Macintosh Quadra 700, 900: Built-In Video (3/93)

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Article Change History

03/23/93 - REVISED
             • To break into separate articles.
             • To synchronize with similar article on Macintosh Centris
               series and Quadra 800.
          - RETITLED
             • To specify Quadra 700 and 900 models.

TOPIC --

This article, by the designer of the Macintosh Quadra's video hardware,
discusses a number of general Quadra video topics.

DISCUSSION ---

The Quadras were designed with a flexible video hardware section in order
to support a wide variety of displays. Since the purchaser of one of these
systems is paying for a frame buffer on the logic board (whether (s)he wants
it or not), and since the Quadras were designed to be high-performance
machines, the frame buffer was designed to be both very flexible (to
support most displays a user may want to use) and to be relatively high
performance (to match the computer's capabilities).

Obviously every display made by every third-party monitor vendor can't be
supported by the onboard video, but the Quadras do support a much wider
range of displays at a higher level of performance than any previous
Macintosh. The Quadra 700 and 900 support pixel depths ranging from 1 to
32 bits per pixel (bpp), Apple displays ranging from the 512 x 384 12-inch
color monitor through the 1152 x 870 21-inch color monitor, pixel clocks
ranging from 12 to 100 MHz, and a variety of industry standards such as
VGA, SVGA, NTSC, and PAL. The Quadra video port produces RS-343 RGB,
and also provides horizontal, vertical, and composite sync outputs.

Composite or S-video output is not provided, but can be accomplished by use
of an external RGB-to-composite encoder. The Quadra 700 and 900 also
support Apple convolution for flicker-reduction on interlaced displays
(i.e., NTSC and PAL) at up to 8 bpp. The Quadras automatically detect

the type of display attached to the video connector via three 'sense' pins on
the video connector. Depending on the wiring of these three pins, software in
ROM configures the video hardware for one of the supported display types.
(A full description of sense pin wiring and supported display types is in
another article.)

The Quadra series provides the highest built-in video performance of any
Macintosh to date. In a (very) simplified graphics model, we could say
that performance depends on two main factors: processor horsepower and the
bandwidth the processor has into frame buffer memory.   These systems
already have a fast processor -- the 68040 -- which runs standard 32-bit
QuickDraw. To provide high bandwidth into frame buffer memory, dedicated
video RAM (VRAM) was used for the frame buffer, and that VRAM was placed
directly on the 68040 processor's local bus. This provides the 68040 the
same access time into frame buffer memory that it has into main system RAM.
(Transfer rates can exceed 40MB/sec.) In addition, memory options such as
fast page mode are supported, which can improve graphics performance for
operations such as scrolling, offscreen-to-onscreen pixmap transfers, etc.

In a number of cases the design was optimized for high performance over
low cost. A good example of this is 32 bpp operation on Apple's standard
13-inch RGB monitor at 640 x 480 resolution (and this also applies to VGA
and NTSC), which is probably the most common color monitor in use on the
Macintosh. The actual number of memory bytes needed to support 24 bpp is
640 x 480 x 3 = 921,600. This would seem to fit within 1MB of memory
(as is the case with the Macintosh Display Card 8•24), but the Quadras actually
require 2MB of VRAM for this mode. The 8•24 card supports 24 bpp at
640 x 480 by using a storage mode called 'chunky planar' to fully utilize
all its 1MB of VRAM. However, this results in having to perform three
separate memory accesses for each 24-bit pixel read from or written to the
frame buffer. (This is done in hardware, so software only performs a
single read or write.) On a NuBus video card, this inefficiency is
partially masked by the synchronization delays which occur at the
processor-bus/NuBus interface. However, when frame buffer memory is
placed directly on the processor bus, this approach results in a nearly 3x
performance degradation. This was judged unacceptable for the Quadras.
Each 24-bit pixel occupies one longword (4-bytes) in VRAM, so the Quadras
actually provide 32 bpp for the 640 x 480 resolution. This pushes the
memory requirement for this mode over the 1MB boundary (640 x 480 x 4
= 1,228,800 bytes). Performance is improved still more by another frame
buffer architectural feature. Frame buffer memory in the Quadras is
organized into 4 'banks' of 512 KBytes per bank. As mentioned earlier,
Quadra VRAM can operate in fast page mode. In addition, each bank of VRAM
operates in fast page mode independently of the other 3 banks. This
causes the number of in-page 'hits' to increase, and thus improves the
effective bandwidth into the frame buffer. Also, at 32 bpp, 640 x 480
resolution, each row is set to 4096 bytes, or 1024 32-bit pixels. Each
successive row is assigned to a different VRAM bank (modulo 4, of course).

This memory organization improves performance during certain commonly
performed graphics operations such as vertical scrolling.

In any design there are a number of tradeoffs to be made, and this is

certainly true for the frame buffer in the Quadras. While the
video does operate at 32 bpp on up to 16-inch displays, it does not
support 21-inch displays at this pixel depth since this would have
significantly raised the cost of the motherboard. (Memory capacity and
bus bandwidths would essentially have to double, and this would be
expensive.) It does support NTSC and PAL timing, but does not provide a
composite video output. While it is much faster than any non-accelerated
video card, there are accelerated video cards that are faster (and much
more expensive). A separate graphics processor was not
added primarily for cost reasons. However, a graphics processor such as
the 29000 RISC chip on the Display Card 8•24 GC can only speed up the graphics
operations that it was designed to know about. If an application program
bypasses QuickDraw (which is what most Macintosh graphics accelerators are
designed to speed up), a graphics accelerator will not improve
performance, and can actually cause a performance degradation.

Overall, the Macintosh Quadra video provides a reasonable compromise of
cost, performance, and features, which provides the video needed by the
majority of Macintosh users at a reasonable price.
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