI CC knob to control the pitch wheel range (the maximum bend up or down).	

Parameter	Power-on Value for Pitch Wheel Range	
03h	Default Value	02h (2 semitones)
	Power-on value of maximum pitch wheel range (the maximum bend up or down), in semitones.	

Parameter	Smoothing Factor for Pitch Wheel	
04h	Default Value	03h (3)
	Anti-zipper smoothing value for PW (0 = off, 5 = heavy smoothing)	

Parameter	CC for Aux CV (typically the filter)	
05h	Default Value	47h (74)
	MIDI CC knob to control the Aux CV (typically the filter) in real time. In addition to any MIDI CC, the Aux CV can also be controlled by the Pitch Wheel (7Ch), Channel Pressure (7Dh), Aftertouch (7Eh), or Key Velocity (7Fh).	

Parameter	Power-on Value for Aux CV	
06h	Default Value	3Fh (63)
	Power-on value for the Aux CV output.	

Parameter	Anti-zipper Smoothing Factor for Aux CV	
07h	Default Value	03h (3)
	Anti-zipper smoothing value for the Aux CV (0 = off, 5 = heavy smoothing).	

Parameter	CC for LFO Speed	
08h	Default Value	10h (16)
	MIDI CC knob to control LFO speed in real time.	

Parameter	Power-on Value for LFO Speed	
09h	Default Value	55h (85)
	Power-on value for the LFO speed.	

Parameter	Anti-zipper Smoothing Factor for custom LFO	
0Ah	Default Value	02h (2)
	Anti-zipper smoothing value for the custom LFO (0 = off, 5 = heavy smoothing).	

Parameter	CC for LFO Shape	
0Bh	Default Value	11h (17)
	MIDI CC knob to control the LFO shape in real time.	

Parameter	Power-on Value for LFO Shape	
0Ch	Default Value	00h (0, triangle)
	Power-on value for the LFO shape.	

Parameter	CC for LFO Phase (Wave Start)	
0Dh	Default Value	12h (18)
	MIDI CC knob to control the LFO phase in real time.	

Parameter	Power-on Value for LFO Phase	
0Eh	Default Value	00h (0)
	Power-on value for the LFO phase.	

Parameter	CC for Modulation Control (Mod Wheel)	
0Fh	Default Value	01h (1)
	MIDI CC knob to control modulation (typically the Mod Wheel). In addition to any MIDI CC, the Modulation Control can also be controlled by the Pitch Wheel (7Ch), Channel Pressure (7Dh), Aftertouch (7Eh), or Key Velocity (7Fh).	

Parameter	Anti-zipper Smoothing Factor For Modulation Control	
10h	Default Value	03h (3)
	Anti-zipper smoothing value for modulation control (0 = off, 5 = heavy smoothing).	

Parameter	CC for Modulation Pitch Range	
11h	Default Value	0Fh (15)
	MIDI CC to control the modulation pitch range in real time.	

Parameter	Power-on Value for Modulation Pitch Range	
12h	Default Value	02h (2 semitones)
	Power-on value for the modulation pitch range. Note that if modulation is mapped to the Aux CV, and not pitch, then this value is ignored and the output will be the full 0 to 5 volt range.	

Parameter	CC for Modulation Destination Mapping (Pitch CV or Aux CV)	
13h	Default Value	50h (80)
	MIDI CC button to control the modulation destination mapping in real time (modulate pitch CV, or Aux CV)	

Parameter 14h	Power-on Value for Modulation Destination Mapping	
	Default Value	00h (0, pitch CV)
	Power-on value for the modulation destination mapping. 00h (0) maps the modulation source to the pitch CV. 7Fh (127) maps the modulation source to the Aux CV.	
Parameter 15h	CC for LFO Key-down Restart (Key Sync)	
	Default Value	51h (81)
	MIDI CC button to control the LFO key-down Restart mode (on/off) in real time.	
Parameter 16h	Power-on Value for LFO Key-down Restart (Key Sync)	
	Default Value	00h (0, looping LFO)
	Power-on value for the LFO key-down restart mode. 00h (0) will cause the LFO to loop continuously. 7Fh (127) will cause the LFO to restart on every key press.	
Parameter 17h	CC for LFO MIDI Sync (Internal / MIDI Clock)	
	Default Value	52h (82)
	MIDI CC button to control the LFO MIDI sync mode in real time, between the internal clock, and MIDI clock.	
Parameter 18h	Power-on Value for LFO MIDI Sync (Internal Clock / MIDI Clock)	
	Default Value	00h (0, internal clock)
	Power-on value for the LFO MIDI sync mode. 00h (0) will sync the LFO to the internal clock. 7Fh (127) will sync the LFO to MIDI clock.	
Parameter 19h	CC for Portamento Rate	
	Default Value	05h (5)
	MIDI CC knob to control the portamento rate in real time.	

Parameter	Power-on Value for Portamento Rate	
1Ah	Default Value	40h (64)
	Power-on value for portamento rate.	

Parameter	CC for Portamento Mode (Constant Rate / Constant Time)	
1Bh	Default Value	54h (84)
	MIDI CC button to control the portamento mode in real time.	

Parameter	Power-on Value for Portamento Mode (Constant Rate / Constant Time)	
1Ch	Default Value	00h (0, constant rate)
	Power-on value for the portamento mode. 00h (0) sets the portamento mode to constant rate (traditional portamento). 7Fh (127) sets the portamento mode to constant time between any two notes.	

Parameter	CC for Portamento (On / Off)	
1Dh	Default Value	41h (65)
	MIDI CC button to control turning portamento on and off in real time.	

Parameter	CC for Arpeggiator (On / Off)	
1Eh	Default Value	55h (85)
	MIDI CC button to control turning the arpeggiator on and off in real time.	

Parameter	CC for Arpeggiator Latch (On / Off)	
1Fh	Default Value	40h (64, sustain pedal)
	MIDI CC button to control turning the arpeggiator latch mode on and off in real time. The default is the sustain pedal.	

Parameter	CC for Arpeggiator Speed	
20h	Default Value	13h (19)
	MIDI CC knob to control the arpeggiator speed in real time. If the arpeggiator is synced to MIDI clock, then this will control the note quantization for each arpeggiator step.	

Parameter	CC for Arpeggiator Sync Source (Internal / MIDI)	
21h	Default Value	53h (83)
	MIDI CC button to control the arpeggiator MIDI sync source in real time, between the internal clock or MIDI clock.	

Parameter	Power-on value for Arpeggiator Sync Source (Internal / MIDI clock)	
22h	Default Value	00h (0, internal clock)
	Power-on value for the arpeggiator sync source. A value of 00h (0) synchronizes to the internal clock. A value of 7Fh (127) synchronizes to the MIDI clock.	

Parameter	CC for Arpeggiator Gate Width	
23h	Default Value	48h (72)
	MIDI CC knob to control the arpeggiator gate width in real time.	

Parameter	MIDI Program Change Type	
24h	Default Value	00h (0, buttons start at 0)
	Power-on value for the MIDI program change type. 0 represents program change button numbers that start at 0. 1 represents program change button numbers that start at 1 (typically older Yamaha controllers). 3 represents Roland style 'two rows of 8' buttons.	

Parameter	MIDI Button Toggle Type	
25h	Default Value	00h (0, toggle type buttons)
	Power-on value for the MIDI button toggle type. 00h (0) represents MIDI controller buttons that toggle between on (127) and off (0) automatically. 01h (1) represents older style MIDI controller buttons that do not automatically toggle. This can be used for older MIDI workstations without hardware toggle built into them.	

Parameter	MIDI Output Enable	
26h	Default Value	01h (1, enable MIDI out)
	Power-on value to enable MIDI output of the arpeggiator (and notes played live). Set this parameter to 01h (1) to enable, and 00h (0) to disable. To set other MIDI output options (pitch wheel, modulation wheel, key velocity), see parameters 27h to 2Ah.	

Parameter	MIDI Out For Pitch Wheel	
27h	Default Value	01h (1, enable PW out)
	Power-on value to enable MIDI output of the pitch wheel. Set this parameter to 01h (1) to enable, and 00h (0) to disable. The MIDI Output Enable option (parameter 26h) must also be enabled, for this to take effect.	

Parameter	MIDI Out For Modulation Wheel	
28h	Default Value	01h (1, enable MOD wheel out)
	Power-on value to enable MIDI output of the modulation wheel. Set this parameter to 01h (1) to enable, and 00h (0) to disable. The MIDI Output Enable option (parameter 26h) must also be enabled, for this to take effect.	

Parameter	MIDI Out For Key Velocity	
29h	Default Value	01h (1, enable key velocity)
	Power-on value to enable MIDI output of key velocity. Set this parameter to 01h to enable, and 00h (0) to disable. The MIDI Output Enable option (parameter 26h) must also be enabled, for this to take effect.	

Parameter	MIDI Out Default Key Velocity	
2Ah	Default Value	40h (64)
	Power-on value for the default MIDI out key velocity. If the MIDI output for key velocity is disabled (see parameter 29h), then this value will be used for all key velocities. The MIDI Output Enable option (parameter 26h) must also be enabled, for this to take effect.	

Parameter	Gate Type	
2Bh	Default Value	00h (0, V-trig)
	Power-on value for the gate type. 0 represents V-trig. 1 represents S-trig.	

Parameter	Pitch CV Type	
2Ch	Default Value	00h (0, 1 V/octave)
	Power-on value for the pitch CV type. 0 represents 1 V/octave, 1 represents 1.2 V/octave (EML and Buchla), 2 represents 0.32 V/octave (EMS), and 3 represents Hz/volt (early Korg and Yamaha).	

Parameter	Gate Voltage	
2Dh	Default Value	00h (0, 5 volt gate)
	Power-on value for the gate voltage. 0 represents a 5 volt gate. 1 represents a high-voltage gate (equivalent to the DC voltage powering the MIDI-CV-Arpeggiator board).	

Parameter	Key Tracking Mode	
2Eh	Default Value	00h (0, low note priority)
	Power-on value for the key tracking mode. 0 represents low note priority (traditional mode). 1 represents high note priority. 2 represents last note priority (for complex trills or very fast articulation).	

Parameter	Scale Tuning	
2Fh	Default Value	00h (0)
	Power-on value for the scale tuning. 0 represents no scale change. Values from 01h to 3Fh (1 to 63) represent an upward scale stretch (sharp), incrementing by 2 cents each value, for a maximum of 126 cents. Values from 7Fh to 40h (127 to 64) represent a downward scale stretch (flat), decrementing by 2 cents each value, for a minimum of 128 cents. Note that the [KRM-90] has a highly accurate internal voltage reference for tuning, and is factory alibrated. No tuning compensation should be necessary if the host synthesizer is in tune.	
Parameter	Range Offset	
30h	Default Value	00h (0)
	Power-on value for the range offset. 0 represents no range offset. Values from 01h to 3Fh (1 to 63) represent an upward shift (sharp), incrementing 2 cents each value, for a maximum of 126 cents. Values from 7Fh to 40h (127 to 64) represent a downward shift (flat), incrementing 2 cents each value, for a maximum of 128 cents. It is not possible to set the range offset to cause a negative pitch CV output.	
Parameter	MIDI Active Sense Enable / Disable	
31h	Default Value	00h (0, disable Active Sense)
	Power-on value for MIDI active sense enabled (01h or 1), or disabled (00h or 0).	
Parameter	MIDI All Sound Off Enable / Disable	
32h	Default Value	00h (0, disable All Sound Off)
	Power-on value for MIDI All Sound Off enabled (01h or 1), or disabled (00h or 0).	
Parameter	MIDI All Notes Off Enable / Disable	
33h	Default Value	00h (0, disable All Notes Off)
	Power-on value for MIDI All Notes Off enabled (01h or 1), or disabled (00h or 0).	

Parameter	MIDI Reset All Controllers Enable / Disable	
34h	Default Value	00h (0, disable Reset All Controllers)
	Power-on value for MIDI Reset All Controllers enabled (01h or 1), or disabled (00h or 0).	

Parameter	Custom Tuning Table Enable / Disable	
35h	Default Value	00h (0, disable the custom tuning table)
	Power-on value for Custom Tuning Table enabled (01h or 1), or disabled (00h or 0).	

Parameter	Invert Aux CV Output	
36h	Default Value	00h (0, do not invert Aux CV)
	Invert the Aux CV output. A value of 1 enables Aux CV inversion.	

Parameter	Enable Multi-trig on Gate Output	
37h	Default Value	00h (0, multi-trig off)
	Enable multi-trig on gate output. This will re-trigger the gate on every key press, even if played legato (not releasing any keys). The value corresponds to the gate re-trigger time in milliseconds, from 1 to 20 ms. A value of 5 ms gives the best feel for most synthesizers.	

Parameter	CC for Mini Sequencer Record (Enable/Disable)	
38h	Default Value	56h (86)
	MIDI CC button to enable or disable the mini sequencer recording function.	

Parameter	Mini Sequencer Aux CC Channel Record (Enable/Disable)	
39h	Default Value	01h (1)
	A value of 1 enables recording of the Aux CC, and a value of 0 disables recording of the Aux CC. If Aux CC recording is disabled, key velocity will be recorded, even if key velocity is not mapped to any parameter.	

Parameter	Unused	
3Ah	Default Value	00h (0)
	Unused	

Parameter	Unused	
3Bh	Default Value	00h (0)
	Unused	

Parameter	Unused	
3Ch	Default Value	00h (0)
	Unused	

Parameter	Unused	
3Dh	Default Value	00h (0)
	Unused	

Parameter	Device ID	
3Eh	Default Value	00h (0)
	If more that one [KRM-90] is in the same chain of MIDI devices, give each of them a unique device ID.	

Parameter	Unused	
3Fh	Default Value	00h (0)
	Unused	

Appendix C – Custom LFO Waveshapes Via SysEx

In addition to the built-in LFO waveshapes, there are 2 custom LFO waveshapes that can be defined via SysEx.

The wavetable defining each custom LFO is 64 bytes long, and consists of values ranging from 1 to 127. A value of 64 is 'in the center', and corresponds to no modulation. By default, custom LFO 1 is defined as a sinewave, and custom LFO 2 is defined as a stepped shape (major triad).

To program an LFO, follow the procedure shown in **Appendix B - Configuration Update Via SysEx**, for parameters 42h (custom LFO 1), and 43h (custom LFO 2).

For example, to update the custom LFO waveshape 1, as a simple ramp with values increasing from 1 to 127, send the following SysEx message:

FO 00 02 0C 01 01 00 41 42 01 03 05 07 09 0B 0D 0F 11 13 15 17 19 1B 1D 1F 21 23 25 27 29 2B 2D 2F ... 71 73 75 77 79 7B 7C 7D 7F F7

The actual waveshape is defined by the values starting with 01h (1), and incrementing to 7Fh (127). Note that the values increase by 2 for each step, as there are 64 steps, and the values must range from 1 to 127.

Since a wavetable consisting of only 64 values is rather coarse, the first custom LFO waveshape is smoothed using an internal digital filter, to avoid the zipper effect. SysEx configuration parameter 0Ah determines how aggressive the smoothing is.

The second custom LFO waveshape is not smoothed, which allows for very abrupt stepped waveshapes. If the LFO modulation range is set to a full octave, it is possible to define exact musical intervals to each step in the waveshape, as shown in the table below.

Stepped LFO Values and Note Intervals			
Notes Ascending	LFO Value	Notes Decending	LFO Value
C	40h (64)	C	40h (64)
C#	45h (69)	B	3Bh (59)
D	4Bh (75)	A#	36h (54)
D#	50h (80)	A	30h (48)
E	55h (85)	G#	2Bh (43)
F	5Ah (90)	G	26h (38)
F#	60h (96)	F#	21h (33)
G	65h (101)	F	1Bh (27)
G#	6Ah (106)	E	16h (22)
A	6Fh (111)	D#	11h (17)
A#	75h (117)	D	0Ch (12)
B	7Ah (122)	C#	06h (6)
C	7Fh (127)	C	01h (1)

For example, to update the custom LFO waveshape 2, as a stepped shape corresponding to an interval of a fourth (C to F), send the following SysEx message:

F0 00 02 0C 01 01 00 **41 42 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40**
40 40 ... 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A 5A F7

The value of 40h corresponds to C, and 5Ah corresponds to F above C (an interval of a fourth).

Appendix D – Mini Sequencer Recording Via SysEx

The easiest way to program a custom arpeggiator or mini sequencer pattern is by following the procedure in section **1.5 Recording With The Mini Sequencer**, playing it directly from a MIDI keyboard. However, it is also possible to write a custom pattern via SysEx, or to read the current pattern via a SysEx data dump.

To program a pattern using SysEx, follow the procedure shown in **Appendix B - Configuration Update Via SysEx**, for parameter 41h.

The data format for the custom pattern is a series of 64 bytes. The first 32 bytes define the MIDI note numbers in the pattern, and the second 32 bytes define the MIDI note velocities (or Aux CC Channel values).

To define a rest, use a MIDI note number of 7Eh and velocity of 00h (or an Aux CC Channel value between 00h and 7Fh).

All 64 bytes of the custom pattern must be defined, even if the length of the pattern is less than 32 notes.

If the custom pattern is less than 32 notes long, pad the unused note values and velocities with a value of 7Fh.

Appendix E – Custom Tuning Table Via SysEx

In addition to the standard tuning table which gives a voltage curve of V/octave or Hz/volt, a custom tuning table can be defined to give any CV response. This may be useful for VCOs that don't adhere to a traditional curve over their full range, or for DIY VCOs. It is also possible to define other scales or microtonal tunings.

If you have a reference keyboard or other instrument, it is often easier to program the custom tuning table by ear. See section **5.1 Using the Learn Button, 6 Button Presses**.

If you are calculating the tuning table directly, continue with the process described below.

The standard tuning table, and all pitch modulation, is calculated to a resolution of 16 bits. However, the custom tuning table has a resolution of 14 bits.

The custom tuning table is defined as two banks of values (the MSB 7 bits, and LSB 7 bits). There is a 14-bit value for every semitone from C to C, over 5 octaves (61 semitones in total). The values range from 0 (corresponding to 0 volts output), to 16383 (corresponding to 5 volts output).

To program a custom tuning table, follow the procedure shown in **Appendix B - Configuration Update Via SysEx**, for parameters 44h (tuning table MSB), and 45h (tuning table LSB). After uploading the tuning data, enable the custom tuning table by setting SysEx parameter 35h to 1.

When the custom tuning table is enabled, pitch bend is approximated to either the V/octave curve, or Hz/volt curve. Set SysEx parameter 2Ch accordingly.

One of the SysEx configuration actions (62h) allows you to copy the currently used tuning table into the custom tuning table memory. This can be useful to create a starting point for custom tuning.

Appendix F – MIDI Control Change Information

MIDI Control Change messages (CC), are used to control MIDI clock synchronization, the range of pitch bend/modulation, and LFO shapes.

CC Value	MIDI Clock Synchronization (CC 19 for Arpeggiator, CC 16 for LFO)
0 - 9	4 whole notes
10 - 18	3 whole notes
19 - 27	2 whole notes
28 - 36	whole note
37 - 45	half note
46 - 54	half note triplet
55 - 63	quarter note
64 - 72	quarter note triplet
73 - 81	eighth note
82 - 90	eighth note triplet
91 - 99	sixteenth note
100 - 108	sixteenth note triplet
109 - 117	thirty-second note
118 - 127	thirty-second note triplet

CC Value	Pitch Bend/Modulation Range (CC 15 for Pitch Wheel or MOD Wheel Range)
0 - 11	1 semitone
12 - 22	2 semitones
23 - 33	3 semitones
34 - 44	4 semitones
45 - 55	5 semitones
56 - 66	6 semitones
67 - 77	7 semitones
78 - 88	8 semitones
89 - 99	9 semitones
100 - 110	10 semitones
111 - 121	11 semitones
122 - 127	1 octave

CC Value	LFO Shape (CC 17 to select the shape)
0 - 11	Triangle
12 - 23	Sawtooth
24 - 35	Inverted Sawtooth
36 - 47	Custom LFO 1 (smoothed)
48 - 59	Custom LFO 2 (stepped)
60 - 71	Square
72 - 83	40% Pulse
84 - 95	30% Pulse
96 - 107	20% Pulse
108 - 119	10% Pulse
120 - 127	Random

Appendix G – MIDI Implementation Chart

Model: [KRM-90] MIDI-CV-Arpeggiator Retrofit

Function		Transmitted	Received	Notes
Basic Channel		1 - 16	1 - 16	Programmable *1
Mode		4 Omni Off, Mono	3 Omni Off, Poly	MIDI input is Poly, MIDI output is Mono
Note Number		0 - 127	0 - 127	Programmable
Velocity	Note On Note Off	O Fixed at 0	O O	Programmable
Aftertouch	Key (Poly) Channel (Mono)	X X	O O	
Pitch Bender		O	O	
Control Change	1 - 119	O	O	Programmable
Program Change		X	O	
System Exclusive		O	O	
System Common	SPP	X	O	*2
System Realtime	Beat Clock Clock Start Clock Continue Clock Stop	X X X X	O O O O	
Aux Messages	Local On/Off All Notes Off All Sound Off Reset Controllers Active Sense	X X X X X	O O O O O	*3 *3 *3 *3 *3

*1 The transmit and receive channels must be the same.

*2 Song Position Pointer messages will reset the arpeggiator, mini sequencer, and LFO to the nearest bar, if they are under MIDI beat clock control.

*3 These aux messages are disabled by default. They must be enabled via SysEx messages.