EA801A - Laboratório de projetos de sistemas embarcados.

Equipe: Dupla 03.

Integrantes:
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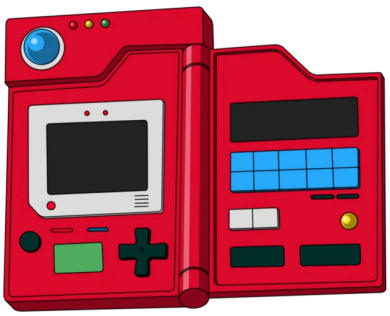
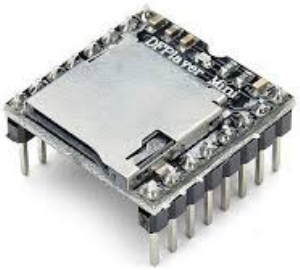
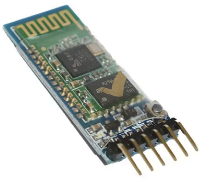

Projeto 03 - Pokédex III

Campinas, 2025.

1. Introdução.

O presente projeto tem como finalidade o desenvolvimento de um sistema embarcado interativo, integrando múltiplos periféricos com funcionalidades gráficas e sonoras, controladas localmente por meio de um joystick analógico e remotamente por comunicação Bluetooth. Em um primeiro momento, foi considerada a possibilidade de incorporar o módulo Bluetooth ao circuito previamente desenvolvido no Projeto 2, com o objetivo de estender suas funcionalidades e reutilizar a base já construída. No entanto, essa integração enfrentou sérias dificuldades técnicas, sobretudo relacionadas à comunicação serial; as instabilidades nas conexões UART, provocadas por conflitos entre os periféricos conectados, comprometeram significativamente o funcionamento do sistema, configurando-se como o principal obstáculo encontrado durante o processo de desenvolvimento.

Diante desse cenário, optou-se por reformular a abordagem inicial, concebendo o Projeto 3 como uma proposta autônoma, desvinculada diretamente do projeto anterior. Ainda assim, manteve-se a estratégia pedagógica de reaproveitamento de módulos e conceitos já explorados, a fim de consolidar os conhecimentos adquiridos ao longo da disciplina. A nova arquitetura do sistema contempla a utilização de um display OLED via interface I²C, um joystick analógico conectado a uma entrada analógica do microcontrolador, um módulo DFPlayer Mini para reprodução de arquivos de áudio e um módulo Bluetooth para recepção de comandos remotos. O microcontrolador, programado em MicroPython, é responsável por gerenciar a lógica de exibição de imagens no display e o controle de reprodução e volume das faixas de áudio, a partir de entradas locais e remotas.

Cabe destacar que, diferentemente dos projetos anteriores, esta proposta incluiu a confecção de uma placa de circuito impresso (PCB), desenvolvida com o apoio do SATE (Serviço de Apoio Técnico ao Estudante). Essa etapa representou um avanço significativo no processo de prototipagem, proporcionando maior organização, robustez e confiabilidade ao circuito final. Dessa forma, o projeto evidencia não apenas a aplicação prática dos conhecimentos teóricos adquiridos, mas também o amadurecimento técnico dos integrantes do grupo na concepção e implementação de soluções embarcadas mais profissionais.

2. Requisitos de projeto.

O presente projeto consiste na implementação de um sistema embarcado interativo, desenvolvido com base na placa Raspberry Pi Pico W programada em MicroPython, cuja finalidade é integrar múltiplos periféricos com o intuito de oferecer uma interface de navegação gráfica e controle multimídia. Os principais módulos conectados ao sistema são: um joystick analógico, um display OLED (modelo SSD1306), um reprodutor de áudio DFPlayer Mini com alto-falante acoplado e um módulo de comunicação Bluetooth. A proposta do sistema é permitir a navegação entre imagens armazenadas, por meio do controle

direcional do joystick, e o controle de reprodução de faixas de áudio via comandos recebidos por interface sem fio.

A unidade central de processamento do sistema é a placa de desenvolvimento que abriga o microcontrolador. Essa placa é responsável pela aquisição de dados, gerenciamento das comunicações (I²C e UART) e execução da lógica de controle. A alimentação elétrica é fornecida via conexão USB com um computador, o que também permite a programação e a depuração do firmware.

O joystick analógico, responsável pela navegação entre os diferentes bitmaps, está conectado a uma entrada analógica do microcontrolador (pino GPIO27), que realiza a leitura do eixo X por meio de um conversor analógico-digital (ADC). A alimentação do joystick é realizada por meio dos trilhos de VCC e GND da protoboard, devidamente conectados à fonte principal do sistema.

O display OLED, com resolução de 128x64 pixels, realiza a exibição gráfica dos bitmaps em tempo real. Este componente é conectado via barramento I²C, sendo os sinais SDA e SCL conectados aos pinos GPIO14 e GPIO15, respectivamente. A alimentação elétrica do display é feita através da linha de 3,3V, com conexão apropriada ao terra comum do circuito.

O reprodutor de áudio DFPlayer Mini é responsável pela reprodução das faixas armazenadas em cartão microSD. Esse módulo é conectado ao microcontrolador por meio da UART0, sendo o pino TX do DFPlayer conectado ao pino RX (GPIO17) do microcontrolador, e o pino RX do DFPlayer conectado ao TX (GPIO16). A alimentação do módulo é feita pela protoboard, e a saída de áudio é direcionada a um alto-falante fixado em suporte plástico, garantindo estabilidade e isolamento acústico.

Adicionalmente, o módulo Bluetooth (possivelmente dos modelos HC-05 ou HC-06) permite o recebimento de comandos remotos oriundos de dispositivos externos, como smartphones. Esse módulo opera via UART1, estando seus pinos TX e RX conectados, respectivamente, aos pinos RX (GPIO9) e TX (GPIO8) do microcontrolador. Por meio desta interface, o usuário pode alternar entre faixas, ajustar o volume e pausar ou retomar a reprodução de áudio.

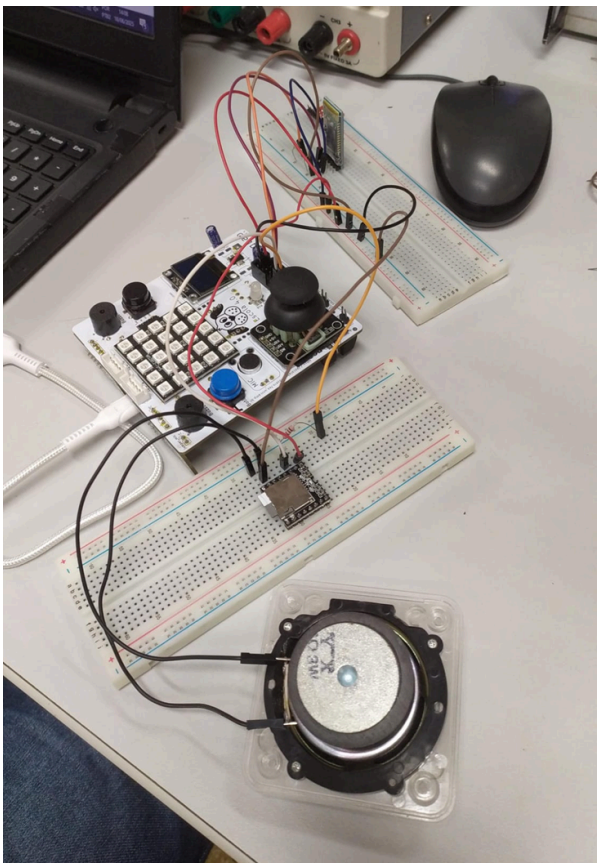

Imagem 1: Conexões do circuito, para a montagem inicial sem a PCB.

3. Metodologia e resultados.

O código apresentado nos anexos implementa um sistema embarcado interativo desenvolvido como parte de um projeto laboratorial, utilizando um microcontrolador compatível com MicroPython. Esse sistema integra múltiplos periféricos — incluindo um display OLED, um joystick analógico, comunicação via Bluetooth e um reprodutor de áudio (DFPlayer Mini) — com o objetivo de fornecer uma interface multimodal para visualização gráfica e controle sonoro.

Inicialmente, o barramento I²C é configurado nos pinos 14 (SDA) e 15 (SCL), operando a uma frequência de 400 kHz, para comunicação com o display OLED do tipo SSD1306, com resolução de 128x64 pixels. O código realiza uma verificação da presença do dispositivo no barramento, por meio de varredura do endereço I²C (0x3C). Caso o display não seja detectado, o sistema entra em um estado de espera indefinido, interrompendo a execução e informando o erro ao usuário.

A leitura do eixo horizontal de um joystick analógico é realizada via entrada analógica (ADC) no pino 27. Essa leitura é utilizada para permitir a navegação entre diferentes imagens armazenadas no sistema, exibidas sequencialmente no display.

O projeto também estabelece duas interfaces UART. A primeira (UART1), configurada nos pinos 8 (TX) e 9 (RX), é destinada à comunicação com um módulo Bluetooth, permitindo o envio de comandos remotos ao sistema, como a troca de faixas e o controle de volume. A segunda interface (UART0), nos pinos 16 (TX) e 17 (RX), é reservada à comunicação com o módulo DFPlayer Mini, responsável pela reprodução de arquivos de áudio armazenados em um cartão microSD. Após inicialização, o reprodutor é configurado com um volume inicial de 12 (em uma escala de 0 a 30), e a reprodução da primeira faixa é iniciada automaticamente.

Para a visualização gráfica, o sistema utiliza uma função que recebe uma matriz de bytes representando um bitmap monocromático. Essa matriz é convertida para um objeto do tipo `FrameBuffer`, compatível com o driver do display SSD1306, e exibida na tela. Um conjunto de até dez imagens (bitmaps) pode ser armazenado em uma lista e navegado sequencialmente através da movimentação do joystick.

A navegação pelas imagens ocorre com base nos valores lidos do eixo X do joystick. Valores superiores a 50000 indicam movimento para a direita, enquanto valores inferiores a 10000 indicam movimento para a esquerda. Em ambos os casos, o índice da imagem atual é atualizado de forma circular, permitindo retorno ao início ou ao fim da lista conforme necessário. A leitura do estado do joystick é feita de forma a evitar repetição de comandos enquanto o movimento estiver constante.

Além disso, o sistema monitora constantemente a chegada de comandos via comunicação Bluetooth. Cada comando é interpretado conforme um conjunto de instruções pré-definidas: o caractere `'a'` retrocede para a faixa anterior, `'d'` avança para a próxima faixa, `'w'` aumenta o volume, `'s'` reduz o volume, e `'p'` alterna entre pausar e retomar a reprodução. Cada comando recebido é seguido de um pequeno atraso (50 ms) para evitar múltiplas leituras não intencionais.

Por fim, o código é executado dentro de um laço principal contínuo, garantindo o monitoramento em tempo real das entradas do joystick e da interface Bluetooth. A combinação desses recursos resulta em uma interface embarcada interativa e multimodal, adequada para aplicações como sistemas de mídia portáteis, instalações educacionais ou interfaces experimentais de exibição audiovisual.

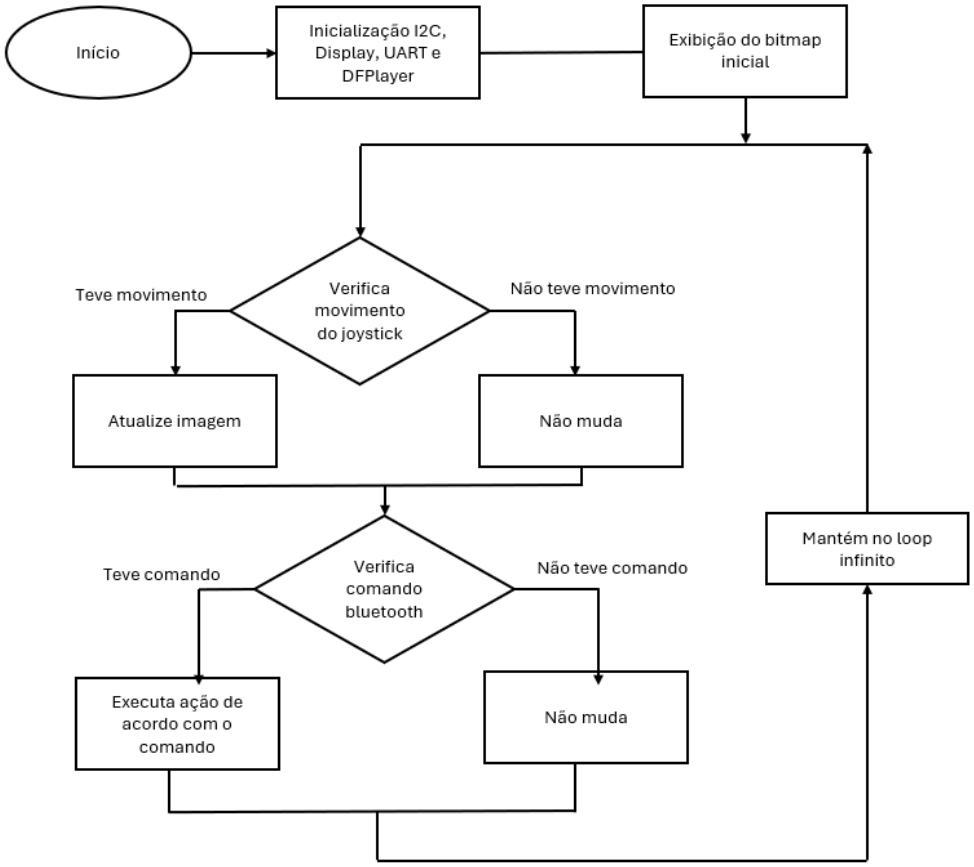

Imagem 2: Fluxograma do código utilizado.

Finalizada a apresentação do funcionamento do firmware embarcado, logo tem-se que a placa de circuito impresso (PCI), desenvolvida através da ferramenta KiCad, realizada para comportar o circuito elétrico, tem sua disposição apresentada na imagem adiante.

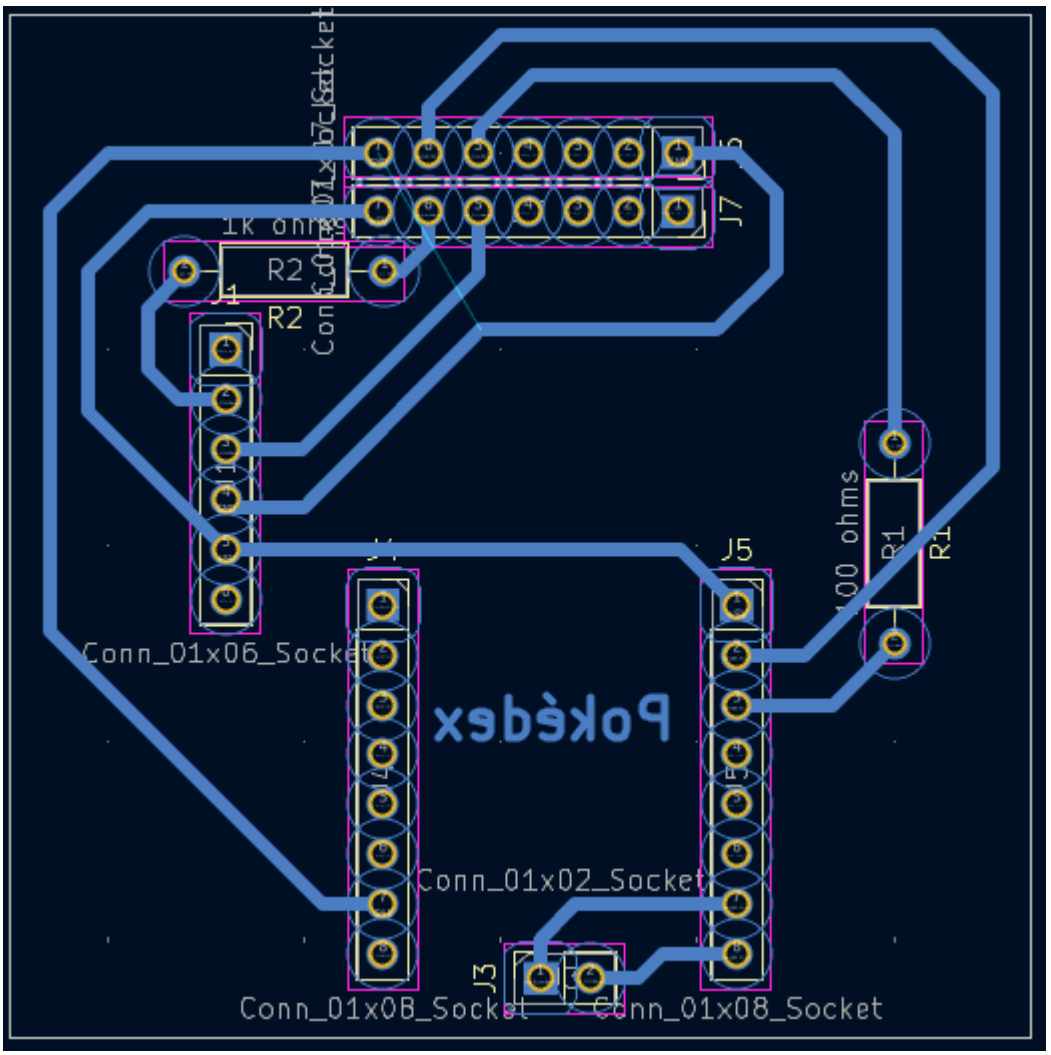

Imagem 3: Layout da PCI.

Uma vez com que os arquivos de furação e para realização das trilhas e do corte foram devidamente gerados, logo se repassou estes para o SATE que confeccionou a placa, sendo a versão final desta apresentada abaixo.

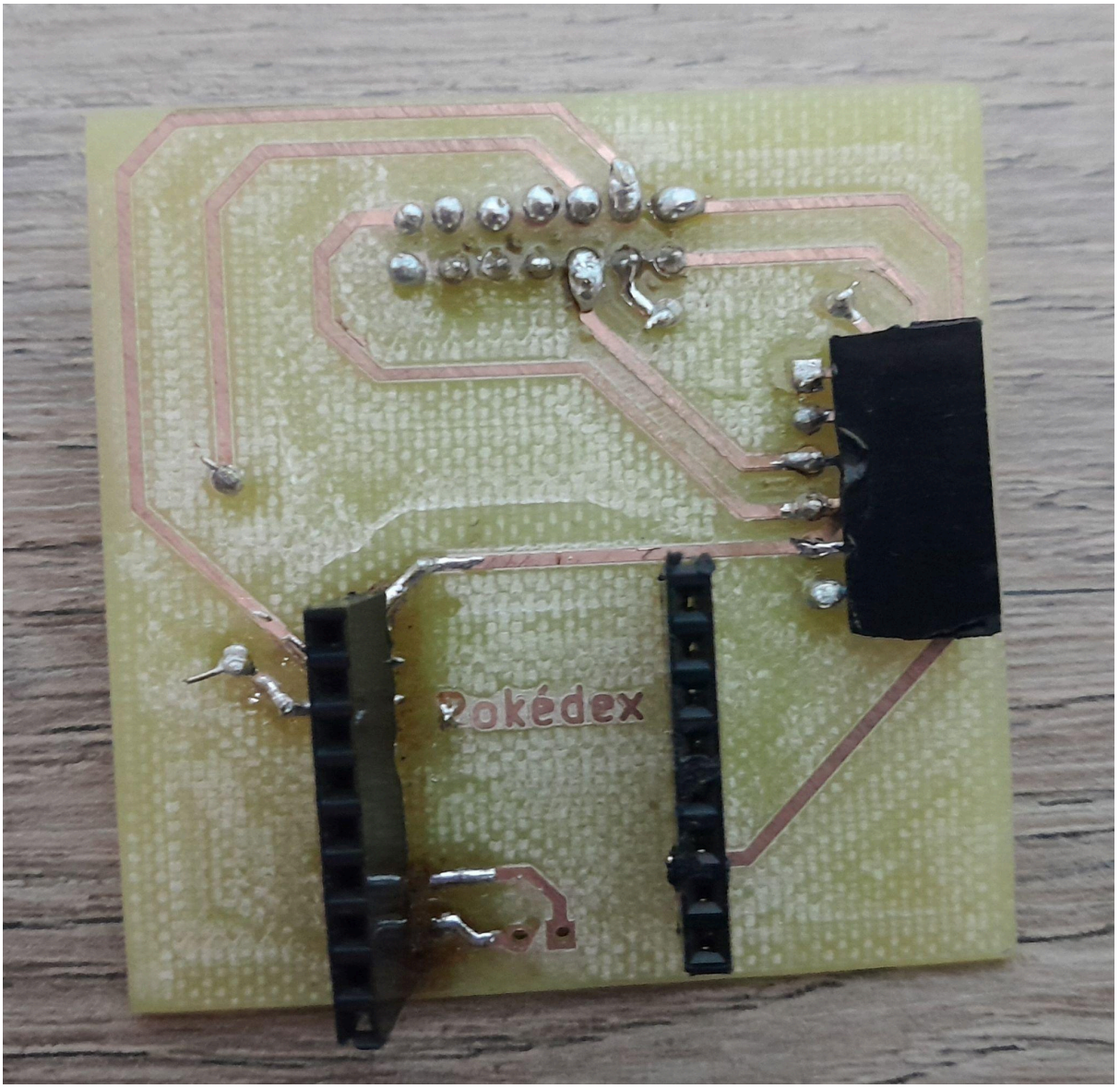

Imagem 4: Visão da parte de trás da PCI.

Uma vez com a placa se realizou a solda dos componentes, contudo, devido a problemas muito provavelmente associados a solda destes ou de eventuais conexões, logo não se foi capaz de implementar as funcionalidades descritas pela PCI, utilizando para a gravação do funcionamento do sistema a montagem inicial com placa de teste.

O vídeo do funcionamento do projeto é apresentado em https://youtu.be/VlzRxHUEqs4?si=khivdI4icKIIs2n3, onde também em [7] se encontra a documentação via GitHub da atividade contemplando o vídeo, o firmware utilizado, o atual relatório e a forma de execução do projeto, com também os arquivos do KiCad.

4. Referências.

[1] Cia, Arduino e. “Como Usar O Módulo MP3 DFPlayer Mini.” *Arduino E Cia*, 25 Oct. 2017, www.arduinoecia.com.br/modulo-mp3-dfplayer-mini-dfrobot-arduino/. Accessed 14 May 2025.
[2] “Raspberry Pi Pico W GPIO Pinout.” *Pinout.xyz*, 2025, picow.pinout.xyz/. Accessed 14 May 2025.
[3] BitDogLab. “BitDogLab-C/Neopixel_pio at Main · BitDogLab/BitDogLab-C.” *GitHub*, 2024, github.com/BitDogLab/BitDogLab-C/tree/main/neopixel_pio. Accessed 14 May 2025.
[4] Oliver, Lucas, and Fabio Henrique. “BitDogLab.” *GitHub*, 11 Feb. 2025, github.com/BitDogLab. Accessed 14 May 2025.
[5] Nothingtopus. “EA801A_1S2025_Dupla03/Projeto_02 at 21fc542448e8de90de1982a8bf6c5e61f9b66ec0 · Nothingtopus/EA801A_1S2025_Dupla03.” *GitHub*, 2025, github.com/Nothingtopus/EA801A_1S2025_Dupla03/tree/21fc542448e8de90de1982a8bf6c5e61f9b66ec0/Projeto_02. Accessed 19 May 2025.
[6] https://youtu.be/VlzRxHUEqs4?si=khivdI4icKIIs2n3.
[7] Nothingtopus. “EA801A_1S2025_Dupla03/Projeto_03 at Main · Nothingtopus/EA801A_1S2025_Dupla03.” *GitHub*, 2025, github.com/Nothingtopus/EA801A_1S2025_Dupla03/tree/main/Projeto_03. Accessed 4 July 2025.

5. Anexos.

```
#////////////////////////////////////////////////////////////////
#//    EA801A - Laboratório de projetos de sistemas embarcados.  //
#//    Equipe: Dupla 03.                                         //
#//    Integrantes:                                              //
#//    Antonio Francisco Morino Neto, RA: 194308;                //
#//    Otávio Briske Lima, RA: 220716;                           //
#//    Pedro Gimeno de Oliveira, RA: 239934 .                    //
#//    Projeto 03 - Pokédex III                                  //
#//    Campinas, 2025.                                           //
#////////////////////////////////////////////////////////////////

#//////////////////////////////
#// Importação de Recursos: //
#//////////////////////////////

from machine import Pin, I2C, ADC, UART
from ssd1306 import SSD1306_I2C
import framebuf
from time import sleep_ms
from dfplayermini import DFPlayerMini

#////////////////////////////////////////////////
#// Inicialização I2C, Display, UART e DFPlayer //
#////////////////////////////////////////////////

# Inicializa I2C
i2c = I2C(1, scl=Pin(15), sda=Pin(14), freq=400000)

# Inicializa display
oled = SSD1306_I2C(128, 64, i2c, addr=0x3C)

# Verifica se o display está presente
if 0x3C not in i2c.scan():
    print("Erro: display não encontrado.")
    while True:
        pass

# Inicializa Joystick
joy_x = ADC(Pin(27))

# Inicializa UART para Bluetooth
uart_bt = UART(1, baudrate=9600, tx=Pin(8), rx=Pin(9))

# Inicializa DFPlayer
player = DFPlayerMini(0, 16, 17)
player.reset()
sleep_ms(1000)
player.set_volume(12)
player.select_source('sdcard')
player.play(1)

music_playing = True
current_track = 1
volume = 12
max_tracks = 20
```

```
#////////////////////////////////
#// Exibição do bitmap inicial //
#////////////////////////////////
def mostrar_bitmap(bitmap_bytes):
    fb = framebuf.FrameBuffer(bytearray(bitmap_bytes), 128, 64, framebuf.MONO_HLSB)
    oled.fill(0)
    oled.blit(fb, 0, 0)
    oled.show()

bitmap1 = bytes([0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
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0xff, 0xff, 0xff, 0xef, 0xff, 0xff, 0xff, 0xdf, 0xff, 0xff, 0xf6, 0xff, 0xff, 0xff, 0xff, 0xff,
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0xff, 0xff, 0xff, 0xef, 0xff, 0xff, 0xff, 0xdf, 0xff, 0x7f, 0xf6, 0xff, 0xff, 0xff, 0xff, 0xff,
0xf1, 0x87, 0x77, 0x0e, 0x3f, 0x18, 0x47, 0xd1, 0x86, 0x10, 0xf6, 0x9c, 0x3f, 0xff, 0xff, 0xff,
0xef, 0xfb, 0x76, 0xed, 0xbe, 0xd9, 0x37, 0xcd, 0xfb, 0x7f, 0x76, 0x6f, 0xdf, 0xff, 0xff, 0xff,
0xef, 0xc3, 0x76, 0xec, 0x1e, 0x0b, 0xb7, 0xdd, 0xc3, 0x78, 0x76, 0xee, 0x1f, 0xff, 0xff, 0xff,
0xef, 0xbb, 0x76, 0xed, 0xfe, 0xfb, 0xb7, 0xdd, 0xbb, 0x77, 0x76, 0xed, 0xdf, 0xff, 0xff, 0xff,
0xef, 0xb3, 0x76, 0xed, 0xfe, 0xfb, 0xb7, 0xcd, 0xb3, 0x76, 0x76, 0xed, 0x9f, 0xff, 0xff, 0xff,
0xf1, 0x83, 0x87, 0x0e, 0x3f, 0x1b, 0xb7, 0xd1, 0x83, 0x90, 0x76, 0xec, 0x1f, 0xff, 0xff, 0xff,
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0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff])

bitmaps = [bitmap1, bitmap2, bitmap3, bitmap4, bitmap5,
           bitmap6, bitmap7, bitmap8, bitmap9, bitmap10]
indice = 0
mostrar_bitmap(bitmaps[indice])

#/////////////////////////////////////
#// Verifica movimento do joystick //
#/////////////////////////////////////

def ler_joystick_x():
    valor = joy_x.read_u16()
    if valor > 50000:
        return 'direita'
    elif valor < 10000:
        return 'esquerda'
    else:
        return 'neutro'

estado_anterior = 'neutro'

#//////////////////////////////////////////////////////////////////////
#// Loop principal: Atualização da imagem e comandos via Bluetooth  //
#//////////////////////////////////////////////////////////////////////

while True:
    estado = ler_joystick_x()
#/////////////////////////
#// Atualiza a imagem  //
#/////////////////////////

    if estado != estado_anterior:
        if estado == 'direita':
            indice = (indice + 1) % len(bitmaps)
            mostrar_bitmap(bitmaps[indice])
            sleep_ms(200)
        elif estado == 'esquerda':
            indice = (indice - 1) % len(bitmaps)
            mostrar_bitmap(bitmaps[indice])
            sleep_ms(200)

#/////////////////////////////
#// Não atualiza a imgamem //
#/////////////////////////////

        estado_anterior = estado

#/////////////////////////////////
#// Verifica comando bluetooth //
#/////////////////////////////////

    if uart_bt.any():
        comando = uart_bt.read(1)

        # Comando: faixa anterior
        if comando == b'a':
            current_track -= 1
            if current_track < 1:
                current_track = max_tracks
            player.play(current_track)
            music_playing = True

        # Comando: próximo faixa
        elif comando == b'd':
            current_track += 1
            if current_track > max_tracks:
                current_track = 1
            player.play(current_track)
            music_playing = True

        # Comando: aumentar volume
        elif comando == b'w':
            if volume < 30:
                volume += 1
                player.set_volume(volume)

        # Comando: abaixar volume
        elif comando == b's':
            if volume > 0:
                volume -= 1
                player.set_volume(volume)

        # Comando: pausar/despausar
        elif comando == b'p':
            if music_playing:
                player.pause()
            else:
                player.start()
            music_playing = not music_playing

        sleep_ms(50)
```