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

II. SOFTWARE ARCHITECTURE

LANGUAGE & OPERATING SYSTEM

MicroPython (Async + Threading)

Event-driven architecture, with I/O polling via coroutines and background threading for concurrent synth playback

III. PROGRAM LOGIC

PROGRAMS AND DATA STRUCTURES

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:
  - START/STOP
  - DELETE STEP
  - CLEAR PATTERN
  - TOGGLE DUAL MODE
- 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	Description
Encoder	Navigation + value editing

Encoder SW	Select / Back
Keypad	Note/sample trigger & sequence edit

Output	Description
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

Dual mode:
- Allows for concurrent synth/sequencer operaiton

Power system:
- USB-C charging via TP4056
- Rechargeable Li-Po battery