CLAMS - The Quest for Portability and Audio

Forth Day 2024

M. Edward (Ed) Borasky

2023-11-16

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 audio output - 96kHz / 24-bit audio hardware
  - Both native and Arduino audio development tools
  - No WiFi or Bluetooth
  - $29.95US quantity one
  - Available in various packaged modules
  - User interface and synthesis both done 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 audio expansion packs available
  - 2.4 GHz WiFi and Bluetooth
  - $7.00 US quantity one
  - User interface and synthesis both done in Forth

Stepping up a level - what does a digital synthesizer need?

- Accurately-timed PCM samples
- Digital-analog conversion for recording / performance
- A user interface for the composer / performer

I2S protocol

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 architecture), -C3 and -C6 (RISC-V architecture)
  - (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
- No WiFi / Bluetooth
- Comprehensive native audio library
- (https://www.pjrc.com/teensy/td_libs_Audio.html)
- HDMI video
- $29.60US quantity one

Raspberry Pi Zero 2 W

- Microcontroller board 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
- Runs Linux
- USB audio and MIDI
- Hardware for WiFi and Bluetooth
- HDMI video
- $15US quantity one

Previous concepts problem 2: Limited audio capability

- Only built-in DAC or I2S 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

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 audio is supported on all boards
  - DAC is 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 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

- Virtual regiters
- 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!
- I will evaluate it when Arduino support is done

Road map - Tasks mostly in Priority Order

Integrate C3 and AMY on Raspberry Pi Zero 2 W

- Devlopment cycle is easier on Linux
- Linux USB audio and MIDI are well understood
- Many supporting audio software tools available
- Total hardware cost is $54.00US
- https://vilros.com/products/vilros-raspberry-pi-zero-w-2-port-n-play-ready-to-use-kit

Make an album

- Using the Raspberry Pi Zero 2 W
- Adding AMY synthesizer has shortened development time
- The dogfooding process will hone the Forth user interface
- Some recording and editing software runs on the Zero 2 W

Integrate C3 and AMY on Pico I2S

- Backporting of album to small system will stress-test the system

Integrate C3 and AMY and USB audio on Teensy 4.1

- Teensy has no native I2S / DAC hardware
- Teensy does have native USB audio and MIDI in Arduino
- More powerful MCU than the Pico

Add CLAMS to Experimental Music Toolbox

- Another project of mine
- Open source on GitHub (AlgoCompSynth by znmeb 2024)
- Collection of open source tools for experimental music
  - CSound
  - SuperCollider
  - Pure Data
  - ChucK
  - My own R music software
  - JupyterLab with Python audio and AI software = Probably won't run on Pi Zero 2 W but runs fine on Pi 4

Longer range

- Electrosmith Daisy port
- ESP32 port
- USB MIDI
- USB audio on non-Teensy boards

Back Matter

CLAMS on the web

- GitHub: https://github.com/AlgoCompSynth/CLAMS
- blog: https://www.algocompsynth.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

AlgoCompSynth by znmeb. 2024. "Experimental Music Toolbox on GitHub." https://github.com/AlgoCompSynth/Experimental-Music-Toolbox; AlgoCompSynth by znmeb.

Christopher Curl. 2024a. "C3 on GitHub." https://github.com/CCurl/c3/; Christopher Curl.

———. 2024b. "C4 on GitHub." https://github.com/CCurl/c4/; Christopher Curl.

shore pine sound systems. 2024a. "AMY Synth on GitHub." https://github.com/shorepine/amy; shore pine sound systems.

———. 2024b. "Tulip Creative Computer on GitHub." https://github.com/shorepine/tulipcc; shore pine sound systems.