

# CLAMS - The Quest for Portability and Audio

## Forth Day 2024

M. Edward (Ed) Borasky

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# Introduction

# What is CLAMS?

- ▶ Command Line Algorithmic Music System
- ▶ Forth-controlled synthesizer for microcontrollers / SBCs

## Some embedded audio terminology

- ▶ MIDI: Musical Instrument Digital Interface
  - ▶ a protocol for controlling synthesizers
- ▶ PCM: Pulse-Code Modulation
  - ▶ digital audio streams of fixed-width binary words
  - ▶ most common digital audio format
- ▶ DAC: Digital-Analog Converter
  - ▶ converts a PCM stream from digital to analog
- ▶ I2S: Inter-Integrated-circuit Sound
  - ▶ a serial protocol for transmitting stereo PCM
- ▶ DSP: Digital Signal Processing
  - ▶ algorithms for manipulating PCM data

## A typical digital performance setup

- ▶ Controller: keyboard, touchscreen, buttons, knobs, etc.
- ▶ Sequencer: stores programs of MIDI for playback
- ▶ Synthesizer: generates the sound
- ▶ Effects: filters, echo/delay, reverb, chorus, flanger, etc.
- ▶ Headphones / speakers / recorders
- ▶ Can all be in one box or separate boxes

## A CLAMS performance setup

- ▶ A microcontroller / single board computer
- ▶ A serial terminal
- ▶ A DAC, amplifier, headphones / speakers / recorders
- ▶ Forth / C code DSL controller, synthesizer, effects

Previously on CLAMS

## The original concept - early 2022

- ▶ Forth for the Electro-Smith Daisy Seed
  - ▶ <https://electro-smith.com/products/daisy-seed>
  - ▶ Microcontroller board designed for digital music
  - ▶ ARM Cortex-M7 MCU, running at 480MHz
  - ▶ Hardware floating point and DSP instructions
  - ▶ 64 MB of SDRAM for up to 10 minute long audio buffers
  - ▶ 8 MB external flash
  - ▶ Stereo DAC output - 96kHz / 24-bit audio hardware
  - ▶ Both native and Arduino audio development tools
  - ▶ \$29.95US quantity one
  - ▶ Available in various packaged modules
  - ▶ Plan was both controller and synthesis in Forth



## Revised concept - early 2023

- ▶ Forth for the Raspberry Pi Pico WH
  - ▶ <https://www.raspberrypi.com/documentation/microcontrollers/pico-series.html>
  - ▶ Microcontroller board designed for general applications
  - ▶ Dual-core ARM Cortex-M0+, running at 133 Mhz
  - ▶ Co-processor for division, interpolation and I/O
  - ▶ No floating point or DSP instructions
  - ▶ 262 KB RAM
  - ▶ 2 MB flash
  - ▶ No audio hardware – I2S / DAC / amplifier expansion pack required
  - ▶ \$7US quantity one
  - ▶ Plan was both controller and synthesis in Forth

## Previous concepts problem 1: Lack of portability

- ▶ Need to hand-port Forth to individual MCUs
- ▶ Other desirable boards:
  - ▶ Teensy 4.1
    - ▶ <https://www.pjrc.com/store/teensy41.html>
  - ▶ Raspberry Pi Zero 2 W
    - ▶ <https://www.raspberrypi.com/products/raspberry-pi-zero-2-w/>
  - ▶ ESP32-S3 (Xtensa ISA), -C3 and -C6 (RISC-V ISA)
    - ▶ <https://www.espressif.com/en/products/socs/esp32>

## Teensy 4.1

- ▶ Microcontroller board designed for general applications
- ▶ ARM Cortex-M7, running at 400 MHz
- ▶ Hardware floating point and DSP instructions
- ▶ 1024 KB of RAM
- ▶ 7936 KB of flash
- ▶ No audio hardware but many add-on modules
- ▶ Comprehensive native audio library
  - ▶ [https://www.pjrc.com/teensy/td\\_libs\\_Audio.html](https://www.pjrc.com/teensy/td_libs_Audio.html)
- ▶ \$29.60US quantity one

## Raspberry Pi Zero 2 W

- ▶ Single-board computer designed for general applications
- ▶ Quad-core 64-bit ARM Cortex-A53, running at 1 GHz
- ▶ Hardware floating point and DSP instructions
- ▶ 512MB of RAM
- ▶ No flash - uses SD card
- ▶ No audio hardware but many add-on modules
- ▶ Runs Linux
- ▶ \$15US quantity one

## Previous concepts problem 2: Limited audio capability

- ▶ Only I2s/DAC/amplifier audio is practical in Forth
- ▶ Other desirable interfaces:
  - ▶ Class-compliant USB audio and MIDI
  - ▶ Bluetooth audio and MIDI
  - ▶ Specs too complex for easy Forth implementation
    - ▶ Effort/payoff ratio is enormous
  - ▶ Well-documented and tested C libraries exist

## CLAMS - The New Design

## Arduino or Linux for portability

- ▶ Target MCU boards all have Arduino support
- ▶ Raspberry Pi Zero 2 W has Linux support
- ▶ I2S / DAC audio is available on all boards
  - ▶ either onboard or expansion hardware
- ▶ Bluetooth audio is supported on boards with hardware
- ▶ USB MIDI is supported on all boards
- ▶ USB audio is supported on Teensy and Zero 2 W
  - ▶ Others in alpha testing

## Shore Pine Sound Systems AMY synthesizer

- ▶ Open source on GitHub (shore pine sound systems 2024a)
- ▶ Highly portable - written in C
- ▶ Has Arduino library
- ▶ Has a Python interface for both Linux and MCUs
- ▶ Handles both synthesis and I2S audio
- ▶ Very capable synthesizer - saves me months of Forth coding!
- ▶ Heart of the Tulip Creative Computer (shore pine sound systems 2024b)



Forth base: C3

## C3 Forth

- ▶ Open source on GitHub (Christopher Curl 2024a)
- ▶ Stack-based, byte-coded Forth VM written in C/C++
- ▶ Runs on Windows, MacOS, Linux (native)
- ▶ Runs on development boards - Raspberry Pi Pico and Teensy 4.1 (Arduino)
- ▶ Under active development
- ▶ Well-documented - comprehensive README

## C3 Forth extensions

- ▶ 10 Virtual registers
- ▶ 10 Temporary words
- ▶ Inline words
- ▶ Lexicons
- ▶ Easy to extend with user-defined op codes
- ▶ vi-inspired editor

## Bonus Forth content - C4!

- ▶ Open source on GitHub (Christopher Curl 2024b)
- ▶ “c4: A Forth system inspired by Tachyon and ColorForth”
- ▶ Arduino support in progress!
  - ▶ Very active “next-version” branch

## Road map - Tasks mostly in Priority Order

# 1. Integrate C3 and AMY on Pico WH / audio expansion

- ▶ Complete the second concept
- ▶ All the components work in Arduino
- ▶ Main new code is adding C3 opcodes for AMY

## 2. Make an album

- ▶ Adding AMY synthesizer has shortened development time
- ▶ Forth DSL will be built here
- ▶ The dogfooding process will hone the Forth DSL

### 3. Integrate C3 and AMY on Raspberry Pi Zero 2 W

- ▶ This is really the sweet spot for CLAMS!
  - ▶ Development cycle is easier on Linux
  - ▶ Synthesis capacity many times that of microcontrollers!
  - ▶ Linux USB audio and MIDI are well understood
  - ▶ Bluetooth audio and MIDI may be added
  - ▶ Many supporting audio software tools available
  - ▶ Total hardware cost is \$54.99US
    - ▶ <https://vilros.com/products/vilros-raspberry-pi-zero-w-2-port-n-play-ready-to-use-kit>



## Longer range

- ▶ Teensy with USB audio and MIDI
- ▶ Electro-Smith Daisy with Daisy hardware, USB MIDI
- ▶ ESP32

## Back Matter

## CLAMS on the web

- ▶ GitHub: <https://github.com/AlgoCompSynth/CLAMS>
- ▶ blog: <https://www.algocondsynth.com/#category:CLAMS>
- ▶ this presentation:
  - ▶ <https://github.com/AlgoCompSynth/CLAMS/blob/main/presentations/CLAMS-quest.pdf>

## Me on the web

- ▶ Mastodon: <https://mastodon.social/@AlgoCompSynth>
- ▶ LinkedIn: <https://www.linkedin.com/in/znmeb>
- ▶ Bandcamp: <https://algocompsynth.bandcamp.com>

## References

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