Computer Engineering Capstone Design Summer A 1998–2000:

Handheld Video Games

J. S. McDonald

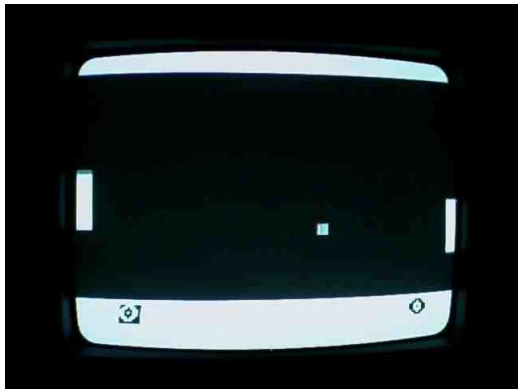
IEEE/HKN Odd-Wednesday Talks

May 24, 2000

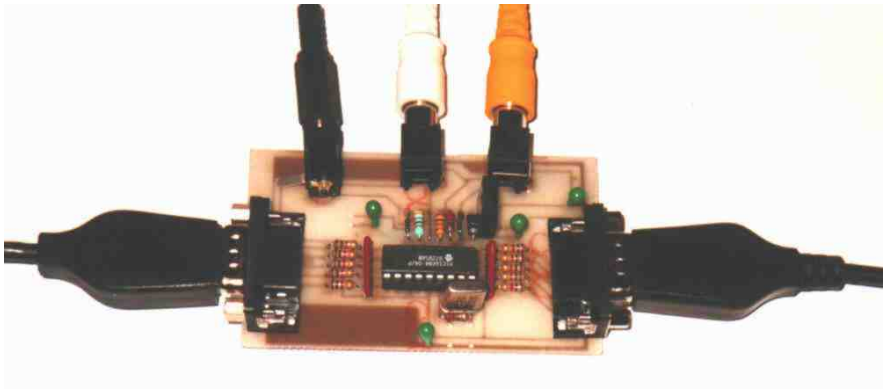
`http://www.kettering.edu/~mcdonald/ece403/`

PIC-Pong

- By Rickard Gunée; uses a 4-MHz PIC16F84 and a TV(!)
- the game in action:



- the game:



Original GameBoy Patent

US005184830A

United States Patent [19]

Okada et al.

[11] **Patent Number: 5,184,830**

[45] **Date of Patent: Feb. 9, 1993**

[54] **COMPACT HAND-HELD VIDEO GAME SYSTEM**

[75] Inventors: **Satoru Okada; Shin Kojo**, both of Kyoto, Japan

[73] Assignee: **Nintendo Company Limited**, Kyoto, Japan

[21] Appl. No.: **899,179**

[22] Filed: **Jun. 15, 1992**

Related U.S. Application Data

[63] Continuation of Ser. No. 462,400, Jan. 8, 1990, abandoned.

[30] **Foreign Application Priority Data**

Apr. 20, 1989 [JP] Japan 1-101028
Oct. 1, 1989 [JP] Japan 1-4452

[51] **Int. Cl.**[5] **A63F 9/22**
[52] **U.S. Cl.** ..... **273/433;** 273/434; 273/435; 273/85 G
[58] **Field of Search** ..... 273/433, 434, 435, 437, 273/85 R, 85 G, DIG. 28; 364/410

[56] **References Cited**

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8302566	8/1983	World Int. Prop. O.	273/85 G

OTHER PUBLICATIONS

Worley, Joyce "Spitball Sparky", Electronic Games, Nov. 1984, p. 86.

Primary Examiner—Jessica J. Harrison
Attorney, Agent, or Firm—Nixon & Vanderhye

[57] **ABSTRACT**

A hand-held electronic game machine for use with attachable/detachable memory game packs wherein the game machine includes a case of a size which may be held by a hand and capable of being sandwiched by both hands with a first switch disposed at a position such that during a game it can be operated by one thumb on a front surface of the case, a second switch disposed at a position such that during a game it can be operated by the other thumb on the first surface of the case and a third operation switch means provided in a region of said front surface where imaginary loci of both thumbs intersect with each other on the front surface, and wherein the game machine can be connected with others for simultaneous multiple player competition.

21 Claims, 12 Drawing Sheets

GameBoy Patent Drawings

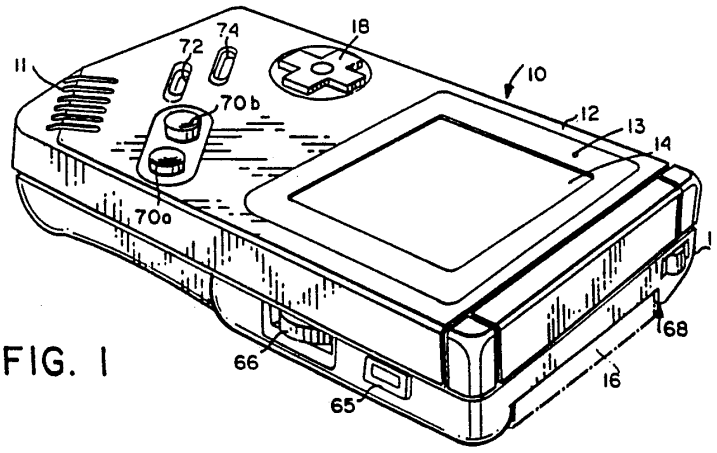
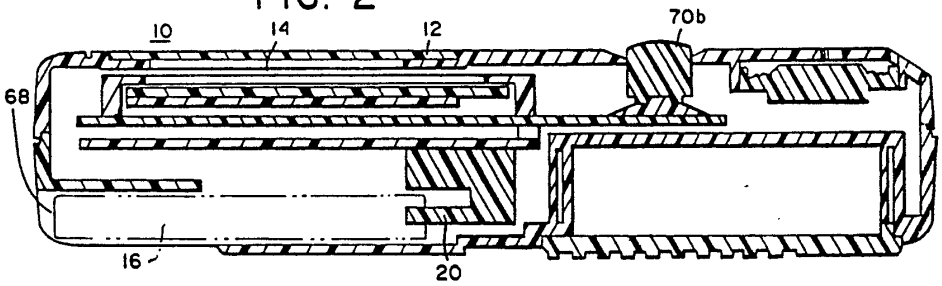


FIG. 1

FIG. 2



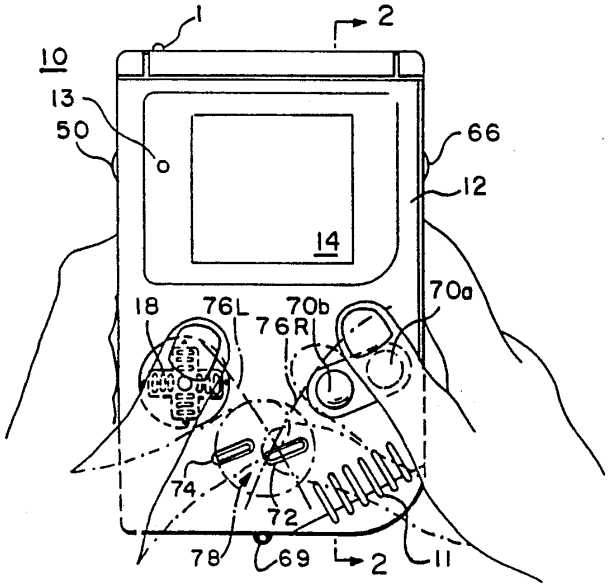


FIG. 3

GameBoy Block Diagram

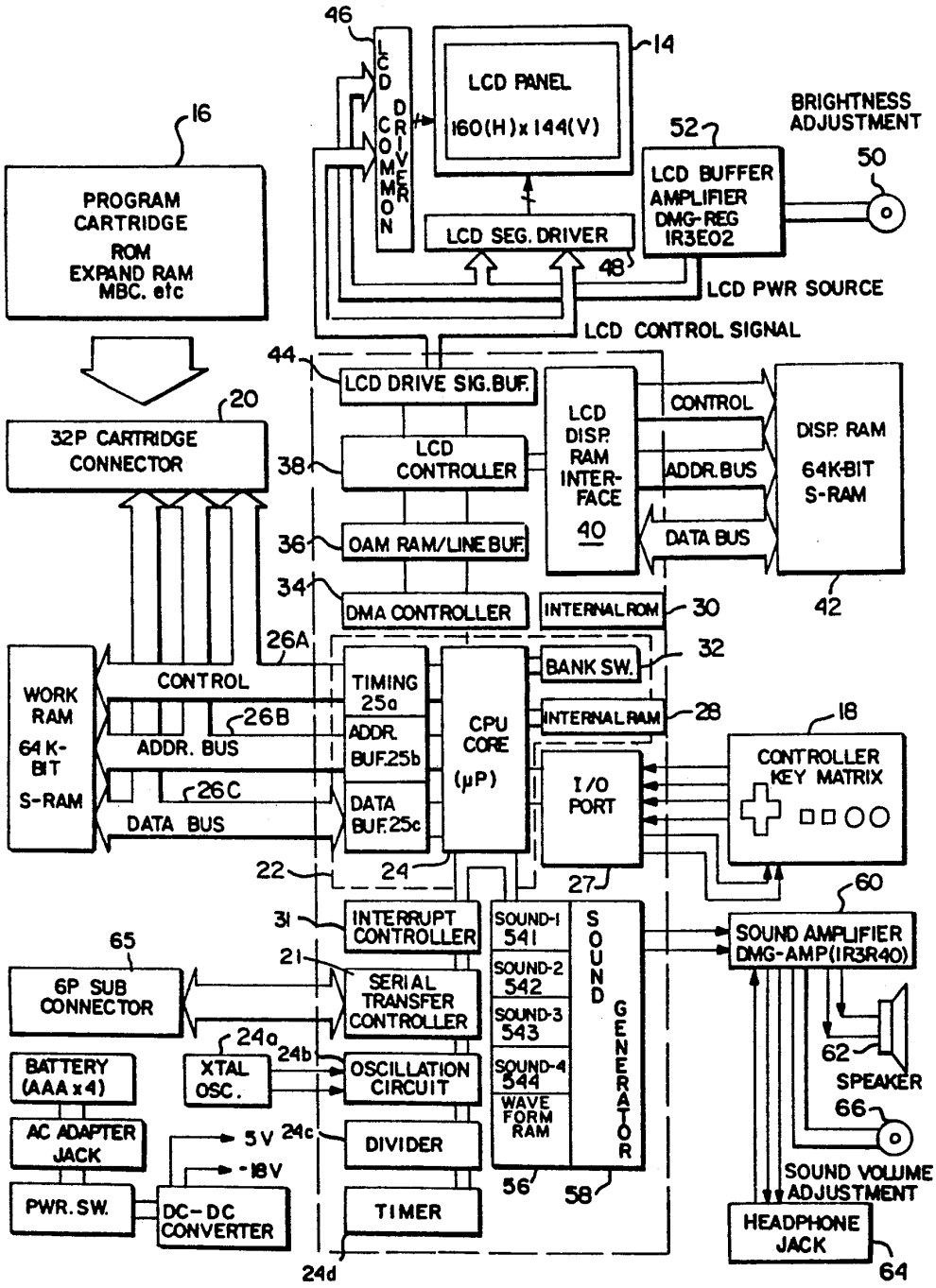
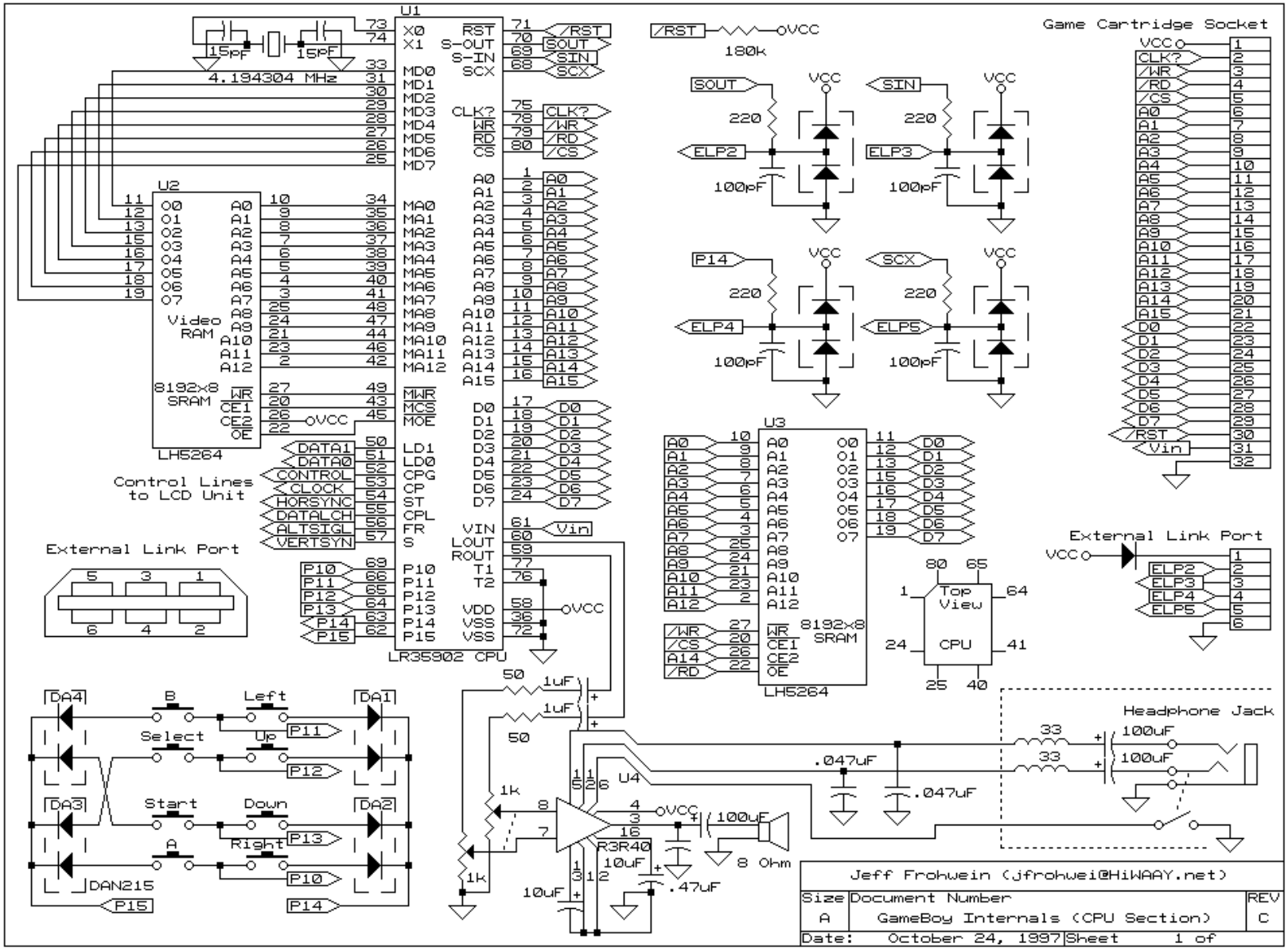


FIG. 4

GameBoy Schematic



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Project Overview (1999)

In a Nutshell

Design and build a hand-held video game.

Some Details

The game must

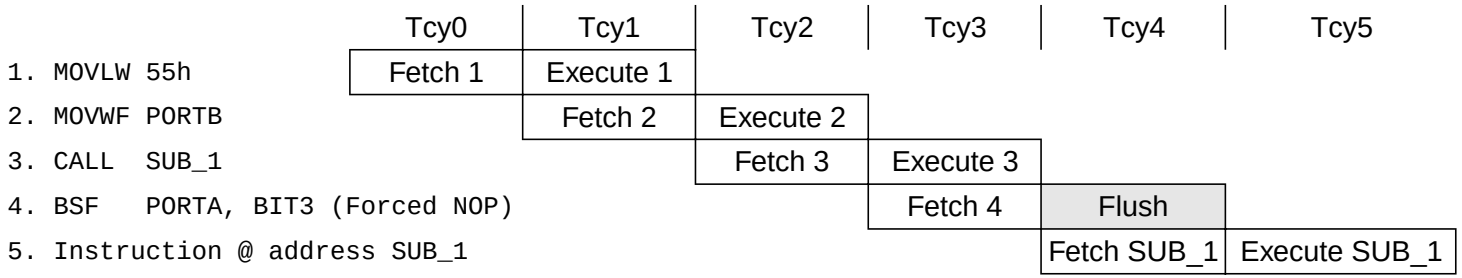
- use a Microchip PIC 16C74A microcontroller
- use a Micro Electronics SG128128 graphic LCD module
- have an appropriate soundtrack and/or sound effects
- be battery-powered, compact, and sturdily constructed
- survive evaluation by a dozen 5th-graders!?!!

Project History

- **1998:** "Original Edition Handheld Video Games":
  - no sound, makeshift buttons and cases
  - **Games:** Street Fighter, Battleship, Breakout, PIC Pilot
- **1999:** "Handheld Video Games II":
  - one- or two-track sound, real NES buttons, smaller cases
  - **Games:** Combat!, Bowling, Go Banana!, Tetris, Missile Command, Duel Tetris, PICman
- **2000:** "Ultimate Handheld Video Games" (as in, the last):
  - custom printed-circuit boards, even smaller cases, in-circuit emulator for development
  - **Games:** ???

PIC Overview

- Harvard architecture (separate instruction and data memories)
  - 14-bit instructions
  - 8-bit data
- Single-cycle instruction execution via instruction pre-fetch

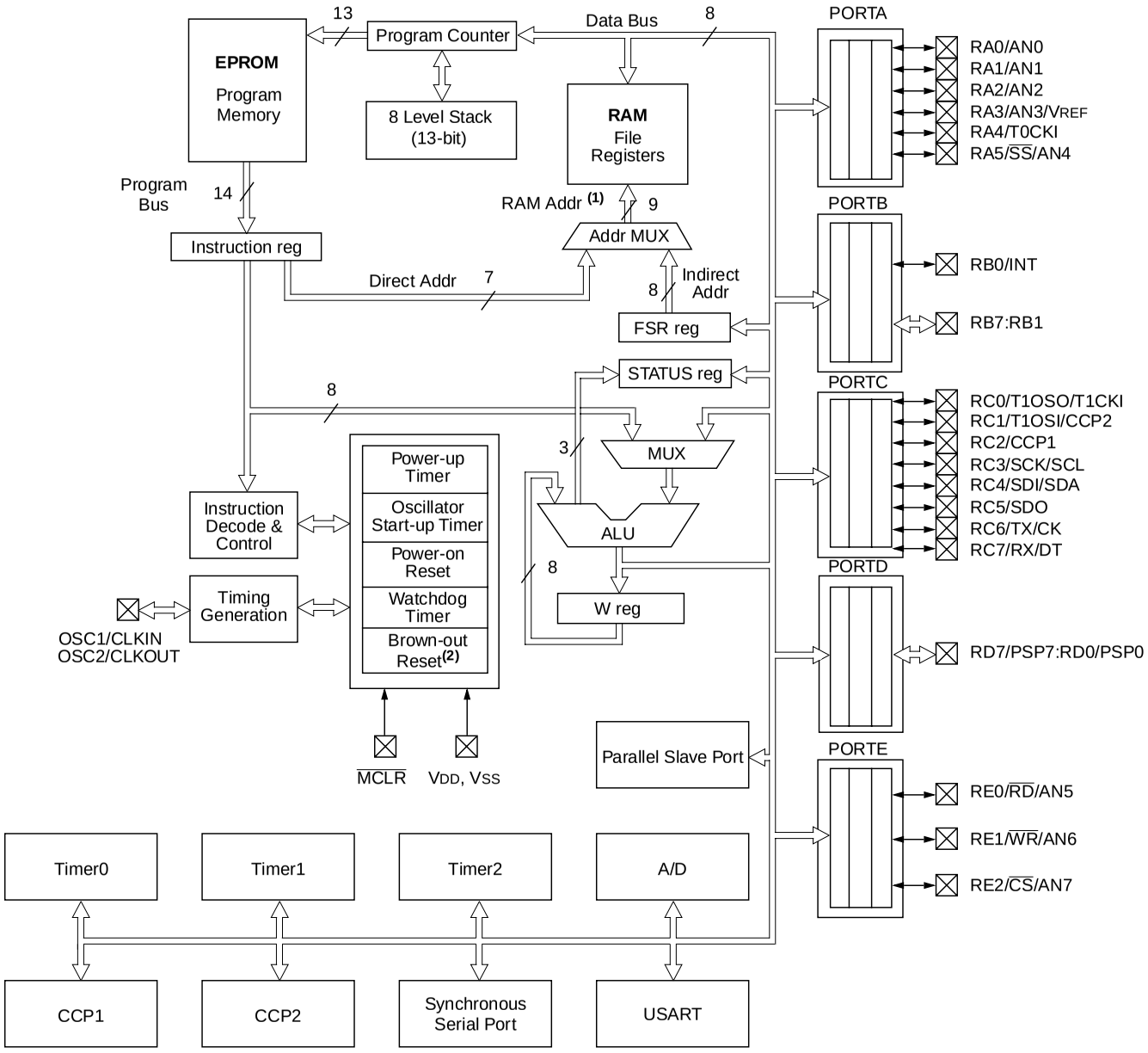


- 200-ns instruction cycle
- Reduced instruction set (35 total) . . .

PIC Instruction Set

Mnemonic, Operands		Description	Cycles	14-Bit Instruction Word MSb			LSb	Status Bits Affected	Notes
BYTE-ORIENTED FILE REGISTER OPERATIONS									
ADDWF	f, d	Add W and f	1	00	0111	dfff	ffff	C,DC,Z	1,2
ANDWF	f, d	AND W with f	1	00	0101	dfff	ffff	Z	1,2
CLRF	f	Clear f	1	00	0001	lfff	ffff	Z	2
CLRW	-	Clear W	1	00	0001	0xxx	xxxx	Z	
COMF	f, d	Complement f	1	00	1001	dfff	ffff	Z	1,2
DECF	f, d	Decrement f	1	00	0011	dfff	ffff	Z	1,2
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00	1011	dfff	ffff		1,2,3
INCF	f, d	Increment f	1	00	1010	dfff	ffff	Z	1,2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00	1111	dfff	ffff		1,2,3
IORWF	f, d	Inclusive OR W with f	1	00	0100	dfff	ffff	Z	1,2
MOVF	f, d	Move f	1	00	1000	dfff	ffff	Z	1,2
MOVWF	f	Move W to f	1	00	0000	lfff	ffff		
NOP	-	No Operation	1	00	0000	0xx0	0000		
RLF	f, d	Rotate Left f through Carry	1	00	1101	dfff	ffff	C	1,2
RRF	f, d	Rotate Right f through Carry	1	00	1100	dfff	ffff	C	1,2
SUBWF	f, d	Subtract W from f	1	00	0010	dfff	ffff	C,DC,Z	1,2
SWAPF	f, d	Swap nibbles in f	1	00	1110	dfff	ffff		1,2
XORWF	f, d	Exclusive OR W with f	1	00	0110	dfff	ffff	Z	1,2
BIT-ORIENTED FILE REGISTER OPERATIONS									
BCF	f, b	Bit Clear f	1	01	00bb	bfff	ffff		1,2
BSF	f, b	Bit Set f	1	01	01bb	bfff	ffff		1,2
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01	10bb	bfff-	ffff		3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01	11bb	bfff	ffff		3
LITERAL AND CONTROL OPERATIONS									
ADDLW	k	Add literal and W	1	11	111x	kkkk	kkkk	C,DC,Z	
ANDLW	k	AND literal with W	1	11	1001	kkkk	kkkk	Z	
CALL	k	Call subroutine	2	10	0kkk	kkkk	kkkk		
CLRWDT	-	Clear Watchdog Timer	1	00	0000	0110	0100	$\overline{TO}$,$\overline{PD}$	
GOTO	k	Go to address	2	10	1kkk	kkkk	kkkk		
IORLW	k	Inclusive OR literal with W	1	11	1000	kkkk	kkkk	Z	
MOVLW	k	Move literal to W	1	11	00xx	kkkk	kkkk		
RETFIE	-	Return from interrupt	2	00	0000	0000	1001		
RETLW	k	Return with literal in W	2	11	01xx	kkkk	kkkk		
RETURN	-	Return from Subroutine	2	00	0000	0000	1000		
SLEEP	-	Go into standby mode	1	00	0000	0110	0011	$\overline{TO}$,$\overline{PD}$	
SUBLW	k	Subtract W from literal	1	11	110x	kkkk	kkkk	C,DC,Z	
XORLW	k	Exclusive OR literal with W	1	11	1010	kkkk	kkkk	Z	

PIC 16C74A



- 4K program and 192-byte data memories
- 33 I/Os, including 8 A/D

PIC 16C74A Registers

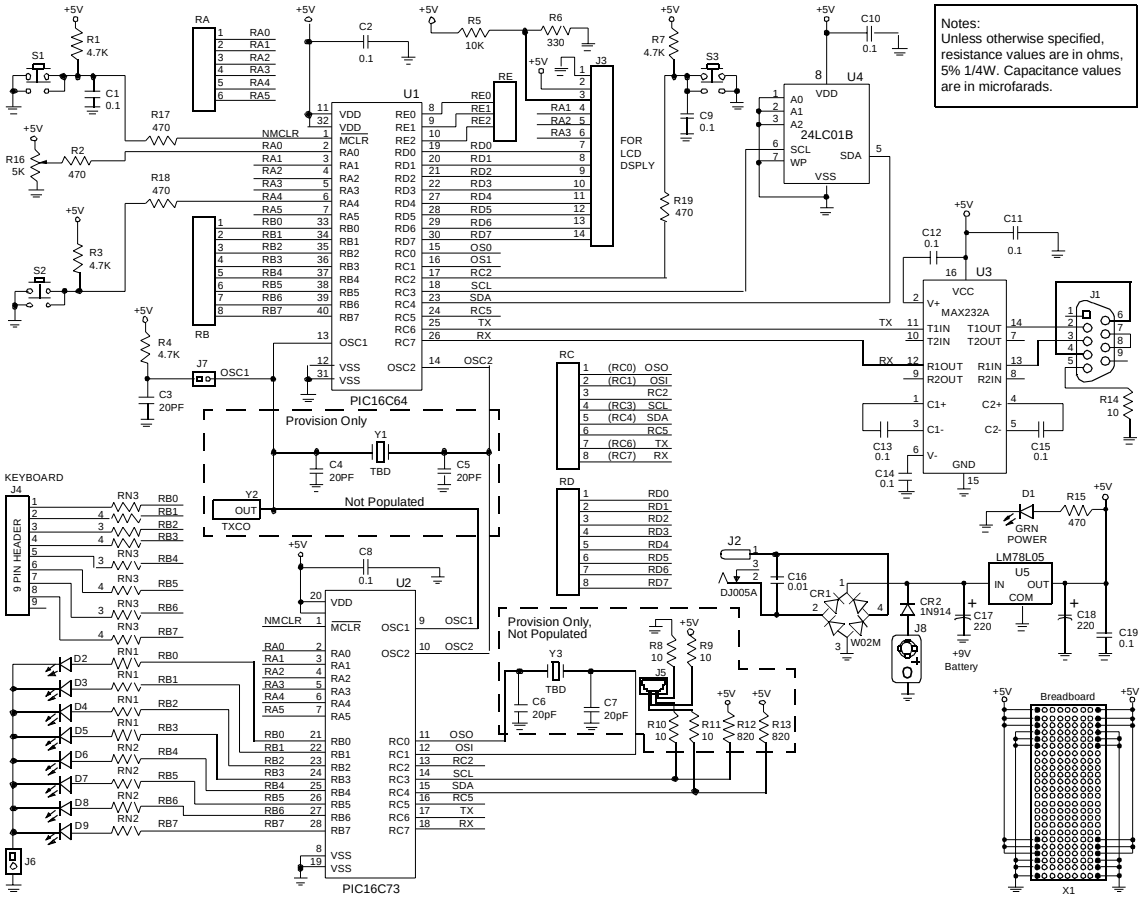
File Address	Bank 0	Bank 1	File Address
00h	INDF(1)	INDF(1)	80h
01h	TMR0	OPTION	81h
02h	PCL	PCL	82h
03h	STATUS	STATUS	83h
04h	FSR	FSR	84h
05h	PORTA	TRISA	85h
06h	PORTB	TRISB	86h
07h	PORTC	TRISC	87h
08h	PORTD(2)	TRISD(2)	88h
09h	PORTE(2)	TRISE(2)	89h
0Ah	PCLATH	PCLATH	8Ah
0Bh	INTCON	INTCON	8Bh
0Ch	PIR1	PIE1	8Ch
0Dh	PIR2	PIE2	8Dh
0Eh	TMR1L	PCON	8Eh
0Fh	TMR1H		8Fh
10h	T1CON		90h
11h	TMR2		91h
12h	T2CON	PR2	92h
13h	SSPBUF	SSPADD	93h
14h	SSPCON	SSPSTAT	94h
15h	CCPR1L		95h
16h	CCPR1H		96h
17h	CCP1CON		97h
18h	RCSTA	TXSTA	98h
19h	TXREG	SPBRG	99h
1Ah	RCREG		9Ah
1Bh	CCPR2L		9Bh
1Ch	CCPR2H		9Ch
1Dh	CCP2CON		9Dh
1Eh	ADRES		9Eh
1Fh	ADCON0	ADCON1	9Fh
20h	General Purpose Register	General Purpose Register	A0h
7Fh			FFh

Development Environment

- PICDEM-2 demonstration board
- MPLAB IDE (Integrated Development Environment)
  - assembler
  - linker
  - *excellent* simulator

  Free for download, with *many* useful application notes
- Chipmaster 6000 device programmer
- U-V eraser

PICDEM-2 Demonstration Board



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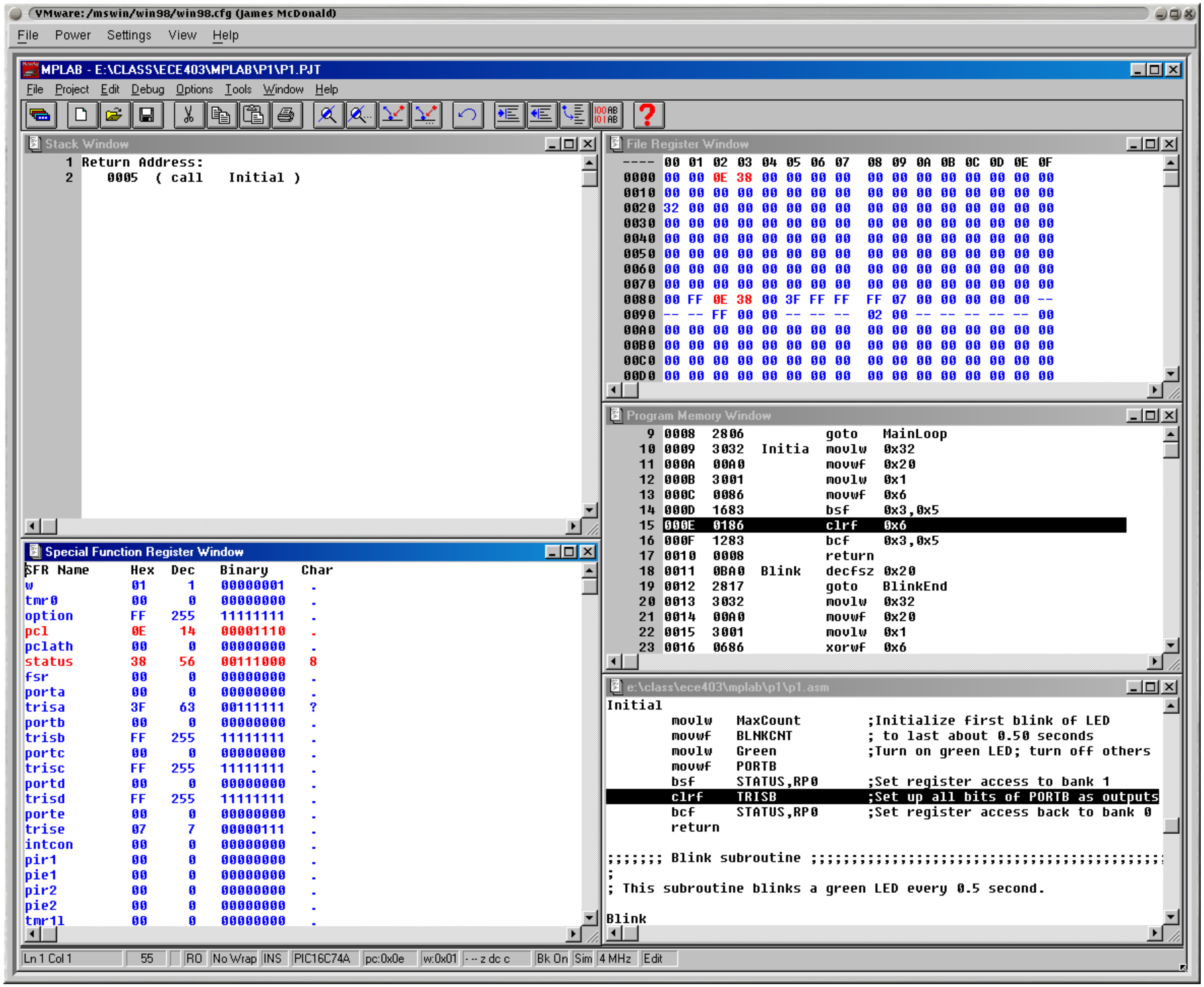
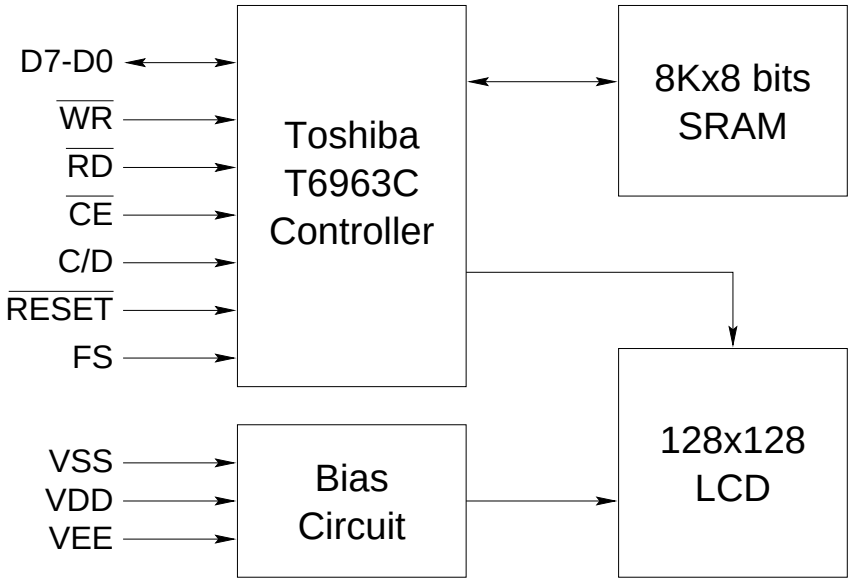
MPLAB IDE


VMware: /mswin/win98/win98.cfg (James McDonald)
File Power Settings View Help
MPLAB - E:\CLASS\ECE403\MPLAB\P1\P1.PJT
File Project Edit Debug Options Tools Window Help
Stack Window
1 Return Address:
2 0005 (call Initial)
File Register Window
---- 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F
0000 00 00 0E 38 00 00 00 00 00 00 00 00 00 00 00 00
0010 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0020 32 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0030 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0040 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0050 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0070 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0080 00 FF 0E 38 00 3F FF FF FF 07 00 00 00 00 00 --
0090 -- -- FF 00 00 -- -- -- 02 00 -- -- -- -- -- 00
00A0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00B0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00D0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
Program Memory Window
9 0008 2806 goto MainLoop
10 0009 3032 Initia movlw 0x32
11 000A 00A0 movwf 0x20
12 000B 3001 movlw 0x1
13 000C 0086 movwf 0x6
14 000D 1683 bsf 0x3,0x5
15 000E 0186 clrf 0x6
16 000F 1283 bcf 0x3,0x5
17 0010 0008 return
18 0011 0BA0 Blink decfsz 0x20
19 0012 2817 goto BlinkEnd
20 0013 3032 movlw 0x32
21 0014 00A0 movwf 0x20
22 0015 3001 movlw 0x1
23 0016 0686 xorwf 0x6
Special Function Register Window
SFR Name Hex Dec Binary Char
w 01 1 00000001 .
tmr0 00 0 00000000 .
option FF 255 11111111 .
pcl 0E 14 00001110 .
pclath 00 0 00000000 .
status 38 56 00111000 8
fsr 00 0 00000000 .
porta 00 0 00000000 .
trisa 3F 63 00111111 ?
portb 00 0 00000000 .
trisb FF 255 11111111 .
portc 00 0 00000000 .
trisc FF 255 11111111 .
portd 00 0 00000000 .
trisd FF 255 11111111 .
porte 00 0 00000000 .
trise 07 7 00000111 .
intcon 00 0 00000000 .
pir1 00 0 00000000 .
pie1 00 0 00000000 .
pir2 00 0 00000000 .
pie2 00 0 00000000 .
tmr1l 00 0 00000000 .
e:\class\ece403\mplab\p1\p1.asm
Initial
movlw MaxCount ;Initialize first blink of LED
movwf BLNKCNT ; to last about 0.50 seconds
movlw Green ;Turn on green LED; turn off others
movwf PORTB
bsf STATUS,RP0 ;Set register access to bank 1
clrf TRISB ;Set up all bits of PORTB as outputs
bcf STATUS,RP0 ;Set register access back to bank 0
return
;;;;;;; Blink subroutine ;;
;
; This subroutine blinks a green LED every 0.5 second.
Blink
Ln 1 Col 1 55 RO No Wrap INS PIC16C74A pc:0x0e w:0x01 --- z dc c Bk On Sim 4 MHz Edit

LCD Module Overview

Block Diagram:



- 128×128-pixel graphics and/or
- 16×16 array of 8×8-pixel characters (including user-defined)

Graphic LCD Controller

(Toshiba T6963C)

COMMAND	CODE	D1	D2	FUNCTION
REGISTERS SETTING	00100001	X address	Y address	Set Cursor Pointer
	00100010	Data	00H	Set Offset Register
	00100100	Low address	High address	Set Address Pointer
SET CONTROL WORD	01000000	Low address	High address	Set Text Home Address
	01000001	Columns	00H	Set Text Area
	01000010	Low address	High address	Set Graphic Home Address
	01000011	Columns	00H	Set Graphic Area
MODE SET	1000X000	—	—	OR mode
	1000X001	—	—	EXOR mode
	1000X011	—	—	AND mode
	1000X100	—	—	Text Attribute mode
	10000XXX	—	—	Internal CG ROM mode
	10001XXX	—	—	External CG RAM mode
DISPLAY MODE	10010000	—	—	Display off
	1001XX10	—	—	Cursor on, blink off
	1001XX11	—	—	Cursor on, blink on
	100101XX	—	—	Text on, graphic off
	100110XX	—	—	Text off, graphic on
	100111XX	—	—	Text on, graphic on
CURSOR PATTERN SELECT	10100000	—	—	1-line cursor
	10100001	—	—	2-line cursor
	10100010	—	—	3-line cursor
	10100011	—	—	4-line cursor
	10100100	—	—	5-line cursor
	10100101	—	—	6-line cursor
	10100110	—	—	7-line cursor
	10100111	—	—	8-line cursor
DATA AUTO READ / WRITE	10110000	—	—	Set Data Auto Write
	10110001	—	—	Set Data Auto Read
	10110010	—	—	Auto Reset
DATA READ / WRITE	11000000	Data	—	Data Write and Increment ADP
	11000001	—	—	Data Read and Increment ADP
	11000010	Data	—	Data Write and Decrement ADP
	11000011	—	—	Data Read and Decrement ADP
	11000100	Data	—	Data Write and Nonvariable ADP
	11000101	—	—	Data Read and Nonvariable ADP
SCREEN PEEK	11100000	—	—	Screen Peek
SCREEN COPY	11101000			Screen Copy
BIT SET / RESET	11110XXX	—	—	Bit Reset
	11111XXX	—	—	Bit Set
	1111X000	—	—	Bit 0 (LSB)
	1111X001	—	—	Bit 1
	1111X010	—	—	Bit 2
	1111X011	—	—	Bit 3
	1111X100	—	—	Bit 4
	1111X101	—	—	Bit 5
	1111X110	—	—	Bit 6
	1111X111	—	—	Bit 7 (MSB)

ISD ChipCorder

Brags by the Company:

Features and Benefits of ChipCorder Products

Single-Chip Solution
Optimal for lightweight, portable products.

Simple Integration
No software development required, quick time to market

Exceptional Sound Quality
Authentic, natural sounding voice and music reproduction

Low Power Consumption
Ideal for battery-powered applications.

Battery-less Voice Storage
Power failure protection

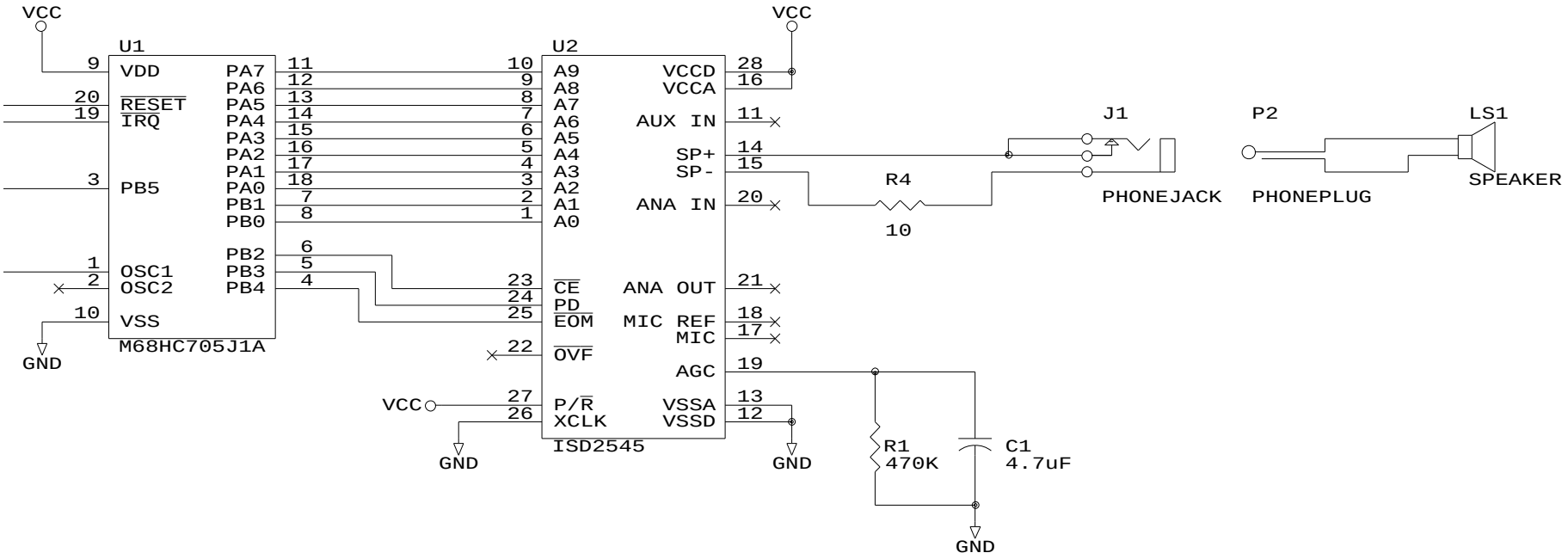
Low Cost
Meets consumer market demands

ChipCorder Products Offer:

- Voice record and playback system on a single chip
- 6 seconds to 8 minutes record and playback durations
- Industry-leading sound quality
- Fully integrated system functions: AGC, mic preamp, speaker drivers, filters, oscillator, memory
- Low voltage operation
- Message management
- Flexible architecture
- Battery-less message storage

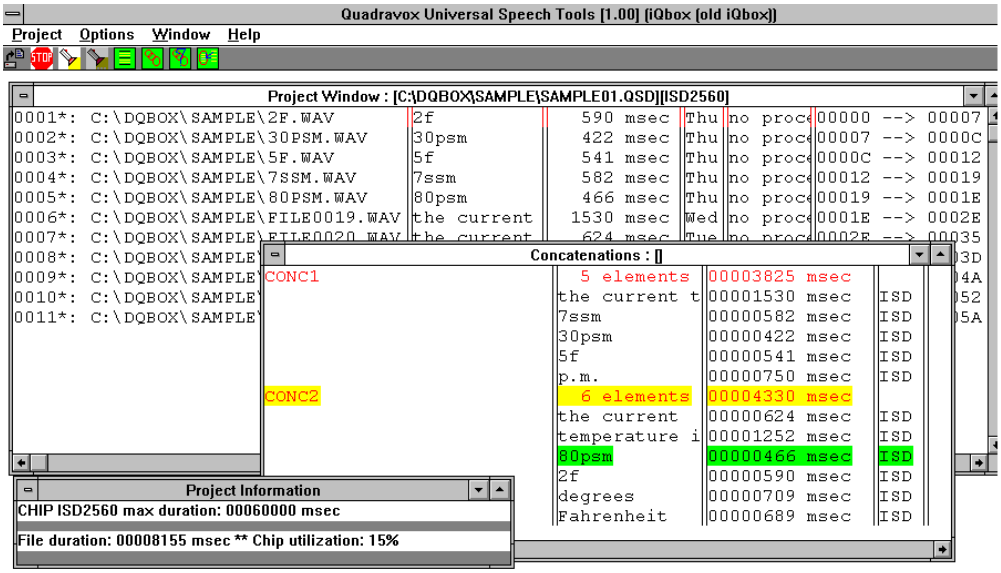
ChipCorder Interfacing

Interface to a Typical Microcontroller:

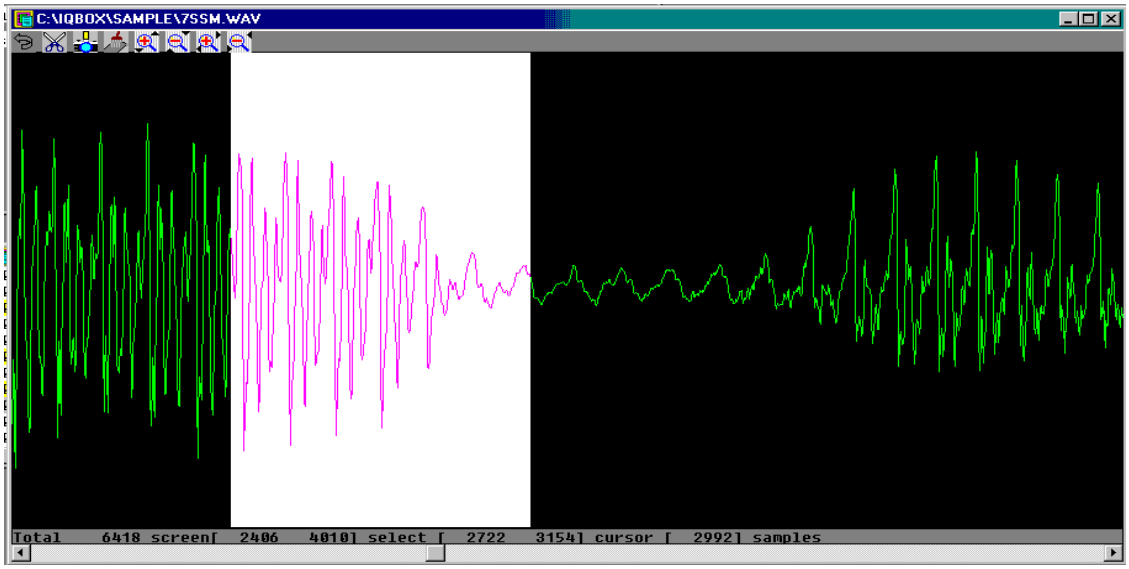


ChipCorder Development

- Quadravox QV-400 development board and software support programming of `.wav` files
- Project window:

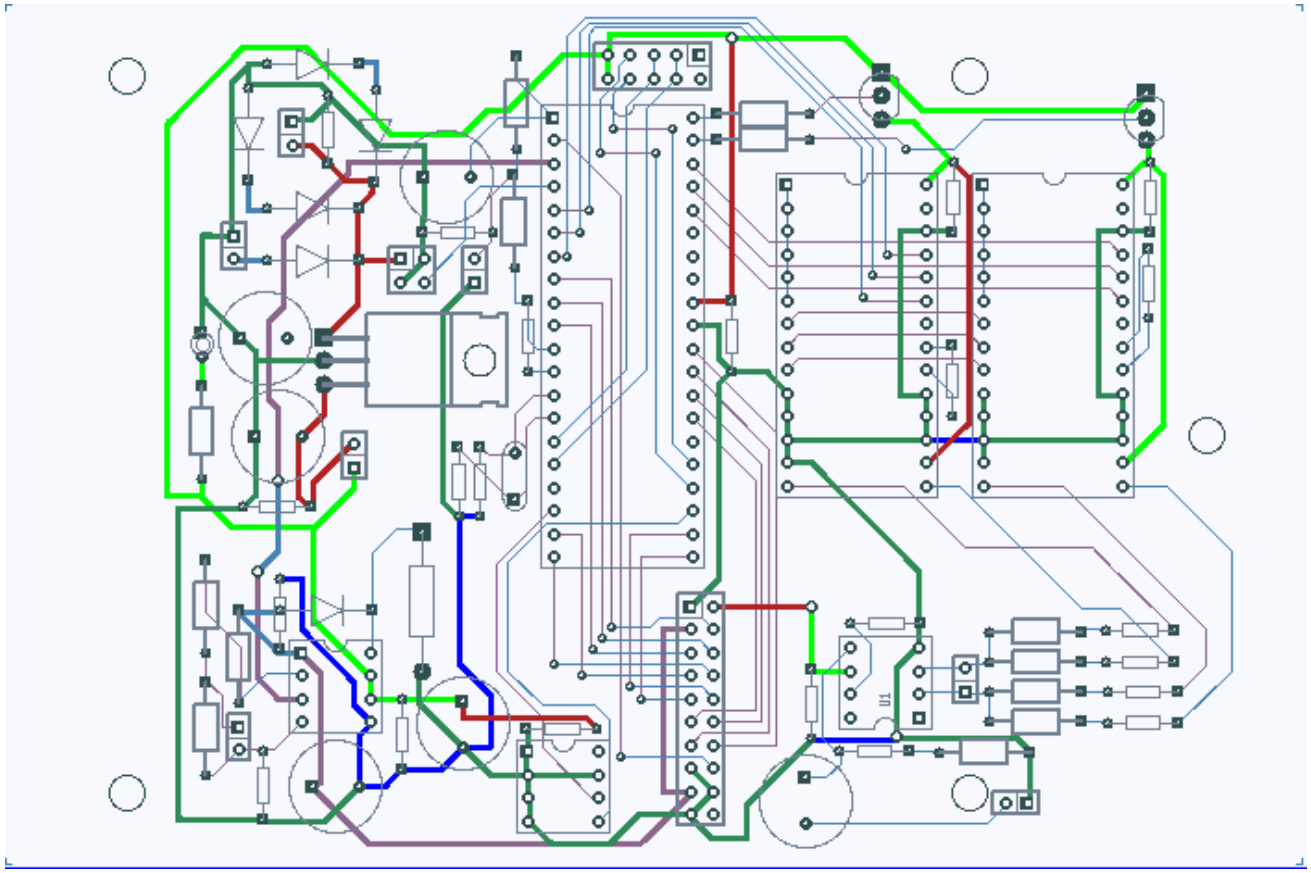


- Waveform editor:



2000: Printed-Circuit Fab

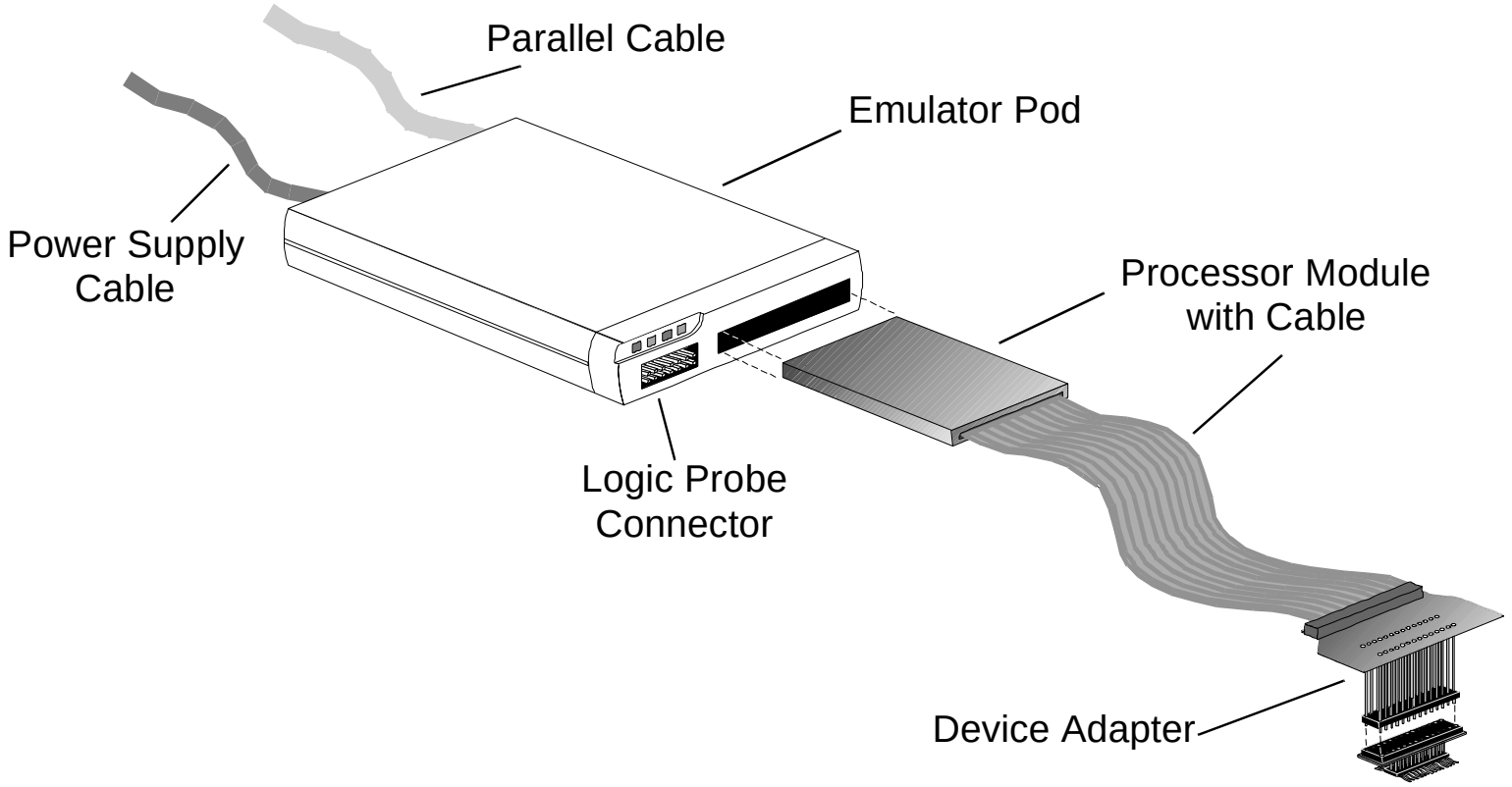
- Layout for Duel Tetris (using Linux freeware `pcb`):



- Fabrication cost at APC: ≈$100 for 2 copies

2000: MPLAB-ICE

- MPLAB-compatible In-Circuit Emulation system:



- No more code, compile, simulate, burn, reset, crash, erase, code, compile, simulate, burn, reset, crash, erase, . . . cycle!