system overview

I. HARDWARE

CURRENT HARDWARE

RPi Pico	Main microcontroller (PWM + GPIO management)
DFR0229	MP3 audio playback module (sampler)
TM1637 Display	4-digit 7-segment for menu and sequence UI
KY040 Encoder	Navigation knob with rotation and button
4x4 Keypad	Primary input matrix (samples, controls)
3.5mm TRS Port 1	Main audio output (stereo or mono blend)
3.5mm TRS Port 2	MIDI OUT or SYNC OUT toggleable
LP Filter	Bandpass filter for PWM synth (23.4 Hz–7.2 kHz)
LM358	Op-amp for signal buffering and blending

FUTURE ADDITIONS

TP4056	Lithium battery charge management (USB-C)
3.7V Li-Po	Power source (2500 mAh)
4x1 Keypad	Possible future I/O expansion
PETG Case	Enclosure for hardware assembly

Optional Audio FX Modules
(modular/expansion-ready)

- PT2399 Delay with control surface
- Diode Clipping Distortion with gain
- Transistor Tremolo (already implemented, toggleable)

II. SOFTWARE ARCHITECTURE

Language & OS

- MicroPython (Async + Threading)
- Event-driven architecture, with I/O polling via coroutines and background threading for concurrent synth playback

III. PROGRAM LOGIC

Programs & Folder Structure

- 4 user-selectable "Programs" (P1–P4)
- Each program saves to its own .json config file
- Program data includes:
    - BPM

    - Waveform
    - Synth Control Mode
    - Sequence Pattern
    - MIDI/SYNC Mode
- Samples are stored and triggered according to DFR0229 folder/file scheme (folder = program number, file = keypad index)

IV. FUNCTIONAL MODES

1. Sampler Mode

- Direct triggering of samples via keypad
- Uses DFPlayer async protocol
- Supports 16 samples (mapped 1–16 on 4x4 matrix)
- Output is stereo or mono (merged via analog blend)

2. Sequencer Mode

- 16-step pattern sequencer with live visual display (TM1637)
- Encoder selects step; keypad assigns sample
- Control buttons:
    - D: Start/Stop playback
    - C: Clear current step
    - B: Clear entire pattern
    - A: Toggle Tremolo FX
- Pattern auto-saves and auto-loads per program
- BPM affects:
    - Sample timing
    - MIDI Clock or SYNC pulse (selected via CONFIGURE)
- Sequence runs asynchronously, with idle visual feedback when stopped

3. Synthesizer Mode

- Monophonic DDS-style digital synth via PWM (GPIO15)
- Waveforms:
    - SIN, TRI, SAW, SQR (generated via 256-point lookup tables)
- Keypad maps to C3–C4 notes
- Encoder adjusts real-time modulation target:
    - DISABLED, CUTOFF, ASDR, FILTER MOD, FILTER SWEEP, PITCH BEND
- Synth playback uses background threading
- Static bandpass filter applied post-PWM
- Output merged via op-amp circuit with DFR0229 stream

4. Configuration Menu

Accessible per program, with options:

- BPM: Set tempo (60–140 BPM)
- WAVE: Select default waveform for synth
- CTRL: Assign encoder's control mode in synth
- MIDI / SYNC:
    - Mutually exclusive
    - Determines output type on TRS Port 2

V. I/O & DISPLAY INTERFACE

Input	Function
Encoder	Navigation + value editing
Encoder SW	Select / Back
Keypad	Note/sample trigger & sequence edit

Output	Purpose
TM1637 Display	4-char mode/status & sequence grid
TRS Port 1	Stereo or mono audio out
TRS Port 2	MIDI or SYNC signal out

VI. ADVANCED FEATURES

- Live pattern recording: Sample assignment while sequence runs
- Async + threading:
  - Asyncio for playback/scheduler loop
  - Thread for continuous synth tone generation
- Power system (planned):
  - USB-C charging via TP4056
  - Rechargeable Li-Po battery