PROGNOSTICATOR-6

A powerful synthesizer that won't break the bank

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Problem Statement

Analog Synthesizer

- Manipulation
  - Akin to an acoustic instrument
- Features
  - Expensive to implement
- Sound Quality
  - It sounds better! (maybe)

Digital Synthesizer

- Manipulation
  - Lives in a world of software
- Features
  - Simpler implementation
- Sound Quality
  - Imitation will never be the real thing

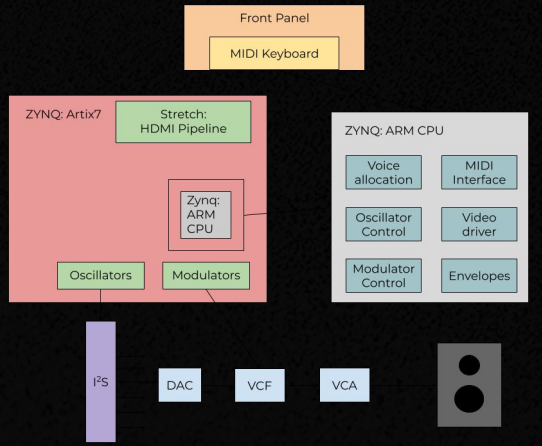
Requirements

Polyphony or Paraphony
Wavetables (wave synthesis)
Oscillators (2 per voice)
Tunable Analog Filters (LPF Amp, resonance)
Effects (pitch shifting, chords, arpeggiators)
Front Panel (rotary encoders, stretch: display)
Robust Enclosure (aluminium and/or wood)

Pitch Correctness (±3¢)
Filter Cutoff (<5% off ideal)
THD (<1%)
Competitive Pricing (<$400)
User Enjoyment (>70% +ve feedback)
Portability (>= toaster, < microwave)

Approach

- Physical
  - MIDI keyboard - purchased
  - Front panel - encoders, potentiometers, buttons
- FPGA (PYNQ Z2)
  - Wavetables?
  - SoC handles many effects
- I^2S Audio DAC
  - DAC output to analog filter
- Analog Filters and Amplifier
  - Voltage controlled cutoff
  - Voltage controlled resonance
  - Reduced scope to only include LPF



Front Panel Knob Allocation

- Synths have lots of parameters to control
  - Need lots of knobs for “analog feel”
- We will use a mix of rotary encoders (notched/unnotched) and potentiometers

System	Purpose	Type	Modulatable?	Mod Sources:	Purpose	Type	
Osc1	Shape		XX	LFO1	Freq	log	
Osc2	Shape		XX		Shape	notched range	
	Octave	notched range		*LFO2*	*Freq*	*log*	
	Fine tune		XX		*Shape*	*notched range*	
Low Pass	Cutoff	log	X	Env1	A	log	gating?
	Resonance		X		D	log	
Voicing	Voice Mode	notched range	see table		S		
	portamento				R	log	
	Chorus	notched range		Env2	A	log	gating?
Control	multipurpose knob	notched button			D	log	
	mod matrix knob	notched button			S		
Mixer	Osc1 amt				R	log	
	Osc2 amt						
	Noise						

Mod Matrix	Osc1 shape	Osc2 shape	Osc2 detune	Low pass cutoff	Amp	pitch
Vel					X	
LFO1						X
LFO2						
Env1					X	
Env2				X		
Env3	X	X				

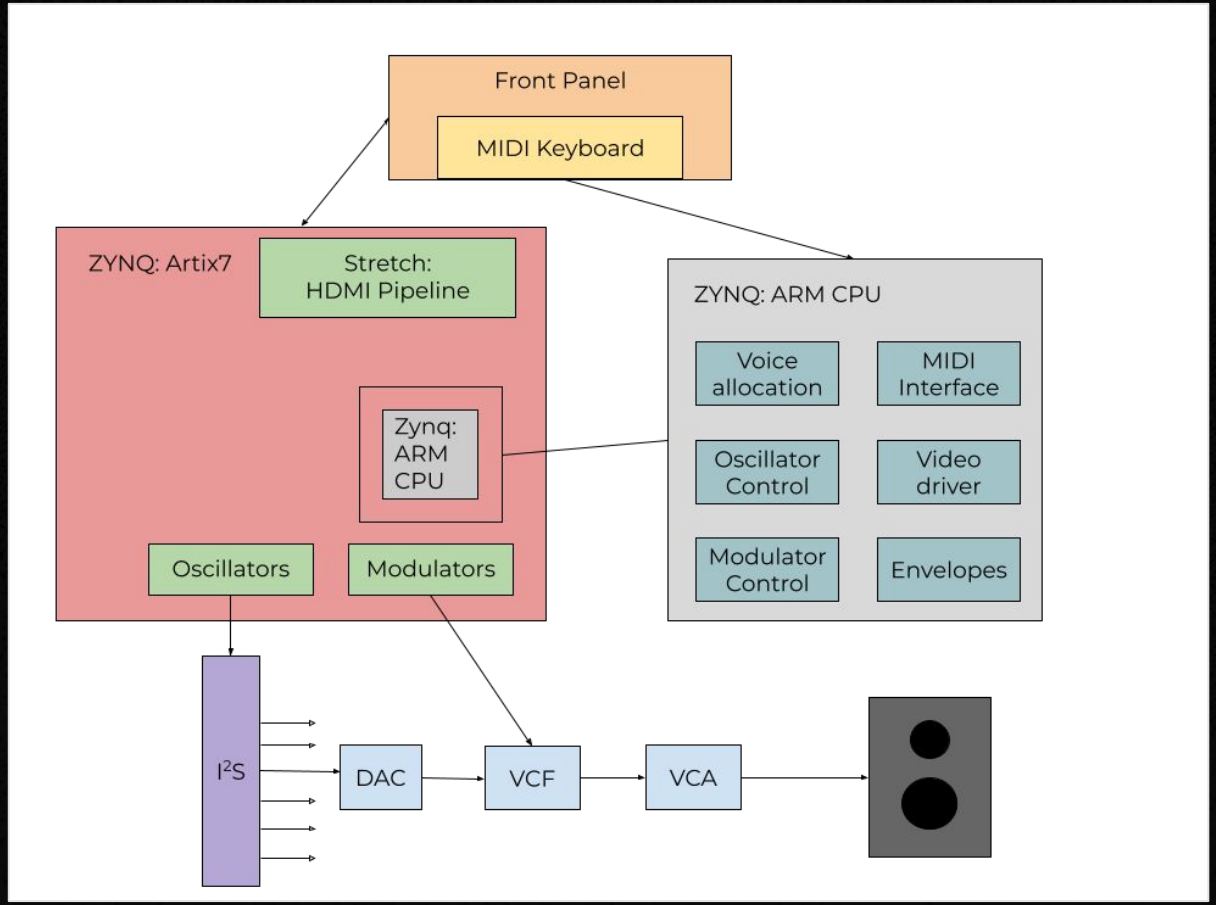
Buttons:		**Pots**	**Filter modulation:**
back button	button	Master Volume	
load patch	button		
save patch	button		

Voice Modes	Num voices	Gating	
single	1	each note	
mono	1	no notes	
para	inf	no notes	
poly	*6?*	*each note*	<- requires multiple filter paths

Ext gating:

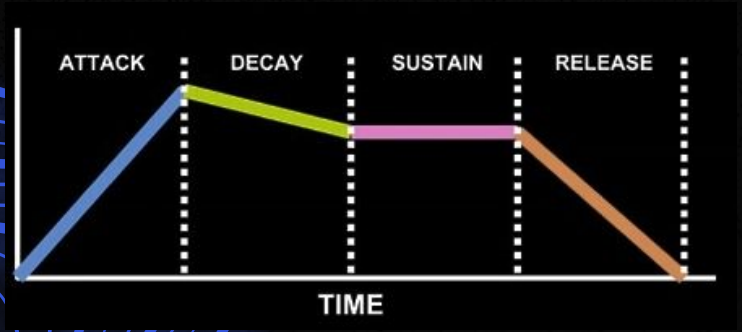
Num encoders: 26

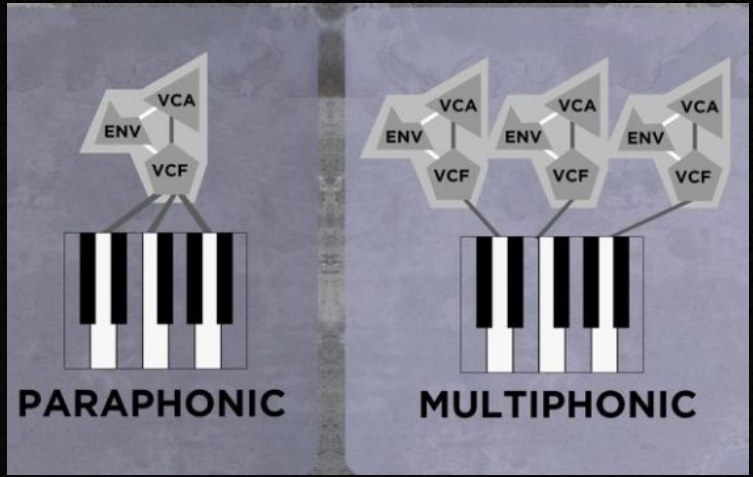
Block Diagram



Paraphonic vs Polyphonic

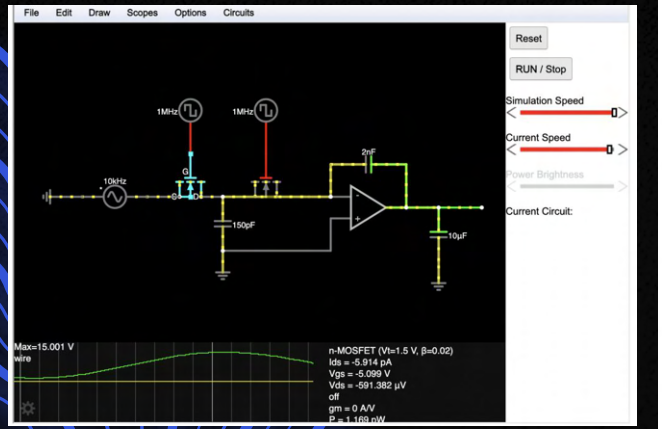
- Polyphonic gives each note pressed its own articulation envelope
- Paraphonic is far simpler and requires less components
  - Still sounds good playing chords

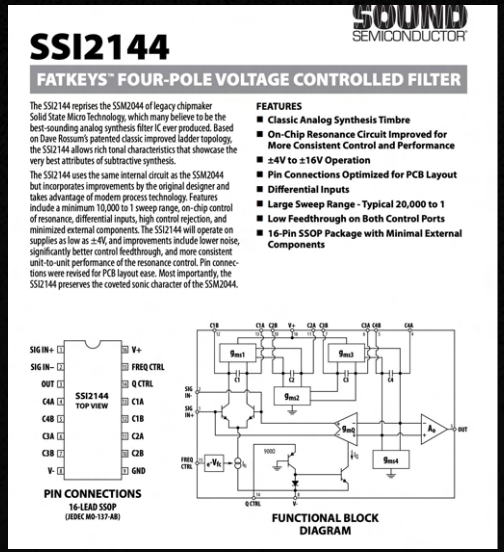


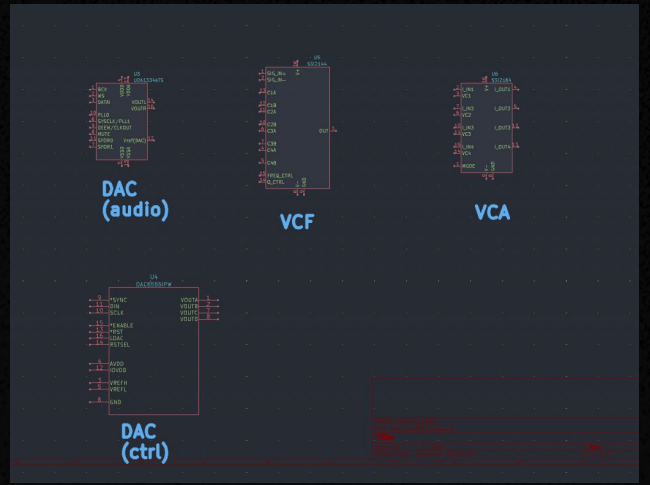


Tunable Filter Design

- Moving away from the discrete switched-capacitor architecture in favor of monolithic filter ICs

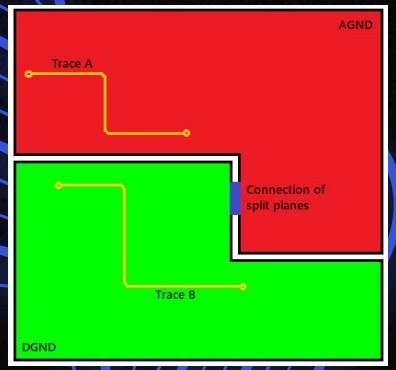


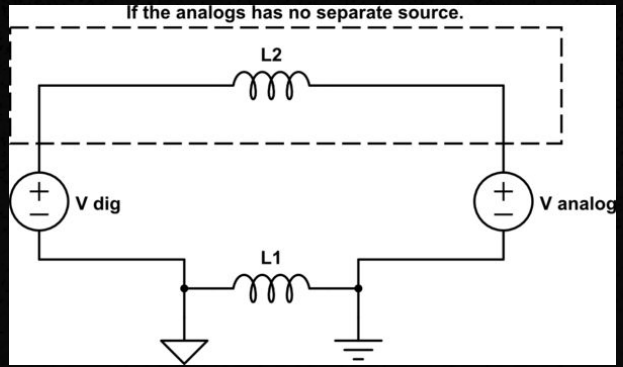


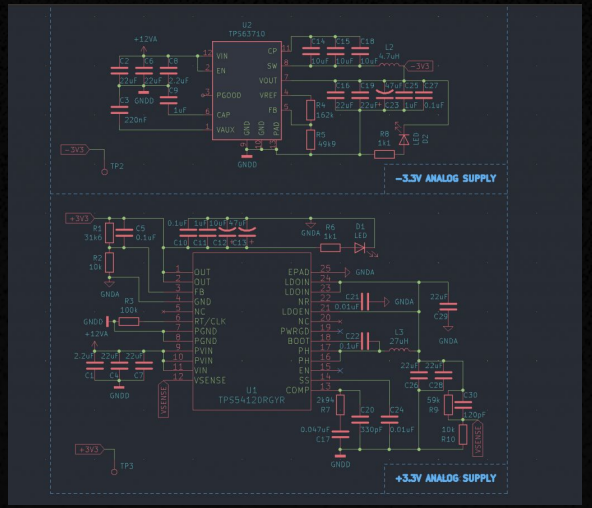


Low Noise Power Supply

- Lots of high frequency noise digital switching
  - FPGA
  - SoC
  - SPI, I2S, I2C
- We will separate digital and analog grounds with inductive chokes or be very careful about component placement and return current paths

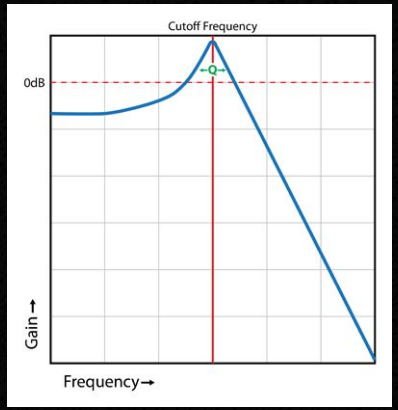


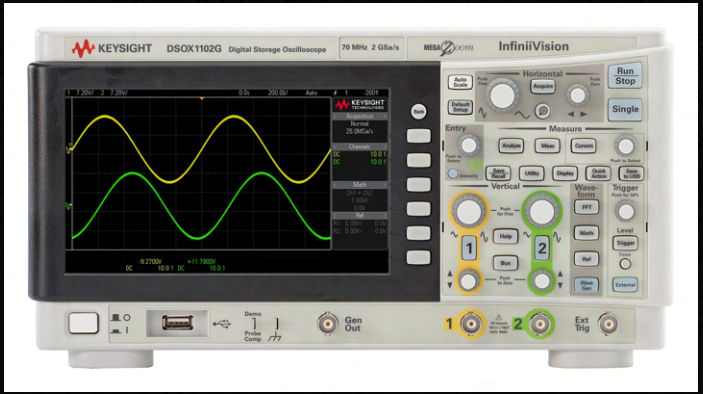




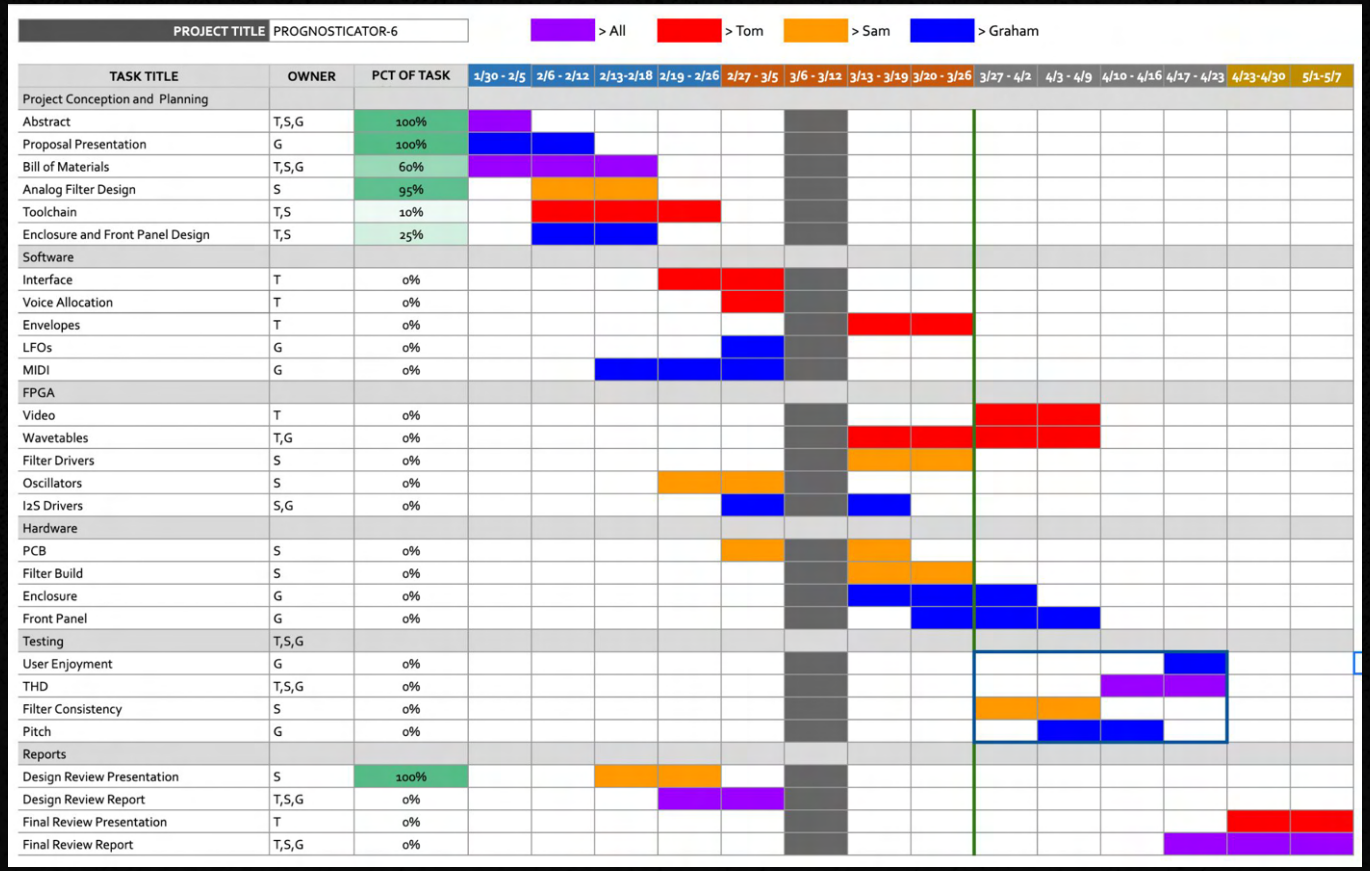
Testing and Verification

- Sound Quality
  - SNR
- Harmonic Distortion
  - Spectrum analyzer
- Latency
  - Input to output delay
- Frequency response
  - Bode plots
- Pitch Correctness
  - Any old tuner





Gantt Chart



TASK TITLE	OWNER	PCT OF TASK	1/30 - 2/5	2/6 - 2/12	2/13-2/18	2/19 - 2/26	2/27 - 3/5	3/6 - 3/12	3/13 - 3/19	3/20 - 3/26	3/27 - 4/2	4/3 - 4/9	4/10 - 4/16	4/17 - 4/23	4/23-4/30	5/1-5/7
Project Conception and Planning																
Abstract	T,S,G	100%														
Proposal Presentation	G	100%														
Bill of Materials	T,S,G	60%														
Analog Filter Design	S	95%														
Toolchain	T,S	10%														
Enclosure and Front Panel Design	T,S	25%														
Software																
Interface	T	0%														
Voice Allocation	T	0%														
Envelopes	T	0%														
LFOs	G	0%														
MIDI	G	0%														
FPGA																
Video	T	0%														
Wavetables	T,G	0%														
Filter Drivers	S	0%														
Oscillators	S	0%														
I2S Drivers	S,G	0%														
Hardware																
PCB	S	0%														
Filter Build	S	0%														
Enclosure	G	0%														
Front Panel	G	0%														
Testing	T,S,G															
User Enjoyment	G	0%														
THD	T,S,G	0%														
Filter Consistency	S	0%														
Pitch	G	0%														
Reports																
Design Review Presentation	S	100%														
Design Review Report	T,S,G	0%														
Final Review Presentation	T	0%														
Final Review Report	T,S,G	0%														

Conclusion

- Future of synthesizers
  - Modular and DIY
  - Accessible Analog
- Our hope
  - Build a solid basic synthesizer
  - Implement as many supplementary features as possible