Featherweight Electronic Book for Rural Education

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Outline

• Overview of TEM
• Overview of Featherweight Electronic Book
• Motivation and Innovation behind Design
• Block Diagrams and Various Alternatives
• Basic Building Blocks of Design
  – Microcontroller
  – MMC and Interfacing
  – Key Pad and Interfacing
  – PWM signal to Audio Generation
    • 5th Order Active Low Pass filter Design
    • Audio Amplifier
    • Speaker interfacing
• Future Directions and Improvements
Technology for Emerging Markets

Goals

Understand (potential) technology users in emerging-market countries
- E.g., urban middle-class
- E.g., rural entrepreneurs

Invent new technologies and make suggestions on policy

Contribute to growth in emerging markets and to socio-economic development of poor communities worldwide

Government-sponsored lunches at a rural school in Tamil Nadu
Featherweight Computing??

• Devices which do a small calculation for their functioning comes under this category.

• Technologists generally call them “Digital Manipulative”. why??

• The Motivation and idea behind the approach is to create a new capability in object without changing Basic overall look and architecture. (i.e. create a talking capability in a book with reprogramming over time so that it can read its text also.)
Smart Computational Toys

• “Smart toys combine the best of the two worlds – traditional toys and the power of computers and electronic chips. Experts predict that almost every toy will be powered by interactive technology in near future”.
  - Herman D’Hooge and team, smart toys: Brave new world

• “Researchers are now exploring ways of adding computational capabilities to everyday objects ranging from notepads and desktops to eyeglasses and shoes”.

• “Our goal in designing new “digital manipulatives” is to make a new set of concepts salient for children. Our basic strategy is to embed computational and communications capabilities in traditional children’s toys”.
  - Mitchel Resnick & team at MIT media lab. Digital manipulatives: New Toys to think With
Featherweight Computing

• Anticipated target user is from remote rural areas. They may be:
  – Illiterate or semi-literate adults
  – Children
  – Physically disabled (e.g., blind)
  – Economically poor
  – Without access to consistent electrical power

• Characteristics of featherweight computing:
  – Serves single purpose well
  – Very cost-effective
  – Simple user interaction
  – Low power
  – Robust, highly reliable
Electronic Book

- **Target customer**
  - Strong interest in improving quality of life through increased literacy and information.
  - Need effective ways to access information (e.g., health, hygiene, agriculture, etc.) in local languages.

- **Solution: electronic book**
  - Designed for education
  - Could cost US$20-30
  - Extends standard “book” format; touching book causes audio playback
  - Uses 4 AA batteries
  - Strong plastic encasing

- **Existing products**
  - LeapFrog LeapPad
  - Fisher-Price PowerTouch
Our Goals at MSRI

• The TEM group is interested in experimenting with electronic books in rural India.

• Existing products do not allow flexibility to create local content.

• We will create an electronic book where we have the flexibility to change the content ourselves.

• If we have time, we would like to experiment with our electronic book and try it with children in Bangalore slums.
Generic Block Diagram: E Book

- Touch Pad
- Page Decoder
- Storage Device
- Internal RAM
- Micro-controller
- Digital Data to Analog Signal Converter
- Speaker
Different Possibilities that We Considered

(1) Serial DAC
- ATmega 162
- SD MMC
- 4x4 Keypad

(2) Parallel DAC
- ATmega 162
- MMC card
- 8x8 Keypad

(3) PIR Sensing Tech
- Capacitance Sensor
- USB drive

(4) Audio Amplifier
- ATmega 162
- NCP MMC
- 4x4 Keypad

Optimized Block Diagram for Final Implementation

Why did we choose?

1. Cheap and Cost Effective
2. Components are Easily available
3. Easy interfacing of Blocks
4. Easy programming for configuration
Basic Building Blocks (Components)

- MuC → ATmega 162
- MMC → NCP 128MB
- Keypad → 4x4
- LPF → 5\textsuperscript{th} Order using LM324
- Audio Amplifier → LM386
- Speaker → 8-ohm

This Estimation is valid for production of 1000 Such books.
Flow Chart of System Events

Power ON
All device

- I/O port DIR_INIT
- MMC_INIT
- Wait for INTR

Keypad
PRESS?

Y

- Calculate ADD (Size, CLUS) of file
- Read SEC 1 by 1 into BUFF

Take A PCM Sample from BUFF
Generate PWM equ. to DIGI_DATA
FILE_SIZE = FILE_SIZE - 512;

0

FILE_SIZE?

N

User Interaction and Responses from Device

Power ON

Touch
An object on PAD

Audio
Feedback

POWER
ON/OFF

ON
Wait for Next INT

OFF
Good Bye
Microcontroller : ATmega-162

• Computer on a chip
  – CPU core
  – Memory (ROM and RAM)
  – Digital I/O ports
  – Easy interfacing

Key features:
• High performance
• Low power consumption (2.7-5V)
• High code density (16KB)
• In-system development
• SPI (MMC Interfacing)
• 2 USARTS (RS-232 Interfacing)
• PWM Signal Generation Capability
• 3 Programmable Timer
MMC

- Multimedia card
  - Storage for audio data
  - Portable
  - Removable

- Advantages:
  - Moderate cost
  - Robust
  - Small size
  - Serial Peripheral Interface
    - 4 signals for interface
      - Data in
      - Data out
      - Clock
      - Chip select
User Interaction : Touch Keypad

• Allows user interaction with device
• Based on contact or pressure
• Considered:
  – IR touch panel
  – Capacitance touch pad
  – Keypad(4x4, 8x8)

• Advantages: (4x4 keypad)
  – Inexpensive
  – Easy to interface
  – Readily available
  – Sturdy
Keypad Interfacing: How It Works?

All the rows are grounded and columns are scanned until one of them is zero.

One row is high at a time and all the columns are read.

For Some Combination all the column will become High.

The combination of column read (0111, 1011, 1101, 1110) and Value sent to Row (1000, 0100, 0010, 0001) will give a unique value which can be easily mapped into “unique Key PRESS”.

Schematic for keypad interfacing
What is a PWM Signal?

- When communication by pulses was introduced, the Amplitude (PAM), Phase (PPM) and Pulse width (PWM) become possible modulation options.
- In PWM the duty cycle of each pulse of a symmetric Square Wave is modified to proportional with the audio sample Value at that Instant.
- How do we Implement that?
PWM Signal: Audio Generation

PWM Signal to Analog Waveform:

1. A simple RC circuit, fourth-order low pass active filter and audio amplifier are used to convert the PWM signal into audio signal.

2. RC circuit and Low Pass Filter is used for harmonics and carrier frequency generated by PWM signals. The RC circuit is for attenuation. It prevents the saturation of the low pass filter and the audio amplifier.

3. The audio amplifier will drive the speaker to generate the audio.

The output sound quality is as good as an AM radio.
Active LPF: PWM signal to Audio Analog wave Generation

5th Order LOW Pass Filter

LM324

850pF

850pF

850pF

46K

33K

68K

56K

Vout

Vin

LM386

200uF

50nF

10ohm

Vout
Complete Schematic (All in One)

Program Structure:

- Include all the library files
- MMC initiation
- FAT16 Implementation
- 4x4 Keypad press detection function
- Reading the clusters, sector by sector
- PWM signal for each byte
- Check the size of file and Data Read
- Read the cluster until the data read==file size.
- Wait for a new key press.

5th Order LOW Pass Filter

ATmega162

MMC

Vcc

ATmega162

Vcc

5.6K

16MHz

22p

20K(each)

4x4 Keypad

16MHz

22p

200uF

50nF

10ohm

5th Order LOW Pass Filter
Future Improvements:

- Keypad can be replaced by a better and sophisticated Touch pad (i.e. Power Touch Pad).
- To improve the audio quality of sound a Low pass filter IC can be used in place of LPF made of Discrete components.
- MMC connectors will make the transfers of files from PC to board Easy.
- Using MP3 decoder files directly can be stored in mp3 format which is most popular because of it’s smaller size and good voice quality. Right now only 8-bit PCM wave format files can be used.
Thanks
Rajkumar
Backup Slides
Analog to Digital Recording and playing Chain

Microphone converts acoustic to electrical energy.

Continuously varying electrical energy is an analog of the sound pressure wave.

ADC (Analog to Digital Converter) converts analog to digital electrical signal. Digital signal transmits binary numbers.

DAC (Digital to Analog Converter) converts digital signal in computer to analog for your headphones.
Basic Digital Audio Concepts

- **Sampling rate**
  - Number of sample taken of a signal in a given time (usually one second)

- **Bit depth**
  - Describes the accuracy of the audio data

- **Channels**
  - E.g. Stereo has two channels

- **Bit rate**
  - Measured in kilobits per second (Kbps) is a function of the bit depth and sampling rate
Basic Wave File Layout

Chunk ID "RIFF"
Chunk Data Size

RIFF Type ID "WAVE"
Chunk ID "fmt"
Chunk Data Size
Sample Format Info

Chunk ID "data"
Chunk Data Size

Digital Audio Samples