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COLLEGE ON MICROPROCESSORS:

TECHNOLOGY AND APPLICATIONS IN PHYSICS

7 September - 2 October 1981

I/O AND STORAGE DEVICE TECHNOLOGY

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I/O AND STORAGE DEVICE TECHNOLOGY

GROUPS TO BE DISCUSSED

1. ALPHANUMERIC DEVICES-ACCEPT OR DISPLAY HUMAN INTELLIGIBLE DATA

   TERMINALS, PRINTERS

2. PAPER TAPE READERS AND PUNCHES

   MACHINE READABLE-HUMAN INTERPRETIBLE

3. BULK DATA STORAGE SYSTEMS-MACHINE READABLE BUT NOT HUMAN INTERPRETIBLE

   ACCEPTING DATA AS NATURAL TO COMPUTER

   (PROGRAMS IN SOURCE, OBJECT, OR IMAGE)

   (DATA IN ANY CONVENIENT FORM OR CODING)

   MAGNETIC TAPE AND DISK

   MAGNETIC BUBBLES

4. DATA COMMUNICATIONS

   NOT STRICTLY HUMAN COMMUNICATIONS OR STORAGE DEVICE, BUT NECESSARY TO REACH REMOTE HUMAN OR DIGITAL SYSTEM

ALPHANUMERIC DEVICES- MUST ACCEPT OR DISPLAY DATA IN FORM OF HUMAN INTELLIGIBLE SYMBOLS OR GRAPHS (VANDONI)

- MOST WIDELY USED BINARY REPRESENTATION IS ASCII = AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE (ALSO ISO)
- EBCDIC = EXTENDED BINARY CODED DECIMAL INTERCHANGE CODE (IBM) COMMON IN LARGE COMPUTERS, RARE IN MICROPROCESSORS.
- CODE MUST CONTAIN
  1. COMBINATIONS FOR TEXT SYMBOLS (LETTERS, NUMBERS, PUNCTUATION, ETC)
  2. COMBINATIONS FOR TEXT CONTROLS (NEW LINE, HORIZONTAL TAB, ETC)
  3. COMBINATIONS FOR COMMUNICATION CONTROL (ENQUIRE, ACKNOWLEDGE, END OF TRANSMISSION,
  4. ESCAPE MECHANISM TO EXTEND CODE

NORMAL ASCII HAS:

7 BITS OF CODE OR 128 COMBINATIONS

1 BIT FOR TRANSVERSE PARITY

32 CONTROL CODES } PLUS SPACE, DELETE

94 TEXT SYMBOLS }

 SEE APPENDIX F, M6800 PROGRAMMING REF. MANUAL

ASCII CONTROL CODES

HEXADECIMAL VALUE | ABBREVIATED NAME | SIGNIFICANCE, USE, KEYBOARD COMPOSITION

00	NUL	NOTHING, NO ACTION	c↑P
01	SOH	START OF HEADING	cA
02	STX	START OF TEXT, END OF ADDRESS	cB
03	ETX	END OF TEXT	cC
04	EOT	END OF TRANSMISSION	cD
05	ENQ	ENQUIRE, WHO ARE YOU? (WRU)	cE
06	ACK	ACKNOWLEDGE, ARE YOU (RU) READY?	cF
07	BEL	RING BELL (TTY), SOUND ALARM	cG
08	BS	BACKSPACE	cH
09	HT	HORIZONTAL TAB	cI
0A	LF	LINE FEED, NEW LINE,	cJ
0B	VT	VERTICAL TAB (TOP MARGIN)	cK
0C	FF	FORM FEED (NEW PAGE)	cL
0D	CR	CARRIAGE RETURN	cM
0E	SO	SHIFT OUT, CHANGE RIBBON TO RED	cN
0F	SI	SHIFT IN, CHANGE RIBBON TO BLACK	cO
10	DLE	DATA LINK ESCAPE	cP
11	DC1	DEVICE CONTROL 1, XON (RESUME OUTPUT)	cQ
12	DC2	DEVICE CONTROL 2, REPEAT INPUT LINE	cR
13	DC3	DEVICE CONTROL 3, XOFF (SUSPEND OUTPUT)	cS
14	DC4	DEVICE CONTROL 4	cT
15	NAK	NEGATIVE ACKNOWLEDGE, ERROR	cU
16	SYN	SYNCHRONOUS IDLE (CHARACTER PHASE)	cV
17	ETB	END OF TRANSMISSION BLOCK	cW
18	CAN	CANCEL	cX
19	EM	END OF MEDIUM	cY
1A	SUB	SUBSTITUTE	cZ
1B	ESC	ESCAPE	c↑K
1C	FS	FILE SEPARATOR	c↑L
1D	GS	GROUP SEPARATOR	c↑M
1E	RS	RECORD SEPARATOR	c↑N
1F	US	UNIT SEPARATOR	c↑O
20	SP	SPACE IN TEXT	SPACE BAR
7F	DEL	DELETE	DELETE

c↑ MEANS FIRST PUSH "CONTROL" KEY
" " " " SHIFT KEY
CHECK c↑ COMBINATIONS ON OWN KEYBOARD

ALPHANUMERIC TERMINAL

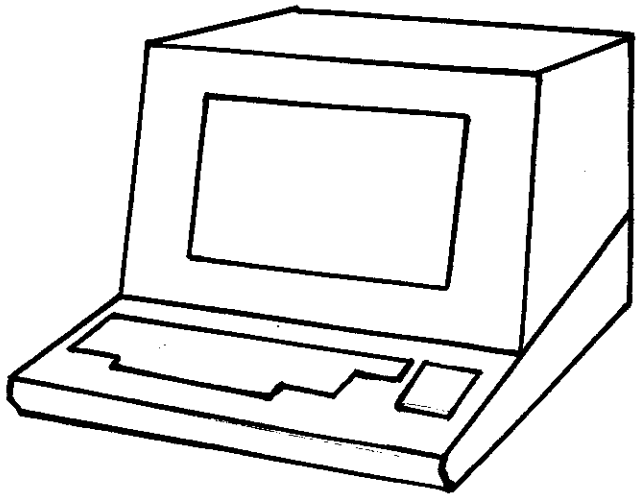
PRINCIPAL MAN-MACHINE INTERFACE FOR INTERACTING WITH COMPUTER SYSTEM

HUMAN INPUT TO COMPUTER ⇒ KEYBOARD (KB)

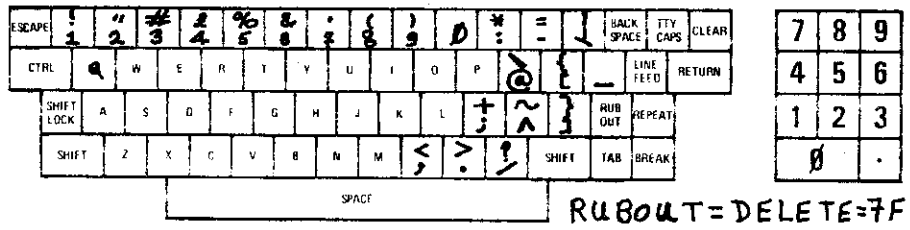
COMPUTER OUTPUT TO HUMAN ⇒ DISPLAY

PRINCIPAL CHARACTERISTICS:

1. OUTPUT (HARDCOPY OR TRANSIENT (CRT))
2. INTERFACE (CURRENT LOOP, RS232, RS422)
3. PROTOCOL (SYNCHRONOUS OR ASYNCHRONOUS)
4. TRANSMISSION MODE (CHARACTER, LINE, PAGE)
5. SPEED IN BITS/SEC (50, 75, 110, 150, 300, 600, 1200 (2400, 4800, 9600, 19200
6. MODE (LOCAL, FULL DUPLEX, HALF DUPLEX
7. KB CHARACTER SET (LC, CAPS LOCK, NUMBERS
8. DISPLAY CHARACTER SET (LC, CONTROL CODES CRT
9. DISPLAY FORMAT (24 LINES * 80 CHAR, 14 * 132, ETC
10. CHARACTER FORMAT (5*7 MATRIX, 7*8, 7*9
11. PRESENCE OF SERIAL OUTPUT PRINTER PORT
12. INVERSE VIDEO (BLACK ON WHITE, WHITE ON BLACK)
13. CURSOR CONTROLLABLE (BY KB AND/OR COMPUTER
14 AVAILABILITY OF COMPOSITE VIDEO SIGNAL
15 SCREEN COLOR (GRAY, GREEN) AND PERSISTENCE (LONG,
16 SMOOTH SCROLL OR LINE JUMP



VIDEOALPHANUMERIC TERMINAL



ESCAPE=1B

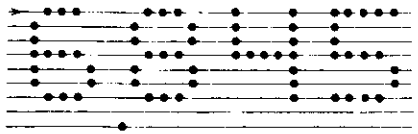
RUBOUT=DELETE=7F

CLEAR DISPLAY

BACKSPACE ≠ DELETE

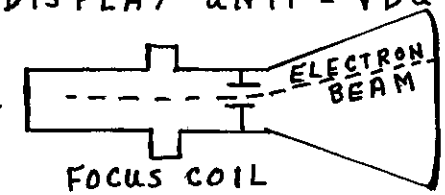
ASCII/ISO Teletype Compatible Keyboard

TAB=cI, LINE FEED=cJ, BACKSPACE=cH, RETURN=cM



ON THE SCREEN

VIDEOALPHANUMERIC CRT TERMINAL OR
VIDEO DISPLAY UNIT = VDU

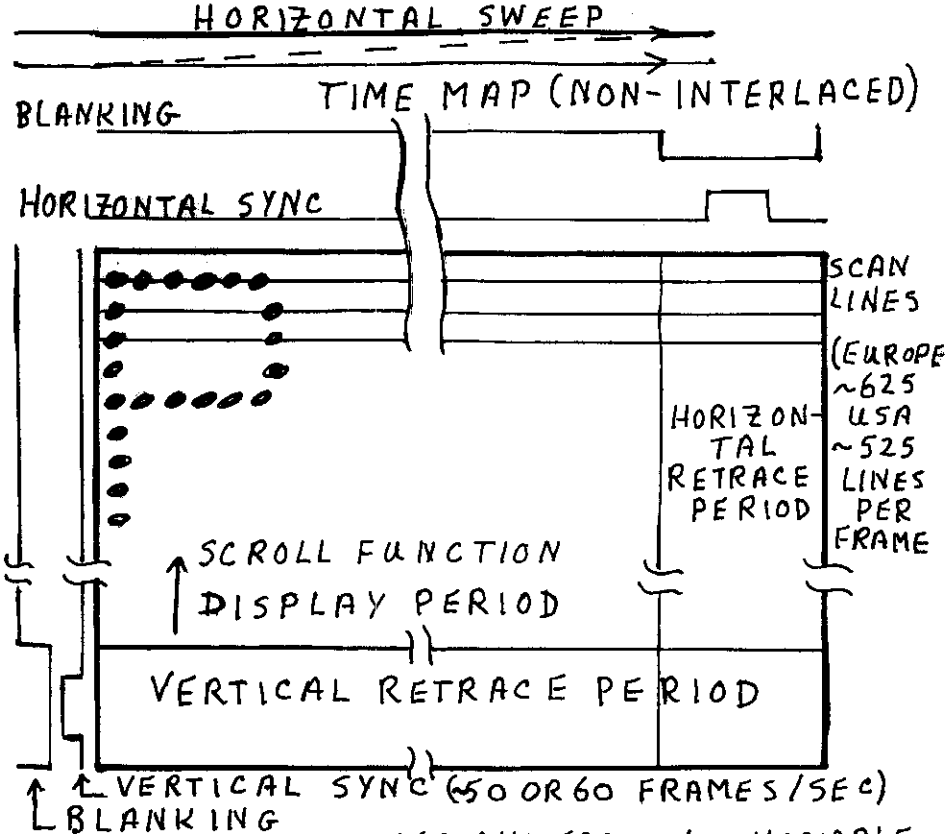


INSIDE OF SCREEN COATED WITH PHOSPHORS WHICH DETERMINE COLOR AND PERSISTENCE

EVACUATED GLASS TUBE
BRIGHTNESS DETERMINED BY ELECTRON BEAM INTENSITY

DEFLECTION - EITHER ELECTROSTATIC OR MAGNETIC

DISPLAY CREATED BY SYSTEMATICALLY SWEEPING BEAM ACROSS ENTIRE SCREEN WHILE VARYING INTENSITY



NUMBER OF SCAN LINES AND FRAMES/SEC VARIABLE

CRT GENERATION OF CHARACTERS ON SCREEN

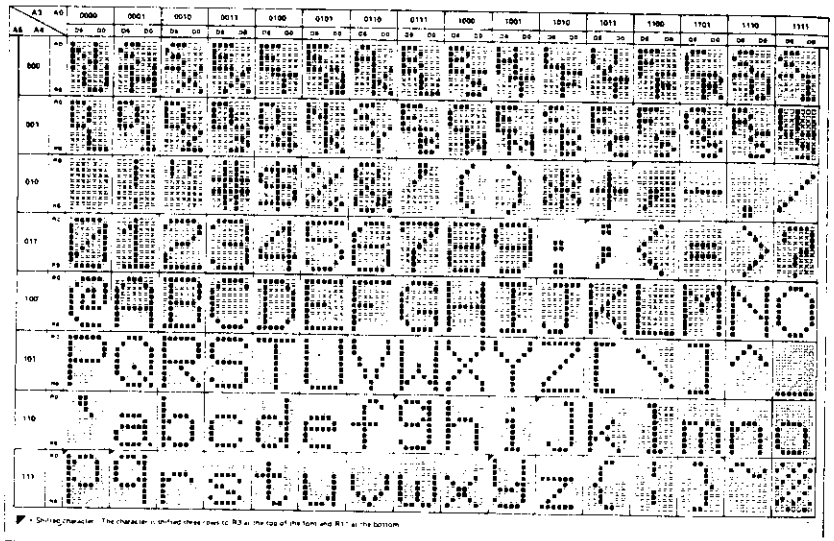


Figure 14-6 MCM66750 pattern.

MATRIX PATTERNS IN CHARACTER ROM

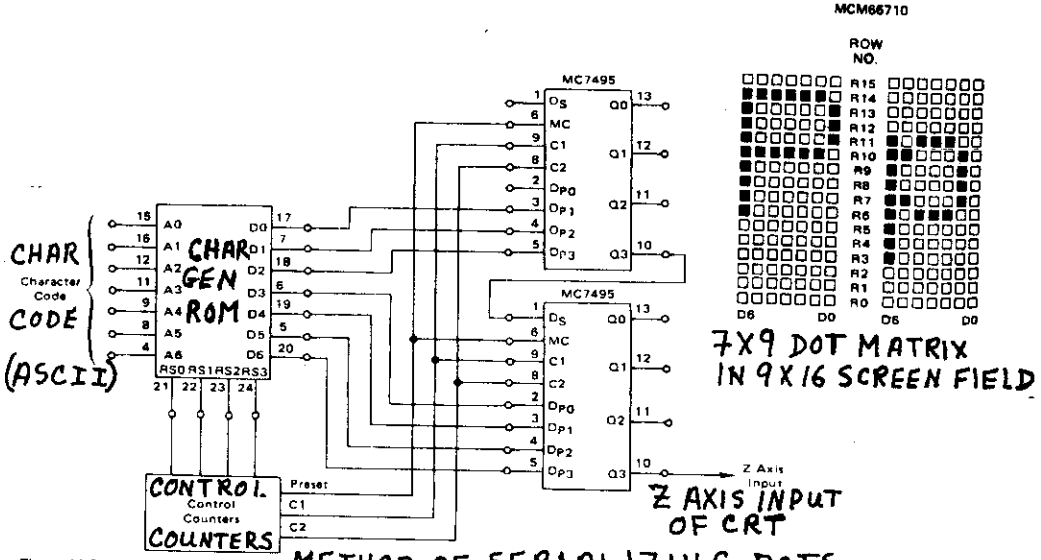


Figure 14-7 Method of serializing the dots.

METHOD OF SERIALIZING DOTS IN MOTOROLA 6845 CRT CONTROLLER.

FIGURES FROM CHAPTER 14 - GREENFIELD + WRAY

TERMINAL CONNECTING

CURRENT LOOP: (DERIVED FROM TELEGRAPHY)

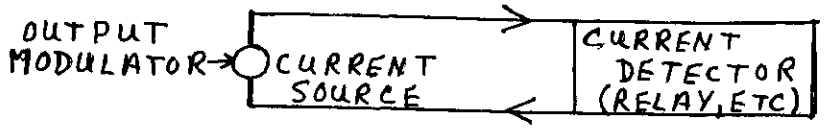
0 = SPACE = CURRENT ABSENT BECAUSE CIRCUIT NOT POWERED OR OPEN

1 = MARK = CURRENT PRESENT BECAUSE CIRCUIT BOTH POWERED AND CLOSED

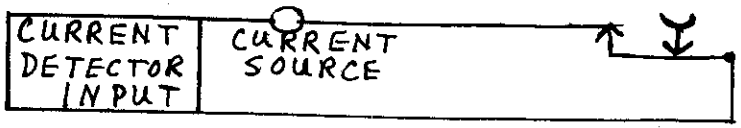
NON-SYMMETRIC BECAUSE TRANSMITTER OF POWER (CURRENT SOURCE) CAN BE EITHER TRANSMITTER OR RECEIVER OF INFORMATION

THUS TWO LOOP CONFIGURATIONS

ACTIVE TRANSMITTER — PASSIVE RECEIVER



ACTIVE RECEIVER — PASSIVE TRANSMITTER



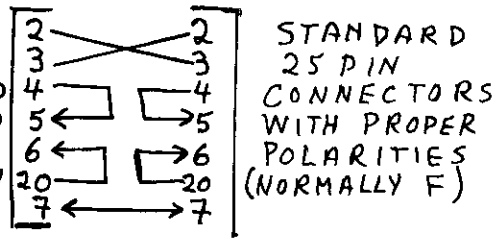
USUAL COMPUTER OR MODEM INTERFACE — USUAL TERMINAL INTERFACE

ATTENTION: DON'T CONNECT CURRENT LOOP INTERFACES ACTIVE-TO-ACTIVE

RS-232C/V24 IS SYMMETRIC - POWER AND INFORMATION HAVE SAME SOURCES.

CAN CONNECT FREELY RS232 DEVICES PROVIDED LOGICAL SIGNAL REQUIREMENTS SATISFIED

NULL MODEM EXAMPLE:



HARD COPY OUTPUT ON PAPER

FROM HARDCOPY TERMINALS AND PRINTERS

PRINCIPAL CHARACTERISTICS

1. PAPER (PLAIN OR SPECIALLY PREPARED) COST?
2. SEQUENCING (BY CHARACTER OR LINE)
3. CHAR FORMED BEFORE (CAST) OR DURING PRINTING
4. CHARACTER SIZES (POSSIBLE WITH MATRIX)
5. SPEED (CHAR/SEC OR LINES/MIN)
6. WIDTHS OF PRINTED LINES IN CHAR OR INCHES
7. TECHNOLOGY ↑ DETERMINE OTHER CHARACTERISTICS AND MARKET

– CHARACTER SEQUENCE

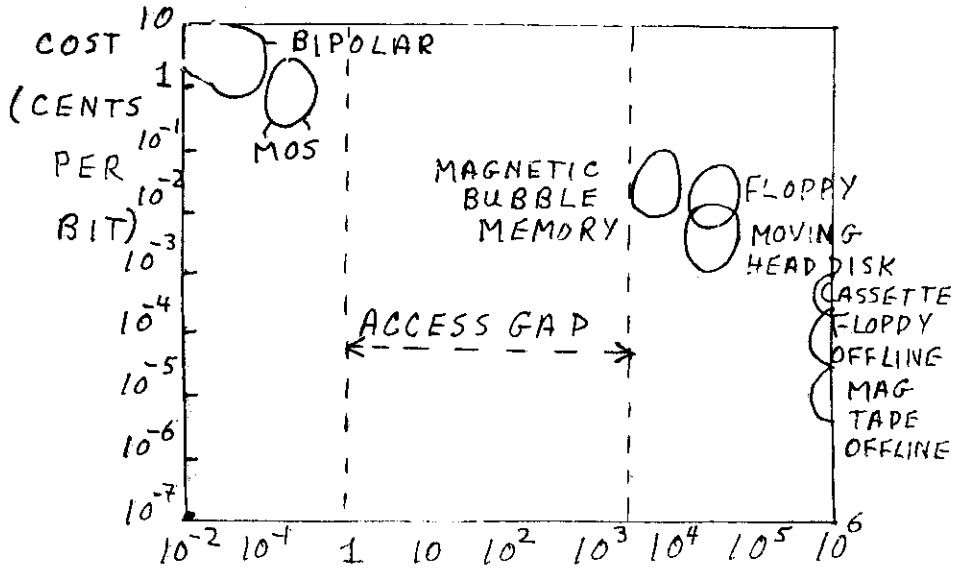
TECHNOLOGY	PAPER	FONT	SIZE	SPEED (CHAR/SEC)	COST ($1000)
CAST CHARACTERS					
HAMMERED	PLAIN	FIXED	10/IN	10-45	2-5
LINE OF SOLENOID HAMMERED PINS	PLAIN	(ROM) PROG	(10-16/IN)	(30-250)	(1-8)
THERMAL BURNING	THERMALLY SENSITIVE	FIXED*	(10/IN)	30	2-3
LASER ELECTROGRAPHIC	PLAIN	VARIABLE	~1000	15-30 (SHARE)	

– LINE SEQUENCE

				(LINES/MIN)	
CHAIN OR BAND HAMMERED	PLAIN	FIXED	(10/IN)	(200-1200)	8-25
ELECTROSTATIC	SENSITIVE	PROGRAMMABLE		200-500	10-20

*COULD BE VARIABLE

STORAGE HEIRARCHY



REFERENCES AND CALCULATIONS

MAGNETIC BUBBLE MEMORY – R. BERNHARD, IEEE SPECTRUM, MAY 1980 GIVES ~ 50 MILLICENTS/BIT.

FLOPPY DISK: ASSUME $4000 FOR DUAL-DENSITY SINGLE-FACE DUAL-UNIT INCLUDING CONTROLLER

$$\frac{4*10^5 \text{ CENTS}}{0.5 \times 10^6 \text{ BYTES} * 8 * 2} = 50 \text{ MILLICENTS/BIT}$$

MOVING HEAD FIXED DISK: ASSUME $4000 FOR 10 MBYTE UNIT INCLUDING CONTROLLER

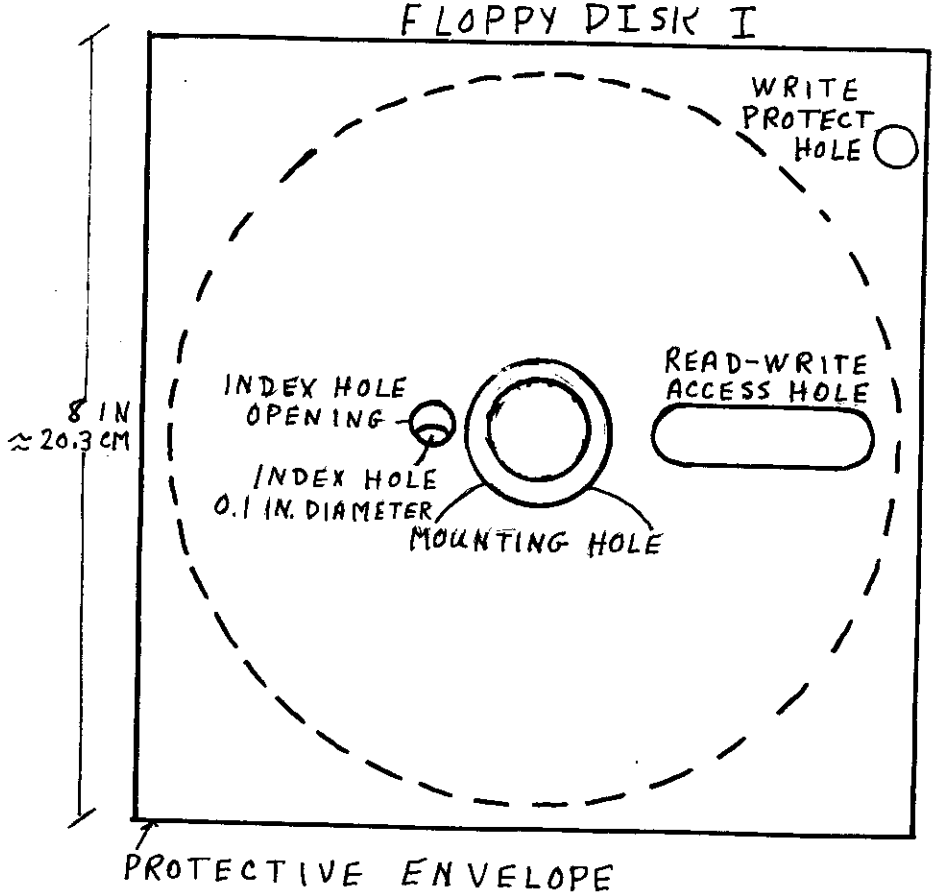
$$\frac{4*10^5 \text{ CENTS}}{80*10^6 \text{ BITS}} = 5 \text{ MILLICENTS BIT}$$

COMPARE: MAGNETIC BUBBLE MEMORY – FLOPPY

AVERAGE ACCESS TIME ~ 10MS 0.2 – 0.5 SEC

TRANSFER RATE 10-100 KBYTES/SEC (ORGANIZATION DEPENDENT) 31.25 KBYTES/SEC
62.5 " (DOUBLE)

FLOPPY DISK I



FLOPPY (FOR NON RIGID) IS MAGNETIC OXIDE COATED DISK OF FLEXIBLE MYLAR, PERMANENTLY CONTAINED IN 8-INCH PROTECTIVE ENVELOPE WITH HOLES FOR MOUNTING IN CENTER, SENSING INDEX HOLE (BEGINNING OF TRACK), ALLOWING READ-WRITE HEAD ACCESS AND WRITE PROTECTION. DISK DIAMETER = 7.88 IN, THICKNESS $\frac{3}{1000}$ IN, OXIDE 100 μIN. ENVELOPE LINER REMOVES ABRASIVE DIRT

FLOPPY DISK II

- PROVIDES ON-LINE RANDOM ACCESS STORAGE
- LOWER COST (AND CAPACITY) THAN RIGID DISKS.
- PROVIDES LOW COST (~$5/FLOPPY) OFF-LINE STORAGE
- WIDESPREAD AGREEMENT ON DATA FORMAT
- LONG LIFE (HEAD TOUCHES ONLY FOR READING/WRITING) ~ 5×10^6 CONTACT TURNS/TRACK
- RELIABILITY: POSITIONING ERRORS: 1 IN 10^6 OPERATIONS
- SOFT ERRORS (RECOVERABLE IN ≤10 TRIES): 1 BIT / 10^9
- HARD ERRORS (NOT RECOVERABLE): 1 BIT / 10^{12}
- GOOD ERROR DETECTION: 2 BYTE CRC CHARACTER (>99%)

ACCESS TIME (.2 TO .5 SEC) IS SUM OF

LATENCY: 83 MS = 1/2 * 167 MS/TURN (360 RPM)

PLUS TRACK-TO-TRACK MOVEMENT (3-10 MS-STEP MOTOR) FASTER WITH VOICE COIL.
PLUS TIME TO LOWER HEAD - 30-40 MS.

77 PHYSICAL TRACKS-74(75) LOGICAL (REST SPARES)

IBM 3740 FLOPPY DISK DATA CAPACITY

DENSITY	SINGLE (FM)	DOUBLE (MODIFIED FM)
$\frac{\text{BYTES}}{\text{SECTOR}} * \frac{\text{SECTORS}}{\text{TRACK}} * 74$		
128 * 26 * 74 = 246,272		256 * 26 * 74 = 492,544
256 * 15 * 74 = 284,160		512 * 15 * 74 = 568,320
512 * 8 * 74 = 303,104		1024 * 8 * 74 = 606,208

NOTE: GREATER CAPACITY AND SIMPLICITY WITH HARD SECTORING.

MAGNETIC BUBBLE MEMORY I

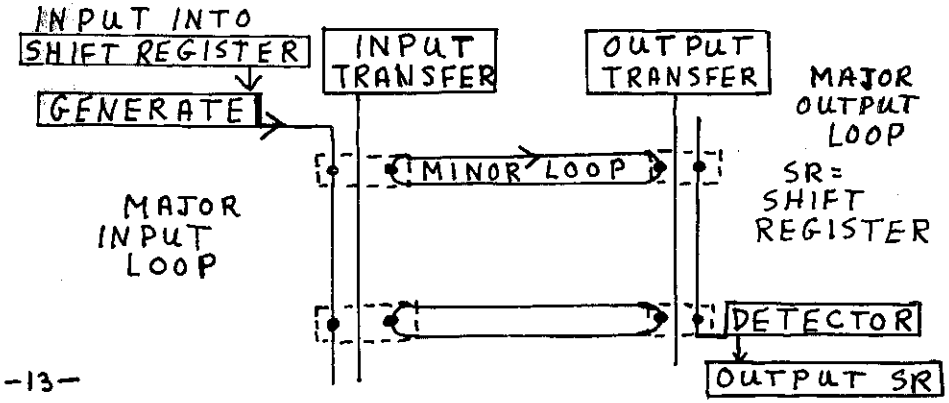
MAGNETIC BUBBLES ARE:
SMALL CYLINDRICAL MAGNETIC DOMAINS

FORMED IN THIN MAGNETIC FILMS (GARNET)

WHEN EXTERNAL MAGNETIC BIAS FIELD ⊥ TO FILM.

- BUBBLES ARE MAGNETIZED OPPOSITE TO BIAS AND REMAIN (NON-VOLATILE) IF BIAS PERMANENT.
- BUBBLE PRESENT = 1; ABSENT = 0
- BUBBLES MOVED IN SHIFT-REGISTER STRUCTURE UPON CREATING MAGNETIC FIELD GRADIENT BY SUPERPOSING ROTATING FIELD UPON PERMALLOY ARTWORK DEFINING BIT LOCATIONS.
- BUBBLES DETECTED BY MAGNETORESISTIVE ELEMENT (RESISTANCE VARIES IF BUBBLE PRESENT, ELSE NO)
- BUBBLES CREATED BY CURRENT PULSE IN GENERATOR LOOP
- ORGANIZED IN MAJOR/MINOR LOOP

EXAMPLE N^2 BITS



MAGNETIC BUBBLE MEMORY - II

RECENT COMMERCIALLY AVAILABLE MBM'S

- ALL USE EXTERNAL PAIR OF COILS TO GENERATE ROTATING MAGNETIC FIELD
- ALL ARE 1 MEGABIT CHIPS

MFR	DATA-RATE Kb/SEC	BUBBLE SIZE — DIAMETER MICRONS	AVG-ACCESS TIME	ORGANIZATION
INTEL	100	NA	6 MS	4 BANKS * 256 Kb
TEXAS	160	2.0	11 MS	2 * 512 Kb
ROCKWELL	350	1.8	4 MS	4 * 256 Kb
NATIONAL	NA	2.2μ	NA	590 LOOPS * 2048 SOME REDUNDANCY

ERROR RATES BASED ON 256 Kb CHIPS

READ: 1 ERROR IN 10^{11} - 10^{12} (SIMILAR TO FLOPPY HARD ERROR CLAIM)

LIFETIME ≳ 20 YEARS (PRINCIPAL APPLICATION STILL IN TELEPHONE SWITCHING)

SOME OTHER APPLICATIONS

INTEL 8080 AND MC6800 (1 Mb) MEMORY CARDS

FLOPPY DISK REPLACEMENT SIMULATED BY Z80 FOR LSI-11

PORTABLE TERMINALS (TEXAS) RECORD AND TRANSMIT

SOME PROMISES;

4 MEGABIT CHIP SHOULD RESULT FROM NEW BUBBLE CONTROL (CONTIGUOUS ELEMENT)

SEE IEEE SPECTRUM, FEBRUARY 1981, PAGE 30

RIGID DISKS

FOR ~~MICRO~~ SINGLE MICROSYSTEMS, FIXED DISK (WINCHESTER TECHNOLOGY, SEALED DUST PROOF HEAD-DISK UNIT)

IS MOST COST EFFECTIVE FOR ON-LINE STORAGE

ACCESS TIME ~ 1/10 OF FLOPPY DISK

CAPACITY ≳ 10 TIMES FLOPPY DISK

BACKUP POSSIBLE EITHER ON

PERMANENTLY INSTALLED FLOPPY WITH PARALLEL IF

OR

PORTABLE INTELLIGENT FLOPPY WITH SERIAL IF

OR

LOW COST "BACKUP" TAPE CASSETTES MATCHED TO DISK IN CAPACITY AND FORMAT. (EXAMPLE - 3M TYPE CARTRIDGE, 2.5 MBYTES, 6KBYTES/SEC TRANSFER)

FOR MULTIPLE MICROSYSTEMS

EXAMINE "INTELLIGENT DISK" SOLUTION

LARGE CAPACITY DISK (POSSIBLY WITH FLOPPY FOR FILE BACKUP AND EXCHANGE) CONTROLLED BY MICROPROCESSOR WHICH

BUFFERS, STORES, AND RETRIEVES FILES FOR ALL ATTACHED MICROSYSTEMS ON

REQUEST BASIS

ALREADY EXISTING SYSTEM

CORVUS INTELLIGENT DISK FOR APPLE COMPUTERS

AUDIO CASSETTE

- VERY LOW COST, SEQUENTIAL ACCESS, STORAGE
- WITH RISE OF HOBBY AND PERSONAL COMPUTER, HAVE COME PROPOSALS FOR INTERFACES WITH RS232C/V24 PORTS. (ALSO LOW COST)
- NOW CAPACITY IS FUNCTION OF ASYNCHRONOUS BIT RATE. AT 2400 BPS, 30 MINUTE CASSETTE RECORDS $\frac{30*60*2400}{10\ \text{BIT/BYTE}} = 432{,}000$ BYTES

USEFUL CAPACITY IS REDUCED BY LONG, MANUALLY INSERTED (USE TAPE LENGTH COUNTER) GAPS.

ALTERNATE TECHNOLOGY

CCD = CHARGE COUPLED SHIFT REGISTER BUILT WITH TECHNOLOGY SIMILAR TO THAT USED TO CONSTRUCT n-CHANNEL DYNAMIC MOS RAMS (SILICON-GATE PROCESS)

- COMPARISON WITH DYNAMIC MOS:

  DENSITY (THUS COST) ADVANTAGE: 2-4

  ACCESS TIME DISADVANTAGE ~ 1000

  ALSO VOLATILE AS DYNAMIC (+STATIC) RAM.

- THUS NOT ADVANTAGEOUS FOR MICRO CASE.

ONE-HALF INCH MAGNETIC TAPE

INDUSTRY STANDARD OFFLINE ARCHIVE STORAGE

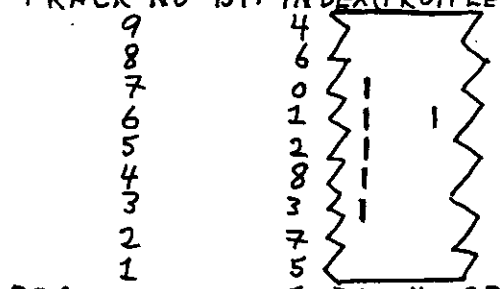
LOW COST- 2400 FT REEL (~$18) HOLDS ~ 36 MEGABYTES
~50 CENT/MEGABYTE OR ~50/10^9 ~ 10^{-5} CENT/BIT
(NOT COUNTING TAPE UNIT) ASSUMING 1600 BPI

UNIT COST ($\gtrsim$ \$10,000) MUST BE DISTRIBUTED
OVER NUMBER OF TAPES IN LIBRARY.

TAPE UNIT HAS FAST ACCESS TO NEXT RECORD
START TIME $\lesssim$ 5MS
TRANSFER RATE $\gtrsim$ (45 IPS * 1600 BPI) = 72 KBYTES/SECOND

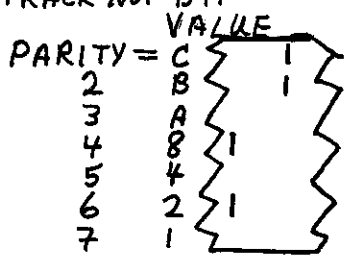
NEEDS CONTROLLER WITH DMA ACCESS TO BUFFER.

TAPE FORMAT-NINE TRACK

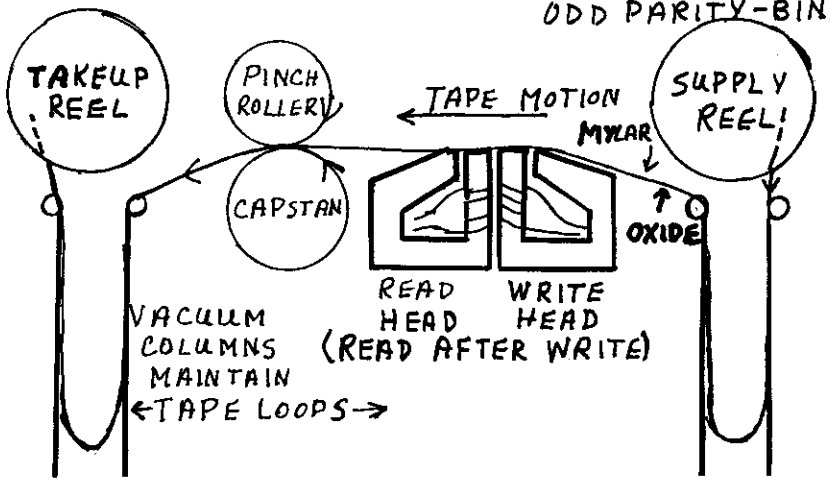


PARITY=ODD F0=ZERO, 40=SP
AVOID EDGE MAGNETIZATIONS
FOR FREQUENT COMBINATIONS

SEVEN TRACK

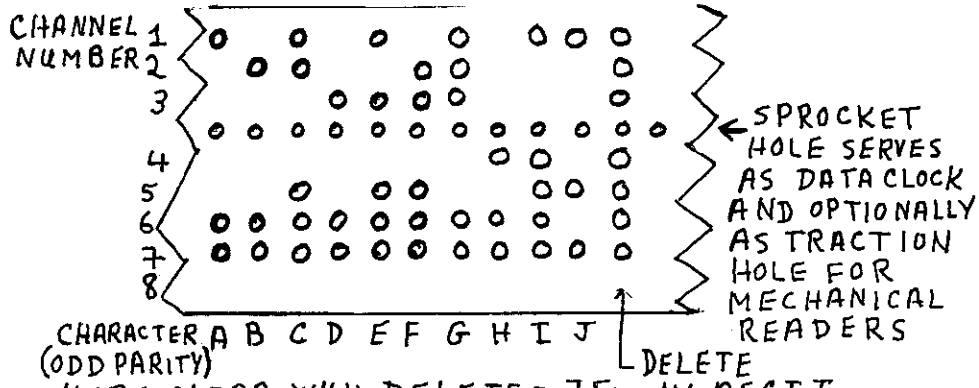


ZERO-SP
EVEN PARITY-BCD
ZERO = 8+2
ODD PARITY-BINARY



PAPER TAPE

MEANS OF STORING BINARY INFORMATION BY
PUNCHING HOLES IN A CONTINUOUS STRIP OF PAPER
IN WELL DEFINED POSITIONS (0=NO HOLE, 1=HOLE



HERE CLEAR WHY DELETE = $7F_{16}$ IN ASCII

CAPACITY: NORMALLY 10 CHAR/IN (80 CHAR/FOLD IN FANFOLD PAPER TAPE)

-8 CHANNEL TAPE CARRIES ONE BYTE OF BINARY DATA PER LINE ACROSS TAPE AS WELL AS CODED ALPHANUMERIC.

CLASSIFICATION BY CHANNELS; 5=BAUDOT-TELEGRAPHIC

ADVANTAGES: CAN BE WRITTEN (PUNCHED) MANUALLY AS WELL AS BY COMPUTER-CONTROLLED PUNCH

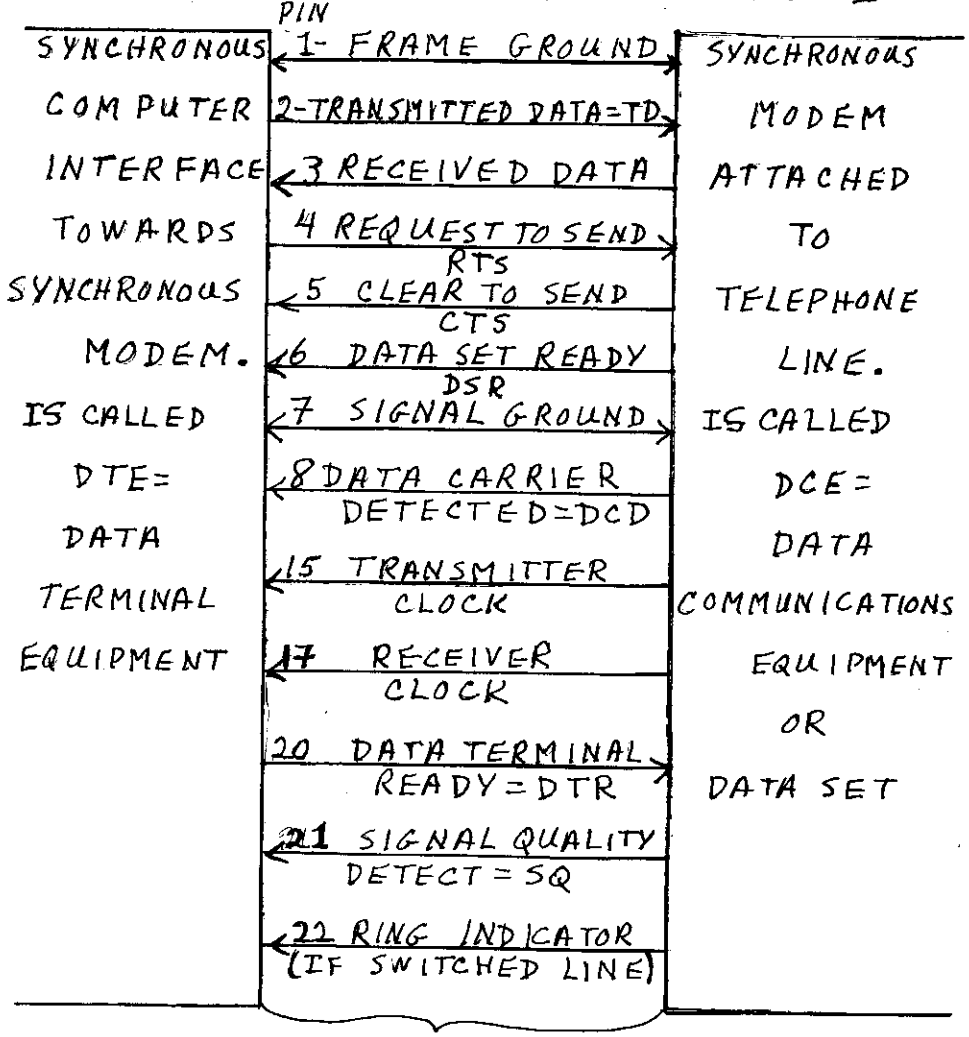
"BITS" NOT WEAKENED WITH TIME & SEQUENCE FIXED

WELL ESTABLISHED COMPATIBILITY (MUCH USED ON NUMERICAL CONTROL MACHINES)
LOWEST COST FOR EXCHANGING SMALL PROGRAMS.

INCREMENTALLY READABLE AND WRITABLE WITH SIMPLE INTERFACE

DISADVANTAGES: NOT REWRITABLE, AWKWARD IF LONG

SYNCHRONOUS COMMUNICATION I



EIA-CCITT MODEM-TERMINAL INTERFACE

1. MODEM ASSERTS DSR(6) IF READY AND DTR(20) = 1
2. MODEM ASSERTS CTS(5) IF RTS(4) ASSERTED, DSR(6) = 1 AND OWN CARRIER ON (OUT CHANNEL FREE). CARRIER ON FURNISHES TRANSMITTER CLOCK INTERFACE FURNISHES BIT STRING ON TD LINE IN SYNCHRONIZATION WITH TRANSMITTER CLOCK

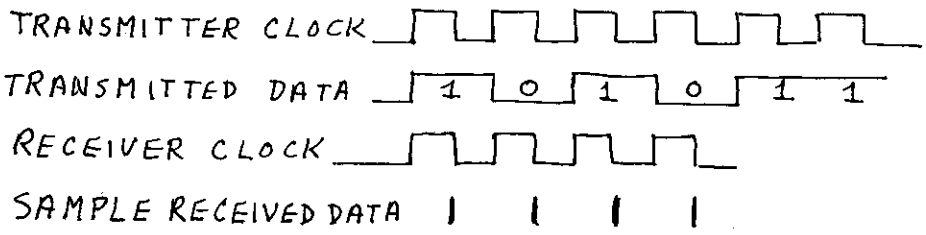
SYNCHRONOUS COMMUNICATION II

- ON FULL-DUPLEX (4-WIRE) LINE, RECEIVER STAGES OF BOTH MODEMS REMAIN IN BIT SYNCHRONIZATION WITH TRANSMITTER STAGES OF OTHER.
- ON HALF-DUPLEX (2-WIRE) LINE, PRESENT RECEIVER BIT-SYNCHRONIZES ITSELF TO RECEIVED CARRIER
- WHEN RECEIVED CARRIER STOPS AND RTS IS ASSERTED,

-LINE TURNAROUND TIME-

MODEM TRANSMITS OWN CARRIER (ROLES EXCHANGE)
MODEM STOPS TRANSMITTING WHEN RTS IS NEGATED.

RELATIONSHIP OF DATA TO CLOCKS



MODEMS TRANSPORT BITS, INTERFACES MUST REGROUP BITS INTO CHARACTERS

- CONVENTION FOR BSC (BINARY SYNCHRONOUS COMM.): PUT SYN CHARACTER (ASCII CODE = 16_{16}) IN FRONT AND AT REGULAR INTERVALS IN TEXT ALSO INSERT SYN CHARACTERS TO MAINTAIN CHARACTER SYNCHRONIZATION IF OTHERS NOT READY.