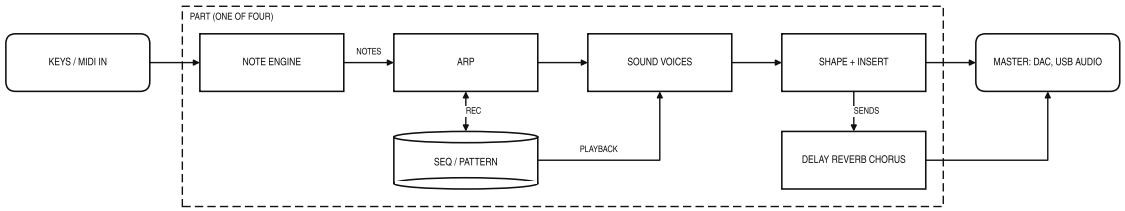
SQRL-1 FIRMWARE

Deep dive, from the SQRL-1 manual (docs/src) and the v1.1.0 firmware.

D.1 FUNCTIONAL DESCRIPTION.

SQRL-1 replaces the FM-1's screens with a shell of its own. Every instrument in it is a *nut*: a SOUND that makes the tone, or a NOTE engine that decides which notes to play. You always play a **pair**, one of each, and the same few gestures work in every pair.

Between the keys and the speaker a note passes through the NOTE engine, the part's arpeggiator and sequencer, the SOUND's voices, the part's own effects, and the buses every part shares.



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Figure D-1. Signal Path of One Part

A part is one of the FM-1's four sound channels, each with its own sound, effects and pattern. The shell maps three tracks onto them, so that what you leave keeps playing:

Table D-1. Tracks and Parts

Track	Part	Holds	NOTE engines
PLAY	1 and 2, in turn	what you play from the keys, with its take	KEYS, CHORD, HARP
LINE	3	the engine that plays by itself, one at a time	LINES, ALIVE, TONNETZ, ENIGMA, S+H, CANON, ACID
BEAT	4	the beat machine	RUDIMENT

PLAY alternates between parts 1 and 2 as you change pairs, so the pair you left rings out, and two takes can loop together. BEAT and LINE run whenever the transport runs, once they hold something.

D.2 THE WHEEL.

The wheel is the octave from C4 to C5. The white keys hold the eight SOUNDs and are fixed; the black keys hold NOTE engines and are yours to set. Hold HOME, press a white key and a black key in either order, and let go.



Figure D-2. The wheel, HOME held: FM6 with KEYS

Table D-2. Default Wheel

Key	Nut	Key	Nut
C4	FM6	C#4	KEYS
D4	LIZARD	D#4	CHORD
E4	SHOCK	F#4	LINES
F4	DRUMS	G#4	TONNETZ
G4	MOUTH	A#4	RUDIMENT
A4	ANALOG		
B4	PHASE		
C5	PHYS		

SQRL

With the wheel open, hold GLO and press a black key for the **slot picker**: every NOTE engine is listed, SELECT chooses, and letting go of GLO puts it on the key. Each engine appears once. The layout is kept over power-off.

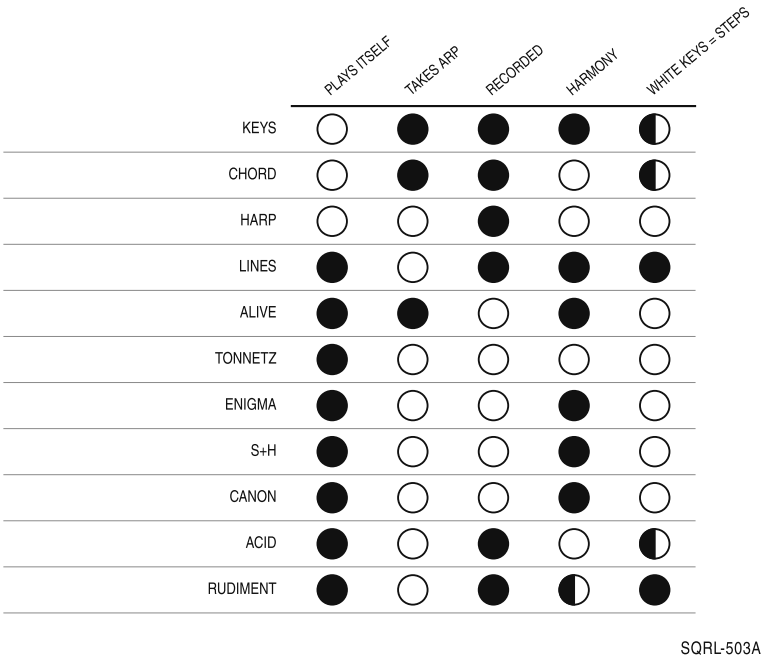


Figure D-3. What Each NOTE Engine Does

D.3 THEORY OF OPERATION.

D.3.1 Buttons: tap, hold and long.

Every button follows one timing rule, so a gesture means the same thing in every nut.

Table D-3. Button Timing

Gesture	Threshold	Effect
tap	released before 300 ms	acts on release
hold	300 ms, or at once when another control is touched	a modifier; nothing on release
long	1.2 s, a ring fills on screen	kept for actions that destroy something
PLAY, REC, OCT-, OCT+	on press	the transport and the octave never lag

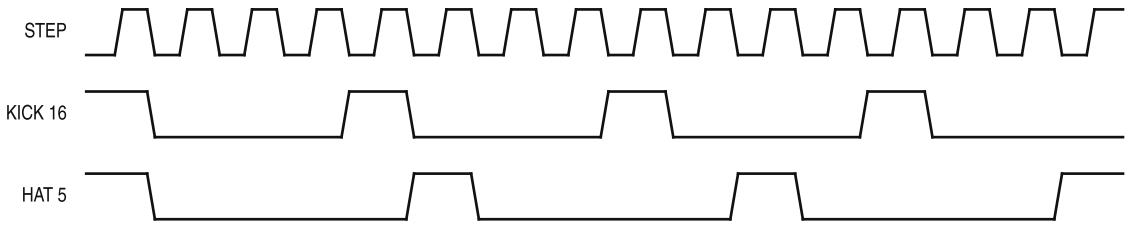
D.3.2 Steps, polymeter and swing.

Every part has its own LEN (1 to 64 steps), and on RUDIMENT and LINES each lane may have its own LEN too. Two loops of lengths L_1 and L_2 line up again after their least common multiple:

$$T = \mathrm{lcm}(L_1, L_2) \tag{D-1}$$

where T = steps until both loops start together again *steps*
L_1, L_2 = the two loop lengths *steps*

LINES at 24 over RUDIMENT at 16 lines up every 48 steps. A five step hat against a sixteen step kick lines up every 80 steps, five bars of the kick:



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Figure D-4. Five Step Hat over a Sixteen Step Kick, First Bar

GROOVE on SYSTEM 2 shapes the swing; its depth is SWG. At SWG 100, SWING puts every other sixteenth at 70 % of the eighth and SHUFFLE on the triplet (two thirds); PUSH moves it early; LAID adds beats 2 and 4 late; HUMAN moves each step up to 8 ms and its velocity up to 10 %, the same in every bar, so a loop repeats exactly.

D.3.3 The audio interrupt.

The audio interrupt fills a half buffer of 128 frames in blocks of 32 samples: events first (keys, sequencer, the shell's block), then each part's voices, the buses and the master. A NOTE engine runs once a block.

$$t_{half} = 128/44100\ \mathrm{Hz} = 2.90\ \mathrm{ms} \tag{D-2}$$

$$t_{block} = 32/44100\ \mathrm{Hz} = 0.73\ \mathrm{ms} \tag{D-3}$$

A half buffer over 85 % twice running, or over 95 % once, sheds a voice: the oldest released voice first, then the oldest extra UNISON voice, then the oldest held note of a POLY part other than its lowest. SYSTEM's DSP meter turns red at a 90 % peak or after any late block. There is no heap and no allocation in the interrupt.

With 2CORE on BETA (SYSTEM 3, the next tap of GLO after SYSTEM 2) the FM-1's second core renders some of the four parts while the first renders the rest. It is Felucca 1.6.1's beta, OFF by default, and takes effect at the next power-on. If the second core misbehaves the firmware carries on with one, says 2ND CORE MISREAD: OFF and turns it off. It is kept with the settings, not a project.

D.3.4 TOUCH: the keys' pressure.

TOUCH is a SOUND page after GLIDE (EDIT). The twenty keys F3 to C5 sense pressure; the rest of the 27 do not. Every 5 ms each held key's lean, its resistance below where it rests, measured in octaves, becomes a pressure:

$$p = \mathrm{round}\left(127 \cdot \mathrm{clamp}\left(\frac{\ell - \ell_0}{s(\mathrm{AT})}, 0, 1\right)\right), \quad s(\mathrm{AT}) = \frac{3154 - 282\,(\mathrm{AT} - 1)}{4096} \tag{D-4}$$

where p = the key's pressure *0 to 127*
ℓ = the lean: the key's resistance below its rest, log scale *octaves*
ℓ_0 = the noise floor, 164/4096 *0.04 octave*
$s(AT)$ = the lean past the floor that gives full pressure: 0.77 at AT 1, 0.15 at AT 10 *octaves*

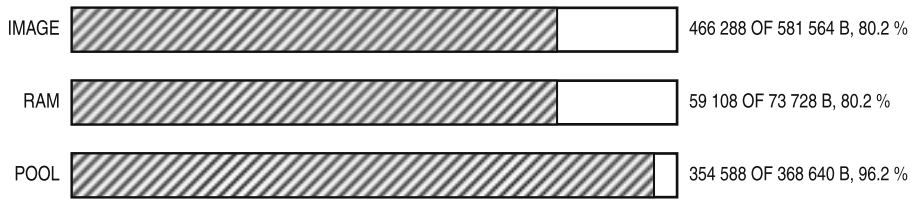
The pressure is smoothed by a step of 11/64 of the gap every 5 ms, about 29 ms. The rest is measured from where the key settles, not where it landed.

Table D-4. TOUCH (EDIT, after GLIDE)

Knob	Values	Does
AT	OFF, 1 to 10	the sensitivity: 1 the firmest lean for full pressure, 10 the lightest; OFF reads none
DEST	22 targets	PITCH CUT SHP AMP PAN DIST CHO DLY REV RATE VIB E1-E8 DEPTH VEL TIME
AMT	-64 to 63	how far the pressure moves DEST

AT turned on with no DEST set routes to CUT (DIST on DRUMS) at AMT 32, so it is heard at once. MIDI channel pressure reaches the same route, AT OFF included, and the keys' pressure goes out on USB MIDI as channel pressure.

D.4 PERFORMANCE AND DESIGN DATA.



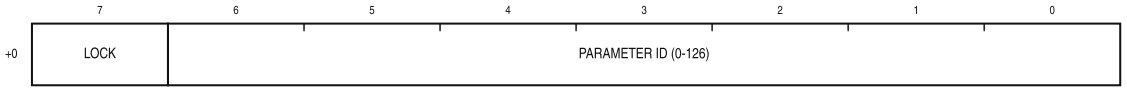
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Figure D-5. Memory at v1.1.0

Table D-5. Gates the Build Enforces

Resource	Used	Capacity	Gate	Spare
app image	466288 B	581564 B	fits the app slot	115276 B
RAM	59108 B	73728 B	at least 4096 B free	14620 B
.pool section	354588 B	368640 B	at least 8192 B free	14052 B
parameters (`P_COUNT`)	127	127	motion stores the id in 7 bits	0
shell parameters (`SP_*`)	160 to 245	254	page ids are a byte, 0xFF is none	9
locks and knob moves		128 a part	LOCKS FULL	
notes a step		6	PROJECT TOO FULL	
pattern length		64 steps	DOUBLE stops at 64	
user sound slots		32, every SOUND	SAVE says so	
project slots		4, A to D		

From v1.0.0 to v1.1.0, with Felucca 1.8.0's base under it, RAM grew by 6944 B and the pool shrank by 2684 B; both gates hold. In v1.0.0 the 10.27 trim had paid for the new features: the USB console's buffer went from 2048 to 512 bytes, the shell keeps a snapshot only for the SOUNDs on the wheel, ALIVE's rows and the MIDI note map were packed, and Felucca's song chain went to one source, since the PROJECTS queue plays a song.

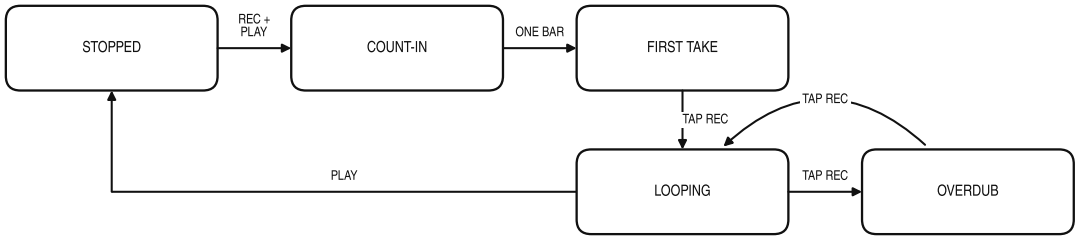


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Figure D-6. A Motion Record's Parameter Byte

A lock and a recorded knob move share one record per step and parameter, which is why `P_COUNT` cannot pass 127.

D.5 RECORDING.



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Figure D-7. Transport and Take States

The first take on an empty pattern sets the loop: the bars it ran, rounded to the nearest (2.4 make 2, 2.6 make 3), up to 64 steps, never short of a note you played. Armed while the transport already runs, the loop starts at the bar of your first note. Later takes overdub at that length: a note adds to what a step holds and never erases it.

Table D-6. REC MODE (hold REC, turn SELECT)

Mode	A pass
ADD	adds its notes to what each step holds (the default)
ADD + KNOBS	the same, and knob moves record
REPLACE	the first note a pass puts in a step replaces an earlier pass's
REPLACE + KNOBS	the same, with knob moves

Holding REC fills two rings. Released after the first: UNDO TAKE (or UNDO BEAT, UNDO SOUND, UNDO NEW, as the ring names it). Held through the second: the pattern and its knob moves are cleared. One level of undo, and a clear can be undone the same way.

D.5.1 A held step.

Where the white keys are steps, hold one to edit it. The knob cards become the step's own:

Table D-7. Step Edit (hold a white key)

Control	Sets
C#5 / D#5 / F#5	ACCENT / SLIDE into the next / TIE from the one before
black key F#3-A#4	lanes: that lane's hit; KEYS and ACID: the note, that scale degree
OCT+ / OCT- / SELECT	the note an octave up or down / a semitone
KNOB 1 CHNC	0-100 %, then 1:2 to 4:4, FILL, !FILL
KNOB 2 RATCH	x1 to x4 in the step
KNOB 3 NUDGE	-8 to +7 sixteenths of a step
KNOB 4 VEL	the step's velocity
any SOUND knob	a lock on this step only (card starred, `*CUT`)

D.6 SCALE, HARMONY AND MOVE.

SCL opens one scale that every nut shares. QNT decides what a part does with it:

Table D-8. QNT Settings

QNT	Keys	Pattern notes
OFF	as played	as stored
SNAP	down to the scale	as stored
WHITE	the scale on the white keys from ROOT at C4; black keys silent	as stored
SEQ	as SNAP	mapped onto the scale
SEQ+T	as SNAP	as SEQ, following TRN
NEAR	to the nearest; a tie goes toward the last note	to the nearest
DROP	silent if off the scale	silent if off the scale; steps kept
CHORD	to the nearest tone of the chord PLAY sounds	the same; generators pick chord tones

Drawing a scale. On SCALE the keys are silent and show the scale, ROOT lit. Press several together and on release they are the scale, the lowest the ROOT (SCALE reads USER). A single tap toggles one note; a named scale is copied first, so MIN with its sixth tapped becomes Dorian. USER is saved with the project.

HARMONY, the second tap of SCL, adds notes from the scale to every note the NOTE engine in front plays. Each NOTE engine keeps its own.

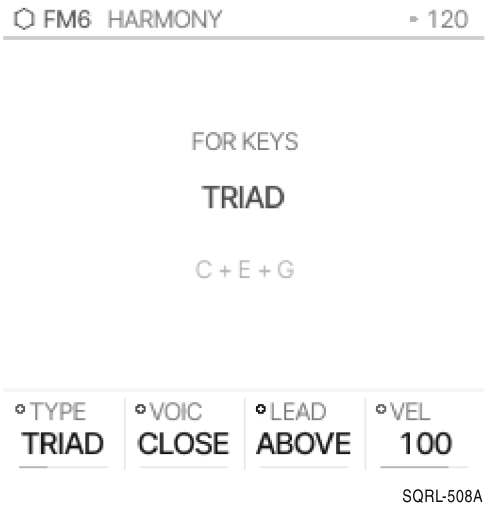


Figure D-8. HARMONY: TRIAD for KEYS

Table D-9. HARMONY Knobs

Knob	Values
TYPE	OFF 3RD 5TH TRIAD 7TH SUS2 SUS4 6TH ADD9 OCT
VOIC	CLOSE, OPEN, DROP2, WIDE
LEAD	ABOVE (you play the bottom), BELOW (the top)
VEL	the harmony's level against the note

The harmony's voices end with the note that started them, come out of the part's eight voices, and are never recorded: a take holds what you played and plays it harmonized. It needs VOICE mode POLY; CHORD, TONNETZ, HARP and DRUMS take none, and the page says why.

MOVE, SELECT on from SCALE, moves the scale by itself on the bar line: every 1, 2, 4 or 8 bars, by MODE (the next darker mode on the same root), 5TH, ALT (between yours and another) or RAND, home again after BACK moves.

D.7 STORAGE.

Table D-10. What Is Kept over Power-off

What	Written by	When
your sounds, 32 slots	SAVE, OCT+	at once, stopped
a project, slots A to D	GLO x3, OCT+ OCT+	at once; while playing, at the stop
the music (autosave)	itself	10 s quiet and stopped, at most once a minute
wheel layout, last pair, engines' four knobs	itself	once settled and quiet
MOUTH phrases U1 to U8	SAVE on SPELL	at once

The autosave is written only once something has changed, the transport is stopped and the FM-1 has been quiet for ten seconds, at most once a minute, so the flash wears only when there is something new. After a crash it is not restored; it is kept, and nothing is written over it until you save to or load from PROJECTS.

A project holds every part's sound and pattern, the motion, the tempo, GROOVE, ROUT, the drawn scale, each NOTE engine's HARMONY and the pairs on the tracks, and beside it the takes parked with pairs no part holds. A save asked for while playing waits for the stop (SAVES TO C AT STOP).

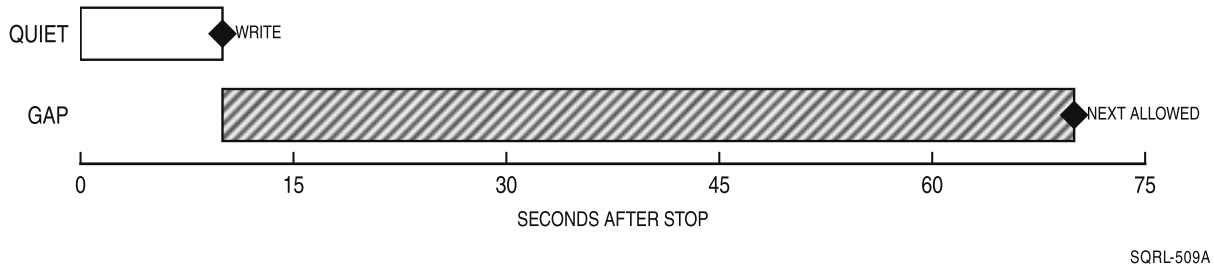


Figure D-9. Autosave After a Stop

D.8 CONNECTIONS.

Table D-11. USB Functions (device name SQRL-1, class compliant)

Function	Carries
USB MIDI	notes and CCs in, the keys and their pressure out, clock in; the installer and editor
USB audio	the output, 16-bit stereo at 44.1 or 48 kHz (resampled from 44.1)
Serial console	`status`, `stack`, `crash`, `inp`, `params`, `dbg`, `memr`, `flr`

The TRS jack is MIDI in at 31250 baud: notes, CCs, bend, aftertouch, Program Change and clock, on the same channels as USB. SysEx on it is ignored and SQRL-1 sends nothing on it. ROUT on SYSTEM 2 picks the channels: SEL sends every channel to the pair in front; CH1-4 (or a later block of four) gives each part its channel.

Table D-12. Fixed Controllers

CC	Sets	CC	Sets
1	mod wheel	72	REL
5	GLD	73	ATK
7	LVL	74	cutoff or brightness
10	PAN	75	DEC
11	expression	91 / 93 / 94	REV / CHO / DLY send
64	sustain	120 / 123	all sound off / all notes off
71	resonance	121	reset controllers

D.9 PROCEDURES.

INSTALL SQRL-1 — **OWNER, CHROME OR EDGE**

```
1  connect the FM-1 straight to the computer
     a USB data cable, no hub
2  close every DAW and app using the FM-1's MIDI
port
3  open the installer, allow MIDI with SysEx
4  read the ready line
     the build named is the one meant
5  press Install
6  leave the cable alone until the page says done
     an interrupted install resumes on Install
```

NOTE

From v1.1.0 the update loader refuses a package made for another device.

FIRST LOOP — **PLAYER**

```
HOME + C4 + D#4 ...... FM6 CHORD
REC + PLAY ........... COUNT IN
CHORDS FROM D4 ....... PLAY
REC .................. TAKE CLOSED
REC .................. OVERDUB
PLAY ................. STOP
GLO X3, KNOB 1 ....... SLOT
OCT+, OCT+ ........... SAVED
```

NO SOUND — **PLAYER**

```
1  MASTER up
2  generators: PLAY, or hold a key
3  HOME glowing: a part is muted
     HOME + its pair + PLAY brings it back
4  PLAY stops after half a second
     CLK is USB or TRS with no clock: set INT
```

D.10 CAUTIONS.

WARNING

A stock Felucca backup shows SQRL-1's project slots as empty and saves them empty, so restoring it erases them. Back up with SQRL-1's own editor.

CAUTION

An FM-1 running M-VAVE's FM1 Open keeps its projects where SQRL-1's code goes; the installer stops. Back up and return to official V15 first.

CAUTION

M-UPGRADE does not see an FM-1 running SQRL-1. Use the installer's Return to official V15 first; it checks the file and backs up your music before writing.

NOTE

A change in the last minute before power-off may not be in the autosave. Save to PROJECTS what you mean to keep.