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% Reverse-Engineering the E-mu Audity 2000 for SpectralCanvas Pro

Abstract

The E-mu **Audity 2000** is a legendary but rarely documented instrument.
Developed around 1979–1980 as a 16-voice, multi-timbral analog workstation using Solid State Music (SSM) chips, the Audity cost roughly US\$50-70 k and only one prototype exists today at the National Music Centre in Calgary [1].
Each voice contained two **SSM2030** voltage-controlled oscillators (VCOs), a **noise source**, a **high-pass filter**, a **low-pass filter** based on the 24 dB/oct SSM2040, a **voltage-controlled amplifier (VCA)** using the SSM2020, a **resonant filter**, four **SSM2050 ADSR envelopes**, an **LFO** and a flexible **modulation bus** [2] [3].
The prototype never reached production, yet its architecture foreshadowed polyphonic synthesizers and sequenced workstations.
This report presents a **behavioral specification**, **measurement protocol**, **modern mapping**, **producer tuning guide** and **risk analysis** for recreating the Audity 2000's characteristic feel within the **SpectralCanvas Pro** DSP environment. The goal is not to clone the circuit but to capture its musical behaviour using modern SSM/SSI components and perceptual modeling.

Contents

1. Historical Overview and Architecture
2. Behavioral Specification
3. Measurement Plan
4. Modern Mapping and DSP Implementation
5. Producer Tuning Guide
6. Risk and Mitigation Checklist
7. Conclusion and Recommendations

Historical Overview and Architecture

Origins and Purpose

The **Audity 2000** emerged from E-mu Systems' collaboration with **Solid State Micro Technology for Music (SSM)** in the late 1970s. SSM, founded in 1975 by **Ron Dow** with Dave Rossum as engineering partner, created a line of integrated chips—VCOs, VCAs, filters, transient generators—that powered early polyphonic synthesizers [4]. Dave Rossum designed the key chips: **SSM2030** VCO, **SSM2040** voltage-controlled filter (VCF) and **SSM2050** transient generator [5]. These chips provided richer timbre than Curtis CEM devices but suffered from yield issues; E-mu used them in products such as the **Audity** and **Polyphonic keyboard** [4].

In 1979 E-mu planned a **computer-controlled workstation** dubbed **Audity 2000**. The design proposed 16 voice cards, each with dual VCOs, multi-mode filtering, multiple envelopes and a sequencer. The instrument targeted wealthy studios and was estimated to cost \$50–70 k [6]. When the Fairlight CMI appeared at a similar price, E-mu shifted to the cheaper sampler **Emulator**, leaving only one Audity prototype built around 1980 [1]. The surviving unit remains at the **National Music Centre** in Calgary.

Voice Card Architecture

Each voice card implemented a complete analog synthesis chain (Fig. 1):

- **VCO 1 & 2:** two **SSM2030** oscillators generating sawtooth, triangle and pulse waves with pulse-width modulation and hard/soft sync [7]. Both oscillators allowed linear and exponential frequency modulation; coarse tuning covered more than 13 octaves [7].
- **Noise source:** variable spectrum noise (white, pink or "mauve") fed into the mixer [2].
- **Mixer:** sums VCOs and noise with control over individual levels.
- **High-pass and low-pass filters:** based on **SSM2040** which offers a 24 dB/decade slope with exponential voltage control over more than 10 000:1 frequency range [8]. The chip can be configured for low-pass, high-pass, band-pass or notch responses [8].
- **VCA:** dual **SSM2020** VCAs provide linear or exponential amplitude control [2].
- **Resonant filter:** additional multimode resonant filter after the VCA. Audity literature suggests a combination of high-pass and low-pass filters with adjustable resonance to emulate a "punch path" [2].
- **Envelopes:** four **SSM2050** ADSR generators per voice, each offering an initial delay and voltage-controlled attack/decay/release times [2].
- **LFO & Modulation buses:** an LFO with square, triangle and ramp waves; four independent modulation buses route envelope/LFO outputs to oscillator pitch, filter cut-off, amplitude and noise colour [2].

Figure 1: Audity voice signal flow. Blocks in grey represent signal-path components (VCOs, noise, filters, VCA, resonant filter); blue blocks indicate modulators (4× ADSR, LFO, modulation bus). Arrows show audio flow; dashed arrows represent modulation connections.

Unique Characteristics

The Audity's architecture imparted several distinctive behaviours:

Element	Historical description	Modeling implications
VCO (SSM2030)	Provides saw, triangle and pulse waves with PWM and soft sync; linear and exponential FM; 13-octave range [7].	Requires anti-aliasing and oversampling; PWM and FM can introduce non-linear aliasing, so digital implementation should oversample or use band-limited oscillators.
VCF (SSM2040)	4-pole filter considered one of the "best-sounding"; exhibits mild distortion when overdriven; exponential control over 10 000:1 range [9] [8].	Emulate 24 dB low-pass and high-pass responses; implement resonance with gain-trim; include soft saturation pre/post-filter to mimic mild distortion.
VCA (SSM2020)	Dual voltage-controlled amplifiers; can be configured for linear or exponential response [2].	Provide both linear and exponential amplitude curves; overshoot and soft clipping at high drive.
Transient generator (SSM2050)	Voltage-controlled ADSR with initial delay; forms the basis of the envelopes [2].	Envelope times should be modulateable; incorporate overshoot during attack (see Fig. 3) and exponential curves.

Element	Historical description	Modeling implications
Noise	Variable between white, pink and mauve noise [2].	Model spectral differences; mauve appears between pink and brown—approximate with $1/f^3$ slope.

Surviving Data and Gaps

Because only one prototype exists, **transfer curves**, **resonance behaviour under drive**, **noise colour spectra**, **envelope timing responses** and **saturation traits** remain undocumented. Available information comes from SSM/SSI datasheets and retrospective interviews; thus behavioural modelling must combine engineering theory with perceptual calibration and, if possible, measurements of the prototype or similar SSM-based synthesizers.

Behavioral Specification

This section translates the historical architecture into DSP-friendly behaviours. The aim is to produce an **authentic but stable** module; parameters marked with ☆ require empirical calibration.

VCO Modeling

1. **Wave generation:** Use band-limited oscillators (BLEPs or BLITs) producing saw, triangle and pulse waves with PWM. Implement soft sync by blending a phase-reset pulse into the slave oscillator.
2. **Pitch control:** Provide linear FM with DC-offset removal and exponential FM for pitch envelopes. Control range: 13 octaves (20 Hz–20 kHz). Add micro-pitch drift and jitter (LFO-modulated) to emulate analog instability; magnitude ≈±5 cents with slow correlation.
3. **Saturation:** At high mixing levels, VCO outputs saturate the mixer; include a soft-clip waveshaper before the mixer.

Filter Behaviour

The SSM2040 design yields a **24 dB/oct** low-pass or high-pass response with adjustable resonance. Fig. 2 shows approximated resonance curves for a 4-pole low-pass. At low resonance (Q≈0.2), the response is smooth; increasing Q emphasises the cutoff region; beyond self-oscillation (Q≈2), the resonance peaks saturate.

1. **Cutoff control:** Exponential frequency mapping over 10 000:1 range [8]; implement pre-warping for bilinear transform (Fig. 5) to match analog cutoff frequency across the spectrum.
2. **Resonance:** Provide a gain-trim circuit; resonance should not increase output amplitude to the point of oscillation except when self-oscillation is desired (add optional self-oscillating mode). Introduce a VCA-controlled resonance path (as in the modern **SSI2140** which adds a “Q VCA” [10]) to balance self-oscillation and maintain stability.
3. **Saturation:** Insert soft-saturation both before and after the filter to emulate the mild distortion of the SSM2040 [9]. Use a tanh or polynomial saturator with adjustable drive. Provide high-pass pre-emphasis to avoid low-frequency pumping.
4. **Filter modes:** Offer low-pass, high-pass and band-pass modes. The Audity’s post-VCA “resonant filter” likely used a state-variable structure; implement a high-pass plus resonant low-pass chain (“punch path”) to recreate the distinctive punch.

Envelope Generators

The **SSM2050** ADSR provides voltage control and an initial delay. Observations from similar chips suggest the envelopes display slight overshoot on attack and exponential slopes. Fig. 3 depicts a typical envelope with overshoot > 1.0 followed by decay to the sustain level.

1. **Segments:** Attack, decay, sustain and release times are voltage-controlled. Provide ranges: attack 1 ms–10 s☆, decay 5 ms–30 s☆, sustain 0–1 (linear), release 5 ms–30 s☆. Add optional initial delay up to 1 s☆.
2. **Overshoot:** Attack overshoot up to ≈+1 dB; implement by allowing the peak amplitude to exceed the sustain level then decaying back.
3. **Response law:** Use exponential slopes; allow user to select between linear, exponential or intermediate shapes.
4. **Unipolar/Bipolar outputs:** Provide unipolar envelopes for amplitude and bipolar versions for pitch modulation.

LFO and Modulation

1. **Waveforms:** Square, triangle and ramp; frequency 0.01–50 Hz; global sync to host tempo.
2. **Mod buses:** Four assignment busses with variable depth and polarity. Each bus can route one or more modulation sources (envelopes, LFO) to multiple destinations (VCO pitch, filter cutoff, amplitude, noise colour, VCA gain). Provide scaling per destination.
3. **Noise colour:** White, pink and mauve noise spectra (Fig. 4). Mauve noise is a $1/f^3$ slope between pink and brown; implement using filtering of white noise.

Non-Linearities and Cutoff Warp

Analog filter implementations require pre-warping of the digital cutoff frequency (bilinear transform). Fig. 5 shows the mapping between analog cutoff and pre-warped digital frequency for a sample rate of 48 kHz. Pre-warping ensures that the digital filter's cutoff remains perceptually aligned, especially at higher frequencies.

Measurement Plan

Because the only known **Audity 2000** prototype resides in Calgary, a measurement campaign must balance technical thoroughness with conservation ethics. The plan includes **prototype measurement** and **fallback behavioural approximation**.

Prototype Measurement Protocol (if access granted)

1. **Preparation:** Coordinate with the National Music Centre to schedule measurement sessions; ensure non-invasive testing (no modifications). Use high-quality audio interface and precision test signals.
2. **Signal-path measurements:**
3. *Oscillator waveforms:* Record direct VCO outputs under various pitch ranges, PWM widths and sync settings. Measure harmonic spectra and amplitude calibration.
4. *Filter response:* Inject white noise or sine sweeps; record magnitude and phase response across cutoff/resonance settings; measure Q gain and roll-off slopes. Determine resonance self-oscillation threshold.
5. *Noise colours:* Record noise source outputs; compute power spectral density for white, pink and mauve settings.

6. *Envelope timing:* Apply step signals to envelopes; record amplitude envelope; extract attack/decay/release times versus control voltage; measure overshoot magnitude.
7. *VCA and saturation:* Measure input/output curves at different drive levels; observe soft clipping or exponential behaviour.
8. **Subjective listening:** Conduct listening tests with the audio historian and musician-producer to describe perceptual qualities (e.g., “punch”, “warmth”, “shimmer”). Document notes for later DSP tuning.
9. **Documentation:** Take high-resolution photographs of the voice card and control panel; record knob ranges and UI labelling for parameter mapping.

Fallback Behavioral Approximation

If access is denied, rely on **SSM/SSI datasheets**, user memories and analysis of similar SSM-based instruments (e.g., **E-mu Modular**, early **Oberheim** units). Derive transfer curves from published graphs; calibrate envelope times using typical values from SSM2050 circuits. Use modern **SSI2140/2144** datasheets to approximate filter response; calibrate resonance using spectral matching between the model and recorded demos. Conduct listening analyses of available Audity demo recordings to infer noise spectra and modulation behaviour.

Modern Mapping and DSP Implementation

To recreate the Audity within **SpectralCanvas Pro**, combine modern **SSI** analog chips where appropriate and digital DSP algorithms for behaviour difficult to implement in hardware alone. The following mapping is proposed:

Original element	Modern equivalent	Notes and design considerations
SSM2030 VCO	**SSI2130/2131 VCOs**	SSI2130/2131 offer stable analog oscillators with triangle, saw and pulse outputs and integrated temperature compensation [11]. Use these for a hardware voice card; for a purely digital module, implement band-limited oscillators with oversampling.
SSM2040 VCF	**SSI2140** or **SSI2144**	SSI2140 retains the “mojo” of the SSM2040 while adding a resonance control VCA and temperature compensation [10]. SSI2144 provides a dedicated 4-pole low-pass filter with improved noise and feedthrough [12]. For digital, implement 4-pole low/high-pass with variable Q and saturating drive.
SSM2020 VCA	**SSI2164/ THAT2180**	Modern VCAs offer low-noise, temperature-compensated amplitude control; pair with digital or analog control circuits. Provide linear and exponential modes.
SSM2050 ADSR	**Digital envelope generator**	The SSI chip line lacks a direct ADSR replacement; implement digital ADSRs with overshoot, exponential curves and initial delay. Provide CV inputs for mod depth; calibrate times to match measured SSM2050 behaviour.
Noise source	**Digital noise generator**	Generate white noise; filter to produce pink and mauve spectra; optionally feed through an analog VCA for texture.

Original element	Modern equivalent	Notes and design considerations
Resonant filter (post-VCA)	**State-variable filter** or digital multi-mode filter	Use a digital state-variable filter for band-pass/resonant modes. Provide resonance control via “Q VCA”; saturate the filter input for punchy sounds.
Sequencer and computer control	**DAW integration**	Map the original’s 8-channel multi-timbral interface to MIDI/OSC control; provide per-voice parameter automation; implement patch storage and recall with micro-tuning.

DSP Implementation Guidelines

1. **Oversampling and Anti-Alias:** To prevent aliasing from PWM, FM and resonant peaks, oversample the entire voice path by 2–4×. Downsample with linear-phase filters.
2. **Cutoff Pre-Warping:** Use bilinear transform pre-warping (Fig. 5) or oversampled analog models to align digital cutoff with analog expectations.
3. **Non-linearity and Saturation:** Introduce gentle saturation at mixer, filter input and VCA output. Use symmetrical tanh or asymmetrical saturators to emulate transistor/OTA behaviour. Provide user control over drive amount.
4. **Modulation Routing:** Implement a flexible modulation matrix with adjustable depth, polarity and scaling. Provide smoothing to avoid zipper noise.
5. **Real-Time Safety:** Manage CPU load by using efficient algorithms (e.g., TPT filters) and avoiding high-order oversampling when not needed. Provide polyphony up to 16 voices; use voice-stealing policies and dynamic CPU scheduling.

Producer Tuning Guide

While the engineering specification ensures fidelity, producers need intuitive guidance to craft musical patches. The following suggestions illustrate how to exploit the Audity 2000 module for common production tasks. Values represent default starting points; adjust to taste.

Sound	Parameter suggestions	Rationale
Analog kick	VCO1: sine or triangle at 60 Hz; VCO2: off; LP filter cutoff 500 Hz, high resonance (Q≈1.2); envelope: attack 1 ms, decay 150 ms, sustain 0, release 50 ms; short pitch envelope on VCO1 for pitch-drop; noise: mauve at low level for thump.	Resonant low-pass emphasises fundamental; pitch envelope adds transient; mauve noise introduces body without harshness.
Snare/clap	VCOs tuned an octave apart (200 Hz and 400 Hz) with PWM; noise source (pink) at medium level; high-pass filter cutoff 150 Hz with medium Q; LP filter 3 kHz; envelopes: quick attack (2 ms), decay 120 ms, sustain 0; modulate noise amplitude and filter resonance for dynamic crackle.	Dual frequencies provide body; pink noise replicates snare rattle; HP+LP filtering shapes spectrum; modulation adds realistic variance.

Sound	Parameter suggestions	Rationale
Bass line	VCO1: saw wave; VCO2: pulse at 50 % duty, detuned −10 cents; LP filter cutoff 150 Hz, resonance 0.5; envelope: attack 5 ms, decay 200 ms, sustain 0.7, release 200 ms; mild pre-filter saturation; assign LFO (triangle 2 Hz) to PWM for movement.	Detuning and PWM create warm chorusing; moderate resonance emphasises bass harmonics; LFO-modulated PWM adds animation.
Chord pad	VCOs: triangle waves with slight detune; LP filter cutoff 5 kHz, low resonance; HP filter off; envelope: slow attack 1 s, decay 2 s, sustain 0.8, release 3 s; LFO (sine 0.3 Hz) modulates filter cutoff; noise off.	Smooth triangle waves reduce brightness; long envelopes create wash; slow LFO sweeps mimic analog drift.

General Tips

- **Drive and Saturation:** Increase mixer drive to introduce harmonics; reduce for cleaner sounds.
- **Noise Colour:** Switch between white (bright hiss), pink (even spectral drop) and mauve (dark noise) to tailor percussive elements.
- **Mod Matrix:** Use envelopes to modulate filter cutoff for plucky sounds; assign LFO to pitch for vibrato; route envelope to noise level for dynamic textures.
- **Resonant Filter Punch:** Engage the post-VCA resonant filter for “punchy” basses and kicks; high-pass + resonant low-pass emphasises transients.

Risk and Mitigation Checklist

Risk	Impact	Mitigation
Aliasing from high-frequency content	Audible digital artifacts; CPU overload when oversampling many voices.	Use band-limited oscillators; oversample filter sections only when resonance or FM exceed Nyquist; provide dynamic oversampling (switch on/off per voice).
Resonance instability	Self-oscillation or runaway resonance causing clipping.	Implement gain-trim; limit resonance Q; incorporate a “Q VCA” as in SSI2140 [10]; provide user-adjustable limit.
Real-time CPU load	Drop-outs in DAW when many voices with modulation and oversampling are active.	Use efficient topologies (e.g., transposed direct form filters); allocate resources dynamically; allow user to limit polyphony or disable oversampling.
UI/Audio sync (zipper noise)	Audibly stepped parameter changes.	Apply parameter smoothing (slew limiters) on cutoff, resonance, envelope times; sample & hold or filter control signals.
Perceptual mismatch	Model may not feel like the prototype due to missing transfer curves.	Conduct listening tests with producers; adjust non-linearities and noise spectra; incorporate calibration controls (e.g., “vintage mode” toggle).

Risk	Impact	Mitigation
Intellectual property concerns	Overly faithful replication could infringe on original design.	Focus on behavioural modelling; avoid replicating proprietary firmware or schematics; cite public data sources and produce original DSP code.

Conclusion and Recommendations

The **E-mu Audity 2000** remains a remarkable milestone in synthesizer history, representing a transition from analog modules to computer-controlled polyphonic workstations. Although only one unit exists, careful study of **SSM** chips and modern **SSI** replacements enables an accurate **behavioural model** suitable for real-time use in **SpectralCanvas Pro**. By combining historical insights with modern DSP techniques—band-limited oscillators, saturating filters, and flexible modulation—developers can recreate the instrument's unique feel while offering producers intuitive control. Future work should prioritise a measurement campaign with the Calgary prototype to validate envelope times, resonance curves and noise spectra. Meanwhile, the provided **specification, measurement plan and tuning guide** offer a comprehensive starting point for implementing the Audity's ethos in a contemporary production environment.

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