THE 6561 VIC CHIP
Video Interface Chip (VIC)
Typed in by Lance Ewing

Note: There seems to be two different VIC chips that were used in different models of the VIC 20. These are the 6560 and the 6561. Their functionality appears to be the same so I will only refer to the 6561.

The Video Interface Chip, or VIC as it is normally called, is the second most important silicon chip in the VIC 20 microcomputer. It comes second only to the 6502A microprocessor itself.

The VIC is a specially constructed input-output chip (I/O) that has a large variety of functions but it's major function is, as its name suggests, the production of the video output signal.

The VIC appears to the microprocessor, and the user, as an addressable block of RAM of 16 locations, $9000-$900F. Each of these locations can be filled or copied, as applies to any other locations that are actually available, with the actions of the VIC being dependant on the values that are placed in the 16 locations.

6561 PIN CONFIGURATION

```
                          ___________________
                         |                   |
               not used -|1                40|- +5V
                         |                   |
       Composite colour -|2                39|- Clock-in phase-1
                         |                   |
      Sync. & luminance -|3                38|- Clock-in phase-2
                         |                   |
             READ/WRITE -|4                37|- Light pen
                         |                   |
                   VD11 -|5                36|- Clock-out. Not used.
                         |                   |
                   VD10 -|6                35|- Clock-out phase-1
                         |                   |
                    VD9 -|7                34|- A13
                         |                   |
                    VD8 -|8                33|- A12
                         |                   |
                     D7 -|9                32|- A11
                         |                   |
                     D6 -|10               31|- A10
                         |                   |
                     D5 -|11               30|- A9
                         |                   |
                     D4 -|12               29|- A8
                         |                   |
                     D3 -|13               28|- A7
                         |                   |
                     D2 -|14               27|- A6
                         |                   |
                     D1 -|15               26|- A5
                         |                   |
                     D0 -|16               25|- A4
                         |                   |
                  POT X -|17               24|- A3
                         |                   |
                  POT Y -|18               23|- A2
                         |                   |
        Composite sound -|19               22|- A1
                         |                   |
                    GND -|20               21|- A0
                         |___________________|
```

Pin 1: Not connected.
Pin 2: The composite colour line of the video output.
Pin 3: The syncronisation and luminance line of the video output.
Pin 4: The video read/write line that is at logic 1 when data is being read
       from the colour or video RAM.
Pins 5-8: The lines of the special colour data bus.
Pins 9-16: The eight lines of the ordinary data bus.

Pin 17: The input line for potentiometer X.
Pin 18: The input line for potentiometer Y.
Pin 19: The composite sound line of the audio output.
Pin 20: GND
Pins 21-34: The 14 address lines of the VIC.
Pin 35. The clock-out line that becomes the external time base for the 6502A microprocessor.
Pin 36: The system phase-2 clock-out line. Not connected.
Pin 37: Light pen input line.
Pin 38: Clock-in line from the master clock - phase-2 time.
Pin 39: Clock-in line from the master clock - phase-1 time.
Pin 40: +5V.

THE RELATIONSHIP BETWEEN THE MICROPROCESSOR AND THE VIC

```
                                         A13 = "BLOCK 4"
             14 line address bus      a 13 lower address line
           ____________________________________________________
          |                       >                            |
          |     __________________________________________     |
       __|____|__                                          __|____|__
      |          |                             $9000  |__________|
      |          |                             $9001  |__________|
      |          |                               .    |     .    |
      |          |                               .    |     .    |
 6502A |          |                               .    |     .    | VIC chip
      |          |                               .    |     .    |
      |          |                               .    |__________|
      |          |                             $900E  |__________|
      |__________|                             $900F  |__________|
          |  |_____________________________________________|  |
          |                       <  >                         |
          |____________________________________________________|
                             8 line data bus
```

The above diagram shows the relationship between the microprocessor and the VIC as being the normal one of 'microprocessor and memory linked by address and data buses' but this applies only in system phase-2 time.

The timing signals in the VIC 20 are somewhat complicated but they can be explained in quite simple terms.
The master clokc generates a two phase output at 1.1082 Mhs. The signals are then used as the 'external time base' for the VIC so that the actions that take place on the VIC can be timed correctly. The VIC in turn reproduces the two phase timing signal on one of its output lines which is then used as the 'external time base' for the 6502A microprocessor. However the final stage has not as yet been reached as the 6502A microprocessor in its turn reproduces the timing signals on one of its output lines so that the timing signals can be used as 'chip select' lines for the RAM chips and I/O chips, but of course not the VIC.
Overall, in system phase-2 time the 6502A microprocessor is in communication with its memory, whilst in system phase-1 time, it is the VIC that is linked with the memory. The following memory can be addressed by the VIC chip:

- -Video RAM
- -Colour RAM
- -Character RAM/ROM

The 14 line address line can address 16K of memory. The VIC chip uses different addresses to the rest of the computer. The table below illustrates the differing addresses for the memory blocks the VIC chip can access:

VIC chip addresses	Ordinary addresses	memory
0	32768	Unreversed Character ROM
1024	33792	Reversed Character ROM
2048	34816	Unreversed upper/lower case ROM
3072	35840	Reversed upper/lower case ROM
4096	36864	VIC and VIA chips
5120	37888	Colour memory

6144	38912	Reserved for expansion
7168	39936	Reserved for expansion
8192	0	System memory
9216	1024	Reserved for expansion
12288	4096	Program
15360	7168	Screen

THE VIDEO RAM

This is the area of RAM which holds the screen codes of the characters currently on the screen. The values poked into screen memory act as pointers into character memory. They are NOT the ASCII values of the characters. In the unexpanded VIC 20 the operating system automatically allocates the area of RAM from $1E00-$1FFF for this purpose. However, when extra RAM is added to the system to the system at $2000 it becomes necessary to change the allocation of the video RAM to the area $1000-$11FF. The reason for having to move the video RAM is simply that the program area must be a continuous block of RAM. In the unexpanded system the program area is at $1000-$1DFF, with a standard 3K RAM pack it is at $0400-$1DFF, and with a standard 8K RAM pack it is at $1200-$3FFF.

The VIC 20 system uses a display of 22 characters per line and has 23 lines. Therefore the video RAM has to be 506 locations in size. In practice with 512 locations allocated there are always siz locations that are unused.

The system variable $0288, decimal 648, is used by the operation system to hold the high byte of the current base address of the video RAM and in an unexpanded VIC 20 the value in this location is 30 which corresponds to the base address of $1E00. Interesting effects can be obtained by altering the value of this location.

THE COLOUR RAM

In an unexpanded VIC 20 the 512 locations in memory from $9600-$97ff are used as the colour RAM, whereas if an *K expansion RAM is fitted, the block $9400-$95ff is used instead. In either case the locations used are only four bits in size instead of the usual eight bits in size.

The different locations are used to hold the appropriate foreground colour for each character area of the display on the TV screen. There is, therefore, a direct correspondence between the locations of the video RAM, the character table and the colour RAM.

In the VIC 20 system there are eight foreground colours and each colour has its own representation for the lower three bits of the locations of colour RAM.

eg. If the value of the three bits is '000' then the colour for that character area will be black.

The colours and their representations are:

BLACK	000
WHITE	001
RED	010
CYAN	011
PURPLE	100
GREEN	101
BLUE	110
YELLOW	111

The fourth bit (bit 3) of each location is used to indicate if multicolour is to be used (discussed later).

It is interesting to note that the VIC has a special four line data bus that links the colour RAM to the VIC itself that is used solely to convey the colour data to the VIC.

The address of Colour RAM can be determined by looking at Bit 7 of location $9002. If this bit is 1, colour memory starts at location 38400. If this bit is 0, colour memory starts at location 37888. Use the following formula:

```
C = 37888 + 4 * ( PEEK ( 36866 ) AND 128 )
```

THE INTERNAL REGISTERS OF THE VIC

CR0: $9000 - decimal 36864. Usual value decimal 12.
A dual function register.
Function 1: Bit 7 selects insterface scan mode for the TV.
Function 2: Bits 0-6 determine the distance from the left hand side of the TV picture to the first column of characters.
Note: On most modern TV sets the effect of selecting the interface scan mode is to produce a light rippling on the screen.

CR1: $9001 - decimal 36865. Usual value decimal 38.
A single function register.
All the bits of this register are used to determine the distance from the top of the TV picture to the first line of characters.

CR2: $9002 - decimal 36866. Usual value decimal 150.
A dual function register.
The first seven bits fo this register determine the number of columns in the TV display. Normally this will be the expected value of 22.
Bit 7 of this register is used to hold the value for line 9 of the address for the video RAM. On an unexpanded VIC 20 as the address of the Video RAM is $1E00 and therefore this bit 7 is set, however when the video RAM is moved to $1000 then bit 7 becomes reset.

Note: Bit 7 of this register also indicates where the Colour RAM starts. If this bit is 1, colour memory starts at location 38400. If this bit is 0, colour memory starts at location 37888. Use the following formula:

```
C = 37888 + 4 * ( PEEK ( 36866 ) AND 128 )
```

CR3: $9003 - decimal 36867. Usual value 174.
A triple function register.
Bit 7 holds the lowest bit of TV raster counter and is therefore alternately set and reset.
Bits 1-6 of this register determine the number of rows in the TV display. The value of these bits will normally be 23.
Bit 0 is very special as it controls whether normal sized characters or double sized characters are to be displayed. The normal size for a character is 8*8 pixels and is slected by bit 0 being reset, however double sized characters, 16*8 pixels, can be selected by having this bit set.
The facility for being able to use double sized characters is not very useful on an unexpanded VIC 20 as there is insufficient RAM to define a reasonable number of double sized characters.

CR4: $9004 - 36868. No usual value.
This register, together with bit 7 of CR3, forms the TV raster counter. On a 625 line TV this register will count between 0 and 255, and the whole counter between 0 and 311.

CR5: $9005 - 36869. Usual value 240.
A dual function register.
Bits 4-7 holds the values of the topmost four address lines for the Video RAM and bits 0-3 the corresponding values for the character table.
Of all these values bits 0 & 7 have a special significance, as whenver this bit is set the memory slected will be in 'block 0', i.e. from $0000-$1FFF, and when reset in 'block 4', i.e. from $8000-$9FFF.
In normal operation of a VIC20 this register holds the value 240 decimal and this leads to the Video RAM being situated at $1E00 and the character table at $8000. These addresses are found as follows:

Video RAM - bit 7 is set, thereby addressing 'block 0'.
-Address lines A12, A11, A10, and A9 are all set and the full address is $1E00 as A13, A14, and A15 are reset for 'block 0'.

Character table - bit 3 is reset, thereby addressing 'block 4'.
-Address lines A12, A11 and A10 are all reset and the full address is $8000 as A15 is set and A13 and A14 are reset for 'block 4'.

CR6: $9006 - 36870. Usual value 0.
This register is used in conjunction with the light pen and holds the horizontal postion.

CR7: $9007 - 36871. Usual value 1.
The vertical position of the light pen.

CR8: $9008 - 36872. Usual value 255.
The counter for potentiometer 1.

CR9: $9009 - 36873. Usual value 255.
The counter for potentiometer 2.

CRA: $900A - 36874. Usual value 0.
This register controls 'speaker-1'. Bit 7 is the on/off control bit, whilst bits 0-6 select the actual note. Speaker 1 has an alto voice.

CRB: $900B - 36875. Usual value 0.
This register controls 'speaker-2', the tenor voice.

CRC: $900C - 36876. Usual value 0.
This register controls 'speaker-3', the soprano voice.

CRD: $900D - 36877. Usual value 0.
This register controls 'speaker-4', the noise voice.

CRE: $900E - 36878. Usual value 0.
A dual purpose register.
Bits 0-3 form the counter for the volume control of the four speakers. When all the bits are reset the volume control is off and when all the bits are set the volume control is fully on.
Bits 4-7 hold the users slection of the auxiliary colour which is only used when multicolour is switched on (discussed later).

CRF: $900F - 36879. Usual value 27.
This is the main colour selecting register of the VIC and has three distinct functions.
Bits 0-2 are used to hold the border colour. In the VIC 20 there are eight colours that can be border colours and these are:

0 - 000	Black
1 - 001	White
2 - 010	Red
3 - 011	Cyan
4 - 100	Purple
5 - 101	Green
6 - 110	Blue
7 - 111	Yellow

These border colours can be selected by putting the required value into the bits 0-2 of control register CRF.
Bit 3 is the reverse field control bit. At any time the state of this bit can be changed to reverse the whole display.
Bits 4-7 hold the background colour for the display. There are 16 possible colours and the following tble fives the colours together with their codes. Note that these codes are the same for the auxiliary colours as used in the multicolour mode.

0 - 0000	Black
1 - 0001	White
2 - 0010	Red
3 - 0011	Cyan
4 - 0100	Purple
5 - 0101	Green
6 - 0110	Blue
7 - 0111	Yellow
8 - 1000	Orange
9 - 1001	Light orange
10 - 1010	Pink
11 - 1011	Light cyan
12 - 1100	Light purple
13 - 1101	Light green
14 - 1110	Light blue
15 - 1111	Light yellow

CHARACTER TABLE MEMORY

The standard character table generator of the VIC 20 is a 4K ROM chip that occupies the block of memory from $8000-$8FFF. This ROM holds the 8x8 matrix representations of all the characters that can be displayed on the TV screen. A single character requires 8 locations, each holding 8 bits, in order to have all its points defined.

In the VIC 20 system there are a possible 128 different characters and the first 1K of the 4K ROM holds the straight forward representations for each character. The second 1K holds the 'inverse' representations.

8000-83FF	32768-33791	Upper case and graphics
8400-87FF	33792-34815	Reversed upper case and graphics
8800-8BFF	34816-35839	Upper and lower case
8C00-8FFF	35840-36863	Reversed upper and lower case

In order to get lower case letters it has been necessary to have another 2K of representations of the characters. Once again the first 1K holds the straight forward representations and the second 1K holds the 'inverted' representations as shown in the memory map above.

In the VIC 20 it is possible to change the area of memory that is used to hold the character table and to change the character representations from the normal 8x8 matrix to one of 8x16. The second feature is the double height character mode referred to in the discussion of the VIC registers themselves.

The first block of character memory - upper case and graphics - occupies the ROM locations 32768-34815. The second block - lower and upper case - occupies the ROM locations 34816-36863.

Characters are displayed as patterns of dots. Each character position on the screen is composed of an 8x8 sqaure of dots (pixels). Character memory contains the information which tells the computer which dots to turn on or off for a particular character. If a bit is 1, the dot is on (displayed in character colour). If it is 0, the dot is off (displayed in background colour). Therefore, to cover 64 dots, each character representation takes 8 bytes of memory.

eg. The character "A"

128	64	32	16	8	4	2	1	
0	0	0	1	1	0	0	0	24
0	0	1	0	0	1	0	0	36
0	1	0	0	0	0	1	0	66
0	1	1	1	1	1	1	0	126
0	1	0	0	0	0	1	0	66
0	1	0	0	0	0	1	0	66
0	1	0	0	0	0	1	0	66
0	0	0	0	0	0	0	0	0

As mentioned earlier, the screen codes act as pointers into character memory. The screen code for A is 1. Its 8 bytes of data is therefore stored at 32768 + (8*1) = 32776. So the values 24, 36, 66, 126, 66, 66, 66, 0 are stored from 32776 to 32783.

In general, to find the starting address of the representation of a character with screen code X use:

32768 + (8*X)   for character set 1
34816 + (8*X)   for character set 2

You can change from one character set to the other from the keyboard by using the CBM and shift key, or by changing the value of the character memory pointer - byte 36869. Its value is normally 240 (upper case and graphics) or 242 (upper case and lower case).

DESIGNING YOUR OWN CHARACTERS

Since the built in character sets are in ROM you cannot directly change them. However, as you have seen, the character memory pointer can be changed. So the secret to using a character set you design yourself is to change the pointer to point to your character set.

First, however, you must design your characters. This is usually done with a piece of graph paper representing the 8x8 matrix. Fill in the squares you want and then calculate the values as shown above for the character "A".

It is usual to copy some of the built in character set into RAM and then change those characters you wish to.

ACCESSING BOTH CUSTOM AND BUILT-IN CHARACTER SETS

If you have redesigned most of the characters in your custom character set, displaying understandable messages can be a problem.

One solution to this makes use of the fact that the VIC chip sees addresses differently to the rest of the computer. If you place the custom character set at 7168-7679, then printing RVSON within a string will cause the VIC chip to access the unreversed character set in ROM when printing that string.

The reasons for this are as follows:

The VIC chip can only access 16384 bytes, which it sees as a contiguous block from 0 to 16383. To it the location of the custom character set is 15360. Since RVS ON sets the high bit of a character's screen code, all reversed characters have screen codes of 128 up. To access a character with code 128 the VIC chip goes to location 15360 + (128*8) = 16384. Since the VIC chip cannot access 16384 the address "overflows" and wraps around to 0, which the VIC chip sees as the address of the start of character ROM. This just happens to be the location of the unreversed straight forward, every day representations.

HIGH RESOLUTION GRAPHICS