CLAMS - The Quest for Portability and Audio

Forth Day 2024

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Introduction

What is CLAMS?

- Command Line Algorithmic Music System
- Forth-controlled synthesizer (synth) for microcontrollers / SBCs

Some embedded audio terminology

- MIDI: Musical Instrument Digital Interface
  - a protocol for controlling synth
- 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
- Synth: 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, synth, 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 synth 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 / amplifer expansion pack required
  - $7US quantity one
  - Plan was both controller and synth 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
- $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 synth

- 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 synth and I2S audio
- Very capable synth - 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 synth 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!
  - Devlopment cycle is easier on Linux
  - Synth 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.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

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