Hercules InColor Card: Notes

The InColor Card was Hercules Graphics' attempt to compete with the EGA; like the EGA, it outputs a 16-colour 720×350 display to an EGA monitor. The difference is that unlike the EGA, it's backwards compatible with programs written for the original Hercules Graphics Card and Hercules Graphics Card Plus, rather than those written for the CGA and MDA.

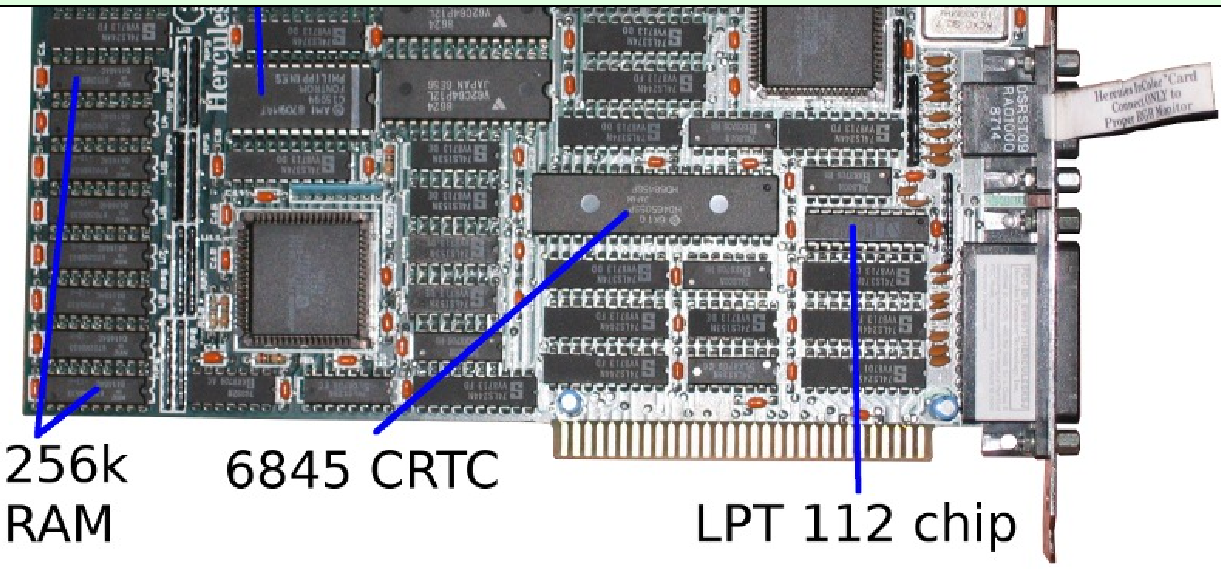
It is not to be confused with the Hercules Color Card, a CGA clone designed to be installed alongside a monochrome (or InColor) Hercules card.

Hardware requirements

The InColor is an 8-bit ISA card containing the display controller and a printer port. When present in a computer, it requires the following system resources:

- 4k-64k of RAM at address 0B0000h.
- I/O addresses 03B0h-03BFh.
- The printer port uses IRQ7.

The hardware

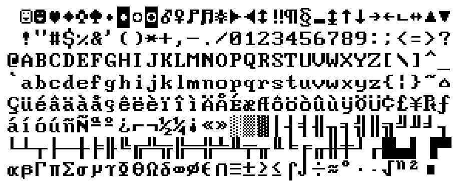


Output is from a DE9 socket. The pinout of this socket is:

1. Ground
2. Secondary red
3. Primary red
4. Primary green
5. Primary blue
6. Secondary green
7. Secondary blue
8. Horizontal sync
9. -Vertical sync

The font rom is marked AMI C15994 FONTROM (the same ROM is used on the Hercules Graphics Card Plus). As on the original IBM MDA, this is a 9264 rather than a 2764, so it can't be read in a standard EPROM programmer. The memory layout isn't the same as on the MDA, so you can't swap the chip with one from an MDA and expect it to make sense. Both ROMs are divided into four 2k blocks; on the MDA, the font is in blocks 0 and 1, but here it is in blocks 1 and 3.

The card uses the 14-pixel font in the ROM:



The ROM also contains two 8-pixel fonts (in blocks 0 and 2) which do not appear to be used.

Memory Map

On power-up, the InColor card behaves like an MDA, producing an 80×25 text screen in white on black. Each character is 9 pixels wide and 14 high, giving a 720×350 pixel resolution. Although the characters are 9 pixels wide, the bitmaps in the ROM (or the RAM) only cover the first 8. For characters 0C0h-0DFh, the ninth pixel column is a duplicate of the eighth; for others, it's blank.

In text mode, the usual MDA-esque scheme is used, with two bytes of RAM for each character. The first byte is the character code, and the second gives the attribute.

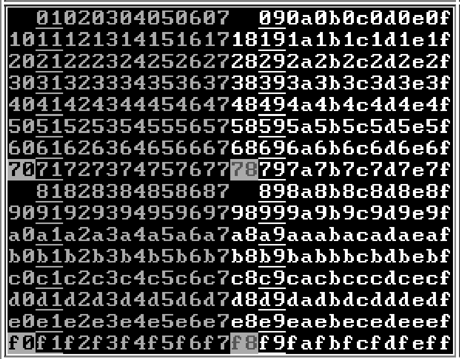
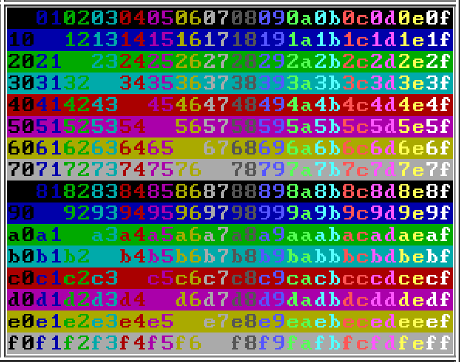
On startup, the character attribute scheme behaves like an MDA:

- Bits 2-0: 1 for underline.
- Bit 3: High intensity (foreground colour is 15, not 7).
- Bit 7: If blinking is enabled: Blink. Else bright background (colour is 8 rather than 0).

with eight exceptions:

- Attributes 00h, 08h, 80h and 88h display as black space.
- Attribute 70h displays as black on grey (colour 0 on colour 7).
- Attribute 78h displays as grey on grey (colour 8 on colour 7).
- Attribute F0h displays as a blinking version of 70h (if blinking is enabled); as black on white (colour 0 on colour 15) otherwise.
- Attribute F8h displays as a blinking version of 78h (if blinking is enabled); as grey on white (colour 8 on colour 15) otherwise.

The card can also use a CGA-like attribute scheme, in which bits 3-0 give the foreground colour, 6-4 the background colour, and bit 7 is set to blink. If blinking is disabled, bits 7-4 give the background colour.

Blink enabled	
MDA-like attributes	**CGA-like attributes**
	

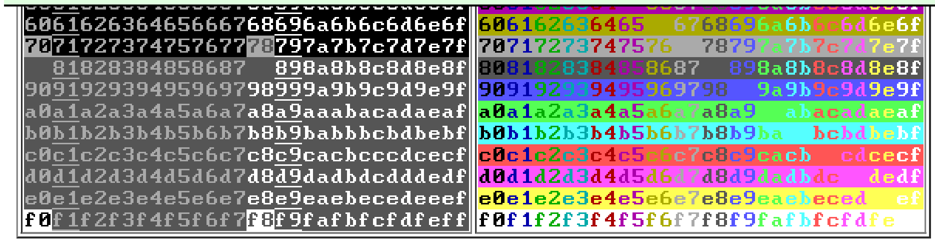
MDA-like attributes:

```
  01020304050607  090a0b0c0d0e0f
101112131415161718191a1b1c1d1e1f
202122232425262728292a2b2c2d2e2f
303132333435363738393a3b3c3d3e3f
404142434445464748494a4b4c4d4e4f
505152535455565758595a5b5c5d5e5f
606162636465666768696a6b6c6d6e6f
707172737475767778797a7b7c7d7e7f
  81828384858687  898a8b8c8d8e8f
909192939495969798999a9b9c9d9e9f
a0a1a2a3a4a5a6a7a8a9aaabacadaeaf
b0b1b2b3b4b5b6b7b8b9babbbcbdbebf
c0c1c2c3c4c5c6c7c8c9cacbcccdcecf
d0d1d2d3d4d5d6d7d8d9dadbdcdddedf
e0e1e2e3e4e5e6e7e8e9eaebecedeeef
f0f1f2f3f4f5f6f7f8f9fafbfcfdfeff
```

CGA-like attributes:

```
  0102030405060708090a0b0c0d0e0f
10  12131415161718191a1b1c1d1e1f
2021  232425262728292a2b2c2d2e2f
303132  3435363738393a3b3c3d3e3f
40414243  454647484 94a4b4c4d4e4f
5051525354  565758595a5b5c5d5e5f
606162636465  6768696a6b6c6d6e6f
70717273747576  78797a7b7c7d7e7f
  8182838485868788898a8b8c8d8e8f
90  92939495969798999a9b9c9d9e9f
a0a1  a3a4a5a6a7a8a9aaabacadaeaf
b0b1b2  b4b5b6b7b8b9babbbcbdbebf
c0c1c2c3  c5c6c7c8c9cacbcccdcecf
d0d1d2d3d4  d6d7d8d9dadbdcdddedf
e0e1e2e3e4e5  e7e8e9eaebecedeeef
f0f1f2f3f4f5f6  f8f9fafbfcfdfeff
```

Blink disabled	
MDA-like attributes	**CGA-like attributes**



Register I/O

03B4h: CRTC address register.

Write a CRTC register number (0 to 1Ch) to this port to select the CRTC register that will appear at port 03B5h. Registers 0-11h are standard 6845 registers and are described on the [6845 datasheet](#).

Registers 14h-1Ch are used to control the InColor card's additional features, and are described below.

On the MDA, the CRTC address and data register are partially decoded, so that any even-numbered address between 03B0h and 03B7h will get you the CRTC address register, and any odd-numbered address gets you the data register. I don't know whether this holds for the InColor card.

This is a write-only register.

03B5h: CRTC register read/write.

This gives access to the selected CRTC data register. Most CRTC registers are write only; some are read/write or read-only.

03B8h: Mode Control Register

This is a write-only register. The following bits are used:

Bit 7: Graphics page to display

If bit 7 is 1, the graphics page at 0B8000h is displayed. Otherwise, the page at 0B0000h is displayed.

Bit 5: 1 to enable blinking, 0 to disable it.

If bit 5 is 1, characters with attribute bit 7 set will blink. If not, they will have high intensity background.

Bit 3: 1 to enable video output, 0 to disable it.

If bit 3 is 0, screen output will not be shown. The usual use of this is if you're reprogramming the CRTC registers; disable video output beforehand and re-enable it after.

Bit 1: 1 for graphics mode, 0 for text.

When the card is switched between text and graphics modes, the 6845 must be reprogrammed with suitable parameters for the new mode.

03BAh: Status Register

This is a read-only register.

- Bit 7: 0 if vertical sync active, 1 if inactive.
- Bits 6-4: Card ID (101b = 5 for InColor).
- Bit 3: Video. This is 1 if a pixel is being drawn on the screen at this moment.
- Bit 1: Light pen flip-flop.
- Bit 0: Retrace. This is 1 if the horizontal retrace is active.

03BBh: Reset light pen flip-flop

Any write to this port resets the flip-flop.

03BFh: Graphics mode enable

This is a write-only register.

- Bit 1: Set to page in the upper 32k of memory at 0B8000h, clear to page it out.
- Bit 0: Set to allow graphics mode, clear to disallow it. Also enables access to memory from B1000h to B7FFFh.

Additional CRTC registers

The additional CRTC registers are:

Register 14h: xMode

This is a write-only register, initialised to 0 on reset. The following bits are used:

Bit 0: 0 to use ROM font, 1 to use RAM font.

If the RAM font is selected, character bitmaps are read from 0B4000h. Each bitmap holds 16 bytes per character; the top 14 (normally) are drawn.

Bit 1: 0 for 80-column mode, 1 for 90-column mode.

If this bit is changed, the first four CRTC registers need to be reprogrammed. For 80-column mode, they should be set to `61 50 52 0F`, and for 90-column mode they should be set to `6D 5A 5C 0F`.

In 90-column mode characters are 8 bits wide, and so there is no special treatment of characters 0C0h-0DFh.

Bit 2: 0 for 4k RAMfont, 1 for 48k RAMfont

In 48k RAMfont mode, the low 4 bits of the attribute byte become a font selector, 0-11 (Values 12-15 are treated as 4-7). This selects the font used for drawing: font 0 is at B4000h, font 1 is at B5000h and so on.

Register 15h: Underline

Register 16h: Strikethrough

This is a write-only register, initialised to 0Dh on reset. It behaves as underline, for characters with the 'strikethrough' attribute. If underline and strikethrough are both set to be drawn on the same line, and a character has both attributes, the strikethrough colour will be used.

Register 17h: Exception

This is a write-only register, initialised to 20h on reset.

Bit 5: 0 for CGA attributes, 1 for MDA attributes

This controls which attribute system is used.

Bit 4: 0 to disable palette, 1 to enable palette

If this bit is 0, all 16-bit colours will be treated as CGA-style IRGB values. If it is 1, the colour will be treated as the index into a 16-byte lookup table which will provide the actual 6-bit colour value.

Bits 3-0: Cursor colour

If the colour is 0, then the cursor will be drawn in either colour 7 or 15, depending on bit 3 of the attribute of its current cell.

Register 18h: Plane mask

This is a write-only register, initialised to 0Fh on reset.

Bits 7-4: Plane protect

Sets which planes are written by a write operation. A 0 bit means the corresponding plane can be written; a 1 bit means it cannot.

Note that in text modes, these values are ignored for the bottom 16k of RAM; all four planes are always written.

Bits 3-0: Visible planes

Sets which planes are visible.

Register 19h: Read/write control register

This is a write-only register, initialised to 40h on reset.

Bit 6: Mask polarity

This modifies the way bytes are read from memory. If this bit is set, the byte returned will have 0 bits where the colour read matches the background colour, and 1 bits where it does not. If the bit is clear, matching pixels will be returned as 1, and non-matching as 0.

Bits 5-4: Write mode

0	1	Last value latched	Foreground colour
1	0	Background colour	Last value latched
1	1	~Last value latched	Last value latched

This will be explained more fully in the Memory Access section below.

Bits 3-0: Don't care

This also modifies the way bytes are read; if a 'don't care' bit is set, that plane will not be checked when a comparison is made against the background colour. Thus if all four 'don't care' bits are set, all pixels will be assumed to match the background colour.

Register 1Ah: Read/write colour register

This is a write-only register, initialised to 0Fh on reset. Bits 4-7 give the background colour for read/write operations; bits 0-3 give the foreground colour.

Register 1Bh: Latch protect register

This is a write-only register, initialised to 0 on reset. It modifies read operations; when a memory read is performed, four latches are loaded with the contents of the four planes at that address. If a bit is set in this register, the corresponding bit of the latches is unaffected by the read.

Register 1Ch: Palette register

This is used to load the palette. First it should be read, to reset the palette counter to zero. Then 16 bytes should be written, giving the colour mapping for each ink. Bits 5-3 of each byte give secondary RGB, bits 2-0 give primary RGB.

Memory Access

The InColor card has 256k of memory, arranged in four planes of 64k each. This means, pretty much, that behind every address there are four bytes. At power-on, this system is transparent; a memory write will set all four bytes to the same value, and a memory read will return the last value written. But for colour graphics or colour RAMfont access, the data path needs to be described in full.

In text mode, memory access to addresses below 0B4000h bypasses most of the plane mechanism; writes always update all four planes to the same value, and reads return the last value written. For addresses above 0B4000h, or for all addresses in graphics mode, the plane system applies.

Memory reads

When the CPU reads a byte from memory, the four bytes at that location are read into the four memory latches. If bits are set in the Latch Protect register (CRTC register 1Bh), the corresponding bits in the latches are unaffected by the read. This still applies in text mode when everything else is being bypassed, so it's not a good idea to leave a value in the Latch Protect register when switching to text mode.

For the eight pixels in the latches, the colour of each pixel is compared to the background colour (bits 7-4 of CRTC register 1Ah). If a Don't Care bit is set in the Read/Write control register (bits 3-0 of CRTC register 19h) then the corresponding plane will be assumed to match. For example:

```
values loaded into the latches:
        01010101b       blue plane
        00110011b       green plane
        00001111b       red plane
        00000000b       intensity plane

The comparison will then match pixels with the pattern 0?01b, which
in this case means bits 6 and 2 of the latches.

        01000100b

And because bit 6 of register 19h is set, the CPU will read the
inverse value: 10111011b.
```

Memory writes

When the CPU writes a byte, it generates bytes for the four planes based on the value written and (depending on the write mode) the contents of the four latches.

Write mode 0

In this mode, a zero bit writes the background colour (CRTC register 1Ah, bits 7-4) and a one bit writes the foreground colour (register 1Ah, bits 3-0). For example:

```
Register 18h = 2Fh      Bit 5 set, so plane 1 will not be written
Register 19h = 40h      Bits 5-4: Write mode is 0
Register 1Ah = 1Fh      Bits 7-4: Background is blue
                        Bits 3-0: Foreground is white

If the byte written is 00010000b, the four values to write to the
planes will be
        11111111b       Blue plane
        00010000b       Green plane
        00010000b       Red plane
        00010000b       Intensity plane

but because bit 5 of register 18h is set, the green plane will not
be touched.
```

Write mode 1

In this mode, a zero bit writes the last value read into the latches, and a one bit writes the foreground colour (register 1Ah, bits 3-0). For example:

```
Contents of the latches:
        01010101b       blue plane
        00110011b       green plane
        00001111b       red plane
        00000000b       intensity plane

Register 18h = 0Fh      Bits 7-4 are 0, so all planes will be written
Register 19h = 50h      Bits 5-4: Write mode is 1
Register 1Ah = 1Fh      Bits 7-4: Background is blue
                        Bits 3-0: Foreground is white

If the byte written is 00110000b, the four values written to the
planes will be
        01110101b       blue plane
        00110011b       green plane
        00111111b       red plane
        00110000b       intensity plane

ie, two pixels in the byte will become white.
```

```
Contents of the latches:
        01010101b       blue plane
        00110011b       green plane
        00001111b       red plane
        00000000b       intensity plane

Register 18h = 0Fh      Bits 7-4 are 0, so all planes will be written
Register 19h = 60h      Bits 5-4: Write mode is 2
Register 1Ah = 1Fh      Bits 7-4: Background is blue
                        Bits 3-0: Foreground is white

If the byte written is 00110000b, the four values written to the
planes will be
        11011111b       blue plane
        00110000b       green plane
        00000000b       red plane
        00000000b       intensity plane

ie, all but two pixels in the byte will become blue.
```

Write mode 3

In this mode, a zero bit inverts the last colour read into the latches, and a one bit writes the last value read. Using the same example:

```
Contents of the latches:
        01010101b       blue plane
        00110011b       green plane
        00001111b       red plane
        00000000b       intensity plane

Register 18h = 0Fh      Bits 7-4 are 0, so all planes will be written
Register 19h = 70h      Bits 5-4: Write mode is 3
Register 1Ah = 1Fh      Bits 7-4: Background is blue
                        Bits 3-0: Foreground is white


If the byte written is 00110000b, the four values written to the
planes will be


ie, all but two pixels in the byte will be inverted.
        10011010b       blue plane
        11111100b       green plane
        11000000b       red plane
        11001111b       intensity plane
```

Character Attributes

Character attributes are a complicated subject on the InColor, for a number of reasons:

- There are three text modes (normal, 4k RAMfont and 48k RAMfont).
- Attributes can be interpreted in four ways: MDA or CGA, and blinking on or off.
- In the RAMfont modes, the character shapes held in memory behave as 16-colour bitmaps, which interact with the attributes in various ways.

Normal mode

This is reasonably straightforward:

	MDA attributes	**CGA attributes**

	70, 78, F0, F8 swap foreground and background	
Blink off	Bit 7=If set, background=8 else background=0 Bit 3=If set, foreground=15 else foreground=0 Bits 2-0=1 to underline 00, 08, 80, 88 blank 70, 78, F0, F8 swap foreground and background	Bits 7-4=Background Bits 3-0=Foreground

4k RAMfont mode

Now the fun begins. If, when loading the character set, you write the same value into all four planes, this mode behaves just like the normal text mode. But if you don't, the colour of a pixel is determined like this:

- Work out the foreground and background colours as for the normal mode.
- For each plane, if the bit in the plane is '1' use that bit of the foreground colour, otherwise use that bit of the background colour.

For example, drawing a byte which contains 8 colours:

```
Foreground = 2 (green).
Background = 1 (blue).
First byte of character definition is
                                        fg      bg
        01010101b  blue plane            0       1
        00110011b  green plane           1       0
        00001111b  red plane             0       0
        00000000b  intensity plane       0       0

Colours drawn:

        10101010b  blue plane
        00110011b  green plane
        00000000b  red plane
        00000000b  intensity plane

ie, some pixels will be black, some blue, some green and some cyan.
```

48k RAMfont mode

In this mode, the semantics of the attribute byte change considerably. The low 4 bits are always a font number; the high 4 bits behave thus:

	MDA attributes	CGA attributes
Blink on	Bit 7=Bright (background = 8) Bit 6=Blink Bit 5=Strikethrough Bit 4=Underline	Bits 7-4 = ~Foreground colour
Blink off	Bit 7=Boldface Bit 6=Inverse (background = 15) Bit 5=Strikethrough Bit 4=Underline	

Character drawing differs in the three cases:

MDA attributes, blink on

MDA attributes, blink off

- Work out the background colour for the cell. This is 15 if inverse, else 0.
- For each plane, if the bit in the plane is '1' use the inverse of that bit of the background colour. Otherwise use that bit of the background colour.

CGA attributes

- The background colour for the cell is 0.
- For each plane, if the bit in the plane is '1' use the inverse of that bit of the foreground colour. Otherwise use 0.

So, for example, using the same character definition as before:

```
01010101b  blue plane
00110011b  green plane
00001111b  red plane
00000000b  intensity plane

With attribute=0, all colours are drawn as in the memory:

MDA, blink on   MDA, blink off  CGA
01010101b       01010101b       01010101b       blue plane
00110011b       00110011b       00110011b       green plane
00001111b       00001111b       00001111b       red plane
00000000b       00000000b       00000000b       intensity plane

With attribute=12 (1100b):

MDA, blink on   MDA, blink off  CGA
01010101b       10101010b       01010101b       blue plane
00110011b       11001100b       00110011b       green plane
00001111b       11110000b       00000000b       red plane
11111111b       11111111b       00000000b       intensity plane

high intensity  inverted        only blue,green,cyan drawn
```

Different fonts in each plane

The reason for treating the fonts as colour bitmaps is that the card can then support 48 fonts rather than 12. The program would load four sets of fonts, one into each plane, and output all its text in colour 1, 2, 4 or 8 on a black background. The palette could be used to make the four colours all map to the same RGB values, so the fonts would not differ in appearance.

Recommended CRTC values

Hercules graphics cards do not include any form of BIOS extension, and the standard IBM BIOS treats them as an MDA. Consequently, to switch between text and graphics modes (or 80- and 90- column modes), the CRT controller has to be reprogrammed manually. These values should be set at the same time as the text/graphics bit in the Mode Control register, or the 80/90 column bit in the xMode register.

In the tables below, all values are in hexadecimal.

Register	80-column text	90-coluumn text	Graphics
00 Horizontal total	61	6D	35
01 Horizontal displayed	50	5A	2D

05 Vertical adjust	06	06	02
06 Vertical displayed	19	19	57
07 Vertical sync position	19	19	57
08 Interlace and skew	02	02	02
09 Max raster	0D	0D	03
0A Cursor start	0B	0B	00
0B Cursor end	0C	0C	00

The manual also provides timing values for different character heights, allowing (for example) a 43-line display with 8-pixel characters. In this situation, a suitable font of the correct height should be loaded into RAM.

Register	**Character height**												
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
04 Vertical total	5C	4A	3D	34	2D	28	24	20	1D	1B	19	17	16
05 Vertical adjust	02	00	04	06	02	01	00	07	0A	06	06	0A	02
06 Vertical displayed	58	46	3A	32	2B	26	23	1F	1D	1A	19	17	15
07 Vertical sync position	59	46	3B	33	2C	27	23	20	1D	1B	19	17	16

The printer port

According to the manual, the printer port can be disabled (if it conflicts with another piece of hardware) by removing the chip marked HCT LP112 adjacent to the port.

The printer port behaves like the one on an MDA:

- Write to port 03BCh: Set data lines.
- Read from port 03BCh: Reads last value sent to printer.
- Read from port 03BDh: Get printer status.
  - Bit 3: ~Error
  - Bit 4: Select
  - Bit 5: Paper out
  - Bit 6: ~Acknowledge
  - Bit 7: Busy

  Bits 2-0 always appear to be 1,0,1.
- Write to port 03BEh: Set control lines.
  - Bit 0: ~Strobe
  - Bit 1: ~Auto Feed
  - Bit 2: Initialize printer
  - Bit 3: ~Select input
  - Bit 4: Enable interrupt when the printer sets ~Acknowledge to 0.
- Read from port 03BEh: Reads bits 4-0 of last value written. The top 3 bits always appear to be 1,0,0.