

Personal Jukebox (PJB)

Systems Research Center and PAAD

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What Is This?

- ♣ Cool consumer device, exploring convergence of:
 - cheap, low power, fast, imbedded computers
 - powerful, common, home PC's with Internet access
- ♣ Portable audio system: 100 CD's in your pocket
 - Take all your music everywhere
- ♣ Research project that became a product

The Technology

- ♣ CD-quality audio compression: 11-to-1 (1 MB/min)
- ♣ 2.5" disk is 6.5 GBytes, 4 ounces, 3/8" thick
 - 110 hours of CD-quality music (340 hrs on 20 GB)
- ♣ Lithium-Ion cell: 5 Watt-hour, 2 ounces
 - We achieve 11-hour playing time between charges
- ♣ PC for acquisition, management, content labeling

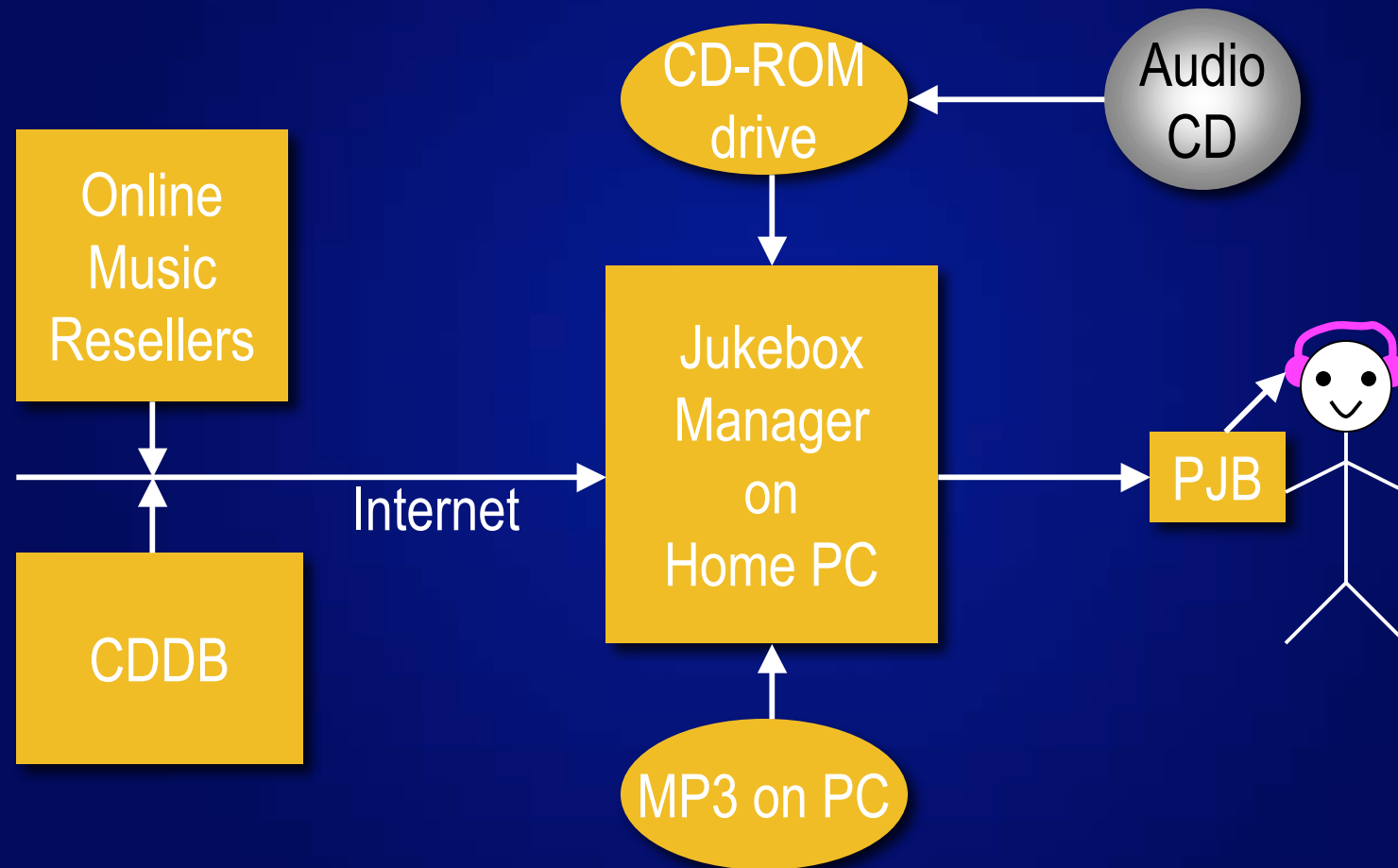
Using the PJB

♣ Everywhere:

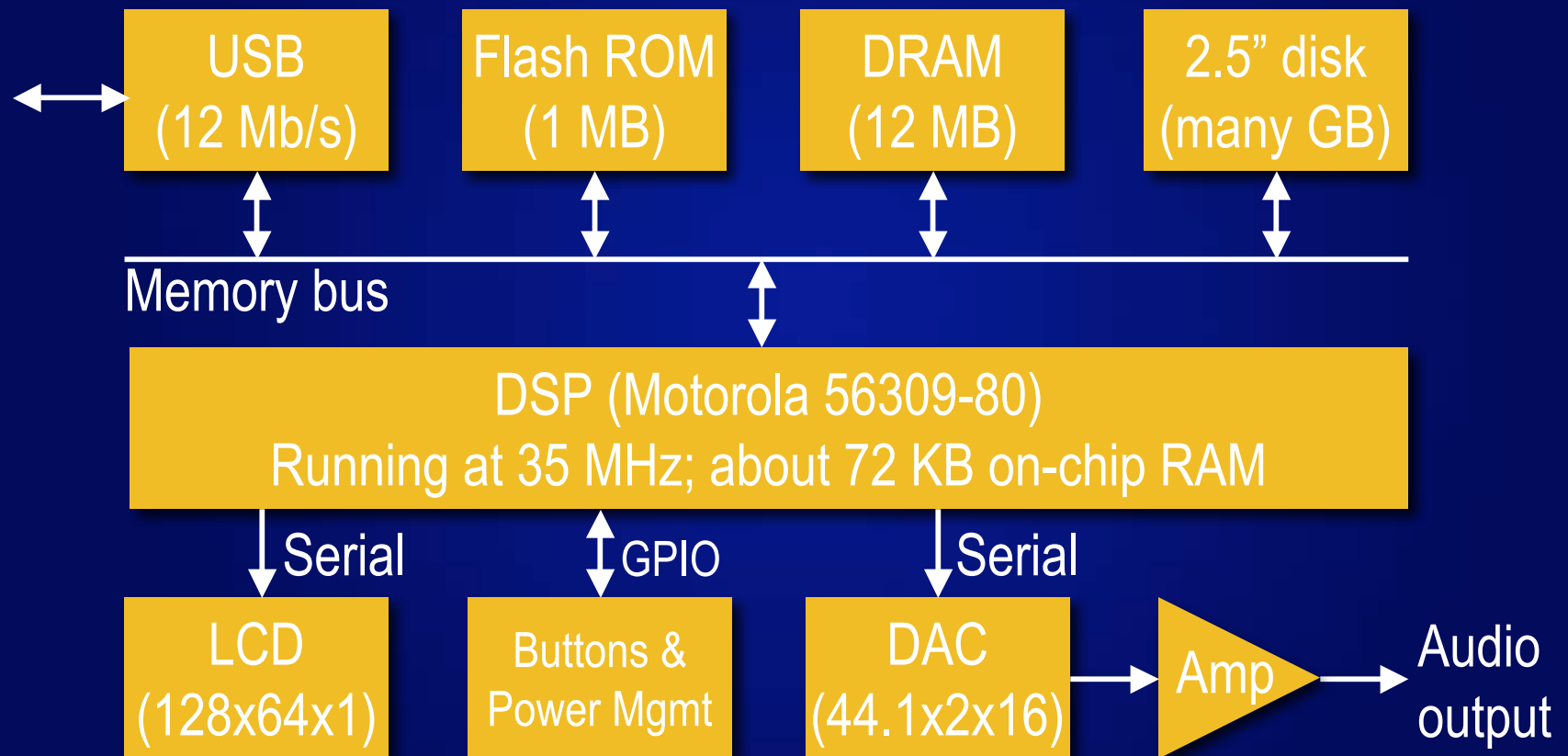
- On that 11-hour flight
- In your car
- In your office
- At home

♣ Choose your music after you leave home

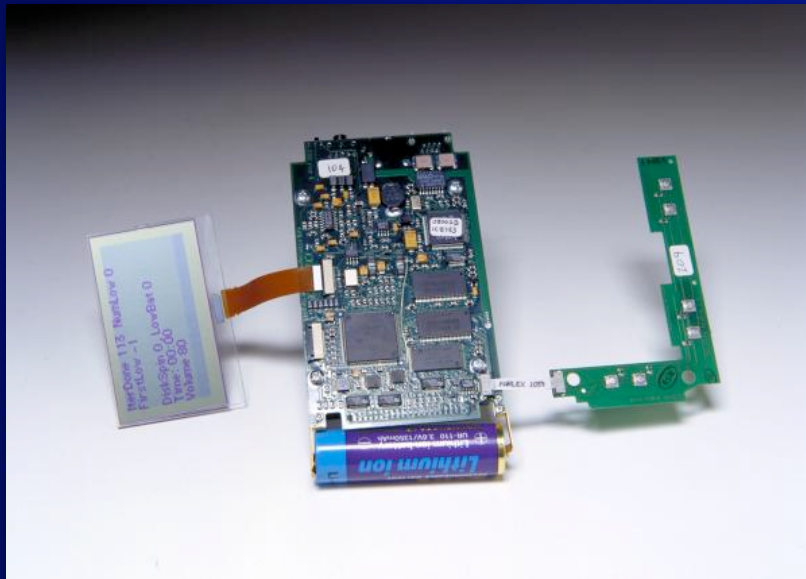
PJB Workflow



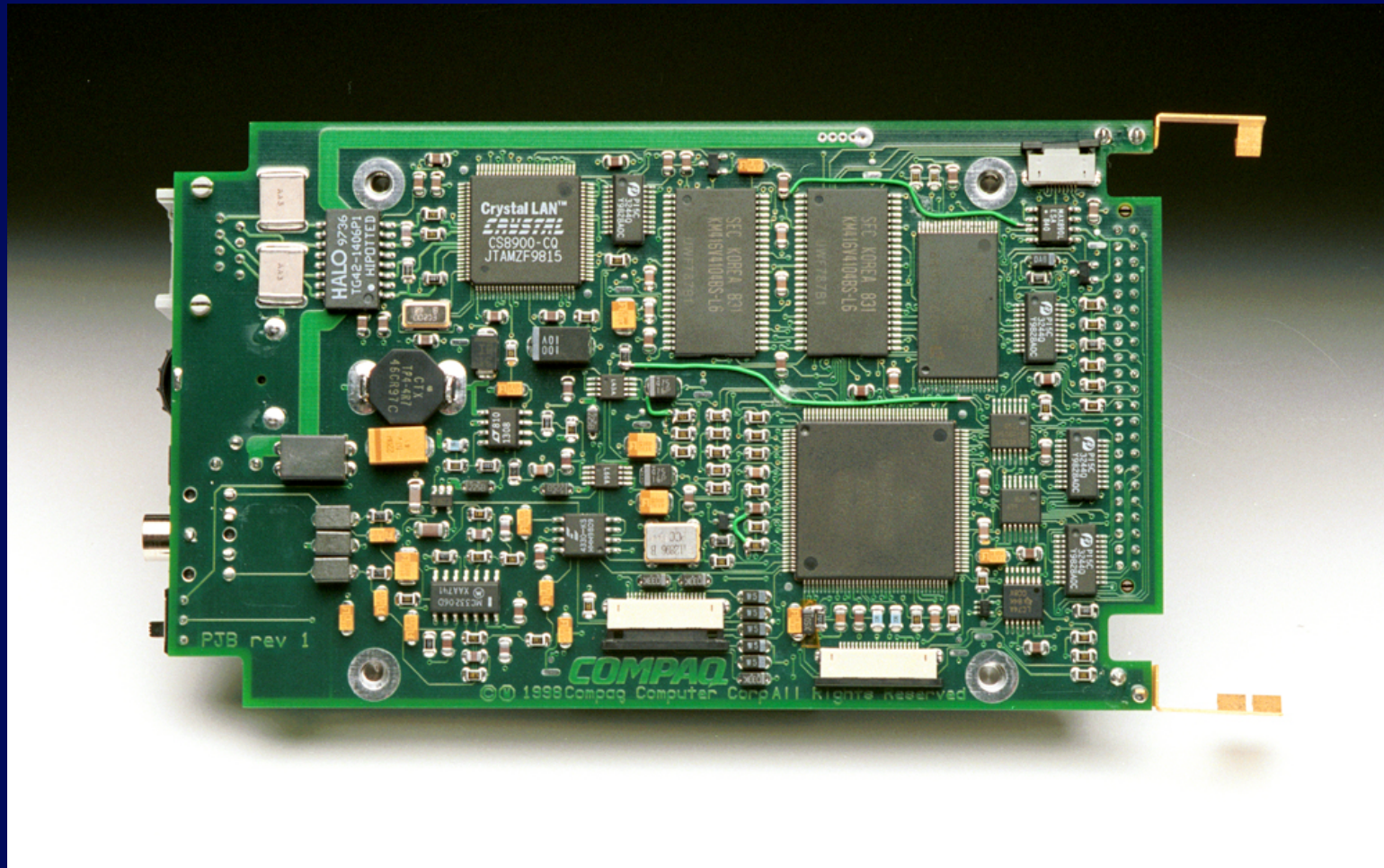
Hardware Overview



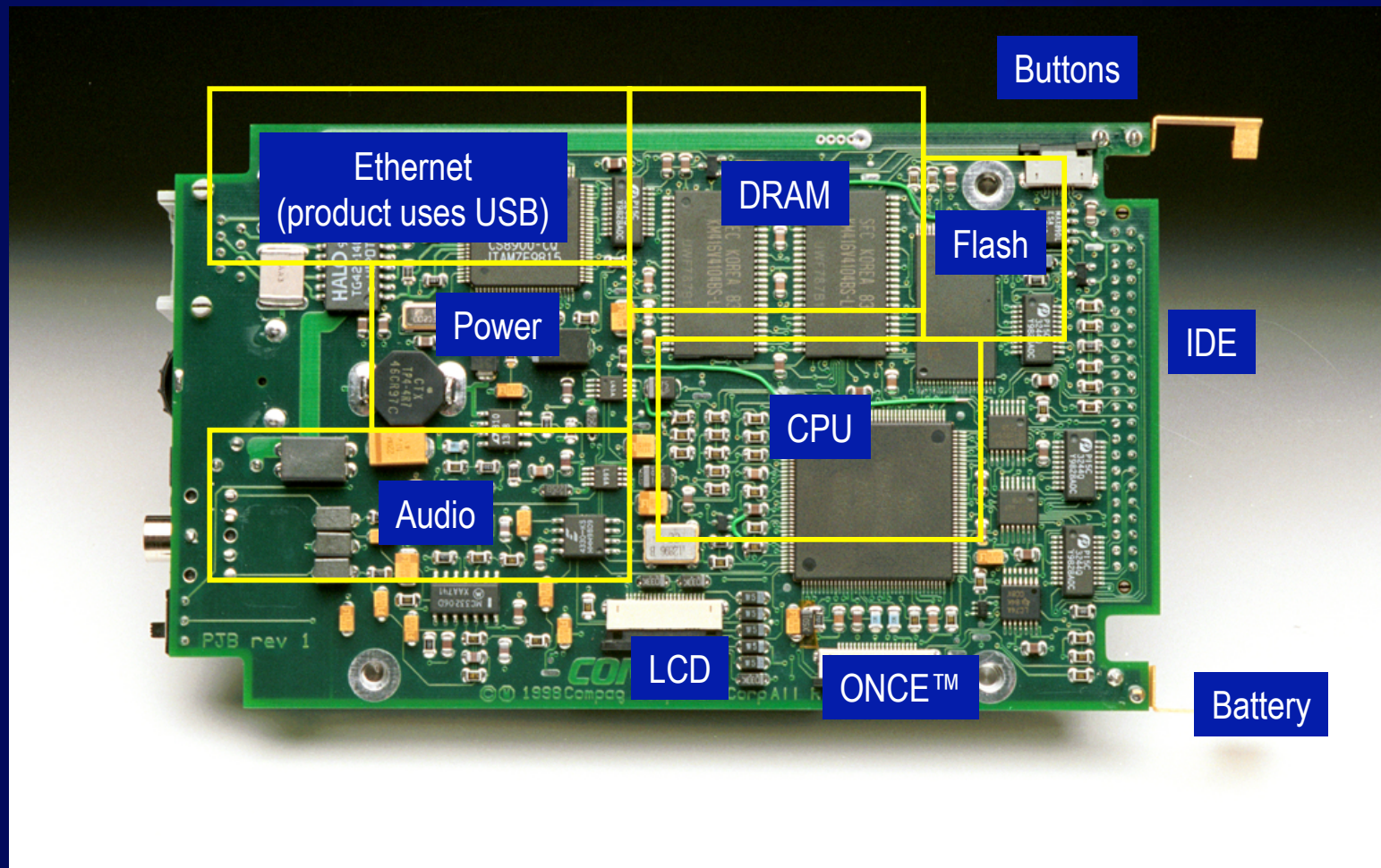
Hardware Reality



Hardware Close-up (Prototype)



Hardware Anatomy (Prototype)



Physical Robustness

- ♣ Disk withstands 150G for 2ms while operating
 - roughly a drop from a desk onto carpet
- ♣ Reality: some temporary non-recoverable errors
 - (while running)
- ♣ Firmware can continue with small audio loss
- ♣ LCD is most liable to permanent damage

Player Unit UI Overview

- ♣ Human-sensible names (from CDDB initially)
- ♣ 3-level hierarchy: “set”, “disk” (playlists), “track”
 - multiple copies of a track or disk are (almost) free
- ♣ 6 buttons: start/stop, up/down, left/right (+volume)
- ♣ Bitmapped display allows redesigns (& games!)

UI Physical layout (prototype)



User Interface Details

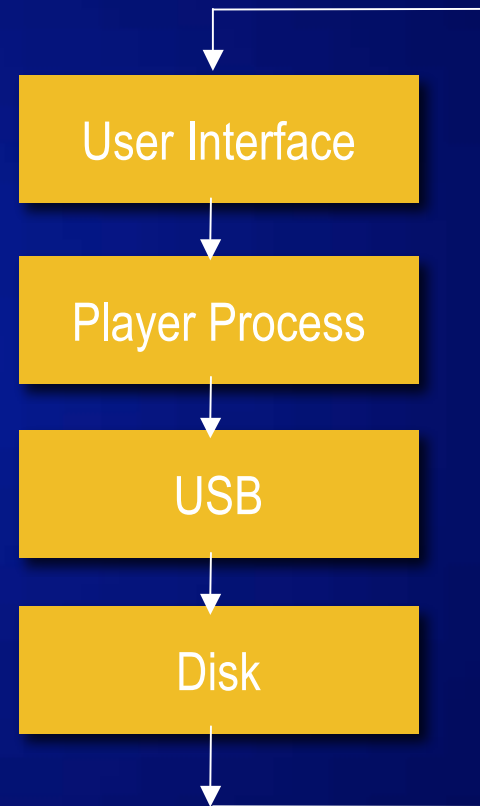


Firmware Overview

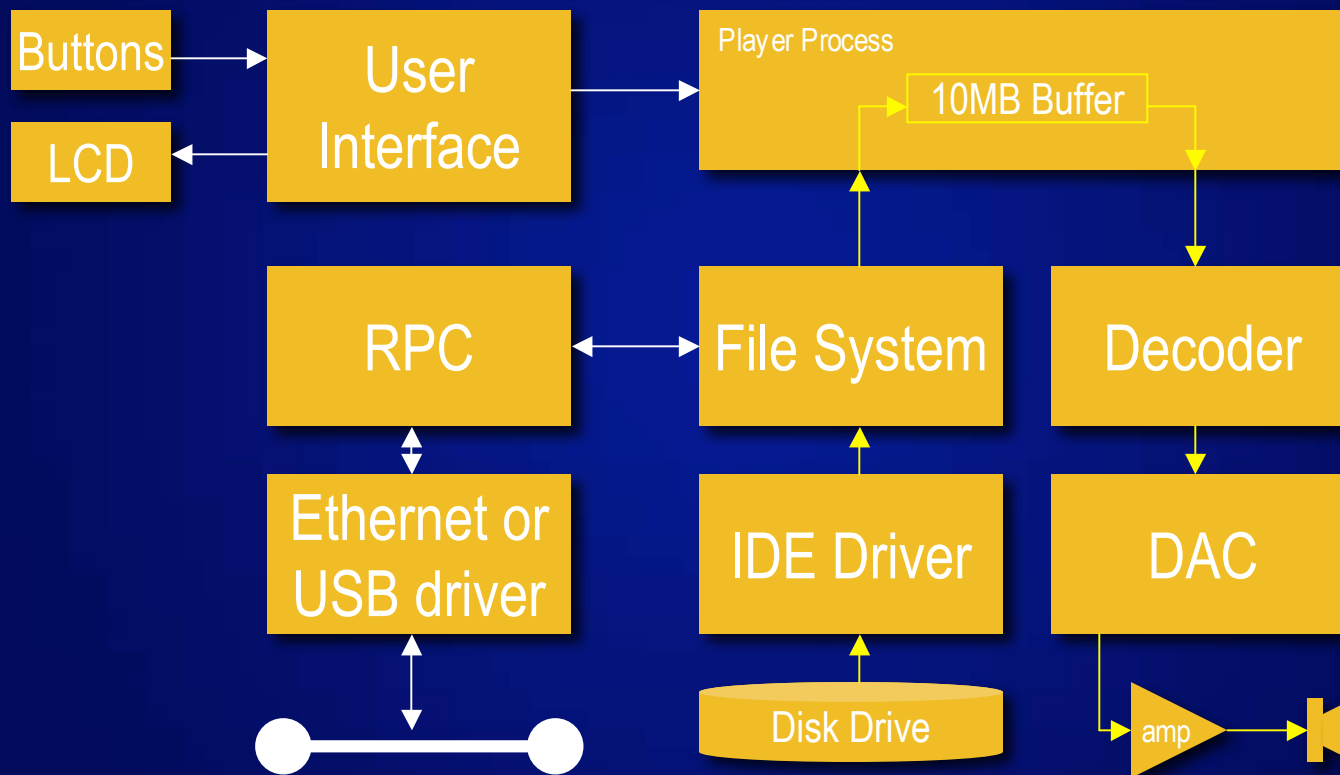
- ♣ No operating system! (manual event loop)
- ♣ Compression format neutral (select per-track)
 - MP3, AAC, MSAudio, SDMI, ...
- ♣ About 40,000 lines of C (“char” is 24-bits!)
 - but ... assembler is factor of 10 faster
- ♣ Decoder, CRC, and disk read loop in assembler

Firmware - main loop

- ♣ Poll the devices
 - simpler than interrupts
- ♣ Main loop calls each component in turn to give it processor time.
- ♣ Need to call player process frequently enough!



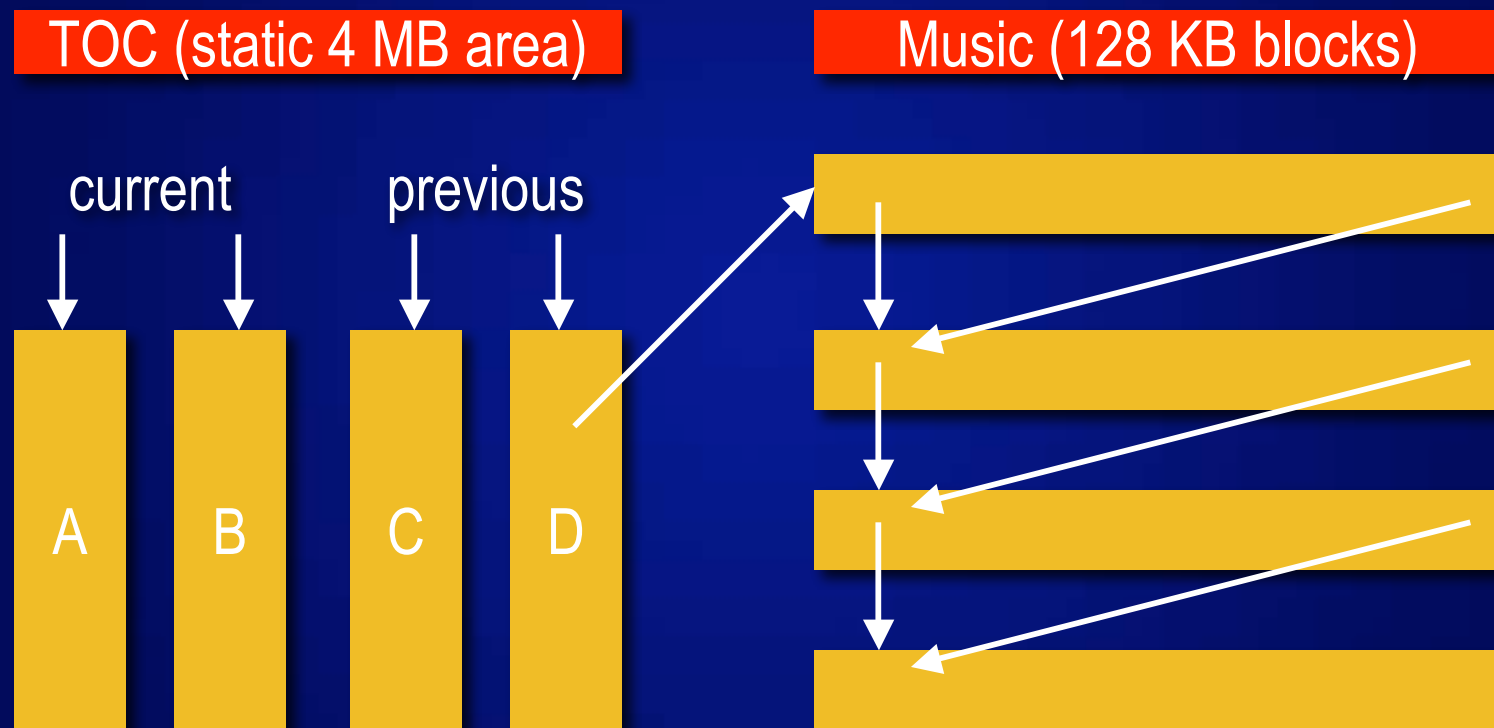
Firmware - logical flow



File System Overview

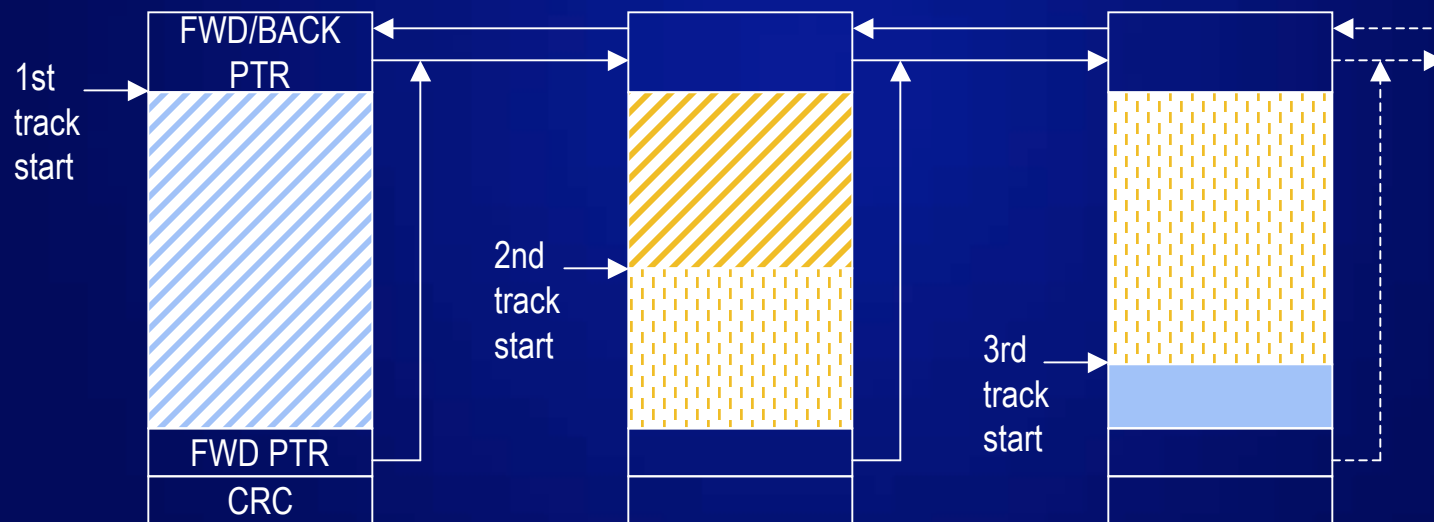
- ♣ Single meta-data object “Table of Contents” (TOC)
- ♣ Managed by PC software
- ♣ Single stream of plain text:
 - Identifies PJB, set, disk, track (each by text name)
 - “track” has location (first allocation block number)
 - Includes map of blocks-in-use
 - Includes CDDB keys

File System On-disk Structure



Content blocks in detail

- ♣ Doubly linked lists (w/ redundant forward links)
- ♣ Header identifies content and origin (for scavenging)
- ♣ Supports continuously encoded music (extents)



Disk Error Handling

- ♣Bad TOC - use replica
- ♣Bad TOC replica - use old version
- ♣Bad forward pointer in block - use replica
- ♣Bad replica forward pointer - abandon track
- ♣Bad payload in block - skip and resync music

File System Maintenance

- ♣ No fragmentation worries
 - worst case is seek every 128KB (8 seconds)
- ♣ No fsck or scandisk (no inconsistent states)
- ♣ Relies on:
 - large files
 - no file modification
 - single writer

Power Management

- ♣ 2.5" disk in sleep mode consumes about 100 mW
- ♣ Disk spin-up takes 5W-secs (2x AA's don't work)
- ♣ Power-up disk, read 10 MB into DRAM, power off
- ♣ Use on-chip memory for inner loop, not DRAM
- ♣ Total average PJB power consumption 450 mW

Market Area

- ♣ PJB was the first product in its category
 - Less than \$10/hour of music (Rio is \$200/hour)
 - Only prerequisite is owning a PC
- ♣ Lots of other possibilities in this area, e.g.:
 - Internet music purchase: store in PJB, cache on PC
 - Caching CD player in your car
 - Home network with custom audio in each room

Status

- ♣ Research project ended up with 100 prototypes
- ♣ Licensed to third party (HanGo)
- ♣ Now shipping (<http://www.pjbox.com>)
- ♣ Project details:
 - <http://research.compaq.com/SRC/pjb/>

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