Construction project:

Multi-mode video card for AT compatibles

Here's another state-of-the-art design for a plug-in card suitable for IBM PCs and compatibles (including AT type machines), based on a new super-VLSI chip. This time it's a video display/graphics adaptor, providing monochrome, colour, Hercules and CGA-compatible high definition colour graphics modes – all with literally only a handful of parts on a very short PC board.

by JIM ROWE

When the original IBM PC first came out six years ago, there were two video display adaptor cards for it: the monochrome display adaptor (MDA) and the colour graphics adaptor (CGA). One was basically for display of text and simple graphics in no-nonsense monochrome, the other for text and medium-resolution graphics in colour. From memory both cards were IBM 'full slot' length, and jam-packed with dozens of ICs (although the MDA did include a printer port as well).

But that's the way it was for a while – you either used the MDA or the CGA, depending on taste and budget. Then along came Mr Hercules, with his improved monochrome graphics adaptor, and things started to change.

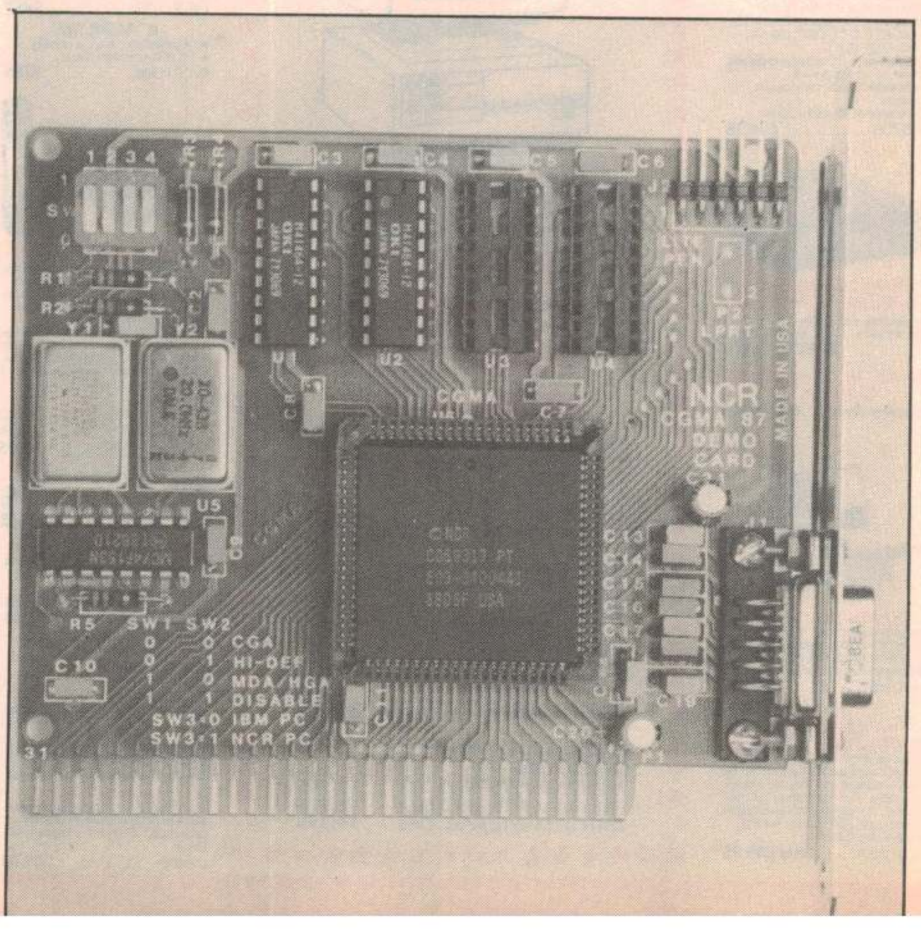
Not only did video cards get more powerful and flexible, with a plethora of display modes, but thanks to the development of fancy new VLSI chips they also started to shrink.

Nowadays there's a very wide range of cards to choose from, some of them offering the ability to emulate the original MDA and CGA, the Hercules card (HGA) and sometimes other fancy cards as well. About the only one that doesn't seem to be emulated on most of these cards is the newer *Professional Graphics Adaptor* (PGA) – presumably because it's either too complicated, or as yet not popular enough.

The only problem with some of these 'commodity' video cards is that they won't necessarily give correct operation with the newer generation of AT-level machines. Many of these machines run at 8MHz, 10MHz or even 12MHz, and some of the display cards can't keep up. They can cause problems by forcing the processor to enter additional *wait states*, 'twiddling its thumbs' until the video card has digested data for display.

Building your own video card hasn't been all that practical until now, mainly because the specialised VLSI chips needed for a small-chip-count circuit have been hard to get. In any case, fully wired and tested video cards have been readily available at quite reasonable prices, giving little incentive for building one.

But things have now changed. The multi-mode video card design described in this article can be built up for rather



The completed card. As you can see it is very compact, thanks to the 72C81 CGMA chip.

less than any comparable wired and tested card. At the same time, it's fully compatible with AT-level machines, so there needn't be any doubt on that score.

Best of all, the card is exceptionally easy to build. In fact it must surely be about the easiest PC-compatible card yet described – the kind of project that uses literally only a handful of parts, and can be wired up in an hour or two at most.

There are actually only four ICs in the basic design, plus a couple of crystal oscillator modules, a DIP switch to set the display modes, five resistors and a few capacitors. That's it!

It all fits on a tiny 'short slot' IBM-type card, measuring only 102mm long. Almost unbelievable, when you compare it with those original MDA and CGA cards...

Make no mistake, though. Despite this apparent simplicity, it's a full multi-mode display and graphics adaptor. It will operate as an MDA, a CGA, a Hercules HGA or a double-resolution CGA – and in either alpha or graphics modes. See Table 1 for a summary of the full range of display modes supported. It's quite impressive.

By the way we at *EA* can't claim the credit for developing the project. The complete design comes from the Microelectronics Division of NCR, based in Colorada Springs, USA. The design has come to us via NCR's Australian representative Energy Control International, of Sumner Park in Queensland, and to make things especially easy for those who want to build it up, Energy Control is making complete kits available by mail order. For details of the kit price and address for ordering, please see the data panel which accompanies the parts list.

Star of the show

You guessed it, most of the card's functions are performed by another of those all singing, all dancing super-VLSI wonder chips. In this case the chip is NCR's new 72C81, which the company describes as a *Colour Graphics and Monochrome Adapter* (CGMA) – which more or less means that it provides pretty well all of the circuitry needed for our complete colour/mono video graphics adaptor.

Essentially all that's needed apart from the 72C81 itself are a few memory (RAM) chips for the actual screen memory, a source of video clock pulses and a TTL-type video monitor, as

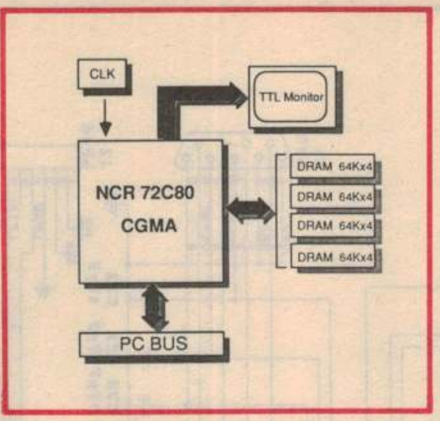


Fig.1: A simplified block diagram showing the card's main functions.

shown in the simplified block diagram of Fig.1.

In reality you do need another clock oscillator or two to cover the various display modes, and a few other parts, as we'll see shortly. But the 72C81 is certainly the star of the show, doing just about everything except sweep the floors and make the coffee.

NCR doesn't tell you a great deal about what's actually inside the 72C81, in its data sheets. However here's a summary of what I've been able to glean about it:

Fairly obviously it's a state-of-the-art ASIC (application-specific IC) device, made using the new 'Megacell' technology (see our article last month, *Meet the VL16C452, a bunch of Megacells*). This involves designing new VLSI devices by slotting together existing and proven designs for subsystem modules.

The 72C81 is a CMOS single-chip device, which comes in one of the new 84-pin PLCC (plastic leadless chip carrier) packages. It combines an industry standard 6845-type video screen controller, plus display character ROMS and virtually all of the buffer circuitry for interfacing to the PC bus, the video display RAM and the video monitor. The pin connections for the 72C81 are shown in Fig.2.

It provides full software compatibility with the IBM MDA and CGA, plus the Hercules HGA. In addition, it provides a special CGA-compatible 'high definition' colour graphics mode, with 640×400 pixel resolution to improve both text and graphics clarity. This is achieved by means of special 'mapper' circuitry inside the 72C81, which intercepts I/O accesses to the internal 6845 video controller and inserts new parameters which are correct for high resolution operation. This gives higher resolution display, while still ensuring compatibility with software designed for a CGA.

The various display modes are selectable either by software commands, or by control voltages applied to a pair of control pins on the device itself (M1 and M2). These are sensed by the 72C81 during its power-up reset sequence. Table 2 shows the way the logic levels on M1 and M2 control the display modes; note that when both pins are at logic 1, the device is disabled. This allows the processor to access another video adaptor, if there are more than one fitted to the system.

In colour alphanumeric modes, two bytes are used to define each character image. The first or *character* byte is used to look up the actual character image data itself, stored in ROM. This data is then serialised and shifted out to the colour encoder. The second or *attribute* byte then controls the encoder, to define things like the colour of the character, the colour of the background and the screen border colour if CGA mode is selected. The attribute byte also controls character blinking, intensity and normal/reverse display.

In colour graphics modes, the display memory is organised in a packed-pixel format with each byte representing four or eight pixels, depending on the mode selected. In 320×200 CGA graphics mode each byte represents four pixels, with two bits per pixel. Data read from the display memory is shifted as bit

Mode	Type	Alpha Format	Charac. Cell	Screen Resolution	Buffer Start	Colors	Page Size
CGA	Alpha	40 x 25	8 x 8	320 x 200	B8000	16	2048
CGA	Alpha	80 x 25	8 x 8	640 x 200	B8000	16	2048
Hi-Def	Alpha	40 x 25	8 x 16	320 x 400	B8000	16	2048
Hi-Def	Alpha	80 x 25	8 x 16	640 x 400	B8000	16	2048
MDA	Alpha	80 x 25	9 x 14	720 x 350	B0000	3	4096
CGA	Graphic	40 x 25	8 x 8	320 x 200	B8000	4	16384
CGA	Graphic	80 x 25	8 x 8	640 x 200	B8000	2	16384
Hi-Def	Graphic	40 x 25	8 x 16*	320 x 400 *	B8000	4	16384
Hi-Def	Graphic	80 x 25	8 x 16*	640 x 400 *	B8000	2	16384
HGA	Graphic	80 x 25	9 x 14	720 x 348	B0000/ B8000	2	32768**

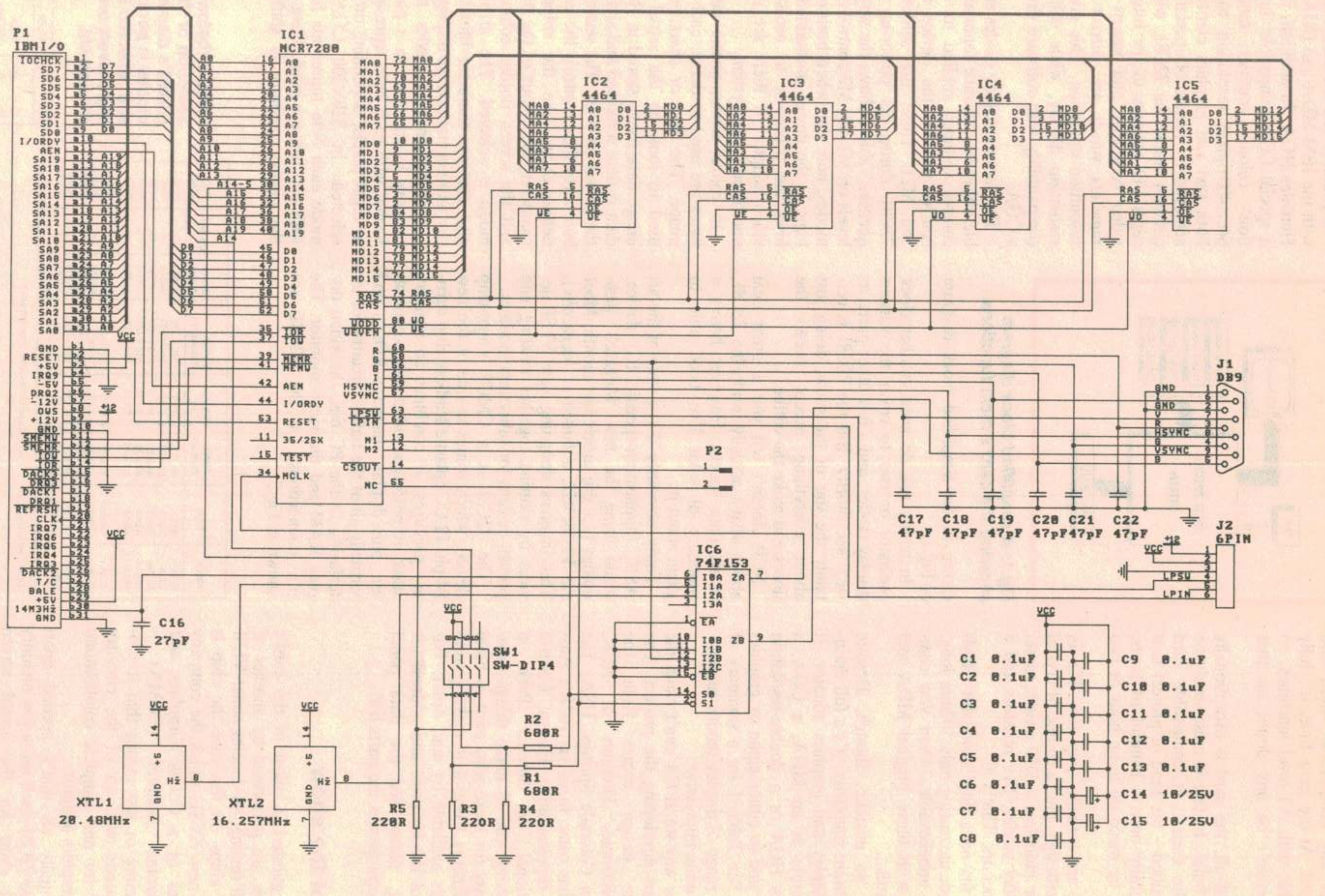
* Scan Double Displayed ** 2 page support in Hercules and Text Mode

Table 1 (above): The range of display modes supported by the new card. It's very flexible.

Table 2 (below): Selection of the CGMA's display modes is performed and reflected by the logic levels on pins M1 and M2.

M1	M2	Mode
0	0	CGA
0	1	Hi-Def
1	0	MDA/HGA
1	1	Disable

MULTI-MODE VIDEO GRAPHICS CARD



The complete circuit for the display adaptor card. As you can see, the CGMA chip itself does almost everything.

Multi-mode video card

	Monochrome	CGA Mode	Hi-Def Mode
Horizontal scan rate	18.432 KHz	15.750 KHz	25.000 KHz
Vertical scan rate	50 Hz	60 Hz	57 Hz
Video rate	16.257 MHz	14.318 MHz	20.000 MHz
Displayable colors	3	16	16
Character size	7 x 9 pixels	5 x 7 pixels	7 x 9 pixels
Character cell size	9 x 14	8 x 8	8 x 16
Maximum resolution	720 × 350	640 x 200	640 x 400

Table 3: The main scanı ameters for the CGMA chip's various display m

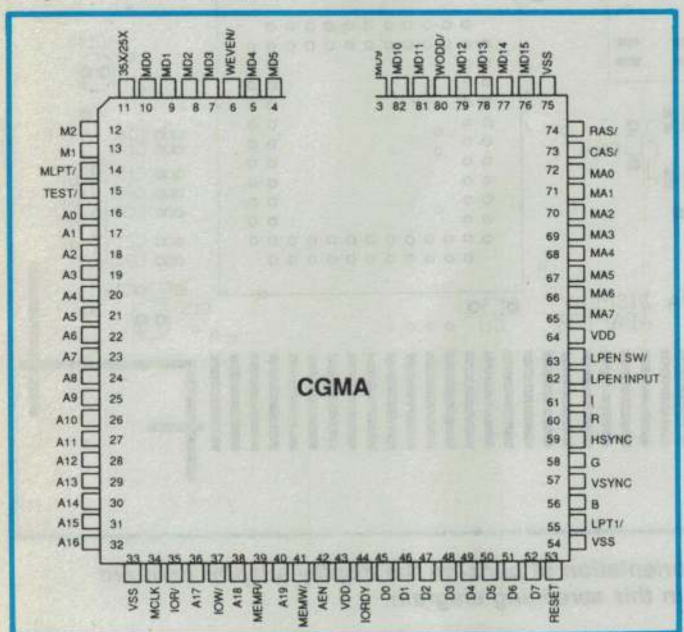


Fig.2: Pin connections for the 78C80/72C81 CGMA chip, which comes in an 84-pin PLCC package.

Which display monitor?

Although the CGMA card described in this article will operate with a normal IBM-compatible monochrome monitor in its MDA/HDA mode, and a similarly compatible RGB colour monitor in its CGA mode, you'll need a special monitor in order to take advantage of the card's other high definition colour mode.

The ideal kind of monitor to choose is one of the type which is capable of automatically locking to any of a range of horizontal and vertical scanning rates – this will allow operation of the CGMA card in *any* of its modes, and switching between them under software control.

We tried out the prototype card with an NEC "Multisync II" type JC-1402HMR monitor, kindly made available by NEC Home Electronics Australia. The Multisync II is a high resolution 14″ colour monitor with 30MHz video bandwidth, a tube with 0.31mm dot pitch, and a potential resolution of 800 dots by 560 lines. It locks automatically to any horizontal scan rate between 15.5 and 35kHz, and any vertical rate between 50 and 80Hz.

Needless to say it worked very happily with the CGMA card in all of its display modes, and gave excellent results.

For further information on the Multisync II contact NEC Home Electronics at 244 Beecroft Road, Epping 2121, or phone (02) 868 1811.

pairs to the colour encoder. The colour of the displayed images is specified separately via the 72C81 (6845) Colour-Select Register (I/O address 3D9).

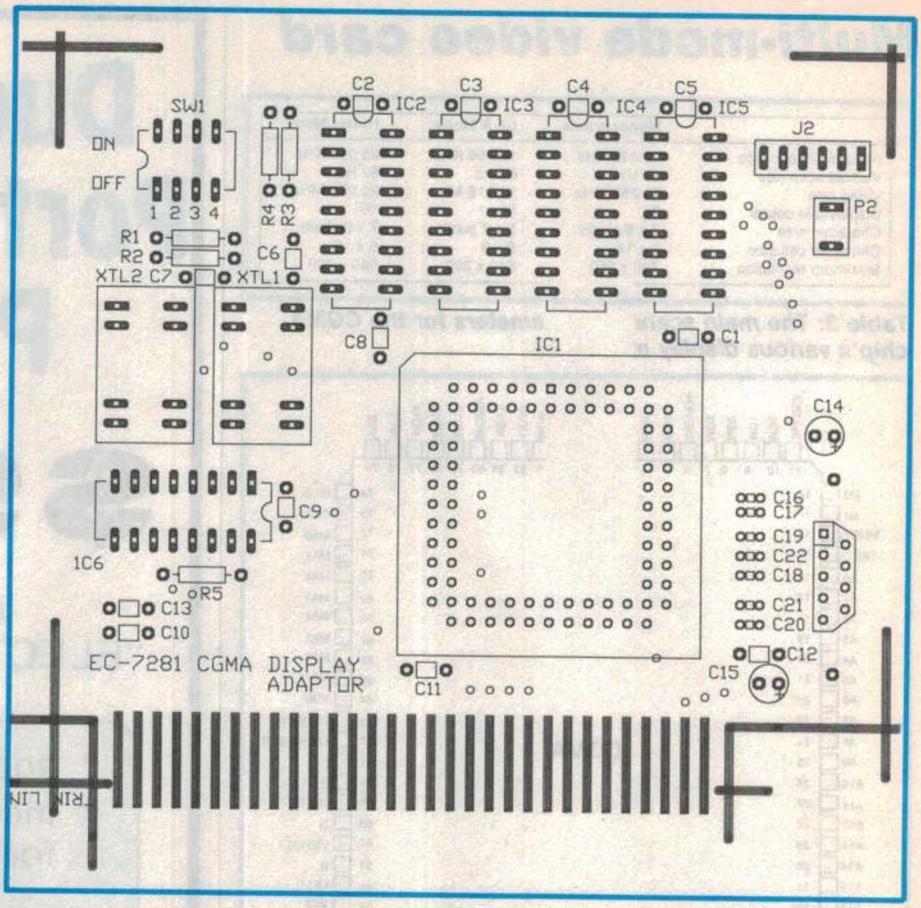
Monochrome alphanumeric modes operate in a similar manner to colour modes except that the 8×14 pixel cell character ROM is selected and an additional horizontal pixel is added for each character, resulting in a 720-pixel wide display (80 characters). In addition, the colour encoder outputs video data on the G output and intensity control on the I output, with the available attributes being blink, blank, underline, reverse video and intensify. Vertical sync output is also inverted in monochrome modes.

In monochrome graphics mode, data from the display memory is serialised and displayed in a 720×348 pixel format.

Essentially the 72C81 responds to both Memory and I/O accesses. Memory operations are used to write and retrieve the actual information to be displayed, to and from the video RAMs. On the other hand I/O operations are used to specify the manner in which this information is displayed.

In order to set up a specific video display, video is blanked by writing to the 72C81's Mode Control Register (I/O address 3D8), the appropriate timing and display parameters are loaded into the internal 6845 register, the display memory RAMs are loaded with the data to be displayed, and video is re-enabled. This process is normally performed by the computer's BIOS routines, or by application programs themselves in the case of those which write directly to the display adaptor.

The scanning parameters for the 72C81 operating in the various display modes are shown in Table 3.



The placement and orientation of parts on the display adaptor card are shown quite clearly in this screening diagram.

Circuit details

As you can see from the circuit schematic for the new video card, there isn't a great deal of circuitry outside the 72C81 CGMA chip itself (U6). There is provision for up to four 4464-type DRAM chips (64K×4 bits) for the video memory buffer, although only two (U1 and U2) are needed for most applications. Adding the other two provides a second 'page' of video RAM, allowing the buffer to be written into by the processor at any time, without additional wait states and without producing snow or video breakup.

DIP switches SW1 and SW2 are for setting the CGMA's display mode, during power-up reset. These connect directly to the M1 and M2 pins (13 and 12) discussed earlier, and also to the control inputs of a 74F153 dual 4:1 multiplexer chip (U5).

One section of the multiplexer is used to select the appropriate video dot clock input for the CGMA (pin 34), for the various display modes. The 14.318MHz system clock is used for CGA mode, while the 16.257MHz and 20.000MHz clocks generated on the card itself by Y1 and Y2 are used for the MDA/HGA and Hi-Def colour modes respectively.

The other section of the multiplexer chip is used to gate the monochrome video output, which appears on the 72C81's 'G' output (pin 58) in MDA/HGA mode. The second section of the multiplexer therefore connects the G output to pin 7 of the video output connector only when SW1 and SW2 are set for MDA/HGA operation.

Note that the M1 and M2 pins of the CGMA chip are not just inputs, but outputs as well. During power-up reset

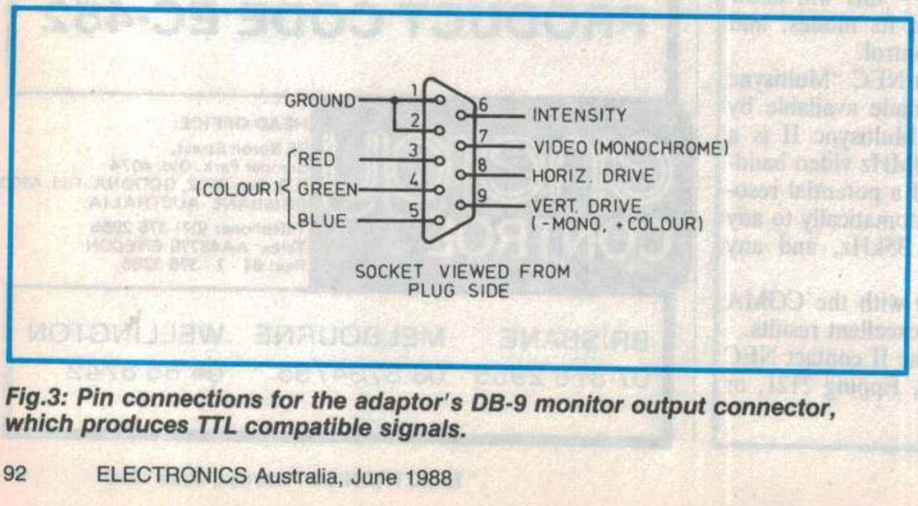


Fig.3: Pin connections for the adaptor's DB-9 monitor output connector, which produces TTL compatible signals.

they act as inputs, reading the settings of SW1 and SW2 to set the initial operating mode of the 72C81. But after this initialisation, the two pins become outputs which reflect the actual display mode bits stored in the 72C81's extended control register.

Resistors R1, R2, R3 and R4 are used to 'decouple' switches SW1 and SW2 from the multiplexer control pins and the CGMA M1/M2 pins, so that the CGMA pins can have ultimate control over the multiplexer. So if the 72C81's display mode is changed by software commands, at some stage after the initialisation sequence, the multiplexer will automatically change along with it.

Switch SW3 is used to configure the card for use either with standard IBM-compatible computers, or with NCR's own machines. For IBM-compatibles the A14 system address line is not brought to the CGMA A14 input, which is instead tied to logic 0 via resistor R5. However for use in NCR machines, SW3 is used to bring the system A14 line in, to give it control over the CGMA. I haven't been able to find out the reason for this – presumably it's due to minor differences between the NCR and other IBM compatibles.

Video and sync drive signals for the monitor come directly from the CGMA chip (apart from the monochrome V signal), and appear at the usual DB-9 connector. This type of connector is now used by most common 'TTL drive' monitors intended for IBM-compatible computers, whether they are monochrome or colour. The standard DB-9 video connections are shown in Fig.3.

Apart from the usual supply line bypass capacitors and capacitors used to dampen any ringing on the video and sync drive outputs, that's about all there is on the card. Although there is a light pen connector (J2), with the standard IBM connections.

One final point is that the 72C81 chip does actually provide decoded I/O address signals to enable parallel printer port circuitry. These appear on pins 14 and 55, being designated MLPT and LPT1 respectively. Both are active low outputs, and go low when the processor accesses I/O address ranges 3BC-3BE and 378-37F respectively. So the first could be used to enable an MDA-configuration printer port, while the second could enable a CGA-configuration port. On the current card these outputs are not used.

Construction

Construction of the card should be very straightforward, as Energy Control is making available complete kits. These include a quality double-sided PCB, provided with a silk-screened pattern showing the position and orientation of all parts. Using this as well as the photograph shown, of the complete card, you should be able to assemble the card quite easily in an couple of hours.

I suggest that you mount the passive components first – the resistors and capacitors – followed by the IC sockets. Note that the big 84-pin PLCC socket for U6 must be orientated with its chamfered corner adjacent to C8. This socket also has 84 fairly fragile pins, so

Continued on page p112

PARTS LIST

1	PCB, 110 x 101mm
J1	DB-9 socket, PCB right-angle mount
J2	6-way right-angle PCB pin header
SW	4-pole DIL switch
Y1	16.257MHz DIL crystal oscillator module
Y2	20.000MHz DIL crystal oscillator module

Integrated circuits

U1-2	64K×4 bit DRAM (4464/100ns or similar)
U3-4	64K×4 bit DRAM (optional, as U1-2)
U5	74F153 dual 4:1 multiplexer
U6	72C81 colour graphics/monochrome adaptor (CGMA) chip

Resistors

R1,2,5	680 ohms 1/4W
R3,4	220 ohms 1/4W

Capacitors

C1-19	10nF monolythic, 100V
C20-21	10uF electrolytic, 16VW

Miscellaneous

84-way PLCC socket for U6;
18-way DIL sockets for U1-4;
PC-type card mounting bracket;
DB connector mounting screws

NOTE: A complete kit for this project will be available from Energy Control International Pty Ltd of 26 Boron Street, Sumner Park 4074, or telephone (07) 376 2955. The cost of the kit is $119.00 plus $23.80 sales tax, plus $6.50 for packing and postage anywhere in Australia.