Nexys4 Audio Player

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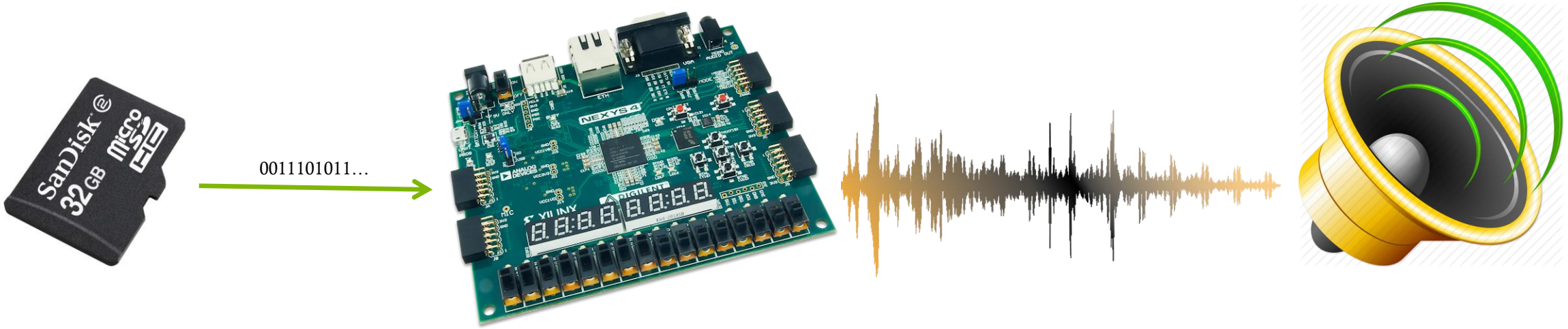
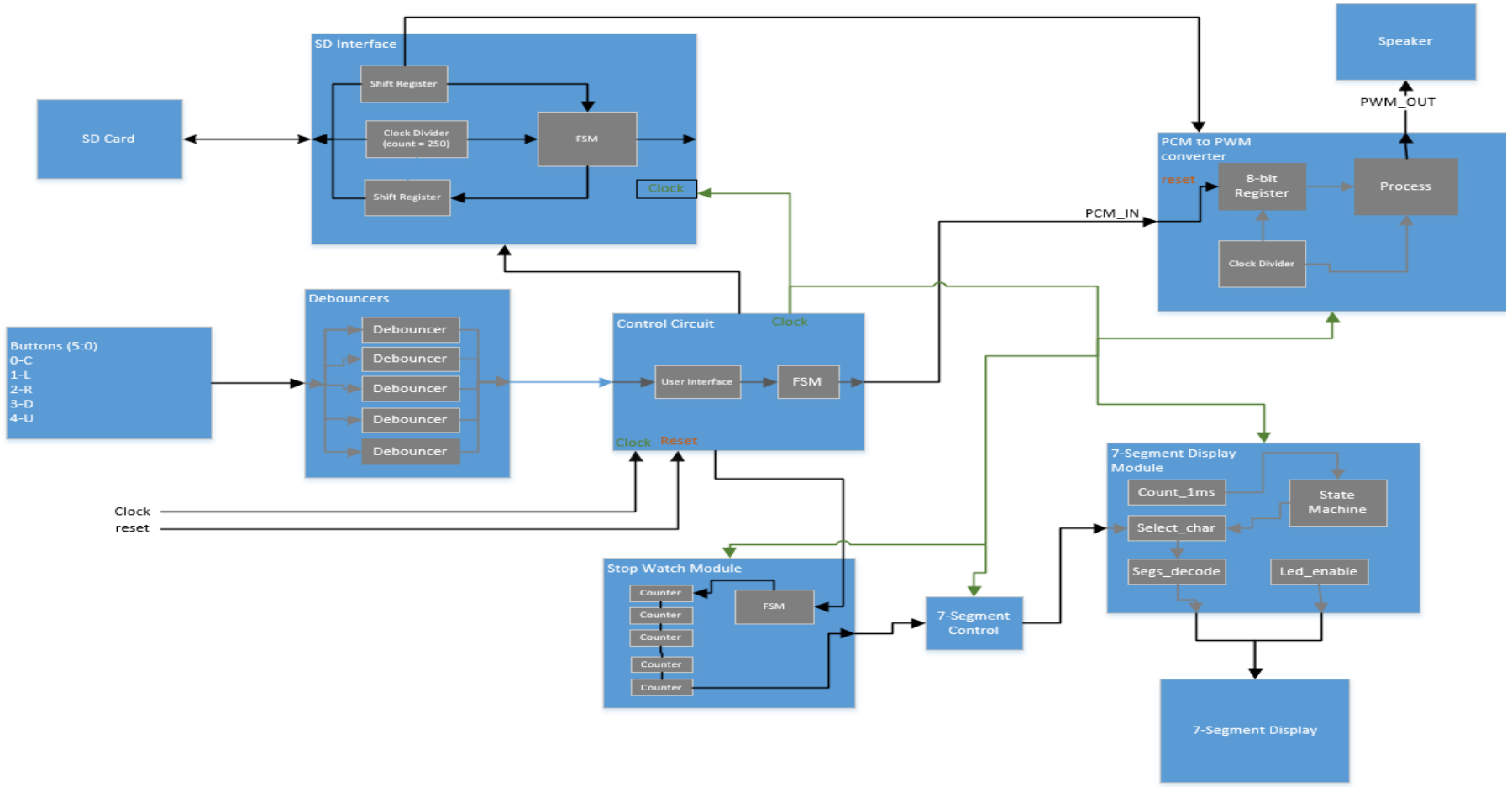
- PCM vs. PWM signals
- Seven Segment Clock (Timer)
- Further Design Implementations

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

Pin	Name	Function (SD Mode)	Function (SPI Mode)
1	DAT3/CS	Data Line 3	Chip Select/Slave Select (SS)
2	CMD/DI	Command Line	Master Out Slave In (MOSI)
3	VSS1	Ground	Ground
4	VDD	Supply Voltage	Supply Voltage
5	CLK	Clock	Clock (SCK)
6	VSS2	Ground	Ground
7	DAT0/DO	Data Line 0	Master In Slave Out (MISO)
8	DAT1/IRQ	Data Line 1	Unused or IRQ
9	DAT2/NC	Data Line 2	Unused

Table 1: SD Card Pin Assignments [2].

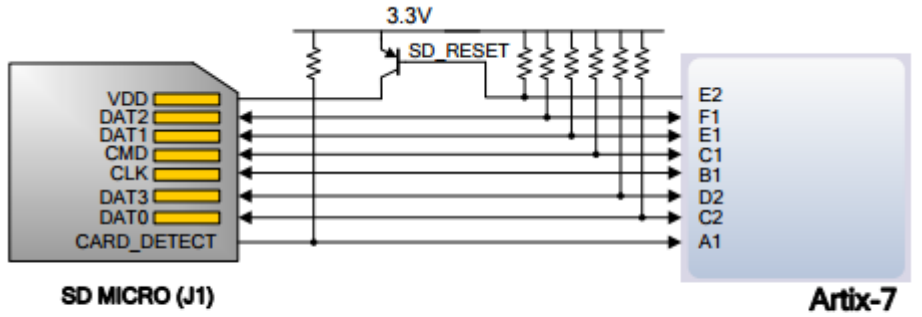


Figure 21. Artix-7 microSD card connector interface (PIC24 connections not shown).

SD Protocol

- 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

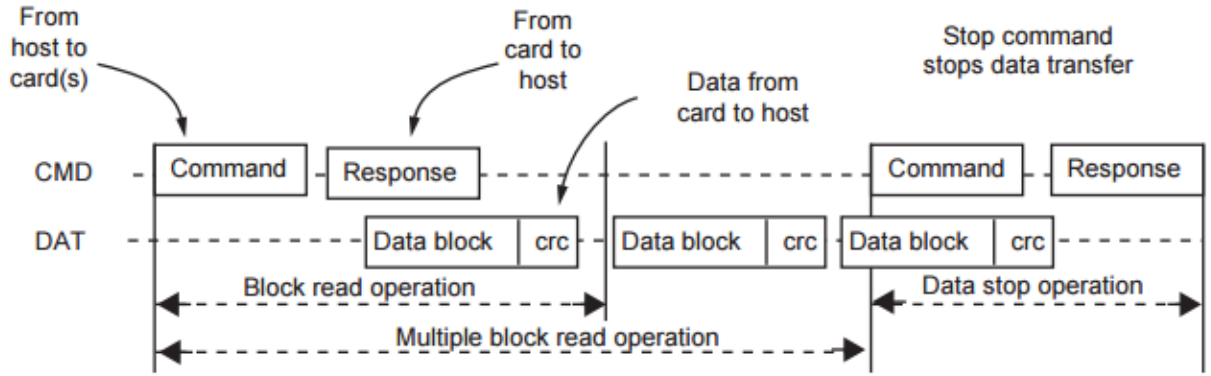
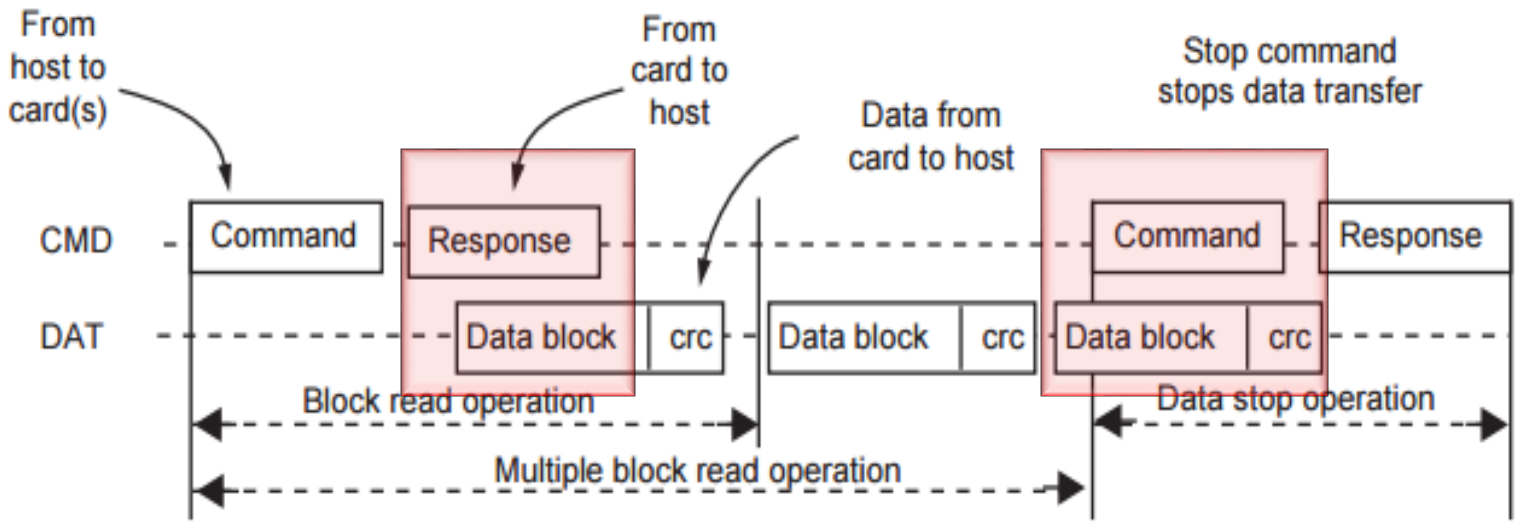


Figure 1: Multiple block read operations

0	1	bit 5...bit 0	bit 31...bit 0	bit 6...bit 0	1
start bit	host	command	argument	CRC7[1]	end bit

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

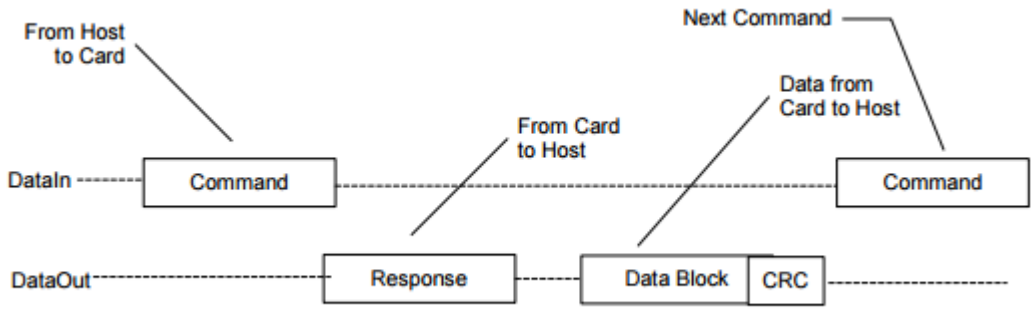


Figure 1. Single block read operation

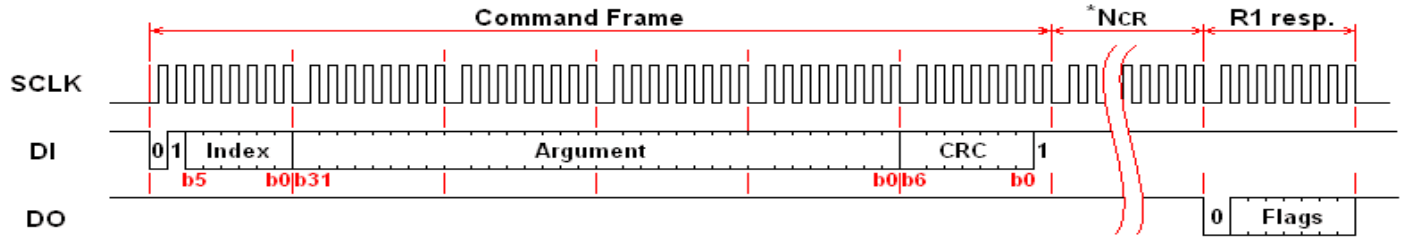


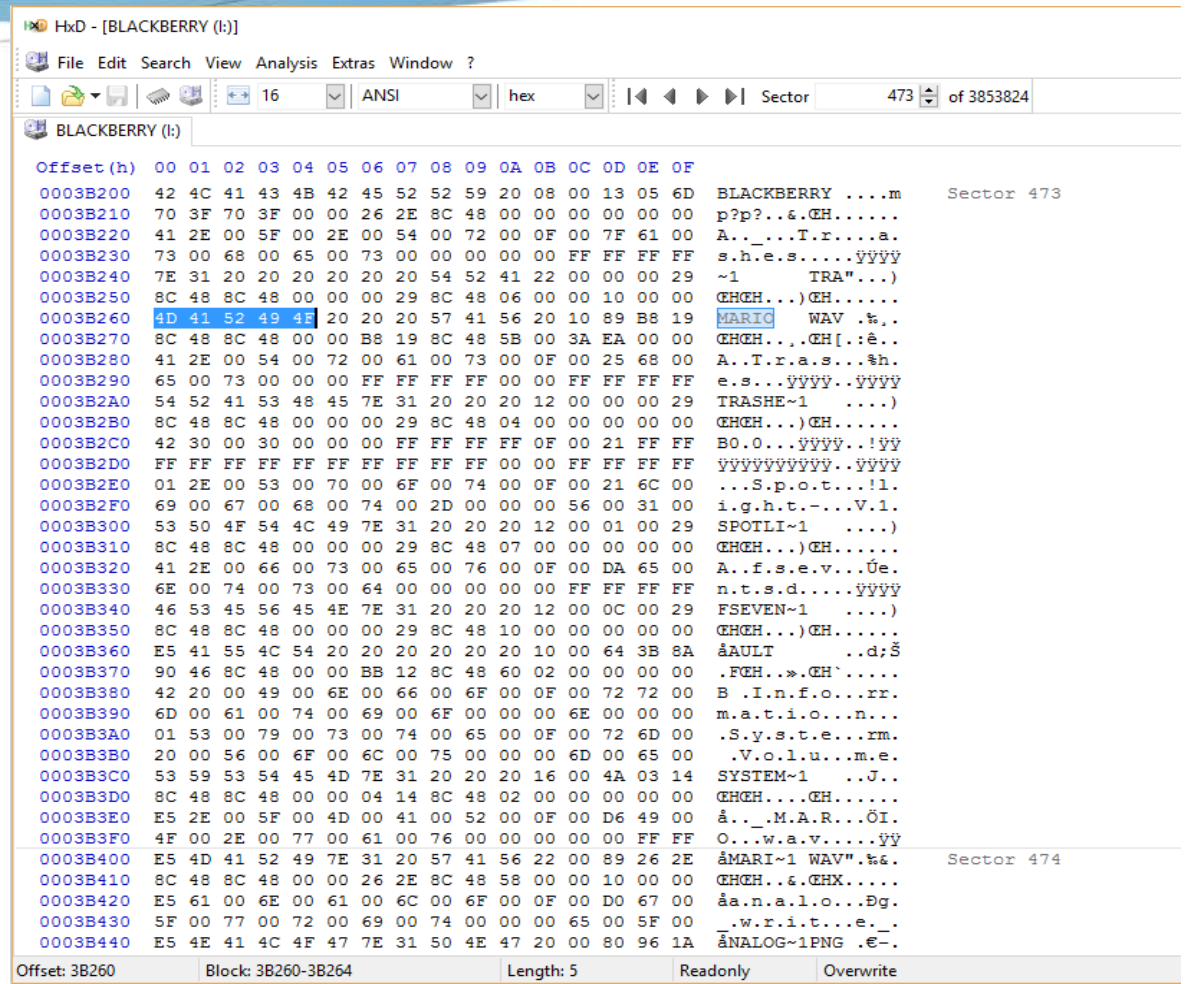
Figure 2. Timing of single block read operation

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



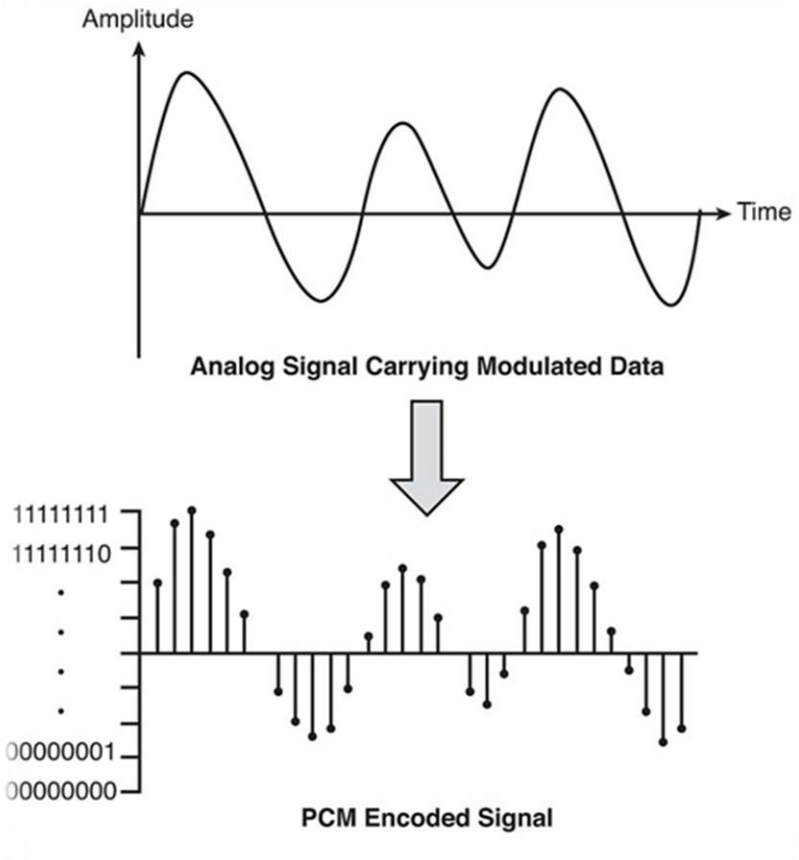
FAT: What We Know

Based on the Boot Sector Information

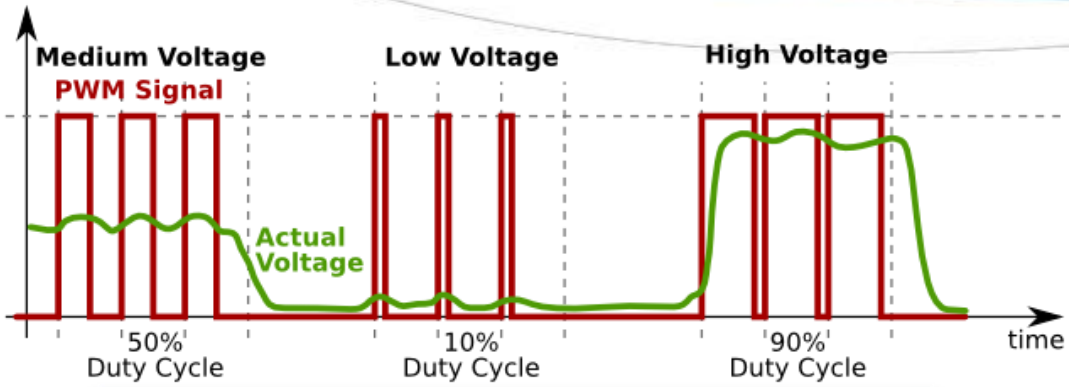
- 512 bytes per sector
- 64 sectors per cluster
- 1 reserved sector
- 512 Root Directory Entries
- 3854329 Sectors in File System
- 2 FAT copies
- 236 Sectors per FAT
- FAT #1
  - Offset: 512 - 121343
- FAT #2
  - Offset: 121344 - 242175
- Total Cluster Size: 32,768 bytes

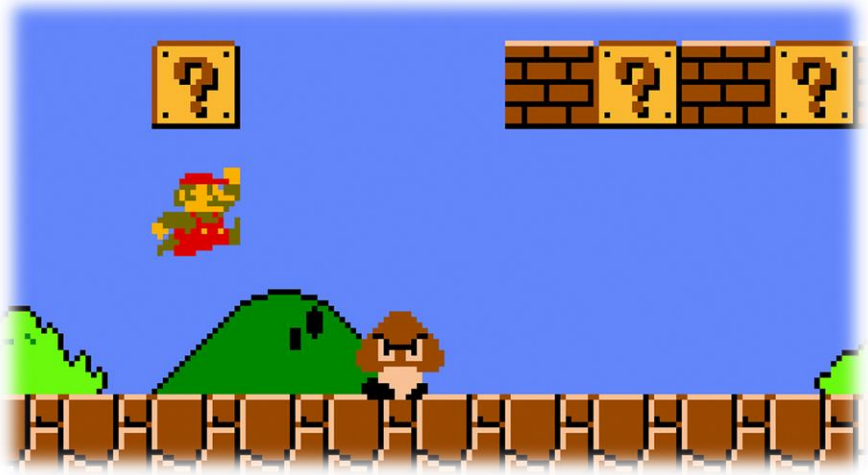
PCM (Pulse Code Modulation)

- 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)

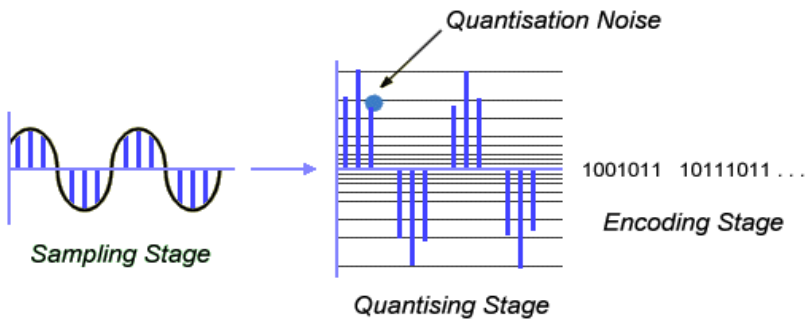




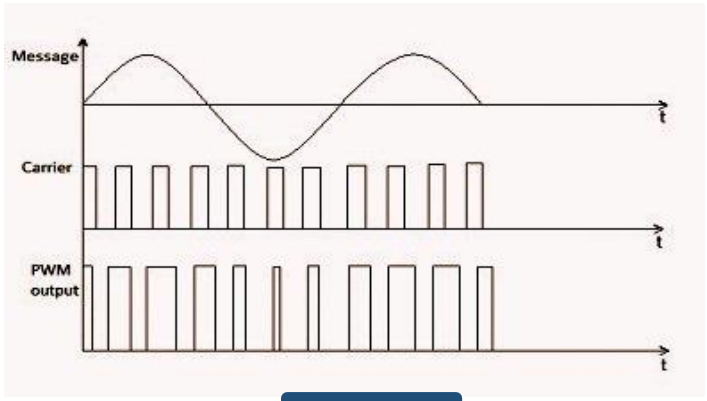
- Modulation technique used to encode a message in a pulsing signal
- Used to control the power supplied to electrical devices
- PWM has been used to play back a crude version of a PCM signal
  - Speakers driven by two voltage levels, 0V and 5V
  - A mono audio output can be obtained by carefully timing 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 to PWM

- 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



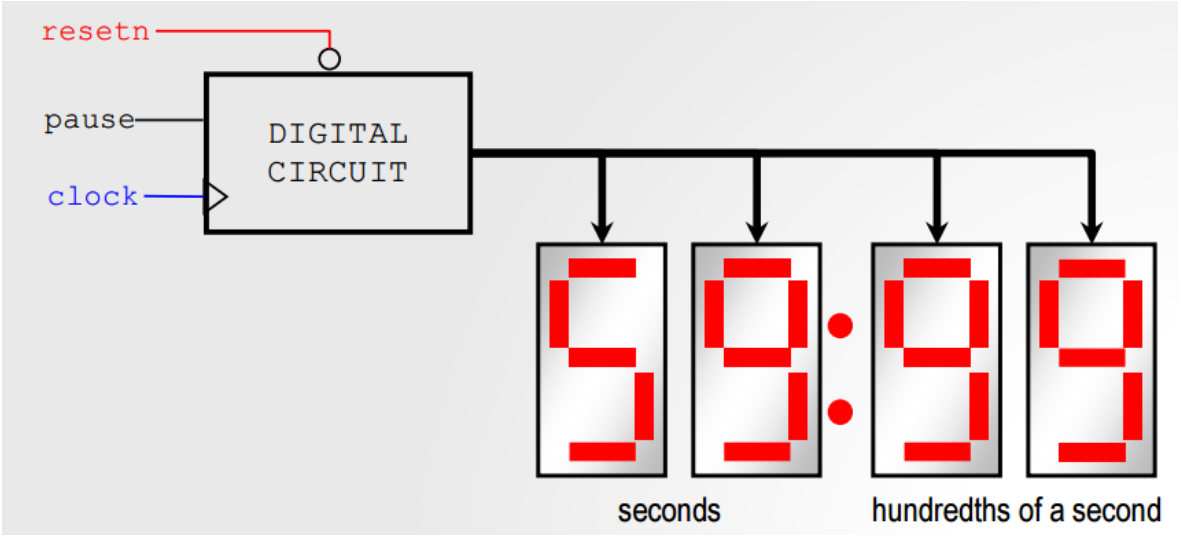
PCM



PWM

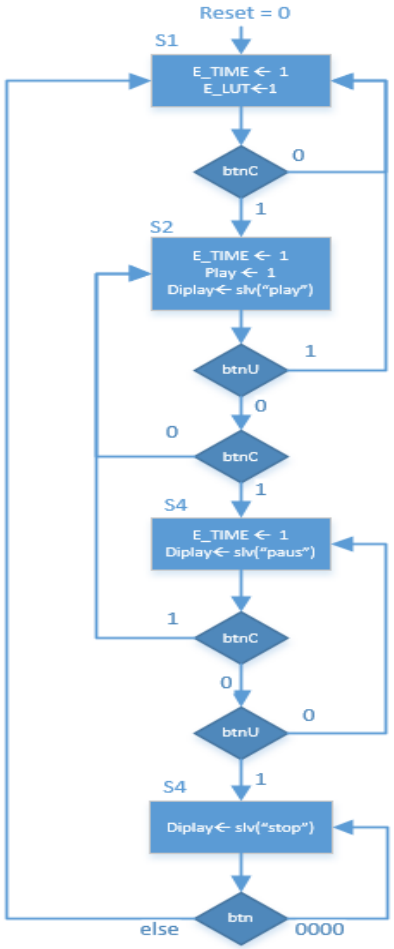
Timer (Seven Segment Display)

- 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

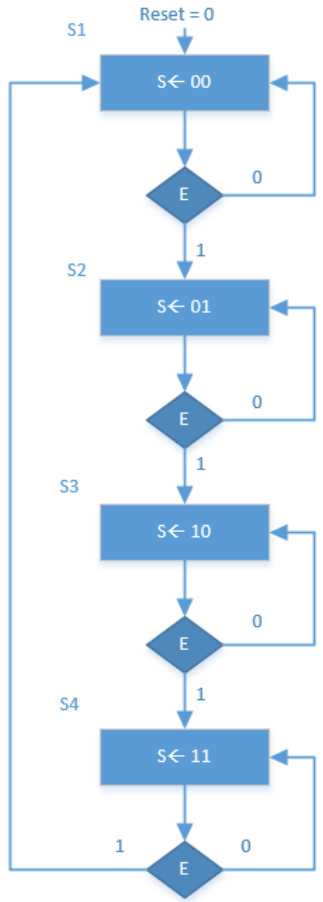


Display FSM's

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