**Specification: DSP Modules and Utility Tools**

**1. Overview**

This document outlines the initial set of audio DSP effect modules and utility tools to be implemented in the Modular DSP Toolkit. These components form the foundation for user-configurable audio effect chains and analysis utilities within both the standalone app and plugin runtime.

**2. DSP Modules (Effects)**

Each effect module will conform to the standard DSPTool interface and support parameter serialization and real-time processing.

**2.1 Dynamics & Envelope Shaping**

* **ADSR Envelope Shaper**
  + Controls: Attack, Decay, Sustain, Release
* **Transient Shaper**
  + Controls: Attack Boost/Cut, Sustain Boost/Cut, Sensitivity
* **Compressor**
  + Controls: Threshold, Ratio, Attack, Release, Knee, Makeup Gain
* **Expander/Gate**
  + Controls: Threshold, Ratio, Hold, Release

**2.2 Time-Based Effects**

* **Delay (Multi-tap)**
  + Controls: Delay Times (up to 4), Feedback per tap, Mix
* **Granular Delay**
  + Controls: Grain Size, Density, Pitch Jitter, Spread, Feedback
* **Reverse Delay**
  + Controls: Delay Time, Mix
* **Time Stretch/Smear**
  + Controls: Stretch Ratio, Smear Intensity, Smoothness

**2.3 Pitch and Frequency Effects**

* **Pitch Shifter**
  + Controls: Semitones, Cents, Formant Correction
* **Formant Shifter**
  + Controls: Formant Shift, Wet/Dry Mix
* **Frequency Shifter**
  + Controls: Frequency Offset, Balance
* **Harmonizer (Simple)**
  + Controls: Interval 1/2, Detune, Mix

**2.4 Spectral Processing**

* **Spectral Freeze**
  + Controls: Freeze On/Off, Decay, Pitch Shift
* **Spectral Blur**
  + Controls: Blur Time, Intensity
* **Band Isolator**
  + Controls: Frequency Band, Gain, Q

**2.5 Filters and Resonance**

* **Parametric EQ (3–5 Band)**
  + Controls: Freq, Gain, Q per band
* **Comb Filter**
  + Controls: Frequency, Feedback, Mix
* **Modal Resonator**
  + Controls: Mode (Tube, Plate, String), Tuning, Damping

**2.6 Distortion and Texture**

* **Bitcrusher**
  + Controls: Bit Depth, Sample Rate, Mix
* **Wavefolder**
  + Controls: Fold Amount, Bias
* **Tape Saturation**
  + Controls: Drive, Bias, Hiss Level
* **Overdrive**
  + Controls: Gain, Tone, Mix

**2.7 Spatial & Stereo Effects**

* **Stereo Widener**
  + Controls: Width %, Delay Offset, Phase Flip
* **Auto-Panner**
  + Controls: Rate, Depth, Shape, Sync to BPM
* **Spectral Panner**
  + Controls: Low/Mid/High Spread

**3. Utility Tools**

Utility tools are non-DSP components that aid in visualization and interaction during chain construction and evaluation.

**3.1 Spectrum Analyzer**

* Real-time FFT-based frequency display
* Adjustable resolution and smoothing
* Input and output overlays

**3.2 Time-Domain Oscilloscope**

* Real-time waveform view
* Triggering options (Free, Peak, Zero-Cross)
* Zoom and scroll

**3.3 Level Metering**

* Peak and RMS meters
* Input/Output channel display
* Clip detection indicators

**3.4 Routing Visualizer**

* Displays internal signal flow between modules
* Optional flow graph view or animated routing lines

**3.5 Modulation Monitor *(future)***

* View LFO/envelope modulation targets in real time
* Show parameter animation based on modulation depth

**4. Future Expansion Concepts**

* IR Convolution Reverb (with importable IRs)
* Re-synthesis (e.g., vocoder or additive-based modules)
* Interactive modulation matrix or patcher

**5. Summary**

This specification defines a flexible, creative set of DSP effects and supporting utility tools for users to shape and understand their sound in both experimental and production contexts. Implementation will follow the DSPTool interface standard and integrate seamlessly into the modular stack framework outlined in the architecture document.