Nexys4 Audio Player

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Design
Top Level Design Architecture
Reading From SD Card

- **Clock**
  - 100-400MHz

- **Communication Method**
  - Secure Digital (SD)
  - Serial Peripheral Interface (SPI)

- **Format**
  - FAT16 vs FAT32

- **Pinouts**
  - Different for each method
  - Initialization will fail if no pullup’s
Operation:
- Single data line (DAT0) or four data lines (DAT0-DAT3).
- Command is transferred serially on the CMD line.
- Response is transferred serially on the CMD line.
- Data is transferred in Blocks
  - Block are always followed by CRC (confirmation) bits

Process:
- Command (48 bits) to SD card
  - Command (CMD17) = “001000” for read
  - Argument = Data Address
- 8 clock cycles (SD card)
- Response (48 bits) from SD card
- Receive .wav data packet

Figure 1: Multiple block read operations

Table 1: Command and Response format
SD Protocol Timing
SPI Protocol

Initialization
- DI and SD = 1
- Wait minimum 90 clock cycles
- CMD0 = 0x00000000
- Sent CMD1 to check status
- Response change from Idle to ready (0x01 → 0x00)

Process
- Send command signal (48 bits)
- Wait 8 clock cycles for SD card to process
- SD card sends 48-bit response
- Command Response Time (N_{CR})
- 0 to 8 bytes
- SD card then sends data stream

Figure 1. Single block read operation
Figure 2. Timing of single block read operation
SD (Secure Digital Card) Uncertainties

- FAT32 SD card formatting
  - Where exactly is the data located within the SD card file directory?

- Timing of the .wav file message

- Was the entire length of the .wav file being received?
SD Format

- File Allocation Table (FAT)
  - Disk divided into clusters
  - First 512 bytes is boot sector
  - Cannot be changed
  - Stores information about disk
  - 4 to 64 sectors per cluster
  - Clusters determine where a file is located
- FAT16
  - Cards 128MB to 2GB
- FAT32
  - Cards 2GB to 32GB
FAT: What We Know

Based on the Boot Sector Information

- 512 bytes per sector
- 64 sectors per cluster
- 1 reserved sector
- 512 Root Directory Entries
- 3854329 Sectors in File System
- 2 FAT copies
- 236 Sectors per FAT
- FAT #1
  - Offset: 512 - 121343
- FAT #2
  - Offset: 121344 - 242175
- Total Cluster Size: 32,768 bytes
PCM (Pulse Code Modulation)

- Method used to digitally represent a sampled Analog Signal
- Amplitude of the signal is sampled at regular intervals
  - Standard form of digital audio in computers, compact discs, etc.
- Each Amplitude or step is “quantized” to the nearest value in a set of digital steps
PWM (Pulse Width Modulation)

- Modulation technique used to encode a message in a pulsing signal
- Used to control the power supplied to electrical devices
- PWM has been used to play back a crude version of a PCM signal
  - Speakers driven by two voltage levels, 0V and 5V
  - A mono audio output can be obtained by carefully timing the pulses and relying on the speakers physical filtering properties
  - Sound output is typically very low quality
  - Generally used in soundtracks of many classic video games
PCM samples are taken at a regular clock interval. These signals represent a value between 0 and 255. Using a clock we can convert these values into the appropriate duty cycles. These duty cycles are converted to the duration at which the pulses are output in the PWM signal. These varying pulse widths are what determine the voltage output which in turn creates the sound output from the speaker.
Timer (Seven Segment Display)

- Interfaced to keep track of the total time for which each sound plays.
- Starts counting when the SD PCM data transfers.
- Uses the PCM output of the Microprocessor unit to know when to stop based on the output.
- First 4 displays used for name of track.
- Last 4 displays used for timer.
Display FSM’s

7 Seg Displays

Timer
Further Design Applications

- Interfacing the SD card with the appropriate and understanding the overall file structure will lead to many different applications including:
  - Loading multiple tracks
  - Saving recorded tracks
  - Looping multiple sounds
  - Audio Amplification