



Classic Game Postmortem: Ms. Pac-Man

Steve Golson
Trilobyte Systems

Introduction

Who am I

Who are you

What was General Computer (GCC)

When did it happen

Why it matters

MIT 1978

Doug Macrae
Kevin Curran



Pinball and video games at MIT dorms

Pioneer

Playboy

Paragon

Fire One

Star Castle

Rip Off

Battlezone

Missile Command
and more...

Speedup Kits

Roller Derby Lido's, all with innovations. CALL 314/636-4096.

60240

100%

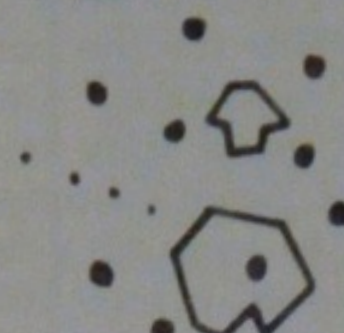
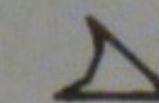
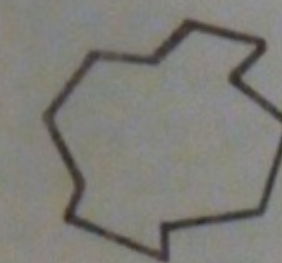
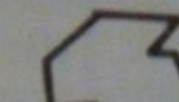
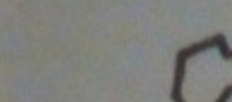
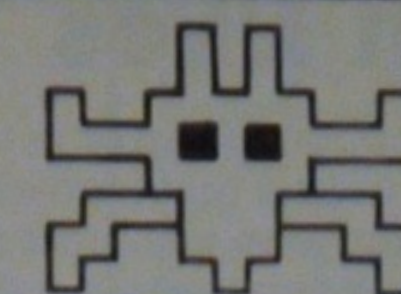
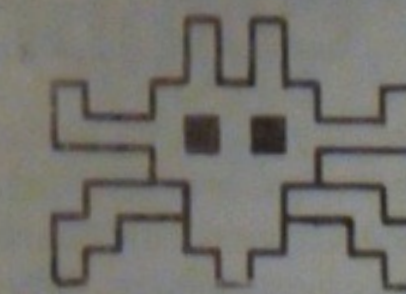
8370

NEW IMPROVED DESIGN

Asteroid Operators - DON'T LET THIS HAPPEN TO YOU! Our modification Kit II is adaptable to all asteroid games allowing you to vary any of 3 speeds, virtually eliminating machine turnover, even with your best players! **TESTED and PROVEN.** Games with this modification kit take in more money and faster than any other game on the street. **Kit II** installs in minutes without changing chips. **Kit II** was designed to improve play and increase profits and is operator adjustable. **INCREASE PROFITS IMMEDIATELY** send \$19.95 +\$2.00 shpg. (includes all parts necessary to modify 1 game)

To: **Design Wizardry, Ltd.**

P.O. Box 519, Brooklandville, Md. 21022



Increase Profits With Super Galaxian Kit

Renew Excitement With

ASTEROIDS SPEED UP KIT

KIT FEATURES:

Galaxian

- Increases number of diving creatures
- Adds new variations to creatures flight path

ASTEROIDS

- Up to 6 speed increments
- 4 different time delay settings
- Easy installation, only one IC to remove

Asteroids

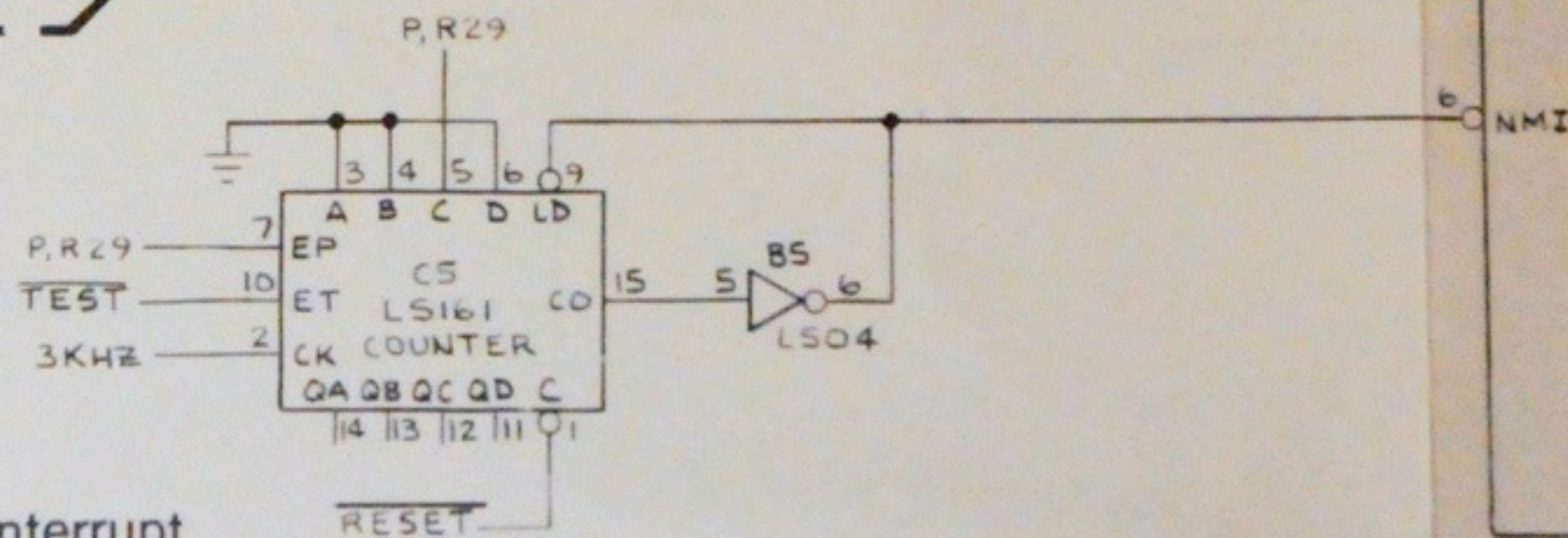
Atari, 1979

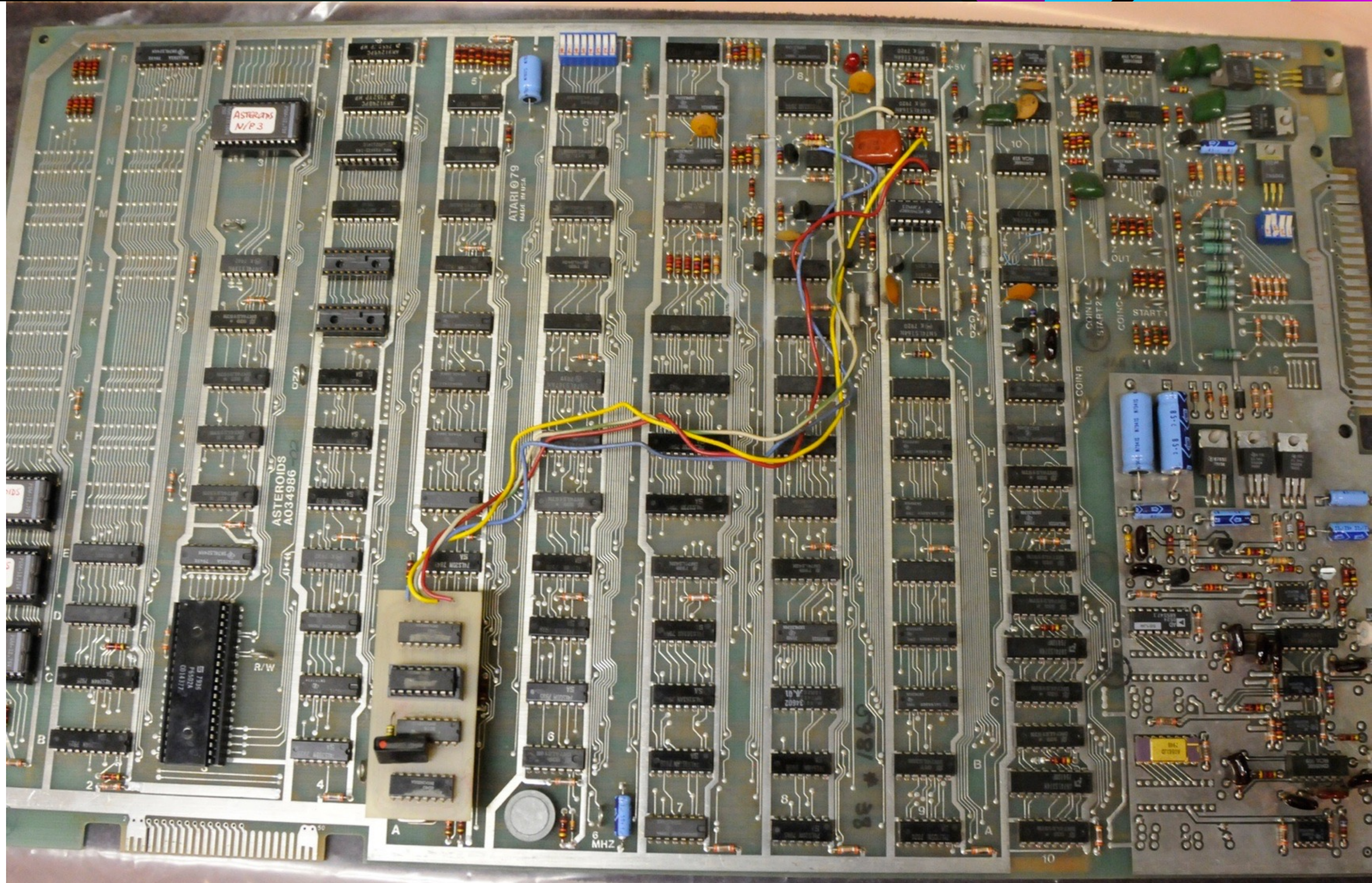
Vector display

Interrupt driven at 250Hz

NMI COUNTER

The NMI (non-maskable interrupt) counter causes an interrupt at the NMI input of the MPU every 4 msec. The interrupt is derived by dividing 3 KHz by a factor of 12 through counter C5. The interrupt occurs when pin 6 of inverter B5 goes low. During power-up, the NMI counter is disabled by RESET. During Self-Test, the NMI is disabled by TEST.





Galaxian

Namco/Midway, 1979

Character display

Tables in ROM

Pac-Man

Namco/Midway, 1980

Character display

Maze tables in ROM

Separate graphics ROMs

Missile Command

Atari, 1980

Sophisticated programming

Bitmap display 256 x 231

Pixel addressable

2 or 3 bits per pixel

March 1981

General Computer Corp.

Super Missile Attack

enhancement kit for
Atari Missile Command





Design flow at GCC

GenRad 6502 microprocessor emulator

- Disassembler (single screen only)
- Memory display/modify
- Interactive edit/assemble/run
- Breakpoints

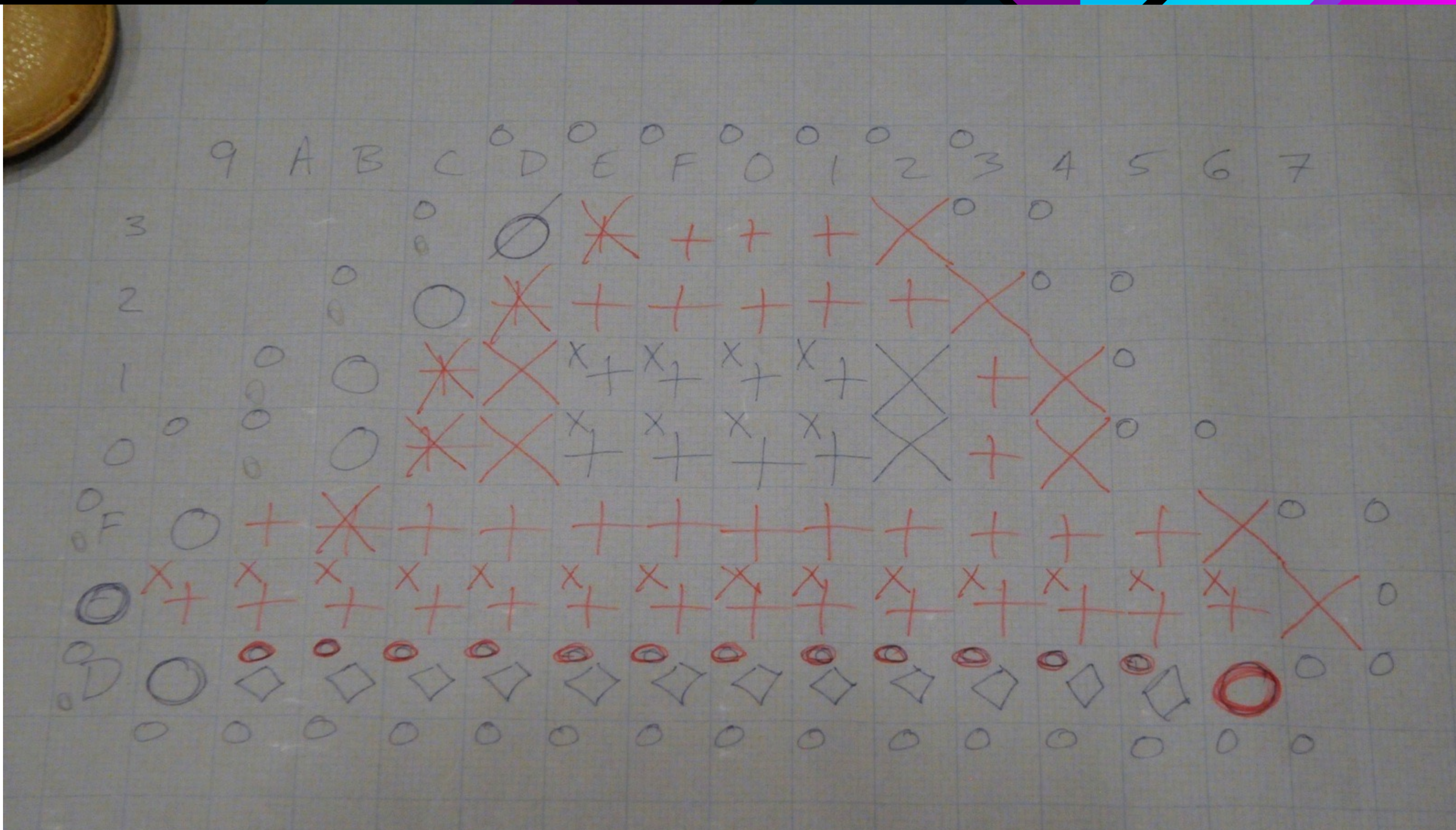
TRS-80 to capture Missile Command code

Address	Instruction	Comments
5458	LDY 00B4	
	DEY	
	BPL 545F	
	LDY #04	
545F	STY 00B4	
	LDA 008E	# CURRENT CLOUDS
	BEQ 54B0	(NO CLOUDS)
	LDX 54B2	
5468	LDA 016E,X	3
	BEQ 54A7	
	STA 009C	
	INC 01C2,X	
	LDA 01C2,X	
	AND #7F	
	TAY	
	CMP #1B	
	BCC 5492	
	LDA 01C2,X	
	BMI 5486	
	DEC 008F	
	CLV	
	BVC 5488	
5486	DEC 0090	
5488	DEC 008E	
	LDA #00	
	STA 016E,X	
	CLV	
	BVC 54A7	
5492	LDA 0139,X	
	STA 009B	
	LDA 54B7,Y	
	STA 00B5	
	LDA 54B8,Y	
	STA 009A	
54A1	JSR 5E71	
	JSR 54D4	
54A7	DEX	
	LDY 00B4	
	TXA	
	CMP 54B1,Y	
	BNE 5468	
54B0	RTS	

Handwritten notes and annotations:

- UPDATE CLOUD STATUS
- EXTRA JUMP 54A2
- CONDITIONAL CHECK
- INC
- JMP NORMAL
- CLOUD RADII CALCULATIONS
- JSR RADIUS 1
- STA 9A
- JMP 54A4
- JSR RADIUS 2
- JSR RADIUS 3
- JSR RADIUS 4
- JSR RADIUS 5
- JSR RADIUS 6
- JSR RADIUS 7
- JSR RADIUS 8
- JSR RADIUS 9
- JSR RADIUS 10
- JSR RADIUS 11
- JSR RADIUS 12
- JSR RADIUS 13
- JSR RADIUS 14
- JSR RADIUS 15
- JSR RADIUS 16
- JSR RADIUS 17
- JSR RADIUS 18
- JSR RADIUS 19
- JSR RADIUS 20
- JSR RADIUS 21
- JSR RADIUS 22
- JSR RADIUS 23
- JSR RADIUS 24
- JSR RADIUS 25
- JSR RADIUS 26
- JSR RADIUS 27
- JSR RADIUS 28
- JSR RADIUS 29
- JSR RADIUS 30
- JSR RADIUS 31
- JSR RADIUS 32
- JSR RADIUS 33
- JSR RADIUS 34
- JSR RADIUS 35
- JSR RADIUS 36
- JSR RADIUS 37
- JSR RADIUS 38
- JSR RADIUS 39
- JSR RADIUS 40
- JSR RADIUS 41
- JSR RADIUS 42
- JSR RADIUS 43
- JSR RADIUS 44
- JSR RADIUS 45
- JSR RADIUS 46
- JSR RADIUS 47
- JSR RADIUS 48
- JSR RADIUS 49
- JSR RADIUS 50
- JSR RADIUS 51
- JSR RADIUS 52
- JSR RADIUS 53
- JSR RADIUS 54
- JSR RADIUS 55
- JSR RADIUS 56
- JSR RADIUS 57
- JSR RADIUS 58
- JSR RADIUS 59
- JSR RADIUS 60
- JSR RADIUS 61
- JSR RADIUS 62
- JSR RADIUS 63
- JSR RADIUS 64
- JSR RADIUS 65
- JSR RADIUS 66
- JSR RADIUS 67
- JSR RADIUS 68
- JSR RADIUS 69
- JSR RADIUS 70
- JSR RADIUS 71
- JSR RADIUS 72
- JSR RADIUS 73
- JSR RADIUS 74
- JSR RADIUS 75
- JSR RADIUS 76
- JSR RADIUS 77
- JSR RADIUS 78
- JSR RADIUS 79
- JSR RADIUS 80
- JSR RADIUS 81
- JSR RADIUS 82
- JSR RADIUS 83
- JSR RADIUS 84
- JSR RADIUS 85
- JSR RADIUS 86
- JSR RADIUS 87
- JSR RADIUS 88
- JSR RADIUS 89
- JSR RADIUS 90
- JSR RADIUS 91
- JSR RADIUS 92
- JSR RADIUS 93
- JSR RADIUS 94
- JSR RADIUS 95
- JSR RADIUS 96
- JSR RADIUS 97
- JSR RADIUS 98
- JSR RADIUS 99
- JSR RADIUS 100

Start -----	End -----	R/W -----	Description -----	Type/bytes -----
..... 002C	0043	R/W	Initials for "High Scores"	A 3
0044	0056	R/W	Scores for "High Scores"	BCD 6
..... 0066	0066	R/W	Number of credits.	Byte
..... 009F	009F	R/W	Important to Interrupt handler	
..... 00A0	00A2	R/W	No. of missiles in a base (L to R)	
..... 00C0	00C0	R/W	Number of cities	
00C5	00C5	R/W	City map !3!5!4!1!2!6!X!X!	(Notation indicates correspondence of bits in the byte to existence of city.)
..... 00ED	00ED	R/W	Coin switches	Bit?
00EE	00EE	R/W	Game switches	Bit?
..... 00F6	00F6	R/W	Coin switches	Bit?
00F8	00F8	R/W	Coin switches	Bit?
..... 01E0	01FF	R/W	Stack	



Intellectual property

Avoid copyright infringement

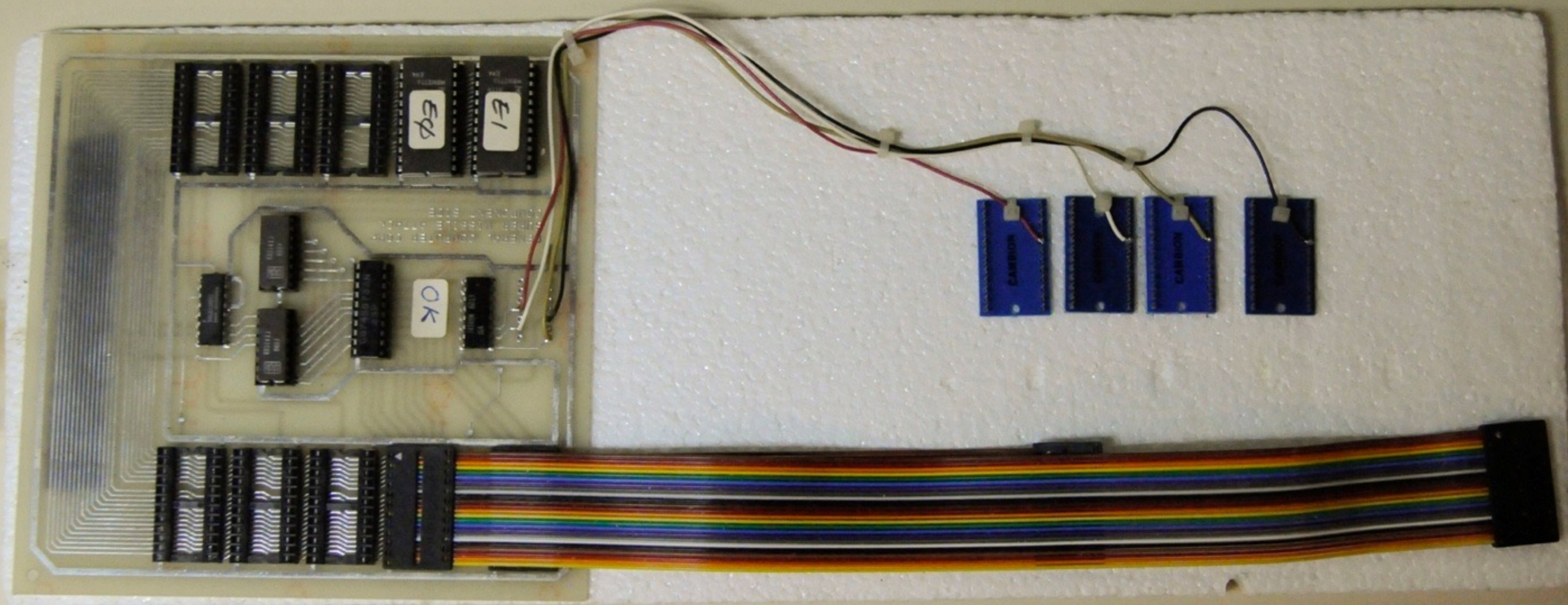
- require existing Atari ROMs
- provide new GCC code as overlay

Keep Atari copyright/phonogram notice © ®

Add GCC copyright notice ©

Avoid trademark infringement (new name)

Protect our code with anti-copy hardware



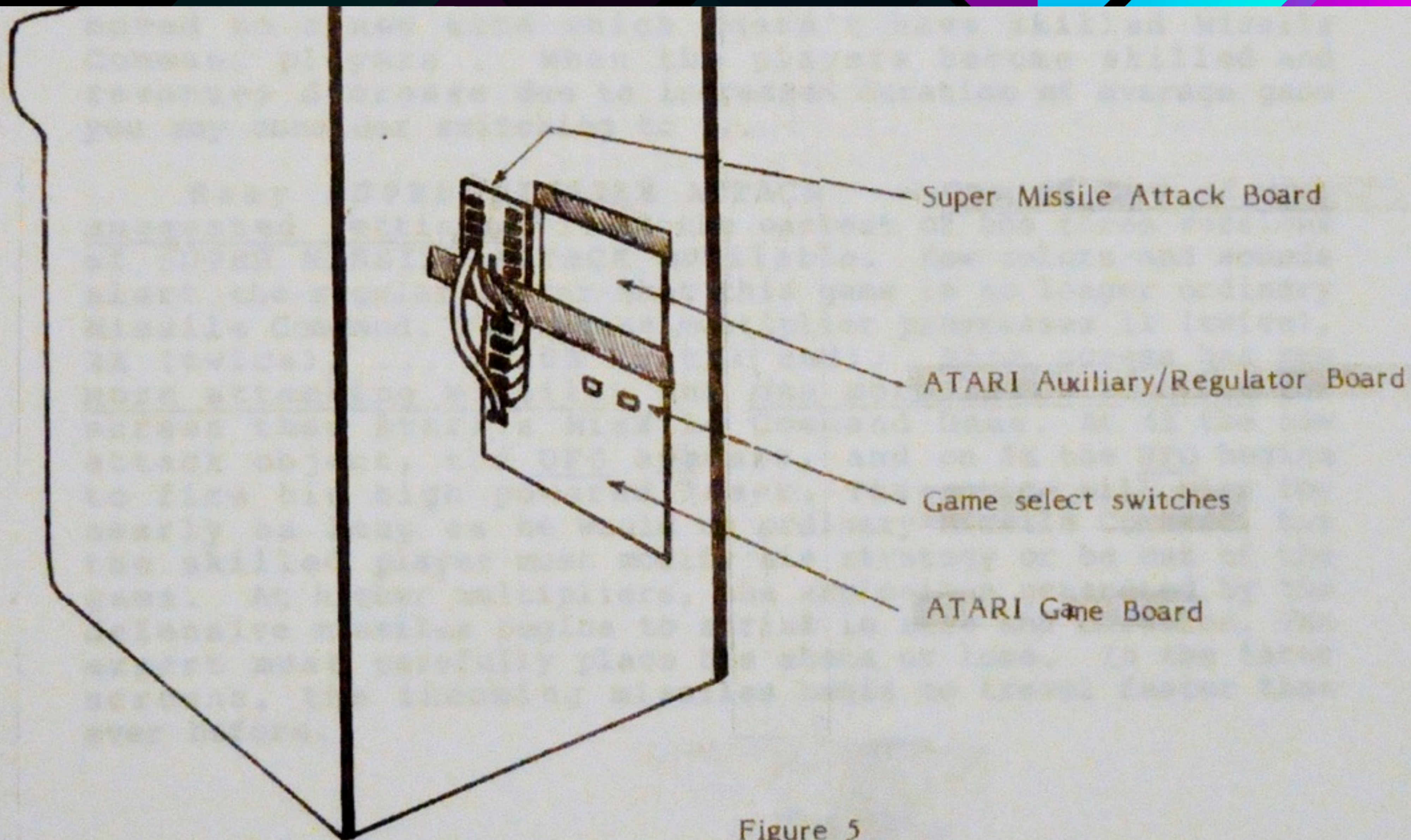
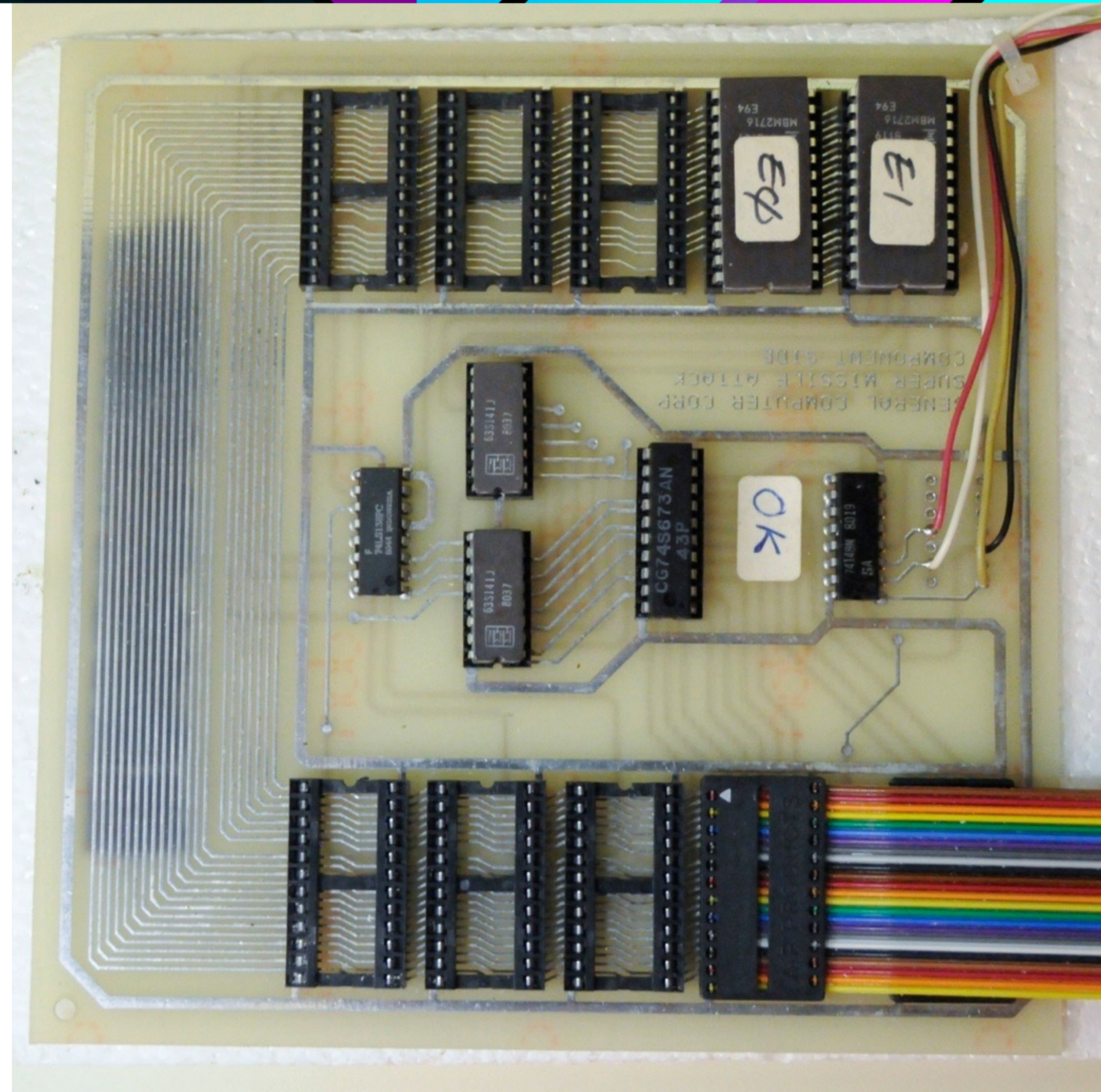


Figure 5
Completed Assembly

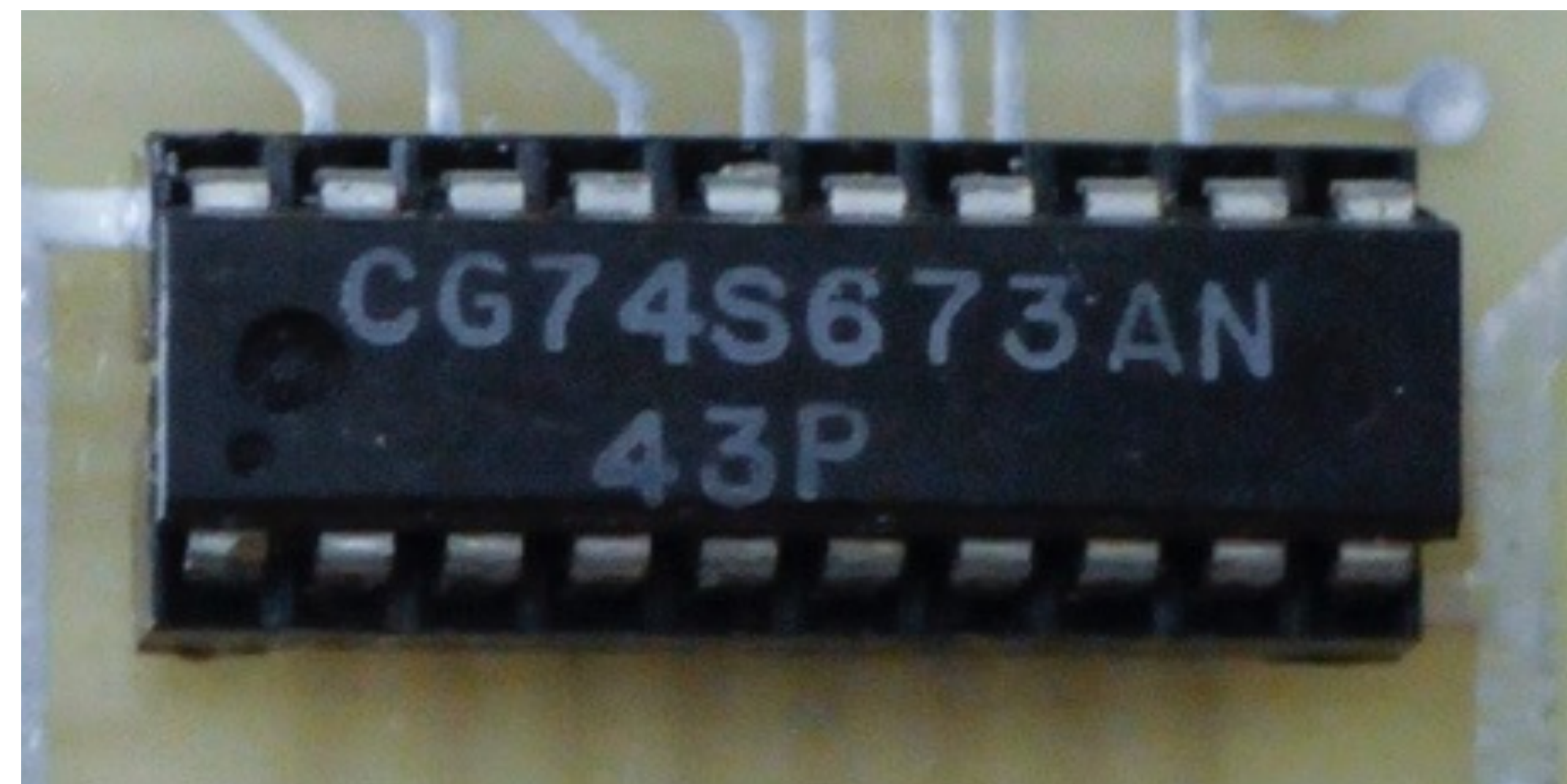
12k bytes MC code

4k bytes SMA code



PAL markings removed
and replaced with:

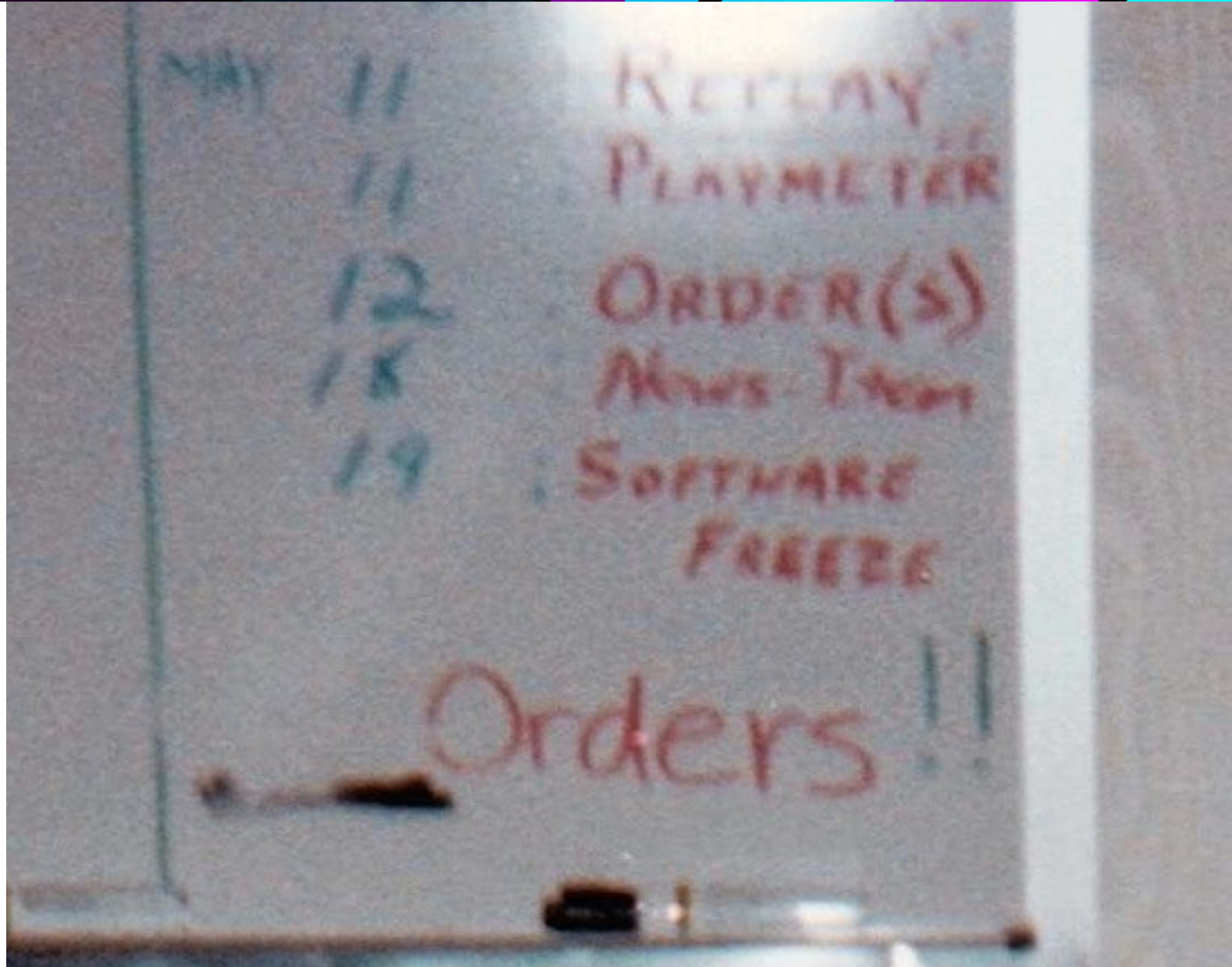
GCC74S673AN
43P



Oops.



Scheduling





explosive profits

MISSILE SUPER ATTACK

It's here! The game enhancement you've been waiting for - SUPER MISSILE ATTACK™. Designed by General Computer for your Atari MISSILE COMMAND™ Cabinet, it breathes new life into a proven winner.

The simple insertion of a plug-in circuit gives new dimensions to your MISSILE COMMAND™ Game. Increase excitement, difficulty, and your revenues.

SUPER MISSILE ATTACK™ is a software enhancement. All the characteristics that made MISSILE COMMAND™ a champion have been retained or improved. SUPER MISSILE ATTACK™ is a cashbox winner in test locations. Set the operator selectable difficulty levels and make it a winner in yours.

A General Computer Software Enhancement is your best equipment investment today. For about 10% of the price of a new game you can get your original investment in your MISSILE COMMAND™ working hard for you today.

Call **800-343-9500**
for immediate delivery or further details.

In Mass. call collect **617-232-9220**

HERE'S HOW TO ORDER:

Gentlemen: I am ordering my **SUPER MISSILE ATTACK™** Enhancement(s).
Enclosed is check or money order for _____
Enhancement(s) at \$295.00 each.

name: _____

address: _____

city/state/zip: _____

Mail to: **GENERAL COMPUTER CORPORATION**
1726 Beacon Street
Boston, Mass. 02146

Immediate Shipment Available

General Computer Corp.

Units sold ~1,000

Profit ~\$250,000

Developers of Super Missile Attack

Doug Macrae

Kevin Curran

John Tylko

Chris Rode

Larry Dennison

Steve Golson

Atari takes notice

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

ATARI, INC., a
corporation,

Plaintiff,

v.

GENERAL COMPUTER CORPORATION,
a corporation, KEVIN CURRAN,
and DOUGLAS MACRAE,

Defendants.

Civil Action No. 81-1883-S

COMPLAINT FOR COPYRIGHT INFRINGEMENT,
FALSE DESIGNATION OF ORIGIN, TRADEMARK
INFRINGEMENT, UNFAIR COMPETITION AND TRADEMARK DILUTION

Plaintiff ATARI, INC. alleges as follows:

GENERAL ALLEGATIONS APPLICABLE TO ALL COUNTS

1. Plaintiff is a corporation duly organized and existing
under the laws of the State of Delaware, having a principal place

UNITED STATES DISTRICT COURT
DISTRICT OF MASSACHUSETTS

----- X
ATARI, INC. :
 :
V. : CA 81-1883-S
 :
GENERAL COMPUTER CORP., ET AL :
----- X
GENERAL COMPUTER CORP. :
 :
V. : CA 81-1854-K
 :
ATARI, INC. :
----- X

HEARING

BEFORE THE HONORABLE ROBERT E. KEETON, U.S.D.J.

Courtroom 11
United States Courthouse
Boston, Massachusetts 02109
Friday, July 31, 1981

Boston Globe, July 31, 1981



Customer plays Atari game.

New game plan lands 2 in \$10m court case

By Ronald Rosenberg
Globe Staff

When Atari's coin-operated video game Missile Command gets dull, arcade operators can breathe new life into it just by sliding in a printed circuit board.

Instead of scrapping the game and buying a different machine, which costs \$2500, General Computer Corp. of Wayland will retrofit it for \$295 with a board that contains the software for a new game that provides more play objects and a greater degree of difficulty to challenge customers anew.

But inexpensively tweaking Missile Command (there are more than 10,000 already installed) for greater play value does not sit well with the joint chiefs at Atari, a wholly owned subsidiary of Warner Communications Corp.

So they have fired off a \$10 million lawsuit against Kevin Curran and Douglas Macrae, who last month founded General Computer, claiming they have violated Atari's copyrights and trademarks.

The suit, filed yesterday in US District Court, Boston seeks to stop the small company from manufacturing and selling the single board. The Sunnyvale game firm also wants \$5 million each in punitive damages from Macrae and Curran along with all profits from the add-in board.

"They (the General Computer game enhancement) appear to our customers and to the public as Atari products, creating confusion and siphoning off legitimate returns from our investment in research and development," said Frank A. Ballouz, Atari's vice-president of marketing for the coin-operated video-game division in a prepared statement.

Curran claims the enhancement, the company's first product, has been originally engineered. It went on sale in early June.

"We have tried to avoid all legal difficulties," he said yesterday. "We have not copied or infringed on their software and we will respond to their suit."

Boston Globe, August 14, 1981

Atari gets restraining order

Atari Inc. has received a temporary restraining order that bars General Computer Corp. of Wayland from selling its Super Missile Attack add-in printed circuit boards. An Aug. 25 review of the situation that led Atari to sue the small startup company was scheduled by US District Court Judge Robert E. Keeton. General Computer sells the boards, which slide into Atari's Missile Command game, to arcade game operators. Atari claims General Computer is infringing and diluting its copyrights and trademarks and is seeking \$5 million in damages.

The Wayland-Weston Town Crier

August 20, 1981

Atari files \$10 million suit against Wayland company

WAYLAND — If you want to add a little kick to your Atari "Missile Command," General Computer Corporation of Wayland will transform the \$2,500 video game into "Super Missile Attack" for a mere \$295.

The company, which was incorporated last March, began selling its software enhancer in June. The additional software is attached to an existing game through an overlay circuit without copying or changing any of the Atari software, according to General Computer Chairman Doug MacCrae.

Atari, however, stated in a press release that the new enhancer "infringes and dilutes" its copyrights and trademarks, labelling it "unfair competition." Last month, Atari slapped General Computer and its founders MacCrae and Kevin Curran with a \$10 million suit.

MacCrae noted that he and Curran had contacted Atari in March while they were in the process of incorporating to see if their enhancement infringed on the company's rights.

Atari told them that it had never prosecuted anyone in the past on an enhancement and that it was not in the process of prosecuting anyone, but that there were rights that were held by Atari, related MacCrae. MacCrae also noted that those rights were never clearly defined.

Necessary Steps

"Back in March we took expensive, but necessary steps not to copy the Atari code," he said, later adding, "I was surprised that it (the suit) was slapped on us without consul-

tation. I still feel that Atari lumped us together with pirates (those that copy and sell Atari software outright). I think they (Atari) decided to go ahead with the suit before they knew what we did."

MacCrae also pointed out that in the past other companies have developed mostly speedup kits; the General Computer version adds characters and difficulty to the game.

On August 11, General Computer submitted a second version of its enhancer to the courts, said MacCrae. In the new version, he explained, everything that Atari specifically complained about on its suit had been changed. The revised enhancer has new artwork for the exterior of the game cabinet and each symbol in the game itself, including the text font, has been changed from those used by Atari, he said.

"Of course, since this is an enhancement to their original game, it is still similar, but improved," commented MacCrae.

Atari had "no comment" about the second version of the enhancer.

Thus far, General Computer has spent between \$20,000 to \$30,000 in legal fees according to MacCrae's estimates. There is also a restraining order preventing the company from selling the original version of the enhancer. MacCrae expects a decision on the sale of the second version of the enhancer this week.

Company beginnings

Before its sales were frozen, MacCrae said, the company was doing very well. He and Curran, both students at the Massachu-

setts Institute of Technology (MIT), had been in business together before. The two owned and operated three video games in the dorms at MIT and had found that within two to six months players learned the game well enough to become bored or play for inordinately long periods of time.

"We decided the best remedy to this was to change the one weak part of the game - the software," said MacCrae.

Using their own machines for testing, Curran and MacCrae, along with several others built a software board which could enhance an existing game by giving the machine operator the option of increasing the difficulty.

Said MacCrae, "Our unit starts off easier and ends up more difficult than Atari's 'Missile Command.'"

Making the board was a full-time job. At the outset, company engineers, most of whom are MIT students, spent 24 hours a day in shifts working on it. After the first two-and-a-half weeks, they continued to spend 14

to 20 hours a day working on the project. To months later it was finished.

Smaller Salaries

Despite the initial success of their project, MacCrae noted that he and Curran are drawing smaller salaries from the company than they had received from other companies they had worked for in the past. MacCrae spent two years at Computervision in Bedford, first as an intern and then as a full-time employee. Working for himself was one of his ambitions.

Things went on schedule once MacCrae and Curran decided to start the business. They did original cost estimates, took out a loan and raised the rest of the capital themselves. Later, John Tylko, the only other shareholder in the company also invested some capital. Only the suit has disrupted their plans.

Stated MacCrae, "If enhancements (in general) are determined illegal, which I can't imagine, we are working on new game development ourselves."

Post Road
Discount Liquors



Zapped by Atari

ATARI HAS LEVELED a \$10 million dollar suit against Doug MacCrae (above) and Kevin Curran for infringing on its trademark and copyright. Their company, General Computer Corporation in Wayland, has built an overlay circuit that "enhances" Atari's "Missile Command." Story on page 5.

De ne

WAYLAN
the futur
B and M
Plain Roa
opportuni
time this

At its
Board hop
discuss th
area whic
ers. Arth
Trust and
area.

The Pla
process o
themselve
linked by
wood, act
6, the bo
longing to
panied by
trust. The
adjacent

Allen B
member
submitted
ment in t
plans, wh
the Plann
velopmen
velopmen

Althoug
receive a
the area,
several te
eral infor
developm
DeVincer
cording t
subdivisi
plan was
Board ha

Accord
parcel is
Michael
explained
approval
said tent
14.3 acre

Development agreement with Atari

Signed October 8, 1981

The Atari Settlement

Atari drops its suit against GCC with prejudice

GCC discontinues sales of Super Missile Attack

GCC will not market enhancement kits

without permission from the manufacturer

Atari pays \$50,000 per month to GCC

to develop video games for Atari

(2 year term)

Meanwhile...

What game to enhance next?

Desire a large installed base

- SMA sold ~1k out of 30k MC cabinets
- so perhaps will sell into 3–5% of market?

Consider availability of development systems

Think of obvious new features

- or write a whole new game
but using the existing cabinet controls

What game to enhance next?

Asteroids

- uses 6502 processor
- perhaps write an original game?

Pac-Man

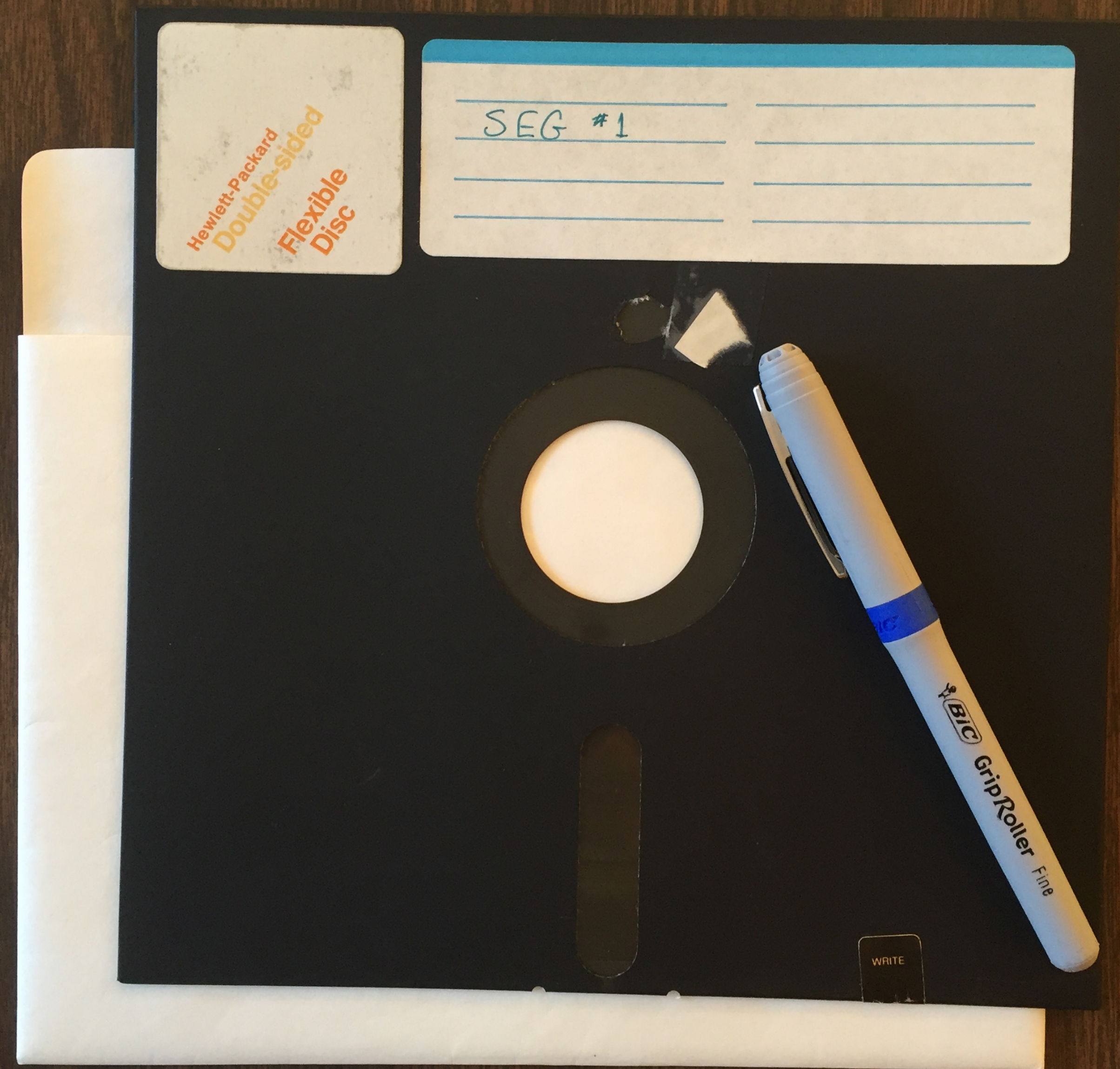
- “hot new game” peaking in popularity
- predictability allows pattern play
- development work begins June 1981...

Tektronix 8550

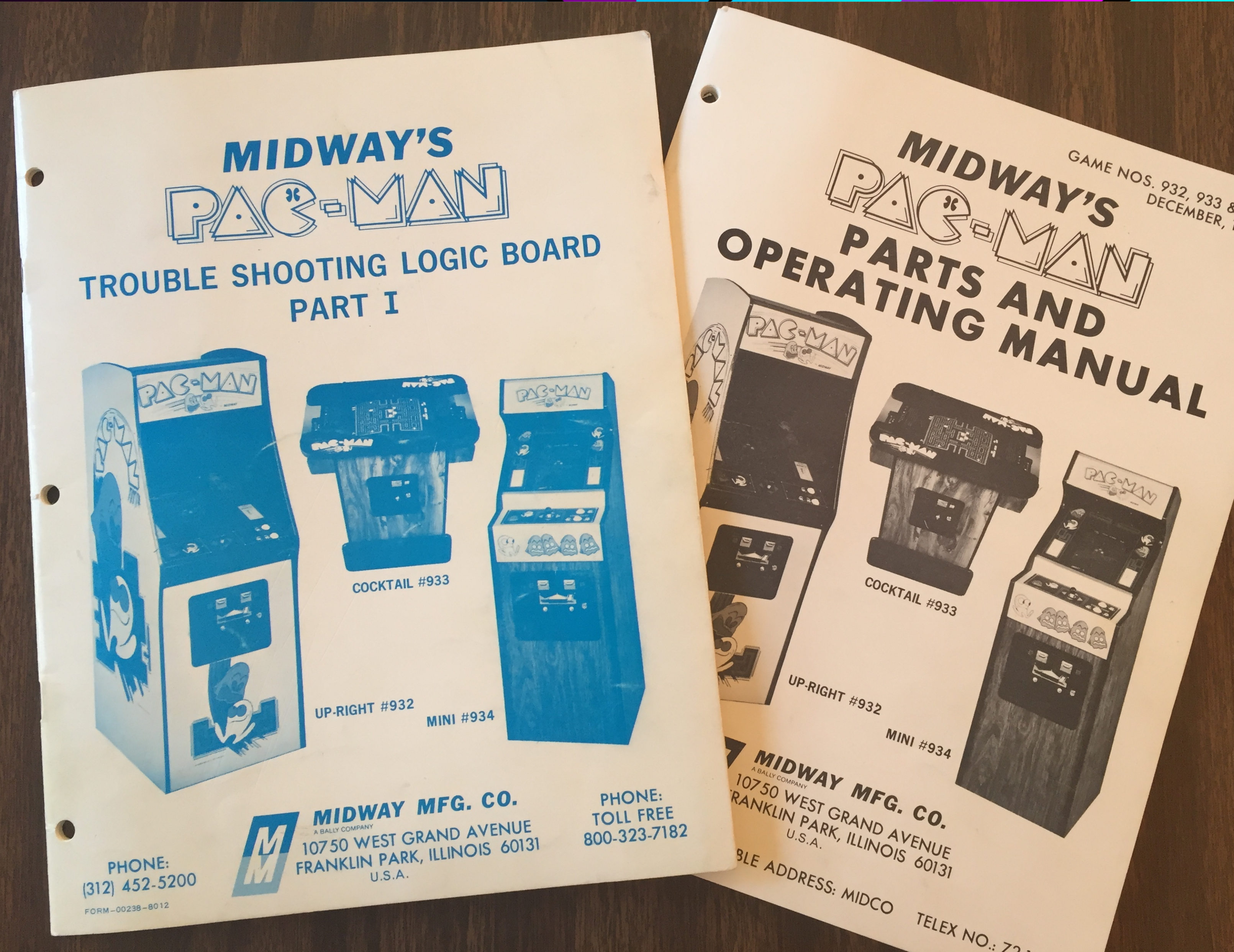
- Z-80 emulator
- 8" floppy disks
- supports line printer!

8" floppies

1 megabyte!

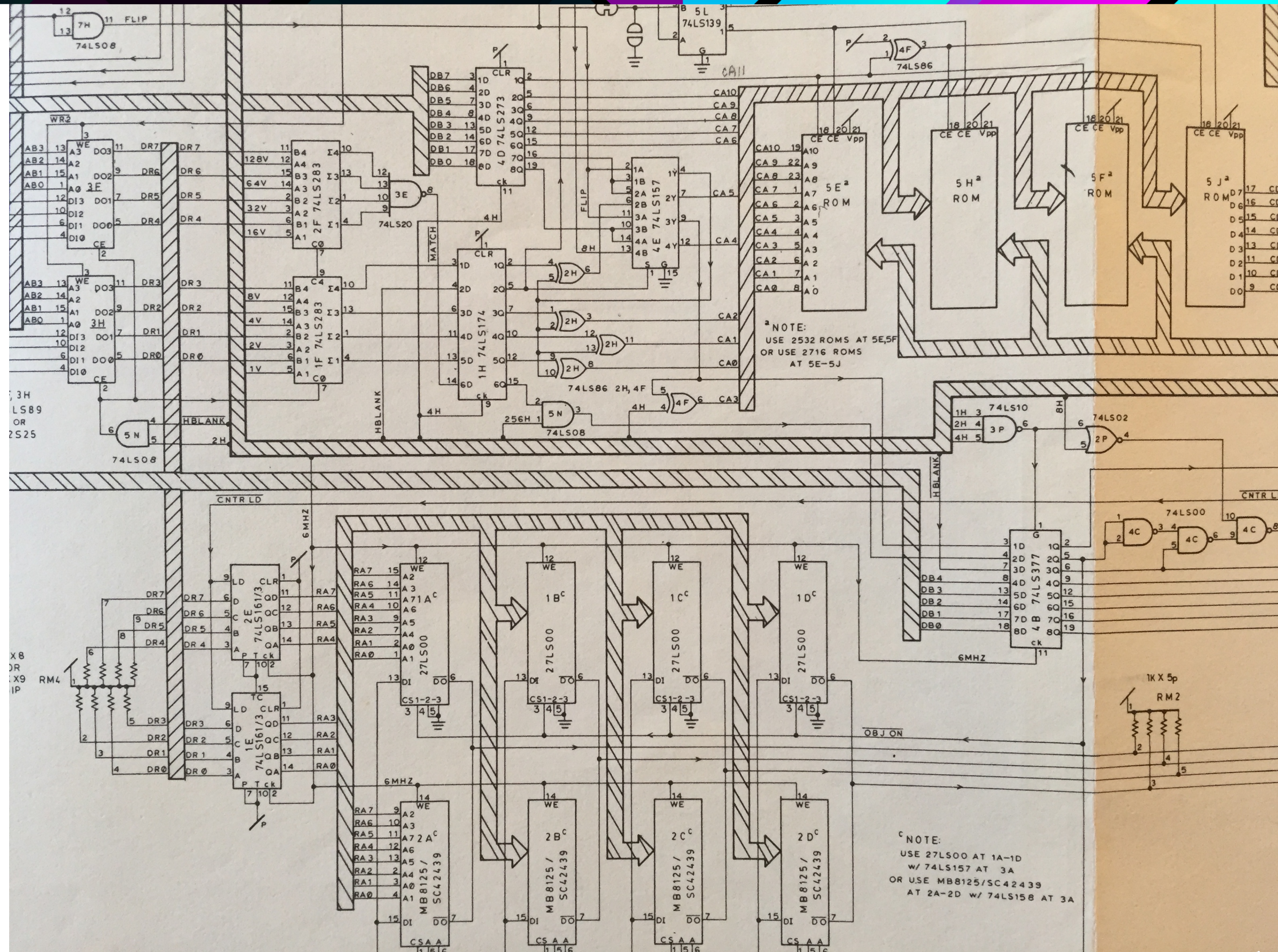


Reverse engineering: Manuals



Reverse engineering: Schematics

- Address map
- Graphics hardware



Pac-Man hardware

16k code ROM, 8k graphics ROM

3k RAM

Fixed character playfield 224x288 pixels

- 36x28 characters, 8x8 pixels each, 4 colors

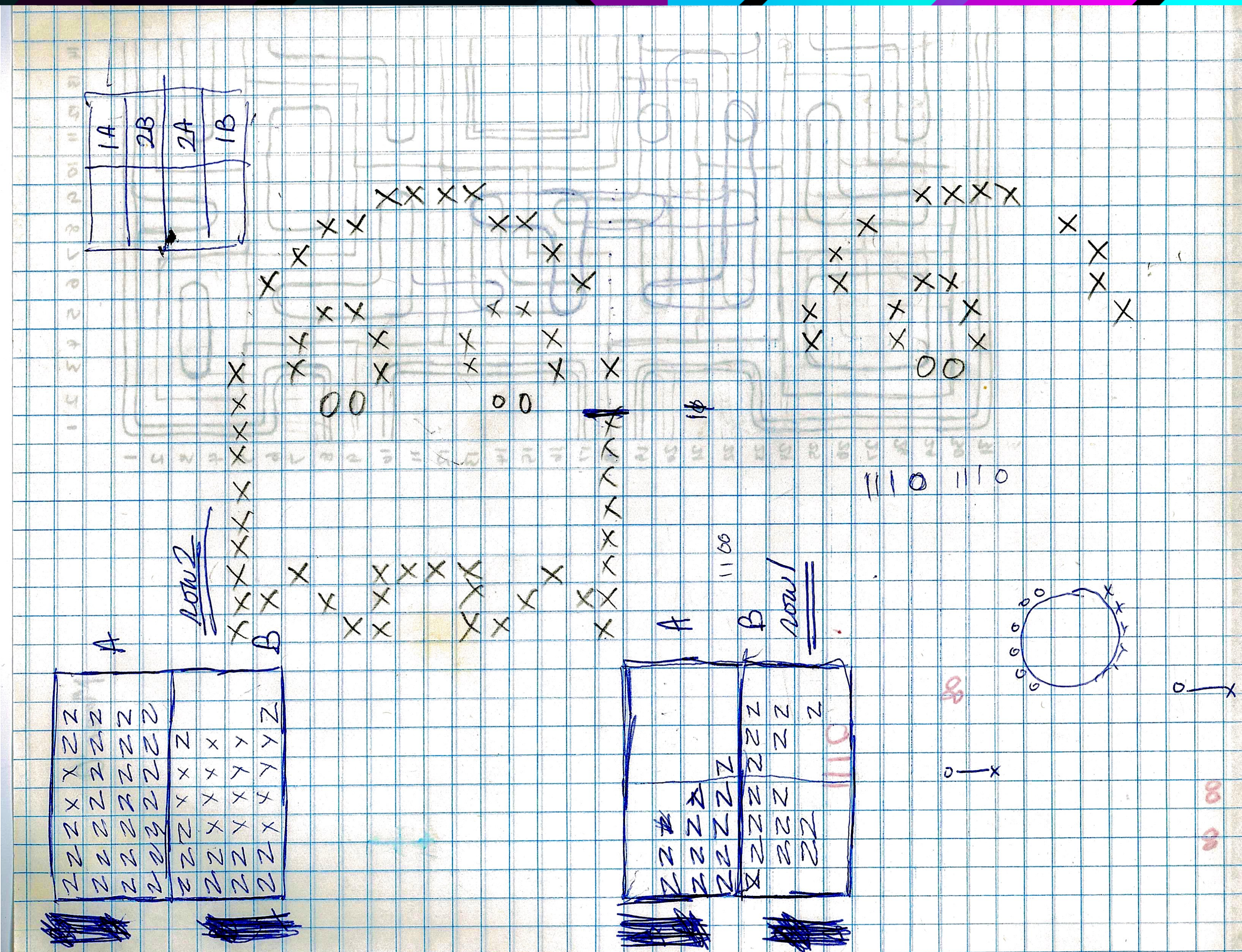
6 moving characters (sprites, stamps)

- 16x16 pixels each, 4 colors

32 palettes of 4 colors each

[illegible]

Reverse engineering: Graphics ROMs



Reverse engineering: Disassembled Code! 16k bytes

0 3FFF

LOC	INST	MNEM	OPER
0000	F3	DI	
0001	3E3F	LD	A, 3F
0003	ED47	LD	I, A
0005	C30B23	JP	230B
0008	77	LD	(HL), A
0009	23	INC	HL
000A	10FC	DJNZ	FE
000C	C9	RET	
000D	C30E07	JP	070E
0010	85	ADD	A, C
0011	6F	LD	L, A
0012	3E00	LD	A, 00
0014	8C	ADC	A, H
0015	67	LD	H, A
0016	7E	LD	A, (HL)
0017	C9	RET	
0018	78	LD	A, B
0019	87	ADD	A, A
001A	D7	RST	2
001B	5F	LD	E, A
001C	23	INC	HL
001D	56	LD	D, (HL)
001E	EB	EX	DE, HL
001F	C9	RET	
0020	E1	POP	HL
0021	87	ADD	A, A
0022	D7	RST	2
0023	5F	LD	E, A
0024	23	INC	HL
0025	56	LD	D, (HL)
0026	EB	EX	DE, HL
0027	E9	JP	(HL)
0028	E1	POP	HL
0029	46	LD	B, (HL)
002A	23	INC	HL
002B	4E	LD	C, (HL)
002C	23	INC	HL
002D	E5	PUSH	HL
002E	1812	JR	12
0030	11904C	LD	DE, 4C90
0033	0610	LD	B, 10
0035	C35100	JP	0051
0038	AF	XOR	A
0039	320050	LD	(5000), A
003C	320750	LD	(5007), A
003F	C33800	JP	0038
0042	2A804C	LD	HL, (4C80)
0045	70	LD	(HL), B
0046	2C	INC	L
0047	71	LD	(HL), C
0048	2C	INC	L
0049	2002	JR	NZ, 04
004B	2EC0	LD	L, C0
004D	22804C	LD	(4C80), HL
0050	C9	RET	
0051	1A	LD	A, (DE)
0052	A7	AND	A, ?
0053	2806	JR	Z, 06

RST 1 $I \leftarrow 3F$ (interrupts @ 3FXX) $(HL) \leftarrow A$ $HL = HL + 1$ \rightarrow LOOP B TIMES

RST 2 $HL \leftarrow HL + A$ $A \leftarrow (HL)$ advance through a table

RST 3 $HL \leftarrow HL + 2 * B$ $A \leftarrow (HL)$ $E \leftarrow A$ $HL \leftarrow HL + 1$ $D \leftarrow (HL)$ $DE \leftarrow HL$ get a new word from a table of pointers

RST 4 $BC = (HL, HL + 1)$ \leftarrow (from TOS) $TOP OF STACK = TOP OF STACK + 2$

RST 5 $2E + 14 = 42$ $DE \leftarrow "4C90"$ $B \leftarrow "10"$ $A \leftarrow 0$ $(5000) \leftarrow 0$ $(5007) \leftarrow 0$ $HL \leftarrow (4C80)$ $(HL) \leftarrow BC$ $HL \leftarrow HL + 2$ $IF HL = XX00, HL = XX00$ $A \leftarrow (4C90)$ $IF A = 0 JMP$

RST 6 **RST 7**

RST 5 CONT'D $put the BC just gotten in location addressed by (4C80)$ $update HL and put it back in 4C80 when L reaches C0, reset to C0$ $(HL goes from XX00 to XXFF)$ $18H words$

INTERRUPT LOOP WAIT?

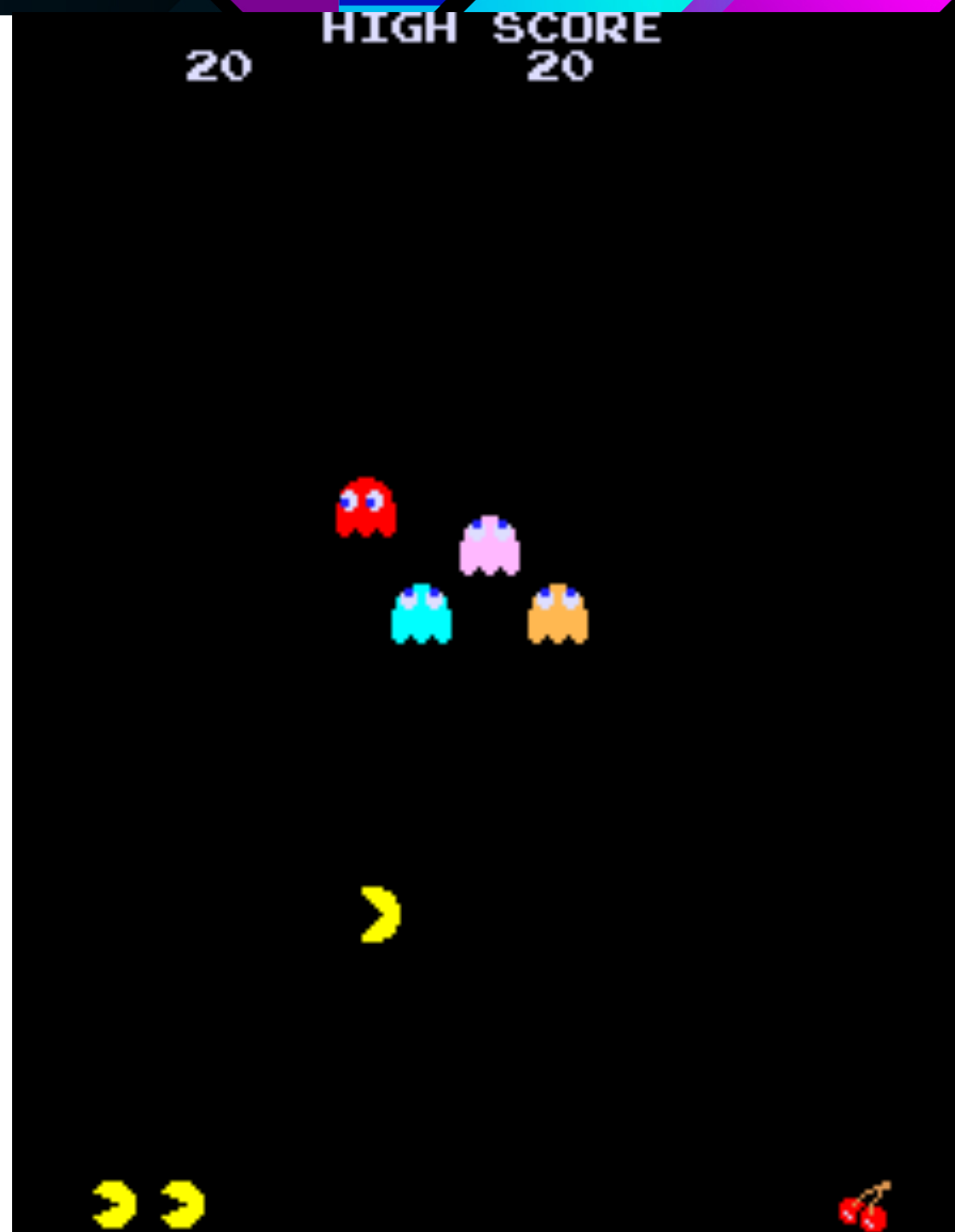
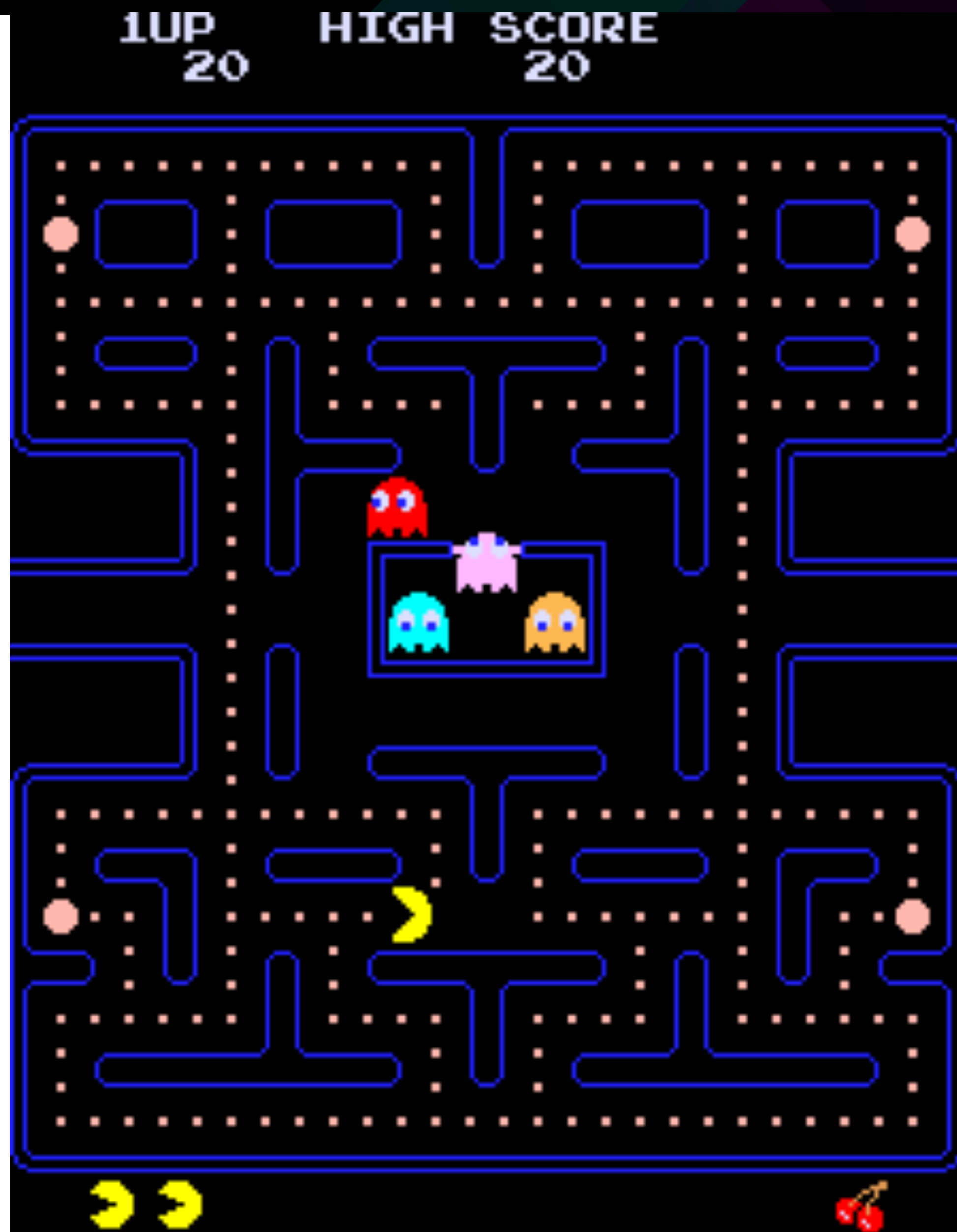
Reverse engineering using 8550

- Breakpoints
- Return statements
- External memory access
- Line printer slo-mo
- Maze hacks

Slow motion

- can see Pac “skid” around corners
- can see monsters look ahead





New gameplay features

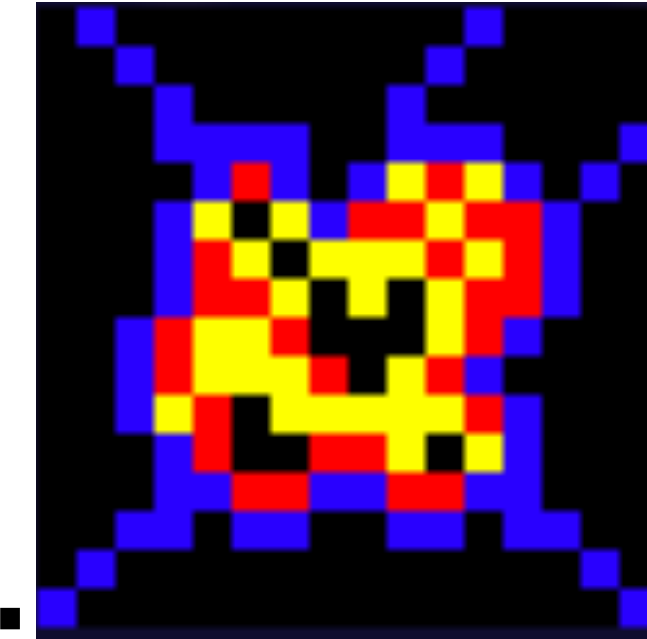
- Four new mazes
- Randomized monster algorithm
- Fruit bonus moves through maze
- Random fruits at higher racks
- No eye return

New non-gameplay features

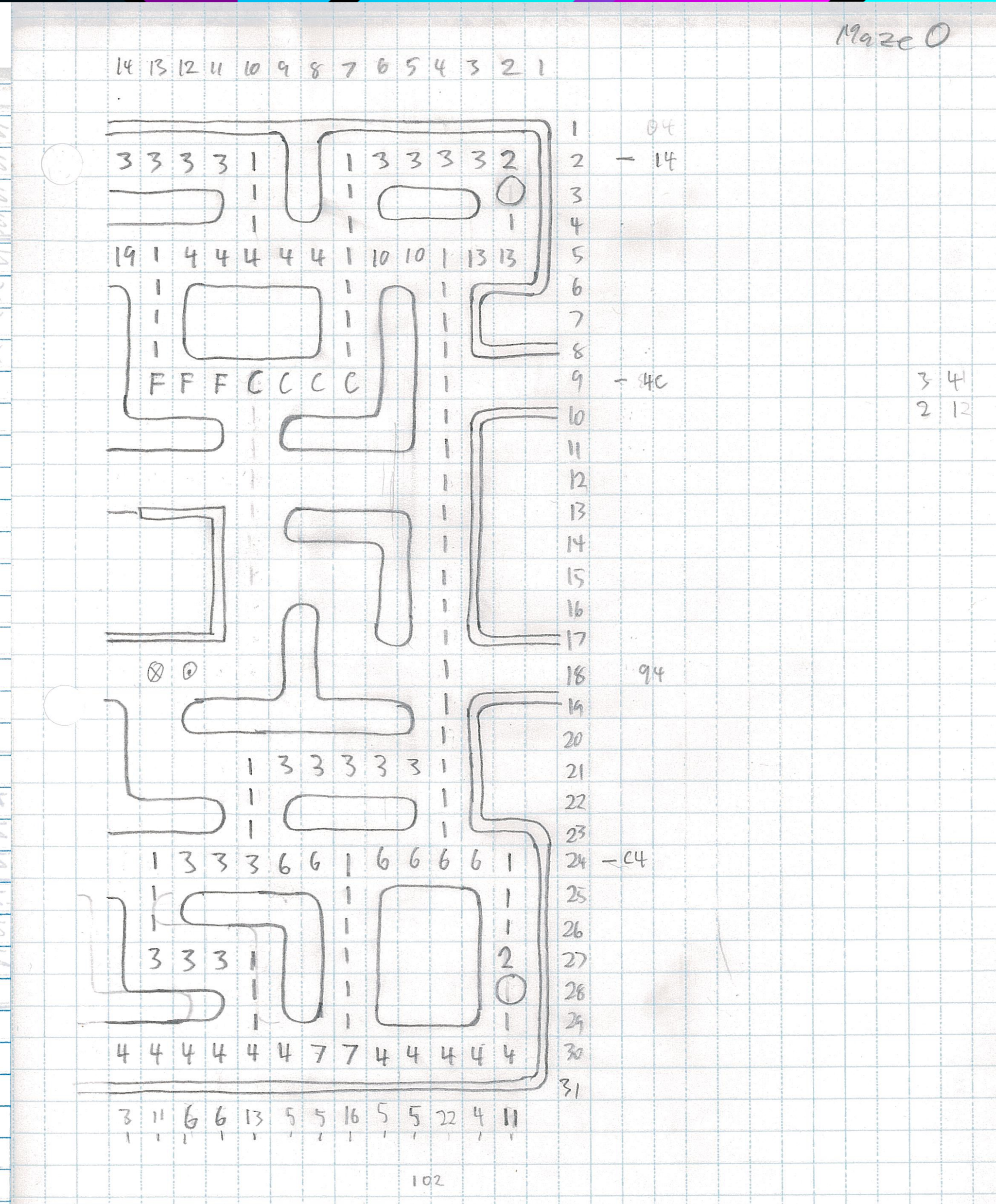
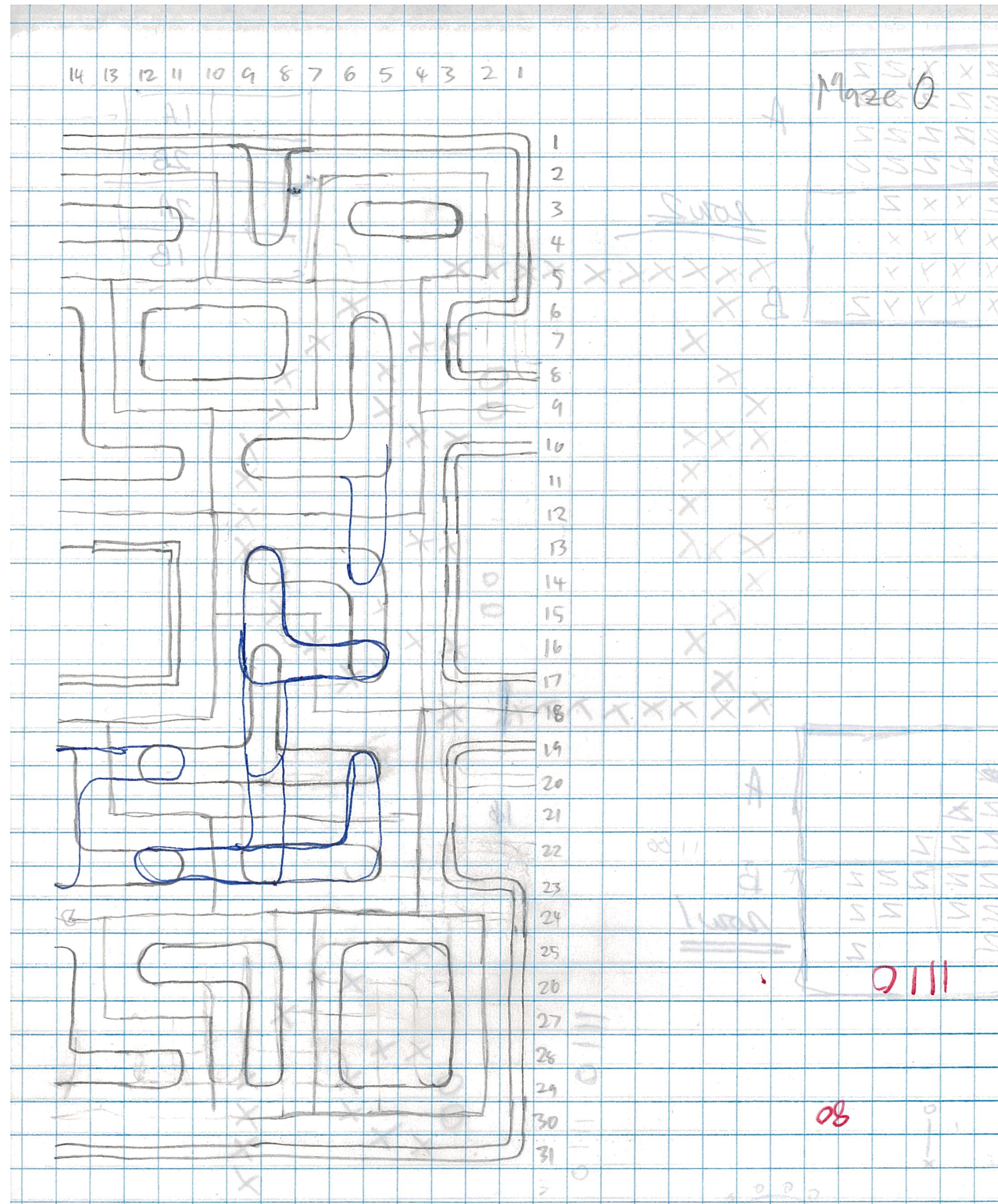
- Colors
- Sounds & Music
- Character designs
- Animations/Cartoons
- Attract mode
- Main character name

Fruit bonus

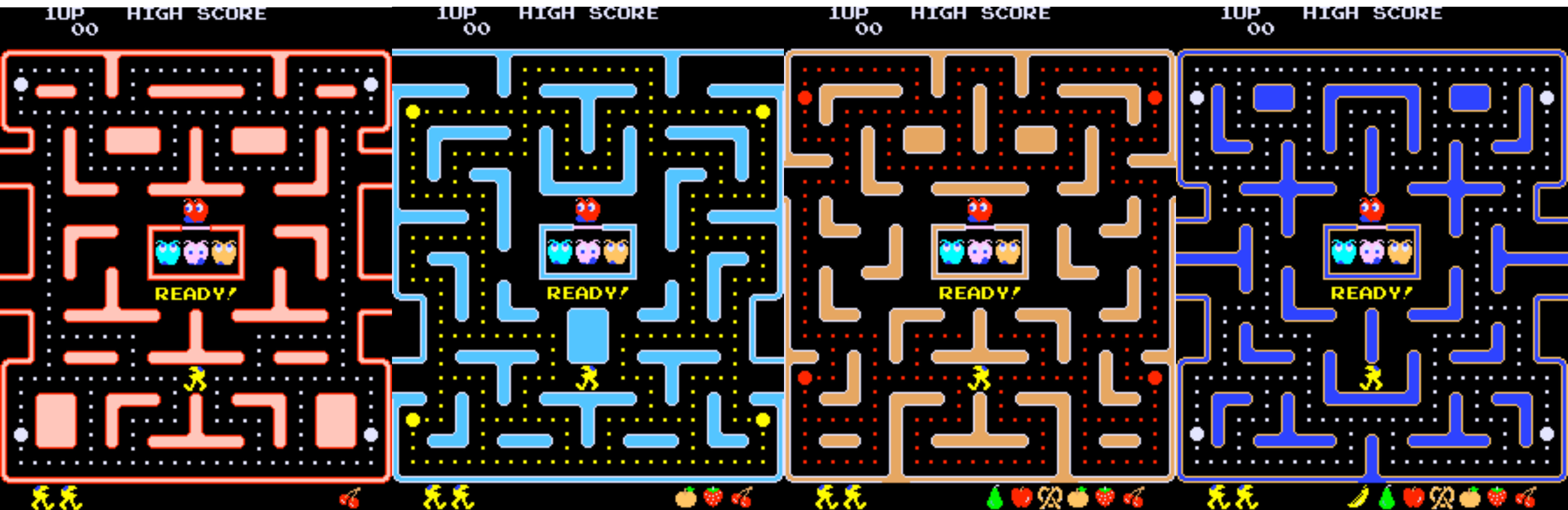
- Move it around the maze!
- Use explosion character?.....
- Bonus value overwrites maze, so create new 16x16 bonus values.....
- Bounce sound
- Random path



Maze design



Four New Mazes



; THE INFORMATION CONTAINED HEREIN IS THE SOLE PROPERTY
; OF GENERAL COMPUTER CORPORATION. USE OF THIS DOCUMENT
; IS RESERVED EXCLUSIVELY FOR GENERAL COMPUTER CUSTOMERS
; AND PERSONNEL. REPRODUCTION OF THIS MATTER IN WHOLE
; OR IN PART IS FORBIDDEN WITHOUT THE EXPRESS WRITTEN
; CONSENT OF GENERAL COMPUTER CORPORATION.
; *****

TITLE	"SONATA FOR UNACCOMPANIED VIDEO GAME"	
GLOBAL	MELODIES, HARMONIES, AUXILIARY	
SECTION	MUSIC	
MELODY	EQU	0
HARMONY	EQU	1
MACRO	TUNE	
	IF '1' = 0 & '2' = MELODY	
BYTE	0F1H, 00H, 0F2H, 02H, 0F3H, 0AH, 0F4H, 00H	
BYTE	41H, 43H, 45H	
BYTE	86H, 8AH, 88H, 8BH	
BYTE	6AH, 6BH, 71H, 6AH, 88H, 8BH	
BYTE	6AH, 6BH, 71H, 6AH, 6BH, 71H, 73H, 75H	
BYTE	96H, 95H, 96H, 0FFH	

Handwritten musical notation on a five-staff system. The notation includes notes, rests, and accidentals. A handwritten note "3/4" is written above the first staff. A handwritten note "6/4" is written below the first staff. A handwritten note "3/4" is written below the second staff. A handwritten note "6/4" is written below the third staff. A handwritten note "6/4" is written below the fourth staff. A handwritten note "6/4" is written below the fifth staff. A handwritten note "6/4" is written below the sixth staff.

Crazy Otto

Attract Mode

Crazy Otto

Attract Mode Fake-o Game



Detail of Otto movement



Crazy Otto Animation #1



Crazy Otto Animation #2



Crazy Otto Animation #3



Character Design



FIXED CHARACTER FORMAT:

20: { 00 07 0F 0F 7F EE EE 7F
00 00 01 03 03 07 07 07

21: { 7F EE EE 7F 0F 0F 07 00
07 07 07 03 03 01 00 00

22: { 00 00 08 00 E0 E0 E0 60
00 0E 0F 0F 1E 16 06 0C

23: { 24 2C 2C 0C 0C 08 00 00
0C 06 07 0F 0F 0F 0E 00

22: { _____ 8C
_____ 04 -
23: { 24 _____
8C
04 06 _____

20: { 00 07 0F 08 77 EE EE 77
00 00 01 03 03 06 06 07

21: { 77 EE EE 77 08 0F 07 00
07 06 06 03 03 01 00 00

20: { 00 07 0F 0F 7F EE EE 77
00 00 01 03 03 05 06 07

21: { 77 EE EE 77 0F 0F 07 00
07 06 06 03 03 01 00 00

20: { 77 EE EE 77 0F 0F 07 00
07 06 06 03 03 01 00 00

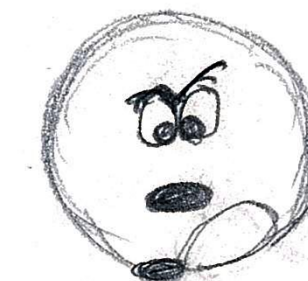
COLOR CODE = 16H



01 - yellow
10 - medium blue
11 - white



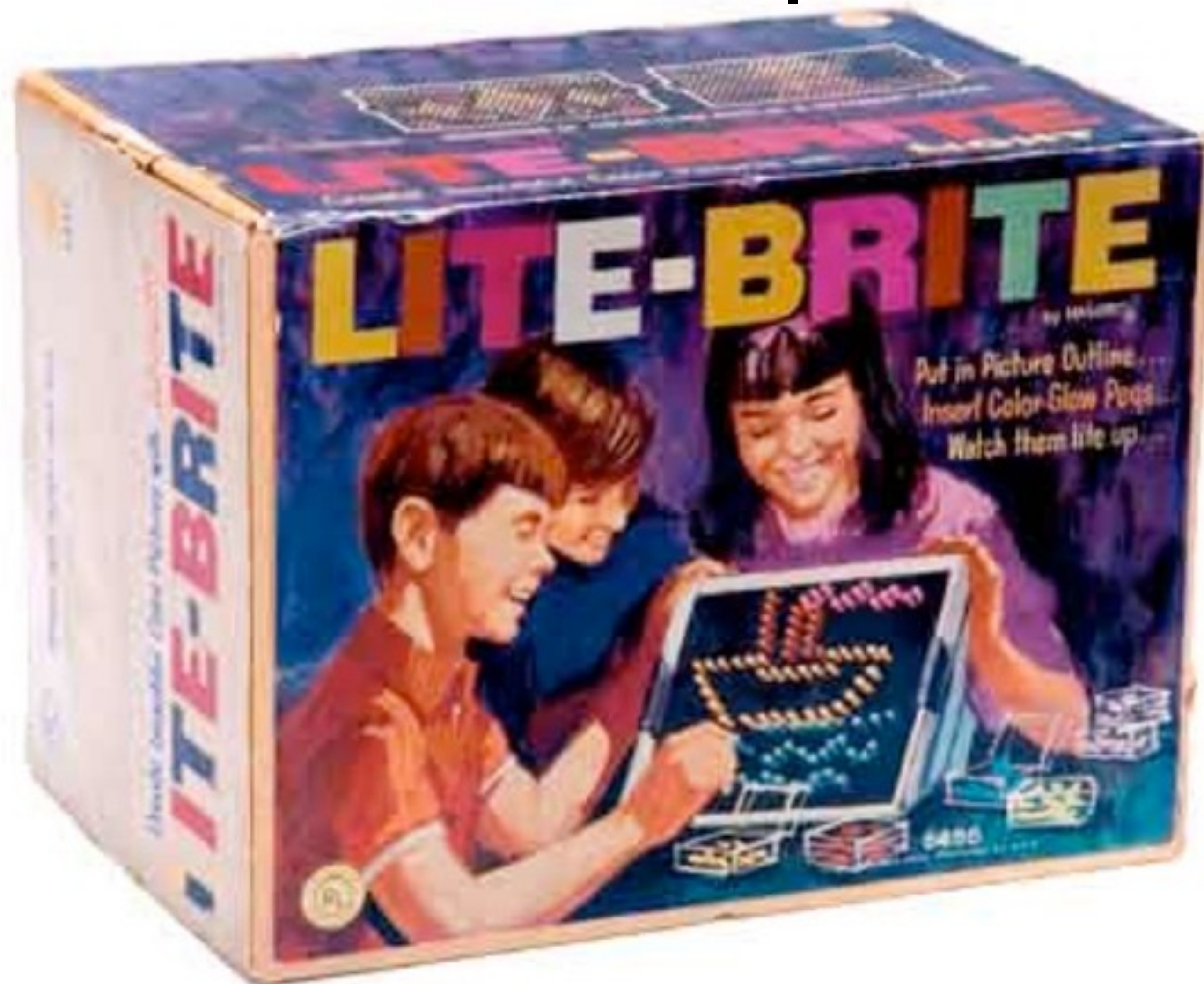
WIDE MOUTH

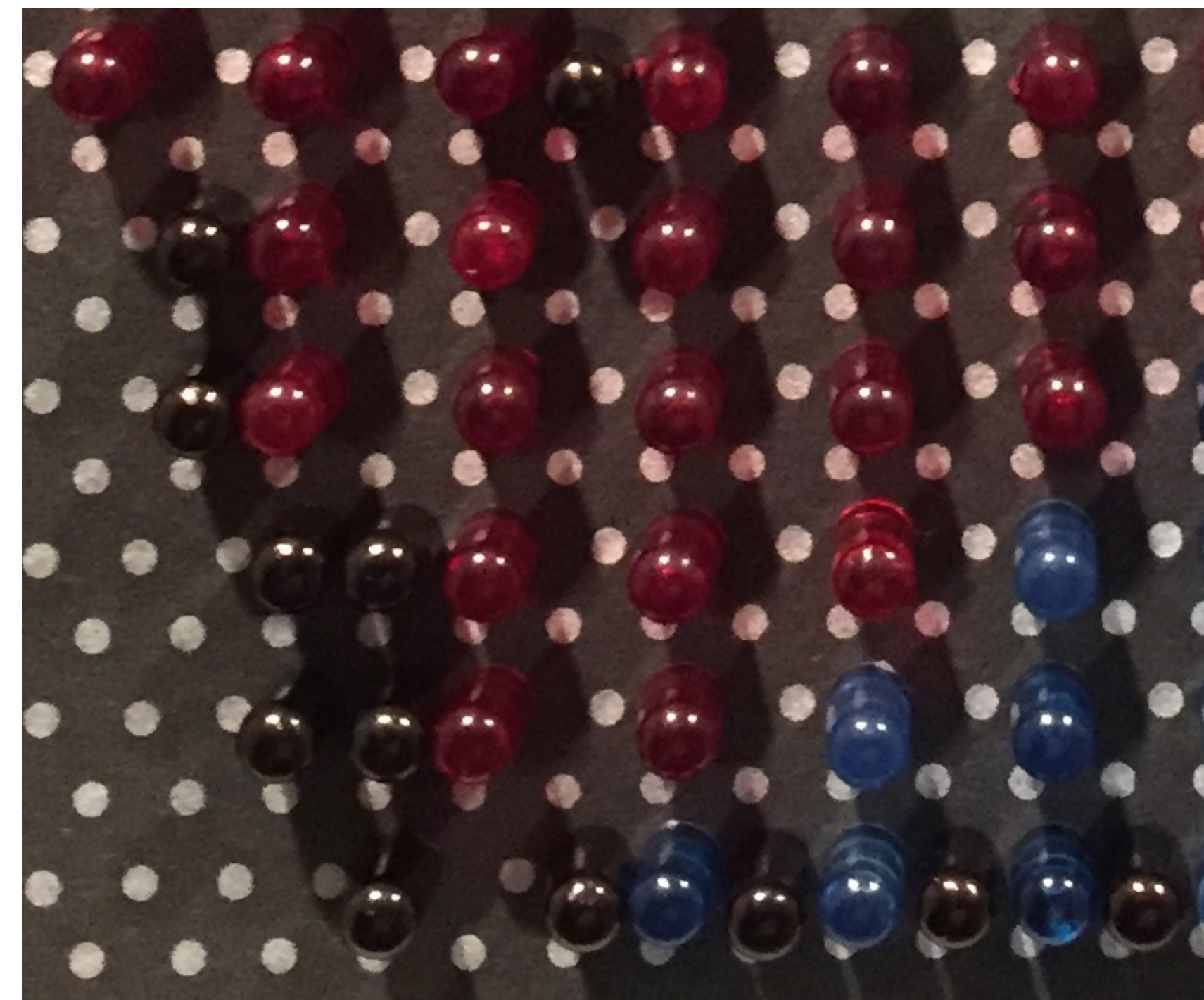
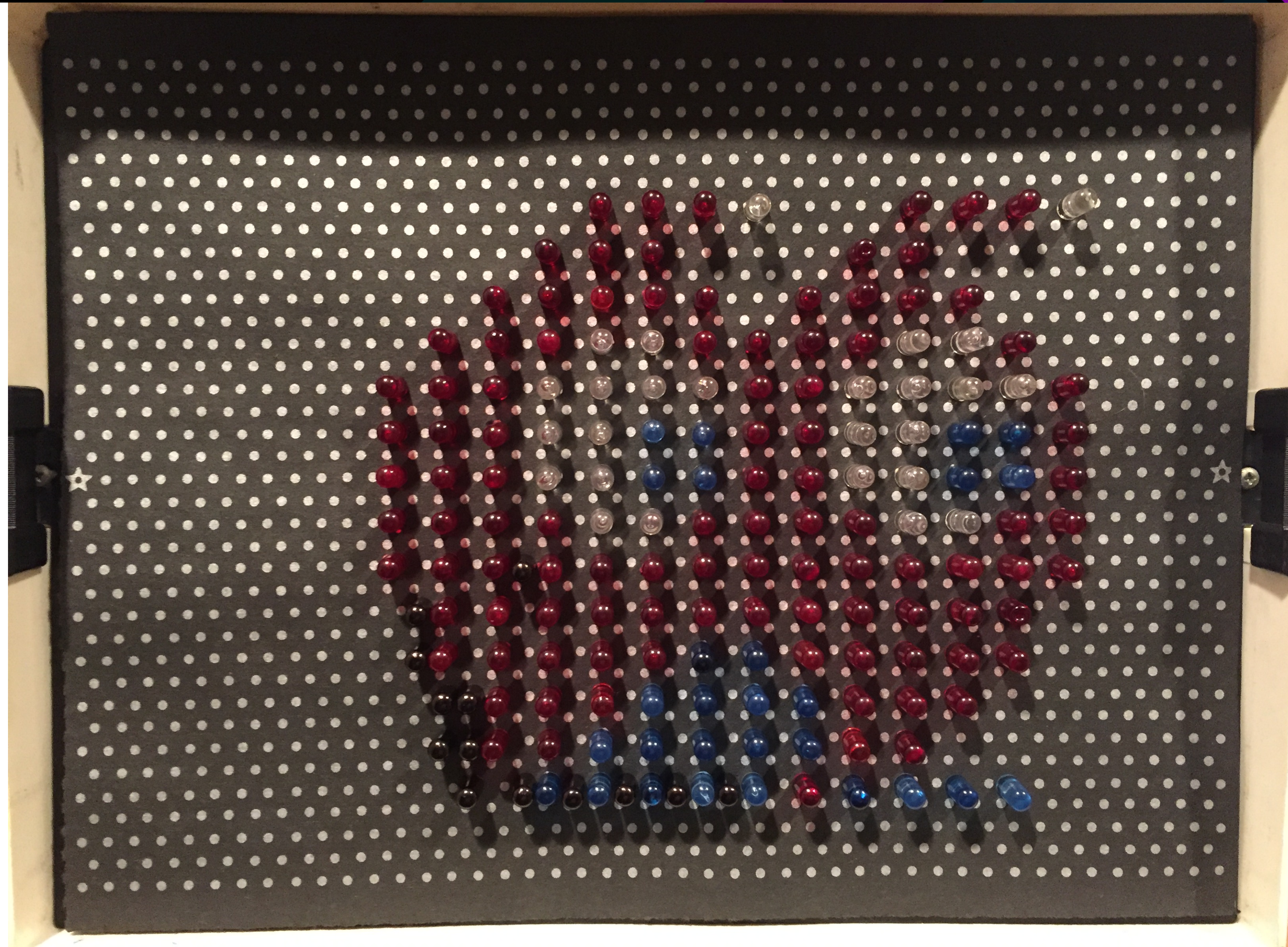


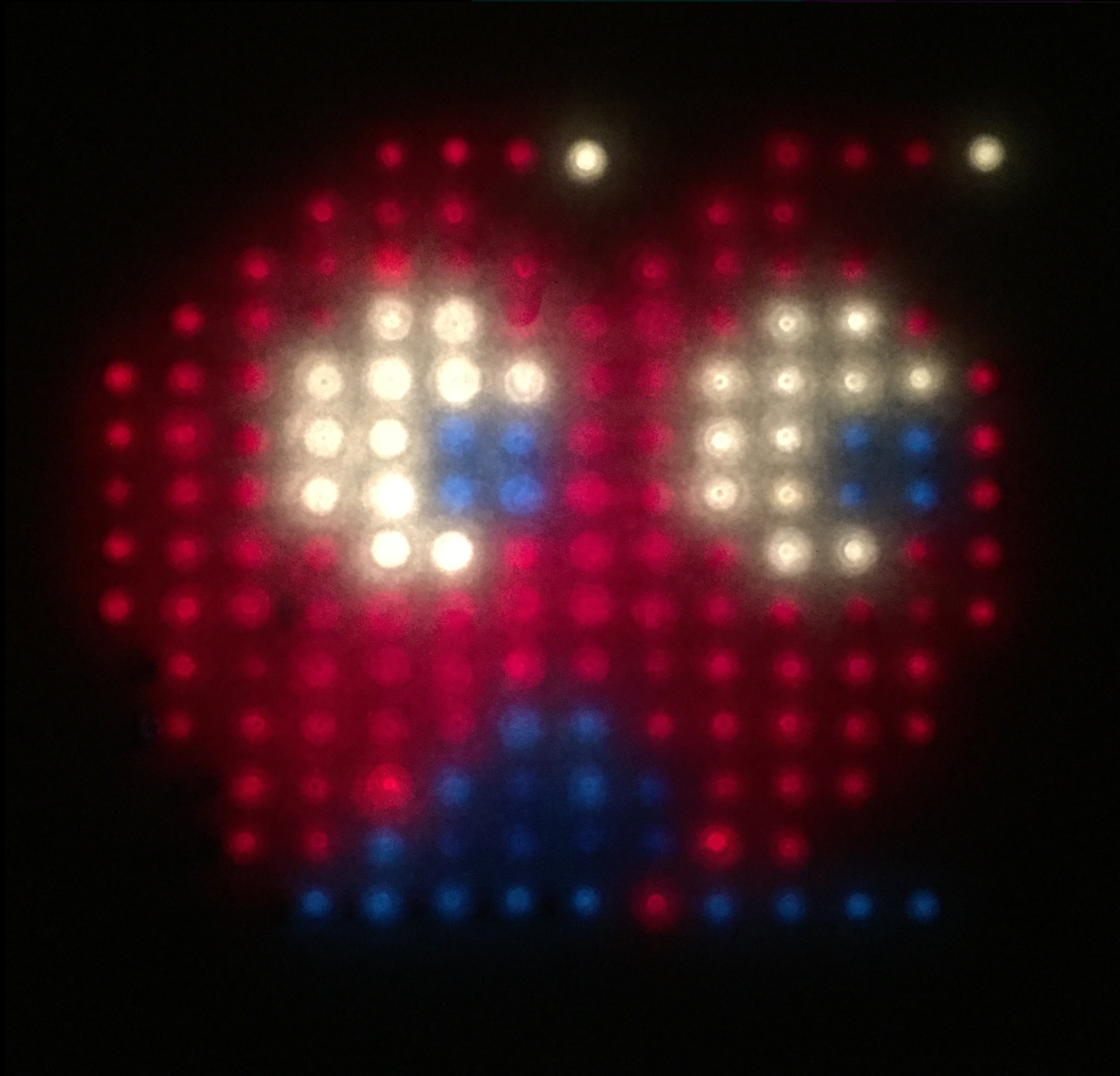
Character design workflow

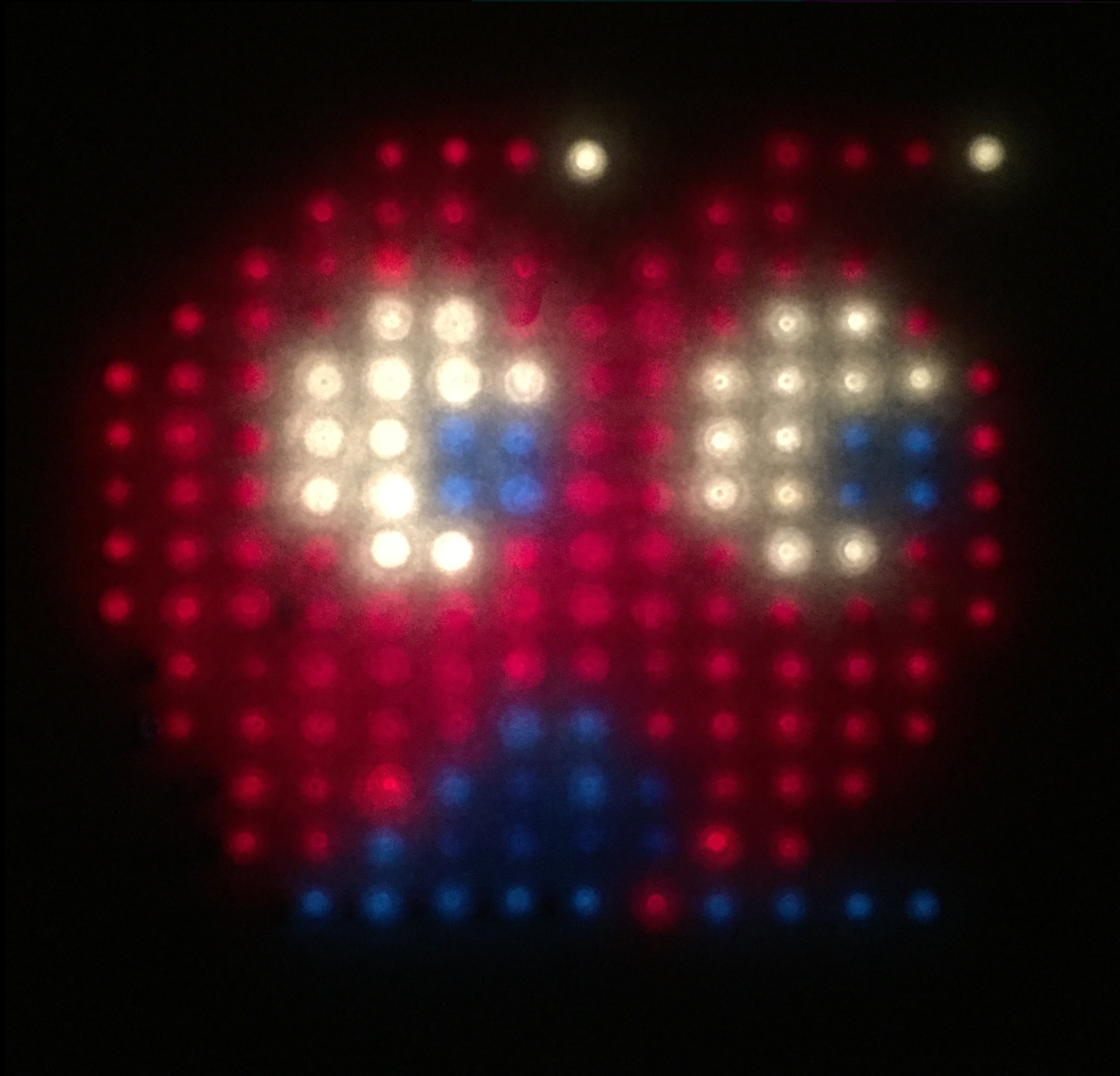
- Sketch on graph paper
- Manually encode into graphics ROM format
- Type in graphics ROM code
- Transfer file to EPROM programmer
- Burn EPROM
- Plug into PCB
- Power on game

GCC Character Development System



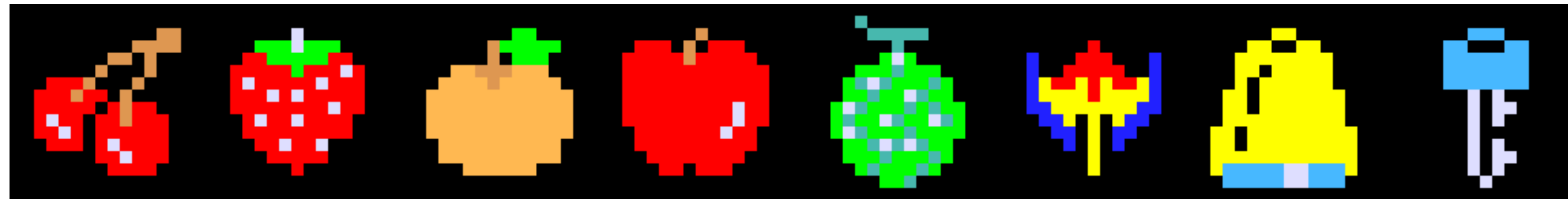




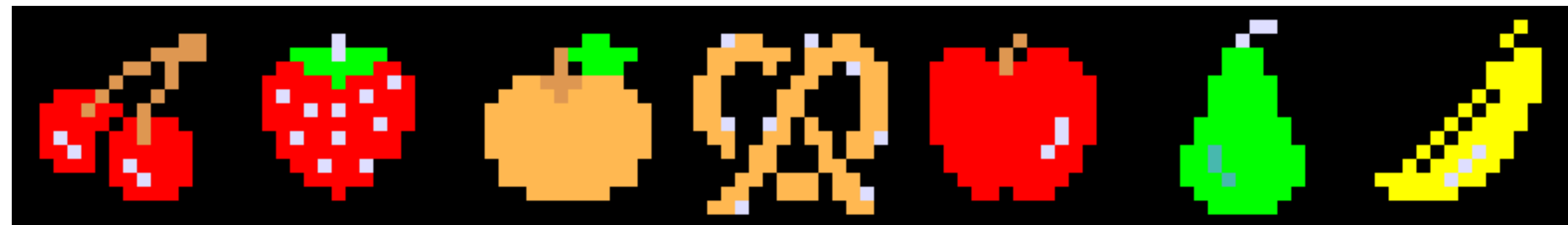


Bonus Fruit

Pac-Man



Crazy Otto



Intellectual property

Avoid copyright infringement

- require existing Midway ROMs
- provide new GCC code as overlay

Avoid trademark infringement

- change all major characters
- change name

Protect our code with anti-copy hardware

Source code


```
TITLE "FRUIT DRIVER"
;THIS CODE IS TO MAKE THE FRUIT BONCE ACROSS THE SCREEN.
;THE FRUIT ENTERS AT P0 AND GOES COUNT0 SPACES BEFORE GOING POOF!!
;IN A SMALL EXPLOSION.  THE PATH IS TABLE DRIVEN.
;EACH MAZE HAS AN ASSOCIATED P0,COUNT0,PATH.

;SOME RAM LOCATIONS:
;THE FRUIT POSITION
FRUITP EQU 4DD2H
;THE VALUE OF THE CURRENT FRUIT (0=NO FRUIT)
FVALUE EQU 4DD4H
;THE CURRENT PLACE IN THE PATH
COUNT EQU 4C40H
;FLAG TO INDICATE THAT THE FIRST FRUIT HAS BEEN RELEASED
FIRSTF EQU 4E0CH
;FLAG TO INDICATE THAT THE SECOND FRUIT HAS BEEN EATEN
SECONDF EQU 4E0DH
```


TITLE "CODE PATCHES (PATCHES)"

```
;PATCH TO MAKE RED MONSTER GO AFTER OTTO TO AVOID PARKING  
ORG 0E5CH  
XOR A  
NOP
```

```
;PATCH FOR NEW ATTRACT MODE  
ORG 0413H  
JP ATTRACT
```

```
;PATCH TO THE PRIMARY FRUIT ROUTINE, THIS ROUTINE IS CALLED ONCE PER  
;GAME STEP (THE MINIMUM TIME IT TAKES A MONSTER TO MOVE A PIXEL)  
ORG 0EADH  
JP DOFRUIT
```


;PATCH TO MAKE THE ENERGIZERS FLASH IN NEW AND EXCITING COLORS

ORG 0C21H

JP FLASHEN

;PATCH TO MAKE THE MONSTERS MOVE RANDOMLY

ORG 274BH

CALL RCORNER

ORG 2781H

CALL RCORNER

ORG 27BBH

CALL R1CORNER

ORG 2803H

CALL R2CORNER


```
ST5      BYTE  SETN,      5AH, PAUSE

          BYTE  SETPOS,    0FFH, 34H
          BYTE  SETCHAR
          WORD   RIGHT_OTTO
          BYTE  SETN,      7FH, PAUSE
          BYTE  SETN,      24H, PAUSE
          BYTE  SETN,      68H, LOOP, 0D8H, 00, 09
          BYTE  SETN,      7FH, PAUSE
          BYTE  SETN,      18H, PAUSE
          BYTE  SETPOS,    00H, 094H
          BYTE  SETCHAR
          WORD   LEFT_ANNA
          BYTE  SETN,      68H, LOOP, 028H, 00, 09
          BYTE  SETN,      7FH, PAUSE
          BYTE  SETPOS,    0FCH, 7FH
          BYTE  SETCHAR
          WORD   RIGHT_OTTO
```


The Atari Settlement

Atari drops its suit against GCC with prejudice

GCC discontinues sales of Super Missile Attack

→ GCC will not market enhancement kits
without permission from the manufacturer ←

Atari pays \$50,000 per month to GCC
to develop video games for Atari
(2 year term)

Kevin Curran calls Dave Marofsky of Midway

Visit to Midway

October 9, 1981



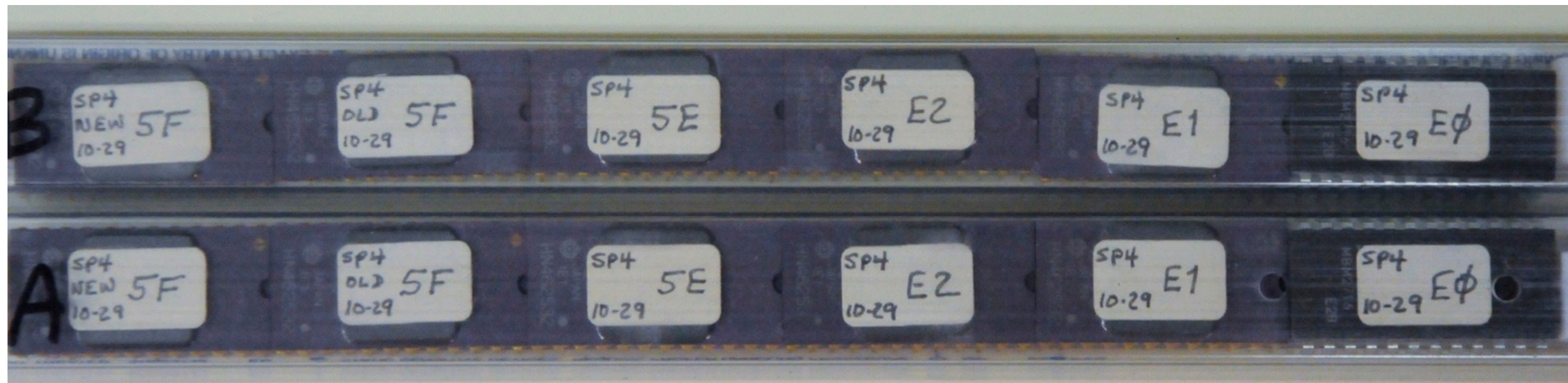
October 29, 1981

Signed Crazy Otto contract with Midway

Three Crazy Otto prototype boards

- 2 delivered to Midway
- 1 at Fun and Games, Framingham, Mass.

ROM dumps



1UP 00 HIGH SCORE 2UP

"CRAZY OTTO"



STARRING

CRAZY OTTO



MIDWAY MFG CO

© 1980

CREDIT 0

1UP 00 HIGH SCORE 2UP

"SUPER PAC-MAN"



STARRING

PAC-MAN



MIDWAY MFG CO

© 1980

CREDIT 0

Stan Jarocki calls GCC

Name and character changes

Crazy Otto



Super Pac-Man



Miss Pac-Man



Pac-Woman

Ms Pac-Man



November 24, 1981

Stan Jarocki of Midway sends a letter
to Masaya Nakamura of Namco:

*Enclosed find a videotape of Midway's Pac-Man game
using the Ms. Pac-Man enhancement program...*

1UP 00 HIGH SCORE 2UP

"MS PAC-MAN"



STARRING

MS PAC-MAN



© MIDWAY MFG CO
1980/1981

CREDIT 0

Hardware design

16k Pac-Man ROM on main PCB

10k Otto ROM on AUX PCB

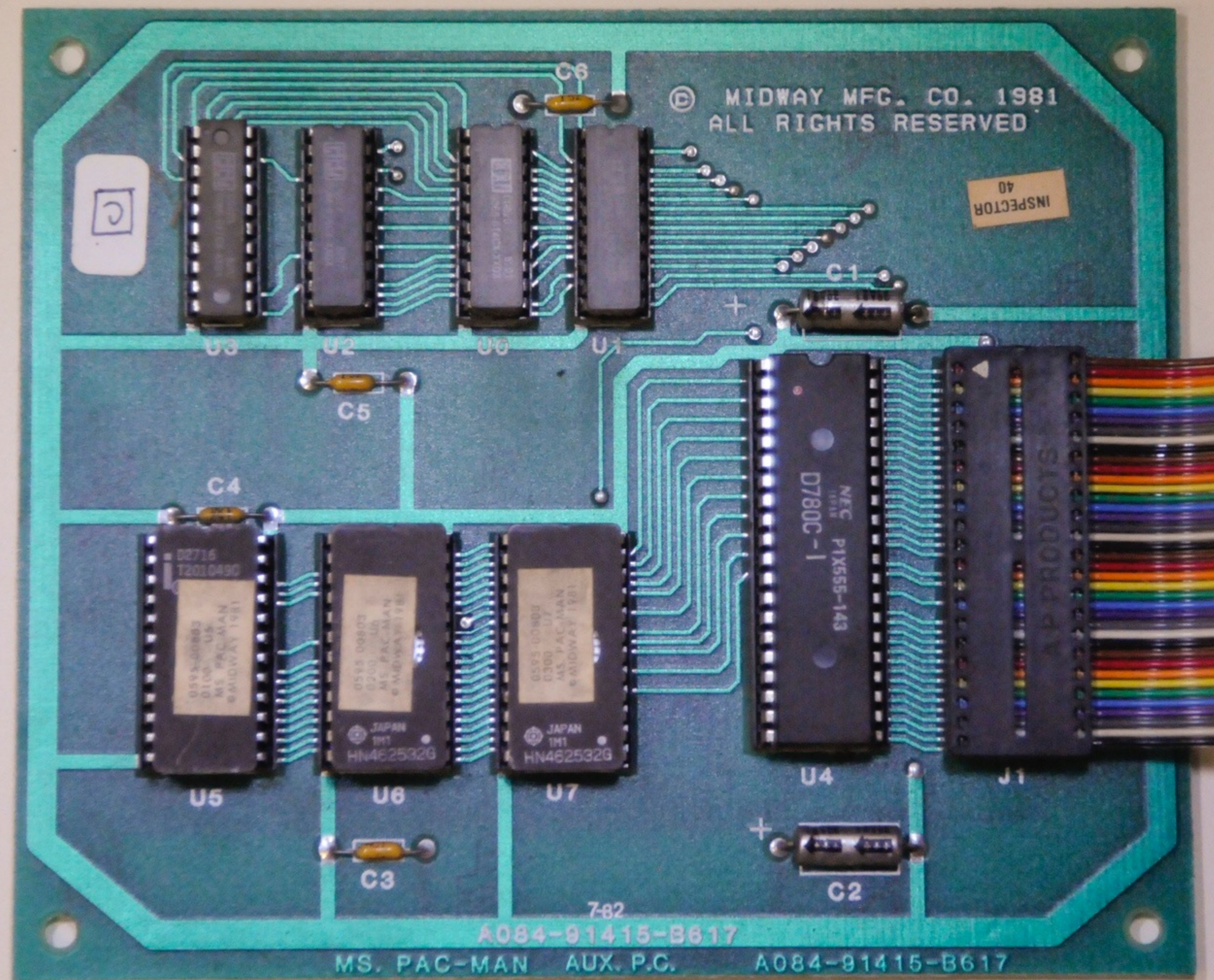
- 6k in new address space
- 4k replaces Pac-Man D ROM

40 8-byte patch code overlay

ROM “encryption” using bitswizzle

Anti-copying hardware

Ms. Pac-Man AUX board





Ms. Pac-Man AUX board installation



United States Patent [19]

Curran et al.

[11] Patent Number: 4,525,599

[45] Date of Patent: Jun. 25, 1985

[54] SOFTWARE PROTECTION METHODS AND APPARATUS

[75] Inventors: Kevin G. Curran, Sudbury; Steven E. Golson, Wayland; Christian S. Rode, Cambridge, all of Mass.

[73] Assignee: General Computer Corporation, Cambridge, Mass.

[21] Appl. No.: 380,771

[22] Filed: May 21, 1982

[51] Int. Cl.³ H04L 9/00

[52] U.S. Cl. 178/22.08; 178/22.09; 364/200

[58] Field of Search 178/22.05, 22.08, 22.09; 364/200, 900; 340/825.34

[56] References Cited

U.S. PATENT DOCUMENTS

3,996,449	12/1976	Attanasio et al.	340/825.34
4,120,030	10/1978	Johnstone	178/22.09
4,168,396	9/1979	Best	178/22.09
4,183,085	1/1980	Roberts et al.	364/200
4,246,638	1/1981	Thomas	364/200
4,278,837	7/1981	Best	364/900
4,306,289	12/1981	Lumley	364/200
4,319,079	3/1982	Best	178/22.09
4,446,519	5/1984	Thomas	364/200

OTHER PUBLICATIONS

IBM Technical Disclosure Bulletin, vol. 21, No. 2, (7/78), Gurugé, pp. 836-837.

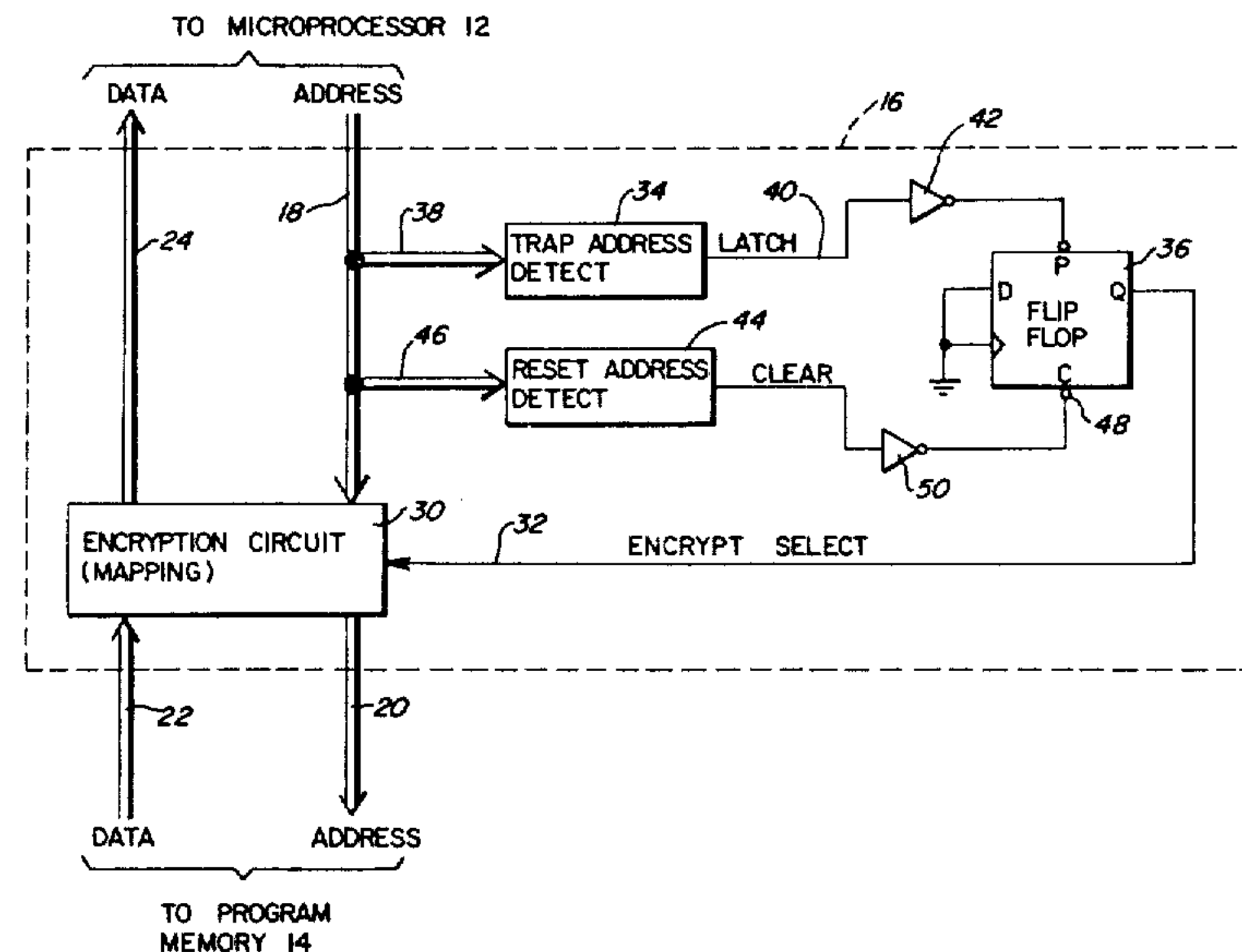
Primary Examiner—Sal Cangialosi

Attorney, Agent, or Firm—Hosier & Sufrin, Ltd.

[57] ABSTRACT

Methods and apparatus are disclosed for inhibiting the unauthorized copying of ROM-resident computer software or the like, for example, the audio-visual display of an electronic video game. A protection circuit including encryption/decryption means is coupled between the microprocessor and the ROM-memory and is operable in a first mode to properly encrypt/decrypt the program information according to a first algorithm and in a second mode to prevent proper encryption/decryption. The address-data buses are monitored by the protection circuit to detect an invalid program event, such as may occur when a microprocessor emulator is used to attempt an unauthorized copying or "dumping" of the program information. Upon detection of the invalid program event or "trap condition", the protection circuit switches to its second operating mode thereby to prevent copying of the decrypted program information.

27 Claims, 4 Drawing Figures



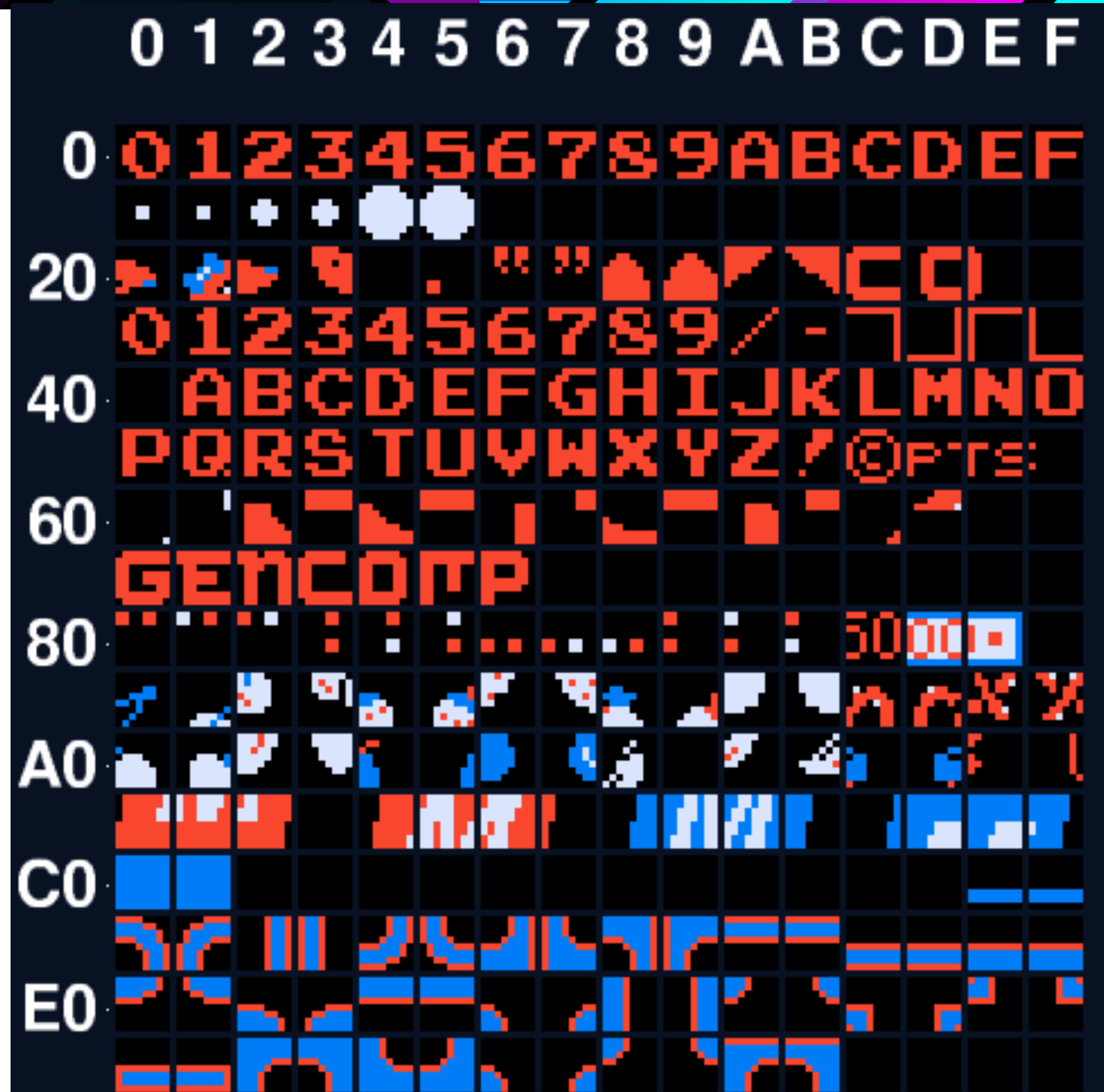
Hidden Messages

Namco Easter Egg



Ms. Pac-Man

fixed character ROM



Ms. Pac-Man

00009770:	71ff	f102	f203	f30a	f402	6590	6870	6867	q.....e.hphg
00009780:	6665	9061	7061	6568	6690	6390	8690	8590	fe.apaehf.c.....
00009790:	8570	8668	65ff	ff3a	004f	fe00	280b	1102	.p.he...:O..(...
000097a0:	4c21	504f	010c	00ed	b03a	094e	2172	4ea6	L!PO.....:N!rN.
000097b0:	280c	3a0a	4cfe	3f20	053e	ff32	0a4c	2185	(...L.? .>.2.L!.
000097c0:	96c3	c42c	ffff	ffff	ffff	ffff	ffff	ffff	...,.....
000097d0:	4745	4e45	5241	4c20	434f	4d50	5554	4552	GENERAL COMPUTER
000097e0:	2020	434f	5250	4f52	4154	494f	4e20	2020	CORPORATION
000097f0:	4865	6c6c	6f2c	204e	616b	616d	7572	6121	Hello, Nakamura!

Bugs

- Parking bug (fixed)
- Table bug (fixed)
- Collision bug
- Level 255 bug

January 1982





Living

COVER STORY

Games That Play People

Those beeping video invaders are dazzling, fun—and even addictive

Let us have no more lamentation that our microprocessed era lacks heroes (plinkety-plunk of Pete Seeger's banjo). The spirit of mighty John Henry, the steel-driving man who beat the steam drill (plunk-plunk-plunk), lives on in the indomitable courage and abused optic nerves of a Mount Prospect, Ill., high school boy named Steve Juraszek (Seeger whacks out several yards of fancy banjo work and begins a ballad):

Well, Steve Juraszek dropped in his quarter.

Just half an hour before noon (plink-plunk).
He would die in the end, when the blasters zapped his men.
But he vowed that wouldn't happen soon, poor boy.
He vowed that wouldn't happen soon.

At six that night they called his mother.
Said, "Ma'am, your boy's not comin' home.
He's shootin' fast and hot, at

the mutants and the pods,
And the microchip is processing a groan, oh my.
The microchip is letting out a groan."

Oh, they fed him on pizza and cola.
His fingers were cramping up and cold.
His eyeballs were raw, when a dum-dee-dum he saw,
And it something, dum-dee-dum foretold.*

What nonsense is this? The answer is very nearly, but perhaps not quite, in the increasingly crowded category labeled If You Have to Ask, You Will Never Understand. What Juraszek, 15, recently did at an Arlington Heights, Ill., arcade called One Step Beyond was play Defender, one of those beeping, flashing, quarter-eating arcade video games, for 16 hours and 34 minutes on the same 25c, ringing up a score of 15,963,100 before he finally made a mistake and lost his last ship. Anyone who knows arcade games, and especially Defender, which is one of the most difficult, will agree that this is very close to being impossible. It is definitely not one of those non-feats thought up by the untalented to memorialize themselves in *The Guinness Book of World Records*, such as eating seven miles of spaghetti, or riding an exercise bicycle for a week and a half.

Defender is an attack-from-outer-space game. It is played on a large color video screen where nullity bombs and destructo beams are hurled at the player by the machine's computer. Increasingly rowdy sound effects suggest what James Joyce, under the influence of William Blake (who would have loved these gadgets), called "the ruin of all space, shattered glass and toppling masonry, and time one livid final flame." The Defender player controls a small cannon-firing jet plane that flies at varying altitudes and speeds over a barren planetscape. He must shoot down a bewildering variety of alien bad guys, each with his own pattern of behavior; dodge an assortment of missiles; and rescue helpless spacemen, vulnerable to being kidnaped, who appear randomly on the planet's surface. He must have reflexive control of a joystick that determines altitude and of five separate buttons that fire the cannon, change forward thrust, reverse direction, make the ship skim off the screen into hyperspace and fire a limited supply of smart bombs, which blow up everything in sight. As is fiendishly true of all of the good new video games, as the game progresses, Defender shifts to subtler strategies and sends out its alien waves with increasing speed. You play the machine and it plays you.

A neophyte has as much chance with Defender as he would if he were to take over the controls of an F-16. A reasonably good video-game athlete—that is how game junkies are beginning to describe themselves—will last it out for a few thousand points, or a couple of minutes. A superb player, the kind not seen in every arcade, may hit 500,000 on his best day. That is why when Juraszek began to close in on 1 million points toward the end of the first hour of his enchanted run, people began to notice. Darrell Schultz, one of the arcade's owners, asked Steve if he thought he could set a record.

"I said, 'Yeah,'" Juraszek recalls.

*Or gold, or fold, or mold. A jar of pickled space invaders to the reader who most ringingly completes this and other appropriate verses.



A young Missile Command warrior defends her cities at a New London, N.H., pizza parlor



Tense combat on-screen in Pleiades game



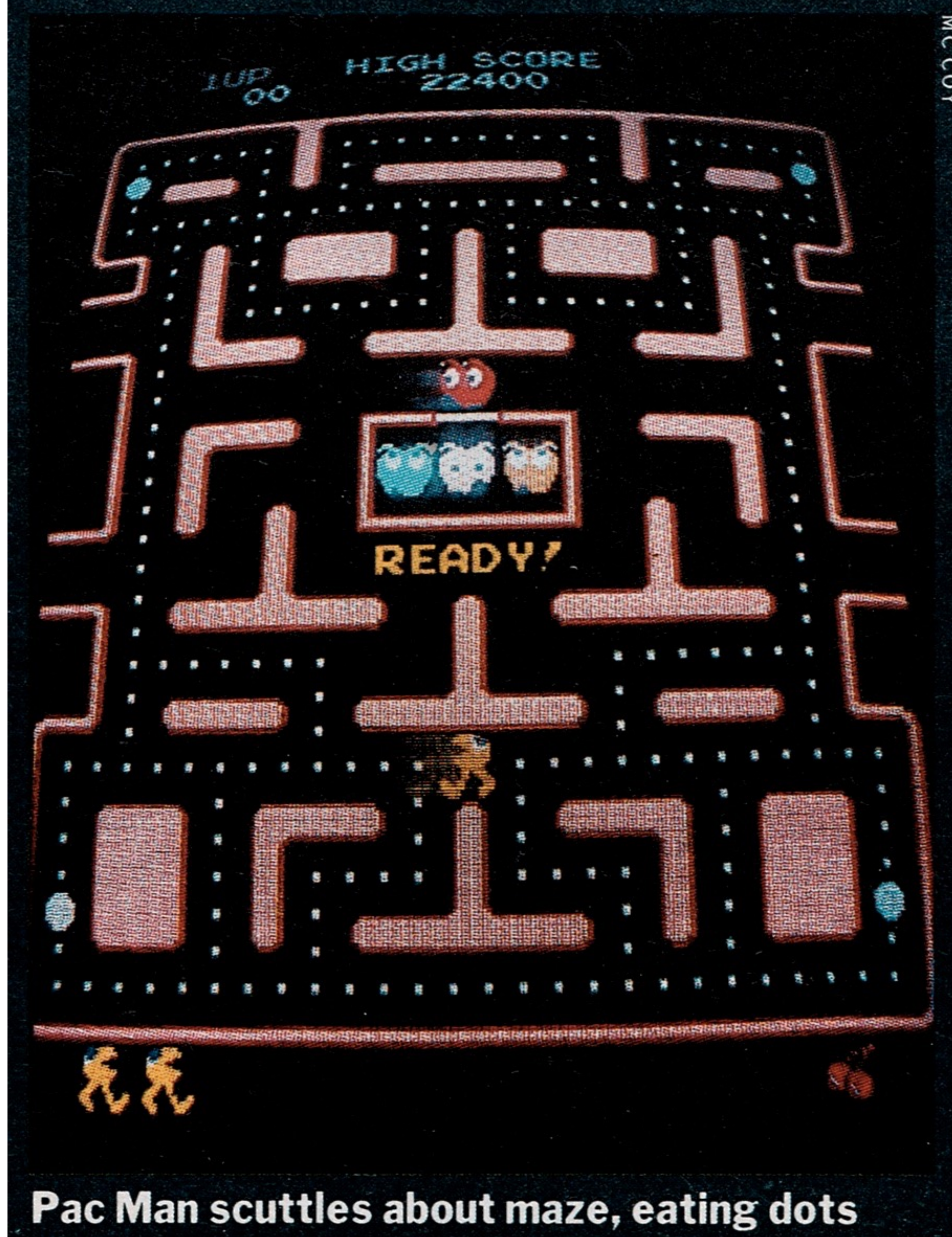
Pac Man scuttles about maze, eating dots

"and he said, 'Go for it!'" Juraszek is a gangly young man who began playing pinball when he was ten, before video games had hit the scene. "I could buy a car or something with the money I've put into games," he says, with no appearance of regret. He started playing Defender in June, and by August he was pretty good. On his record day he kept up his strength by snapping at pizza slices that people held in front of his face. He said later that he was so excited he never even thought about going to the bathroom. His mother Joanne Juraszek watched for a while, utterly unimpressed, and agreed reluctantly to let him play till he dropped. "I just wish," she said later, "that he was this good about doing his homework."

As the scornful cry "So what?" echoes from glen to glen, and as the unmoved Joanne Juraszek admits that she finds her son's new fame "very strange," skeptical citizens might do well to pay attention to a peculiar clinking sound audible across the land. The noise is made by the estimated 20 billion quarters that poured last year into the arcade monsters. This is a figure that may be the public relations roar of a healthy young industry beating its chest, but one that investment analysts who specialize in the entertainment industry agree is not far wrong. While they spent this \$5 billion, video-game addicts also were spending 75,000 man-years playing the machines.

These figures do not include an estimated \$1 billion that consumers paid for video-game consoles that hook up to home television sets, and for the expensive cassettes that make them work. For comparison, \$5 billion is exactly twice the reported take in the last fiscal year of all of the casinos in Nevada. It is almost twice the \$2.8 billion gross of the U.S. movie industry. And it is three times more than the combined television revenues and gate receipts last year of major league baseball, basketball and football.

From what vast aquifer of cash does this astonishing gush of money flow? From the lunch money of schoolchildren, say angry parents who are determined, so



Pac Man scuttles about maze, eating dots

Developers of Crazy Otto / Ms. Pac-Man

Doug Macrae

Kevin Curran

John Tylko

Mike Horowitz

Chris Rode

Steve Golson

Phil Kaaret

General Computer coin-op games

- *Super Missile Attack* enhancement kit for Atari *Missile Command*
- Midway *Ms. Pac-Man*
- Atari *Food Fight*
- Atari *Quantum*
- Midway *Jr. Pac-Man*
- Atari *Nightmare* (never produced)

Products designed by GCC for Atari 2600, 5200, 7800 Game Systems and Atari 400/800 Computers

Asteroids, Atari Video Cube, Ballblazer, Battlezone,
Berzerk, Centipede, Combat II, Desert Falcon,
Dig Dug, Food Fight, Galaga, Galaxian, Joust,
Jr. Pac-Man, Jungle Hunt, Kangaroo, Millipede,
Moon Patrol, Ms. Pac-Man, Phoenix, Pole Position,
Pole Position II, Qix, RealSports Tennis,
Rescue on Fractalus, Robotron 2084, Track & Field,
Vanguard, Xevious

Atari 7800 ProSystem

GCC did the entire design for Atari

- Maria custom graphics processor
- 14 game cartridges for launch (May 1984)
- Encryption/authentication scheme
- High Score cartridge
- Home computer keyboard and peripherals
- Videodisc interface

General Computer

1984



GCC Technologies

HyperDrive

- first internal hard disk for Apple Macintosh

Many other Mac peripherals

Laser printers for Mac and PC

VideoGuide

- early set-top box with on-screen channel guide

exGCCers founded/managed:

Yahoo, Adobe, 38 Studios, Ebay, Cayman Systems, Shiva, American Internet, New Oak, Atlas Venture, Venrock, Digital Lumens, Jisto, VideoGuide, TV Guide Consumer Electronics, AdKnowledge, Covia, Aveo, Endymion, Sonic Solutions, Gracenote/Sony, Creative Data, NameMedia, Dynasil, NewRiver, Broadridge Financial, Avici Systems, Soapstone Networks, NVIDIA, Aurora Flight Sciences, Senté, Sequence Design, InfoScape, Basis Technology, Lotus, Affectiva, Avidyne...
also various professors, authors, engineers, musicians

Twenty years later...

June 2002

Kevin sees a game
that looks familiar...



Contracts and lawsuits

July 1981: *GCC v Atari; Atari v GCC et al*

October 8, 1981: GCC + Atari/Warner

October 29, 1981: GCC + Midway

July 30, 1982: GCC + Atari

1983: *GCC v Midway*

October 5, 1983: GCC + Midway

October 14, 1983: GCC + Namco

November 14, 1985: GCC + Atari

2002: Kevin contacts Namco

2002–2006: negotiations

2006: Demand for Arbitration

Language matters!

What is
different
about these
machines?



Language matters!

What is
different
about these
machines?

“coin-operated game” →



Language matters!

“The term “electronic distribution” shall mean **any use** in which the images, sounds and characters of the Ms. Pac-Man ... game[] are broadcast or in **any other way transmitted** and are intended to be received using devices connected to home television sets **or other receiving devices**. Such methods of transmission include, but are not limited to, cable television, television broadcast, satellite broadcast, including direct broadcast satellite and **any other means** of use of the games where the game images, sounds and characters **are transmitted from a source remote from the receiving device.**”

Reverse engineering to show usage of original code

- Remember “Hello, Nakamura!” message?
- searched for in PlayStation, GameCube, PlayStation Portable, Game Boy Advance, Jakks Pacific, Xbox, etc.

Doug
Macrae



Kevin
Curran



Steve
Golson



Mike
Horowitz



Chris
Rode



John
Tylko



Thank you!

- Namco
- Masaya Nakamura
- Toru Iwatani
- Midway



Classic Game Postmortem

Ms. Pac-Man

Steve Golson
Trilobyte Systems



Classic Game Postpartum

Ms. Pac-Man

Steve Golson
Trilobyte Systems

Q & A

