Proposal: Digital Accordion

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Introduction

Problem

Traditional accordions are expensive, delicate instruments that require regular maintenance. Their sound quality is sensitive to environmental factors such as temperature and humidity, making them less reliable in varying conditions. Additionally, learning to play the accordion presents a steep learning curve, especially for beginners.

Currently, digital accordions on the market cost over $7,000, making them inaccessible to most entry-level players and hobbyists. These challenges highlight the need for an affordable, beginner-friendly, and modular digital accordion that can replicate the traditional instrument’s features while addressing its limitations.

Solution

We propose to build a low-cost (less than $150), modular, and beginner-friendly 12-bass digital accordion. Our design will replicate the sound and functionality of a traditional accordion using modern electronics while offering improved durability and ease of maintenance.

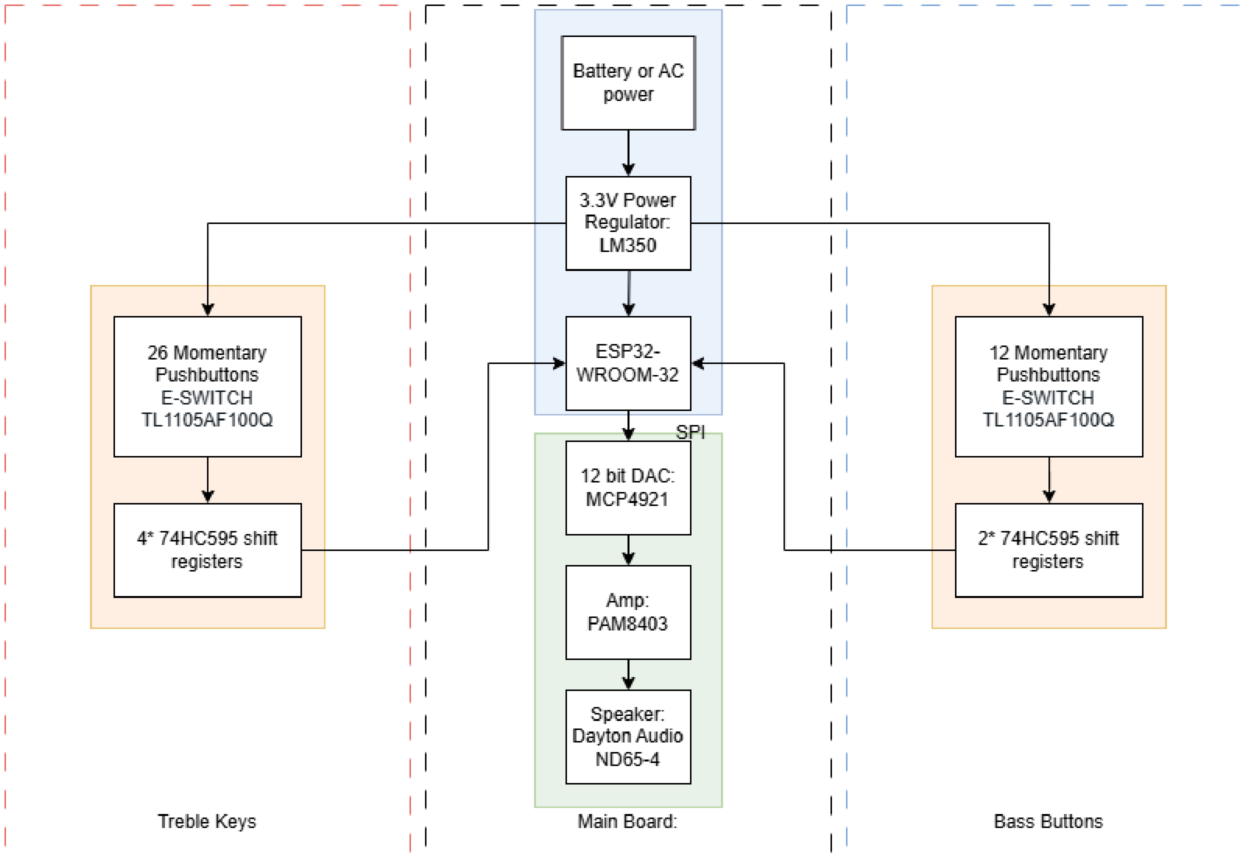
High Level Requirements

Our project will be considered successful if it meets the following testable criteria:

1. Sound output has a signal to noise ratio less than 40dB.
2. Synthesized output has a total harmonic distortion less than 1%.
3. Able to play polyphony sounds (3 or more keys pressed simultaneously)

Design

Block Diagram



Subsystem Overview:

The solution will include the following subsystems:

1. Input Subsystem: Detects user inputs from bass buttons and treble keys.
2. Sound Synthesis Subsystem: Generates high-quality polyphony accordion sounds using an ESP32.
3. Output Subsystem: Delivers high quality audio through wired connections.

The system will detect key presses via shift registers, process the input in theESP32 to synthesize accordion sounds, and output the audio.

Subsystem 1: Key Input

This subsystem is responsible for detecting treble key and bass button presses. A matrix scanning approach will minimize the GPIO usage while ensuring accurate detection.

Design:

Matrix Configuration: A 5x8 matrix (5 rows and 8 columns) will be used to detect inputs from 26 treble keys and 12 bass buttons.

Components:

- Tactile push buttons (low-cost option) or capacitive touch sensors (for enhanced user experience).
- GPIO pins on the micro controller for interfacing with the matrix.

Key Features:

- Accurate key press detection with minimal input lag.
- Scalable design for modularity.

Requirements:

- Must detect all key presses within 5ms latency.
- The key matrix must use ≤ 13 GPIOs (5 rows + 8 columns).
- Key detection must have a debounce time ≤ 10ms.
- If any row or column is disconnected, keys in that section must not interfere with others.

Tolerance:

- To ensure accurate key detection, the scan rate must be faster than the fastest expected key press interval.

Subsystem 2: Sound Synthesis Subsystem

This subsystem synthesizes high-quality accordion sounds in real time based on user inputs.

Design:

- Use a MIDI sound bank with pre-recorded accordion samples to replicate authentic sounds.
- Generate polyphonic sounds by combining waveforms for multiple notes.

- Utilize built-in DAC for waveform generation or an external DAC for higher audio quality.

Components:

- Microcontroller with DSP and DAC capabilities.
- External DAC for better audio quality.
- Flash memory or SD card to store sound samples and MIDI files.
- Optional: Low-pass filter for improved audio output.

Requirements:

- DAC output must have ≥ 12-bit resolution
- SPI clock speed must be ≥ 1MHz

Tolerances:

- The ESP32’s internal DAC is low resolution (8-bit) and creates noise. Using MCP4921 (12-bit) ensures cleaner sound.SPI transfer rate at 1MHz ensures no lag in sound generation.

Subsystem 3: Output Subsystem

This subsystem delivers audio to external devices through both wired and wireless methods.

Design:

- Wired Output: A 3.5mm audio jack with an amplifier will support headphones or external speakers.
- (Optional) Bluetooth Output: Integrate Bluetooth streaming for wireless audio playback.

Components:

- Audio amplifier.
- 3.5mm audio jack and connectors.
- (Optional) Bluetooth module.

Requirements:

- Speaker output must be ≥ 85dB SPL at 1m
- Amplifier must handle at least 3W power per channel

Tolerance:

- The amplifier may not supply enough power for the speaker. Using PAM8403 for 3W output ensures compatibility with 4Ω speakers or Using a higher-power amplifier (e.g., TPA3116D2) would allow louder sound.

Ethics and Safety

Issue 1: Intellectual Property Compliance
Problem: Unauthorized use of MIDI sound banks or pre-recorded accordion samples could violate copyrights.
Solution: Use open-source MIDI libraries or create custom accordion sound samples to avoid legal issues.

Issue 2: Hearing Protection & Volume Limits
Problem: High speaker output levels could cause hearing damage over prolonged use.
Solution: Use automatic gain control (AGC) to limit volume output to ≤85dB SPL.

Issue 3: Overheating Prevention
Problem: The LM350 voltage regulator and PAM8403 amplifier may overheat, leading to fire hazards.
Solution: Add heat sinks or fans to prevent overheating.

Issue 4: Overheating Prevention 2
Problem: Poor ventilation inside the enclosure could trap heat, increasing the risk of fire.
Solution: Design the enclosure with a ventilation slot.