IBM 7090 Simulator Usage

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IBM 701 simulator written by Richard Cornwell

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This memorandum documents the IBM 7090 & 704 simulator.

The follow up to the IBM704. Utilizing ideas learned from the Stretch IBM enhanced the 704 by adding multiple communications channels to speed up processing I/O devices. This allowed the machine to continue processing while the tapes or card readers transfered data. Also this was one of the first machines to feature indirect addressing. Also added as an indicator register to hold flags and other information. The IBM 709 was announced January 2, 1957 withdrawn April 7, 1960. Originally the IBM 709T later to be named the IBM 7090 by customers, the machine was a faster version of the IBM 709 implemented in transistors instead of tubes. The IBM 7090 announced December 30, 1958 withdrawn July 14, 1969. The IBM 7090 also was built out of the same modules as the Stretch and used the same memory modules. The final enhancement was the IBM 7094, this added double percision arithmetic, faster processing, and 4 more index registers. The machine looked like a 7090 until extra indexing mode was entered, then instead of 3 registers begin or-ed together, the 3 bits selected one of 7 index registers. It was latter upgraded to the 7094/II which was still faster. IBM 7094 & IBM 7094/II, announced January 15, 1962 withdrawn July 14, 1969.

IBM also developed two transistorized versions of the IBM 704, these were slower then the IBM 7090, and did not feature an indicator register or indirect addressing. But they came optionally with double precision floating point, and special character operating instructions. It was also possible to purchase a 7040 without index registers or floating point. The machines were meant to be front ends to the IBM 7094, and a direct couple devices was sold, along with the ability to share 1301 drives between systems. Unfortunately no software has been found for the IBM 7040/44.

The IBM 7094 was also one of the first machines to be modified to run time sharing. The Compatible Time Sharing System (CTSS) was developed by MIT to allow for the IBM 7094 to be shared by multiple people while still being compatible with FMS.

# 1. Simulator Files

To compile the IBM 7090, you must define USE\_INT64 as part of the compilation command line.

|  |  |  |
| --- | --- | --- |
| ***Subdirectory*** | ***File*** | ***Contains*** |
| **I7000** | i7000\_defs.h | IBM 7000 simulators general definitions |
|  | i7090\_defs.h | IBM 7090 simulator specific definitions |
|  | i7000\_chan.c | Generic channel interface. |
|  | i7090\_cpu.c | 7090 CPU, Channel, interface |
|  | i7090\_chan.c | 7090 Channel. |
|  | i7090\_sys.c | 7090 System interface |
|  | i7090\_cdr.c | 711 Card reader |
|  | i7090\_cdp.c | 721 Card punch |
|  | i7090\_lpr.c | 716 Line printer |
|  | i7090\_drum.c | 733 Drum memory interface. |
|  | i7000\_com.c | 7750 Communications Controller\* |
|  | i7000\_dsk.c | 1301/2302 disk and 7238 drum controller.\* |
|  | i7000\_ht.c | 7340 Hypertape controller.\* |
|  | i7090\_hdrum.c | CTSS High Speed Drum\* |
|  | i7000\_mt.c | 729 Tape controller. |
|  | i7000\_chron.c | Chrono Clock.\* |

If so desired instead of defining I7090, I704 can be defined and the files marked with ‘\*’ above can be removed. This produces a smaller executable that will only emulate a IBM 704 computer.

## 2. IBM 7090 Features

The IBM 7090 simulator is configured as follows:

|  |  |
| --- | --- |
| **Device Name(s)** | **Simulates** |
| **CPU** | 7090 CPU with 32Kw/64Kw of memory |
| **CH0** | 704 Unit record devices |
| **CH1..8** | 7607/7909/7289 Channels |
| **MT** | 729 Magnetic Tape Controller (On CH0) |
| **MTA** | 729 Magnetic Tape Controller |
| **MTB** | 729 Magnetic Tape Controller |
| **MTC** | 729 Magnetic Tape Controller |
| **MTD** | 729 Magnetic Tape Controller |
| **MTE** | 729 Magnetic Tape Controller |
| **CHRON** | Chrono Clock |
| **HTA** | 7340 Hypertape, default not included. |
| **HTB** | 7340 Hypertape, default not included. |
| **CDR** | 711 Card Reader |
| **CDP** | 721 Card Punch |
| **LP** | 716 Line Printer |
| **DR** | Drum memory. |
| **HD** | CTSS High Speed Drum. |
| **DK** | 1301/2302/7304 disk. |
| **COM** | 7750 communications controller. |
| **COML** | 7750 Communications lines. |

Channels A through H, the corresponding magnetic tape controllers, and the file control, drum control , and communications control are initially set DISABLED. The file control, drum control, and communications control can be assigned to any channel in the range B through H.

The 7090 simulator implements several unique stop condition:

* Undefined CPU instruction
* Undefined channel instruction
* XEC nesting exceeds limit
* Divide check on a divide and halt instruction
* Select of a non-existent channel
* 7607 select of a 7909 channel
* Write select of a write protected device
* Invalid file control format
* Invalid message to 7750
* No buffer storage available for input character on 7750
* No buffer storage available for output character on 7750

The LOAD command will load a card binary image file into memory.

## 2.1 CPU

The CPU options include setting memory size and cpu type. Also the special features required for used by the CTSS project:

|  |  |
| --- | --- |
| SET CPU STANDARD | Standard CPU |
| SET CPU CTSS | Adds extra core memory for CTSS |
|  |  |
| SET CPU 704 | Sets CPU to emulate a 704 |
| SET CPU 709 | Sets CPU to emulate 709 instructions |
| SET CPU 7090 | Sets CPU to emulate 7090. |
| SET CPU 7094 | Sets CPU to emulate 7094. |
| SET CPU 4K | Sets memory to 4K |
| SET CPU 8K | Sets memory to 8K |
| SET CPU 16K | Sets memory to 16K |
| SET CPU 32K | Sets memory to 32K |
| SET CPU TRUEIO | CPU executes I/O in CPU time. |
| SET CPU FASTIO | CPU detects I/O waits and shortens them |
| SET CPU NOEFP | Disables extended precision floating point. |
| SET CPU EFP | Enables extended precision floating point. |
| SET CPU NOFPSM | Disables floating point significance mode. |
| SET CPU FPSM | Enables floating point significance mode. |
| SET CPU TIMER | Enables interval timer and interrupt. |
| SET CPU NOTIMER | Disables interval timer. |

Memory size is 32KW on a standard CPU, 64KW on a CTSS CPU. Set notes below on setting up for CTSS.

The 7090 supported many options which were called RPQ’s, these include extended precision floating point instructions. These were similar to the later 7094 double precision floating point instructions. Significance mode allowed for better detection of bits during floating point operations.

FASTIO mode detects when the CPU is in a loop waiting for a channel to become available and then sets the simulation interval to run any pending I/O. This results if faster simulations without the CPU being aware of this. If the Timer is used, this might result in incorrect timing intervals.

CPU registers include the visible state of the processor as well as the control registers for the interrupt system.

| ***Name*** | ***Size*** | ***Comments*** |
| --- | --- | --- |
| IC | 15 | Program Counter |
| AC | 38 | Accumulator |
| MQ | 36 | Multiplier Quotient |
| ID | 36 | Indicators register |
| KEYS | 36 | Front panel keys |
| XR1..XR7 | 15 | Index registers |
| SW1..SW6 | 1 | Sense Switches 1..6 |
| SW | 6 | Sense Switches |
| SL1..4 | 4 | Sense Lights 1..4 |
| ACOVF | 1 | Accumulator Overflow Indicator |
| MQOVF | 1 | MQ Overflow Indicator. |
| DVC | 1 | Divide Check indicator |
| IOC | 1 | I/O Check indicator |
| TM | 1 | Transfer Trap mode |
| CTM | 1 | Copy Trap mode |
| STM | 1 | Select Trap mode |
| FTM | 1 | Floating Trap mode |
| NMODE | 1 | Storage nullification mode |
| MTM | 1 | Multiple Tag mode |
| ENB | 36 | Interrupt enable register |
| INST\_BASE | 1 | (CTSS) B core instruction execution |
| DATA\_BASE | 1 | (CTSS) B core data access |
| BASE | 14 | (CTSS) relocation base block |
| LIMIT | 14 | (CTSS) address limit block |

The CPU can maintain a history of the most recently executed instructions.

This is controlled by the SET CPU HISTORY and SHOW CPU HISTORY commands:

|  |  |
| --- | --- |
| SET CPU HISTORY | clear history buffer |
| SET CPU HISTORY=0 | disable history |
| SET CPU HISTORY=n | enable history, length = n |
| SHOW CPU HISTORY | print CPU history |
| SHOW CPU HISTORY=n | print first n entries of CPU history |

Instruction history trace shows the Instruction counter for the instruction, the AC and MQ before the execution, the computed Effective Address, the word read from storage, and the three index registers XR1, 2 and 4.

### 2.2 I/O Channels (CH0..CH8)

The 7090 supports up to 8 channels. Channel models include

|  |  |
| --- | --- |
| 7607 | standard multiplexer channel |
| 7289 | high speed drum channel |
| 7909 | advanced capabilities channel |

Channel A is required and is always a 7607. Channel are represented by a number: A=1, B=2, C=3, D=4, E=5, F=6, G=7, H=8. Channel 0 is for 704 devices.

|  |  |
| --- | --- |
| SET CH*n* 7607 | Sets channel to be a 7607 type. |
| SET CH*n* 7909 | Sets channel to be a 7909 type. |
| SET CH*n* 7289 | Sets channel to be a 7289 type. (For CTSS Drum). |
| SET CH*n* FIXED | Fixes channel to specific type. |
| SET CH*n* AUTO | Default, channel configures based on devices on it. |

Generally there is no need to worry about channel configurations, in auto mode they will configure to correct type to support devices attached to them. Or you will get an error when you attempt to run the simulation if there is a conflict.The default layout of devices will work for IBSYS and CTSS.

A show channel command will list out the devices currently assigned to this channel, or all channels if no specific channel is selected.

Channel 0 is a pseudo channel for 704 devices. Currently unit CR3, CP3, LP3,

DR0, and MT are set to this device.

Channels have the following registers:

| ***Name*** | ***Type*** | ***Size*** | ***Comments*** |
| --- | --- | --- | --- |
| ADDR | All | 16 | Channel Data Address |
| CMD | All | 6 | Channel Command. |
| WC | All | 15 | Channel Word Count |
| ASM | All | 36 | Assembly Register |
| LOCATION | All | 16 | Channel Location Counter |
| STATUS | All | 16 | Channel Device Status |
| SENSE | 7909 | 16 | Channel Sense Data |
| COUNTER | 7909 | 6 | Channel Counter |
| SMS | 7909 | 7 | Channel SMS Register |

For meaning of bits in STATUS and SENSE see i7000\_defs.h.

## 2.3 Channel 7607 Devices and 704 devices.

These devices can only be attached to 7607 channels or to the Programed I/O channel 0.

### 2.3.1 711 Card Reader (CDR)

The card reader (CDR) reads data from a disk file. Cards are simulated as ASCII lines with terminating newlines. Card reader files can either be text (one character per column) or column binary (two characters per column). The file type can be specified with a set command:

|  |  |
| --- | --- |
| SET CDR*n* FORMAT=TEXT | Sets ASCII text mode |
| SET CDR*n* FORMAT=BINARY | Sets for binary card images. |
| SET CDR*n* FORMAT=BCD | Sets for BCD records. |
| SET CDR*n* FORMAT=CBN | Sets for column binary BCD records. |
| SET CDR*n* FORMAT=AUTO | Automatically determines format. |

or in the ATTACH command:

|  |  |
| --- | --- |
| ATTACH CDR*n* *<file>* | Attaches a file |
| ATTACH CDR*n* -f *<format> <file>* | Attaches a file with the given format. |

The card reader can be attached to either a 704 PIO channel or a 7607 channel. The channel can be changed by the following command:

|  |  |
| --- | --- |
| SET CDR*n* CHAN=*c* | Set this device to channel *c*. |

The default assignments are:

|  |  |
| --- | --- |
| CDR0 | Channel A(1) |
| CDR1 | Channel C(3) |
| CDR2 | Disabled |
| CDR3 | 704 PIO. |

If the simulator is compiled for only 704 then there is only one Card Reader called CDR.

The card reader can be booted with the:

|  |  |
| --- | --- |
| BOOT CDR*n* | Loads first 3 words of card. |

Error handling is as follows:

error processed as

not attached report error and stop

end of file out of cards

OS I/O error report error and stop

### 2.3.2 721 Card Punch (CDP)

The card reader (CDP) writes data to a disk file. Cards are simulated as ASCII lines with terminating newlines. Card punch files can either be text (one character per column) or column binary (two characters per column). The file type can be specified with a set command:

|  |  |
| --- | --- |
| SET CDP*n* FORMAT=TEXT | Sets ASCII text mode |
| SET CDP*n* FORMAT=BINARY | Sets for binary card images. |
| SET CDP*n* FORMAT=BCD | Sets for BCD records. |
| SET CDP*n* FORMAT=CBN | Sets for column binary BCD records. |
| SET CDP*n* FORMAT=AUTO | Automatically determines format. |

or in the ATTACH command:

|  |  |
| --- | --- |
| ATTACH CDP*n <file>* | Attaches a file |
| ATTACH CDP*n* -f *<format> <file>* | Attaches a file with the given format. |

The card punch can be attached to either a 704 PIO channel or a 7607 channel. The channel can be changed by the following command:

|  |  |
| --- | --- |
| SET CDP*n* CHAN=*c* | Set this device to channel *c*. |

The default assignments are:

|  |  |
| --- | --- |
| CDP0 | Channel A(1) |
| CDP1 | Channel C(3) |
| CDP2 | Disabled |
| CDP3 | 704 PIO. |

If the simulator is compiled for only 704 then there is only one Card Reader called CDR.

Error handling is as follows:

error processed as

not attached report error and stop

OS I/O error report error and stop

### 2.3.3 716 Line Printer (LP)

The line printer (LP) writes data to a disk file as ASCII text with terminating newlines. Currently set to handle standard signals to control paper advance.

|  |  |
| --- | --- |
| SET LP*n* NO/ECHO | Sets echoing to console of line-printer output. |
| SET LP*n* CHAN=n | sets channel for this device |
| SET LP*n* LINESPERPAGE=*lpp* | Sets number of lines per page on printer. |

The default assignments are:

|  |  |
| --- | --- |
| LP0 | Channel A(1) |
| LP1 | Channel C(3) |
| LP2 | Disabled |
| LP3 | 704 PIO. |

The Printer supports the following SPRA *n* selection pulses for controlling spacing (spacing occurs before the line is printed):

|  |  |
| --- | --- |
| SPRA 1 | To top of form. |
| SPRA 2 | Single space. |
| SPRA 3 | Double space. Before printing line. |
| SPRA 4 | Triple space. Before printing line. |
| SPRA 9 | Suppress linefeed after print. Prints characters 73-120 |
|  |  |
| SPT | Will skip if any printer line has been pulsed. |

Default with no SPRA is to single space before printing.

Error handling is as follows:

error processed as

not attached report error and stop

OS I/O error report error and stop

### 2.3.4 729 Magnetic Tape (MTA-D)

These come in groups of 10 units each. The controller defines which channel the devices will be on. MT*x*0 is unit 10.

|  |  |
| --- | --- |
| SET MTx CHAN=*n* | Set mag tape to channel *n*. |

Each individual tape drive support several options: MTA used as an example.

|  |  |
| --- | --- |
| SET MTA*n* ONLINE | Sets the mag tape drive on-line. |
| SET MTA*n* OFFLINE | Sets the mag tape drive off-line and not ready. |
| SET MTA*n* REWIND | Sets the mag tape to the load point. |
| SET MTA*n* LOCKED | Sets the mag tape to be read only. |
| SET MTA*n* WRITEENABLE | Sets the mag tape to be writable. |
| SET MTA*n* LOW | Sets mag tape to low density. |
| SET MTA*n* HIGH | Sets mag tape to high density. |

Options: Density LOW/HIGH does not change format of how tapes are written. And is only for informational purposes only.

Online/Offline is part of a optional RPQ for the 7090 which adds the DRS/TRS instructions.

|  |  |
| --- | --- |
| DRS drive | Will set drive to off-line after current command is finished. Drive is not unloaded and can be re-enabled by setting it on-line. |
| TRS drive | Tests to see if the drive is on-line. If the drive is there and on-line it will skip the next instruction otherwise it takes the next instruction. |

These instructions were put in since accessing a unloaded tape drive would hang the CPU.

Tape drives can be booted with:

|  |  |
| --- | --- |
| BOOT MTxn | Read in first three words of record. |

### 2.3.5 ChronoClock.

Disabled by default. This is a special 729 tape drive which returns the current time. It supports the option of setting the channel and drive that it will occupy. Note: You must disable the real 729 drive that is is replacing. The clock responds to Read and Backspace commands. A read results in a 10 character buffer being generated that has the Month, Day, Hour, Minutes, Seconds and Milliseconds. This time is taken from the local computer time.

|  |  |
| --- | --- |
| SET CHRON CHAN=n | Set channel for chrono clock. |
| SET CHRON UNIT=n | Sets the unit for the chrono clock. |

Example: To set Chronoclock to unit A9 do the following:

|  |
| --- |
| SET MTA9 DISABLE |
| SET CHRON UNIT=9 CHAN=A |

### 2.3.6 733 Drum (DR)

This is the drum for 704/709 and possible 7090. Up to 16 units can be attached to the CPU, all are on pseudo channel 0. Each drum is 2048K words in size. They are all stored in one file.

|  |  |
| --- | --- |
| SET DR0 UNITS=*n* | Set number of units to of storage to attach. |

Drum unit 0 can be booted with:

|  |  |
| --- | --- |
| BOOT DR0 | Read in first three words of record. |

Drum unit can be assigned to a 7607 channel, but this is unsupported by the operating systems. Drum channel is changed with:

|  |  |
| --- | --- |
| SET DR0 CHAN=*n* | Set Drum to channel *n*. |

## 2.4 7909 Devices

These devices must be attached to a 7909 channel to work.

### 2.4.1 1301/1302/2302/7320 Disk devices

The 7631 file control supports up to ten devices, which can be 7320 drums, 1301 disks, 1302 disks, or 2302 disks. Unit types are specified with the SET command.

|  |  |
| --- | --- |
| SET DK*n* TYPE=7320 | Unit *n* is a drum |
| SET DK*n* TYPE=7320-2 | Unit *n* is a drum (two modules). |
| SET DK*n* TYPE=1301 | Unit *n* is a 1301 disk |
| SET DK*n* TYPE=130l-2 | Unit *n* is a 1301-2 disk (two modules). |
| SET DK*n* TYPE=1302 | Unit *n* is a 1302 disk |
| SET DK*n* TYPE=1302-2 | Unit *n* is a 1302-2 disk (two modules). |
| SET DK*n* TYPE=2302 | Unit *n* is a 2302 disk |

Units can be SET ENABLED or DISABLED. In addition, units can be set to enable or disable formatting:

|  |  |
| --- | --- |
| SET DK*n* FORMAT | Enable formatting |
| SET DK*n* NOFORMAT | Disable formatting |
| SET DK*n* HA2 | Enable writing of home address 2 |
| SET DK*n* NOHA2 | Disable writing of home address 2 |
| SET DK*n* MODULE=n | Sets modules for unit, modules can only be even. 0 to 8. |
| SET DK*n* CHAN=n | Sets channel for unit (A-H). |
| SET DK*n* SELECT=n | Sets select on channel (0 or 1). |
| SET DK*n* CTSS | Sets disk to use CTSS bootstrap. |
| SET DK*n* IBSYS | Sets disk to use IBSYS bootstrap. |

Formatting is disabled by default.

All Disk units support bootstrapping with boot command. Bootstrap code is build based on whether CPU is in CTSS mode or not.

|  |  |
| --- | --- |
| BOOT DK*n* | Insert custom Loader into lower memory and start. |

Error handling is as follows:

error processed as

not attached report error and stop

OS I/O error report error and stop

### 2.4.2 Hypertape 7340 Tape drive (HTA/B)

These come in groups of 10 units each. The controller defines which channel the devices will be on.

|  |  |
| --- | --- |
| SET HTA CHAN=*n* | Sets channel for unit (A-H). |
| SET HTA SELECT=*n* | Sets select on channel (0 or 1). |

Each individual tape drive support several options: HTA used as an example.

|  |  |
| --- | --- |
| SET HTA*n* LOCKED | Sets the mag tape to be read only. |
| SET HTA*n* WRITEENABLE | Sets the mag tape to be writable. |

NOTE: Hypertape drives may not be working correctly since there is very little documentation available on them.

Hypertape drives support bootstrapping with boot command.

|  |  |
| --- | --- |
| BOOT HTA*n* | Insert custom Loader into lower memory and start. |

### 2.4.3 7750 Communications Controller (COM and COML)

The 7750 is modeled as a terminal multiplexer with 33 lines. It consists of two device: COM is the multiplexer controller, and COML is the individual lines. For the first 32 lines, the 7750 performs input and output through Telnet sessions connected via a user-specified listening port; the 33rd line is permanently attached to the simulator console window. The ATTACH command specifies the port to be used for Telnet sessions:

|  |  |
| --- | --- |
| ATTACH COM <port> | set up listening port |

where port is a decimal number between 1 and 65535 that is not being used other TCP/IP activities.

Each line (each unit of COML) can be set to one of twp modes: KSR-35 and KSR-37. In KSR-35 mode, lower case input and output characters are converted automatically to upper case, and parity is ignored. In KSR-37 mode, lower case characters are left alone, and even parity is generated on input. KSR-37 is the default.

Once COM is attached and the simulator is running, the 7750 listens for connections on the specified port. It assumes that any incoming connection is a Telnet connections. The connections remain open until disconnected either by the Telnet client, a SET COM DISCONNECT command,or a DETACH COM command.

|  |  |
| --- | --- |
| SET COM DISCONNECT=*n* | Disconnect line *n* |
| SET COM CHAN=*n* | Set channel for com controller. |

The 7750 implements the following special SHOW commands

|  |  |
| --- | --- |
| SHOW COM CONNECTIONS | Displays current connections to the 7750 |
| SHOW COM STATISTICS | Displays statistics for active connections |

The 7750 implements the following special SET commands:

|  |  |
| --- | --- |
| SET COML*n* LOG=filename | Log output of line n to filename |
| SET COML*n* NOLOG | Disable logging and close log file |
| SET COML*n* KSR35 | Set line *n* to ksr-35 |
| SET COML*n* KSR37 | Set line *n* to ksr-37 |
| SET COML*n* 2741 | Set line *n* to 2741 |

The controller (COM) implements these registers:

|  |  |  |
| --- | --- | --- |
| *Name* | *Size* | *Comments* |
| ENABLE | 1 | Enable flag |
| STATE | 6 | Controller state |
| MSGNUM | 12 | Input message sequence number |

## 2.5 7289 High-Speed Drum (HD)

The 7289 (also known as the 7320A) high-speed drum was a late addition to CTSS. Very little is known about the device, other than what is used in the CTSS sources.

The drum can be changed to different channels with the:

|  |  |
| --- | --- |
| SET HD0 CHAN=*n* | Set Drum to channel *n*.The channel must be configured as a 7289 type channel. Otherwise the drum will not work. |
| SET HD0 UNITS=*n* | Sets the number of 256K drums on the unit. |

Error handling is as follows:

error processed as

not attached report error and stop

Drum data files are buffered in memory; therefore, end of file and OS I/O errors cannot occur.

# 3 Symbolic Display and Input

The IBM 7090 simulator implements symbolic display and input. Display is controlled by command line switches:

|  |  |
| --- | --- |
| -c | Display/Enter as BCD character |
| -m | Display/Enter instruction mnemonics |
| -l | Display as lisp pointer. |
|  | Display/Enter as octal number. |

Instruction input uses standard 7090 assembler syntax. There are two basic instruction classes: memory reference and index reference.

Memory reference instructions have the format

memref{\*} address{,tag}

Index reference instructions have the format

idxref{\*} address,{tag},decrement

Specific instructions may disallow indirect addressing or limit the size of the tag, address, or decrement fields.

Channel (I/O) instructions have the same basic two formats.

# 4 Sim Load

The load command looks at the extension of the file to determine how to load the file.

|  |  |
| --- | --- |
| .crd | Loads a card image file into memory.  standard 709 format + 1 card loader. |
| .oct | Loads an octal deck:  address <blank> octal <blank> octal... |
| .sym | Loads a 709 symbolic deck.  address instruction..  address BCD string  address OCT octal  octal |

# 5 Character Codes

| Commercial | Scientific | ASCII | BCD | Card | Remark |
| --- | --- | --- | --- | --- | --- |
|  |  |  | 00 |  | Blank |
| 1 |  | 0 | 01 | 1 |  |
| 2 |  | 0 | 02 | 2 |  |
| 3 |  | 0 | 03 | 3 |  |
| 4 |  | 0 | 04 | 4 |  |
| 5 |  | 0 | 05 | 5 |  |
| 6 |  | 0 | 06 | 6 |  |
| 7 |  | 0 | 07 | 7 |  |
| 8 |  | 0 | 10 | 8 |  |
| 9 |  | 0 | 11 | 9 |  |
| 0 |  | 0 | 12 | 10 |  |
| # | = | = | 13 | 3-8 |  |
| @ | ' | '/@ | 14 | 4-8 |  |
| : |  | : | 15 | 5-8 |  |
| > |  | > | 16 | 6-8 |  |
| √ |  | " | 17 | 7-8 | Tape Mark |
| ƀ |  | \_ | 20 | 2-8 |  |
| / |  | / | 21 | 10-1 |  |
| S |  | S | 22 | 10-1 |  |
| T |  | T | 23 | 10-2 |  |
| U |  | U | 24 | 10-3 |  |
| V |  | V | 25 | 10-4 |  |
| W |  | W | 26 | 10-5 |  |
| X |  | X | 27 | 10-6 |  |
| Y |  | Y | 30 | 10-7 |  |
| Z |  | Z | 31 | 10-8 |  |
| # |  | # | 32 | 10-2-8 | Word Mark |
| , |  | , | 33 | 10-3-8 |  |
| % | ( | %/( | 34 | 10-4-8 |  |
| ` |  | ` | 35 | 10-5-8 |  |
| \ |  | \ | 36 | 10-6-8 |  |
| ⧻ |  | { | 37 | 10-7-8 | Segment Mark |

| Commercial | Scientific | ASCII | BCD | Card | Remark |
| --- | --- | --- | --- | --- | --- |
| - |  | - | 40 | 11 | also -0 |
| J |  | J | 41 | 11-1 |  |
| K |  | K | 42 | 11-2 |  |
| L |  | L | 43 | 11-3 |  |
| M |  | M | 44 | 11-4 |  |
| N |  | N | 45 | 11-5 |  |
| O |  | O | 46 | 11-6 |  |
| P |  | P | 47 | 11-7 |  |
| Q |  | Q | 50 | 11-8 |  |
| R |  | R | 51 | 11-9 |  |
| ! |  | ! | 52 | 11-2-8 |  |
| $ |  | $ | 53 | 11-3-8 |  |
| \* |  | \* | 54 | 11-4-8 |  |
| ] |  | ] | 55 | 11-5-8 |  |
| ; |  | ; | 56 | 11-6-8 |  |
| △ |  | ^ | 57 | 11-7-8 |  |
| & | + | &/+ | 60 | 12 | also +0 |
| A |  | A | 61 | 12-1 |  |
| B |  | B | 62 | 12-2 |  |
| C |  | C | 63 | 12-3 |  |
| D |  | D | 64 | 12-4 |  |
| E |  | E | 65 | 12-5 |  |
| F |  | F | 66 | 12-6 |  |
| G |  | G | 67 | 12-7 |  |
| H |  | H | 70 | 12-8 |  |
| I |  | I | 71 | 12-9 |  |
| ? |  | ? | 72 | 12-2-8 |  |
| . |  | . | 73 | 12-3-8 |  |
| ⌑ | ) | ) | 74 | 12-4-8 | Lozenge |
| [ |  | [ | 75 | 12-5-8 |  |
| < |  | < | 76 | 12-3-8 |  |
| ⧻\* |  | | | 77 | 12-7-8 | Group Mark |