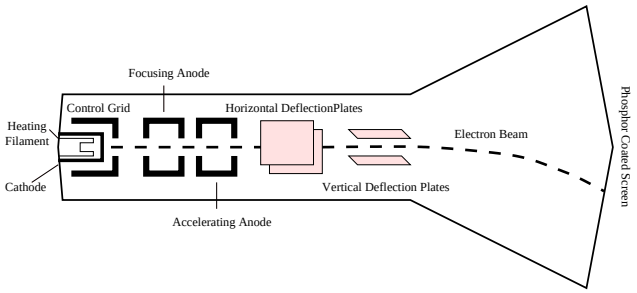
Graphics hardware

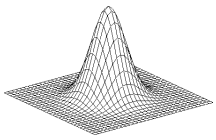
- In order to program graphical routines sensibly it is necessary to have a firm understanding of the hardware issues involved.
- Focus on video display devices.
- Cathode Ray Tubes (CRT) and Liquid Crystal Displays (LCD).
- The Cathode Ray Tube (CRT) is still the standard mechanism for the display of computer information.

CRT



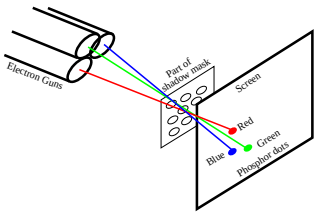
- Phosphors with a persistence time of between 10 and 60 μs are used - means refreshing an issue.

Resolution in CRTs



- The light emitted from a phosphor dot has a spatial support.
- The maximum number of points that can be displayed without overlap is termed the resolution of the CRT.
- Also important is the aspect ratio of the screen: an aspect ratio of 3/4 implies that to represent a given length of line three vertical pixels are need as opposed to four pixels along the horizontal.

Colour in CRTs

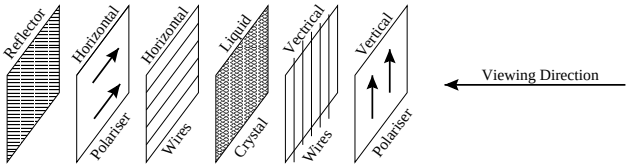


- Additive colour model is used: Red, Green, Blue (RGB).
- Shadow mask ensures each beam is focussed on one phosphor dot of the correct colour.
- The dots are either grouped in triangular clusters (delta-delta) of the three colours, or in lines (inline).

Intensity in CRTs

- Each RGB electron beam being able to be set at one of 256 intensity levels.
- Total colour depth of 24 bits per pixel, referred to as a true colour system.
- Colour and intensity are big topics in CRT design.

LCDs



- Liquid crystals can change their transmission of polarised light by applying an electrical potential.
- LCDs must be refreshed when the older wire technology is used.
- Unlike CRTs, liquid crystals have a rather longer persistence of several hundred milliseconds.

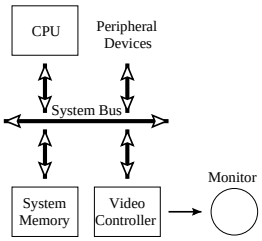
LCDs and other devices

- Most modern LCDs use active matrix panels, where Thin Film Transistor (TFT) technology is used to create tiny transistors at each pixel location.
- TFT displays have traditionally been expensive, because each pixel actually requires three transistor switches.
- LCD displays have a native resolution.
- Displaying different resolutions requires anti-aliasing.
- Alternative display devices have been invented e.g. plasma panels, and projector devices - similar issues apply.

Hardcopy devices

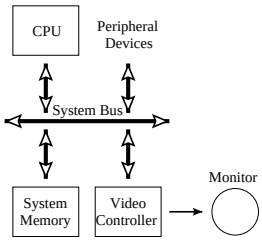
- Hardcopy devices are required for long term display of images.
- Issues are generally very similar - most modern devices are pixel based.
- For colour devices there is an additional problem, that of colour matching.
- Hardcopy devices tend to use the subtractive Cyan, Magenta, Yellow (CMY) colour model.
- Conversion between these in true colour (24 bit) mode is non-trivial.

Graphics system hardware



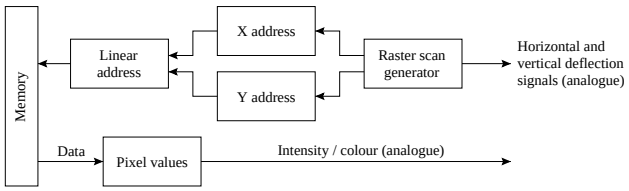
- The simplest type of graphics system has no dedicated graphics display processor, and no internal memory.
- The system memory is used to store the pixmap, and the CPU is used to scan convert and manipulate the graphics primitives.

Graphics system hardware



- The part of system memory where the pixmap is stored is called the frame buffer.
- Needs to have fast access times.

The Video Controller



A typical video controller.

- The raster scan generator is activated each time the screen is refreshed.

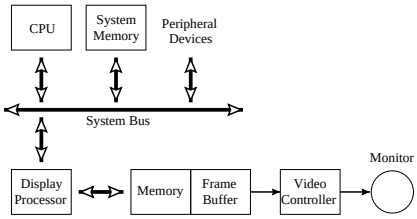
The Video Controller

- To refresh a display of 1024×768 pixels at a moderate refresh rate of 60 Hz requires a memory access every $1/(1024 * 768 * 60)$ seconds $= 21$ ns.
- To set the red, green and blue colour components the video controller often uses a Look Up Table – that is tables are used to convert colours to signal strength.

SI units - background information

Unit	Numerically	English	Standard symbol
tera	10^{12}	trillion	T
giga	10^{9}	billion	G
mega	10^{6}	million	M
kilo	10^{3}	thousand	K
mili	10^{-3}	thousandth	m
micro	10^{-6}	millionth	μ
nano	10^{-9}	billionth	n
pico	10^{-12}	trillionth	p

Current graphics systems

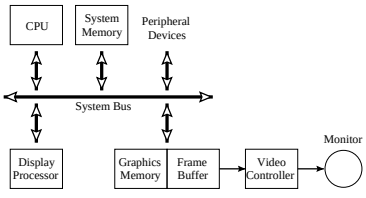


- Most graphics systems possess dedicated graphics processors.
- Cuts down the load on the CPU and the system memory since such designs also often incorporate their own graphics processor memory. This memory is often Video RAM (VRAM) where a complete scan line of pixels is read at each refresh cycle.

Graphics system hardware

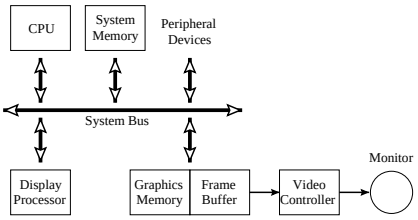
- The graphics processor generally performs scan conversion and raster operations (such as pixel copy, move etc.).
- Many of the new generation of graphics cards also have hardware support for the common graphics libraries such as OpenGL and DirectX.
- The CPU and graphics processor typically communicate via a queueing system.
- The dedicated graphics processor may also store details of the image, in terms of a hierarchical data structure, known as a display storage list, as well as textures and other information.

Integrated display processor



- Integrated display processor, also known as the Single Address Space (SAS) display system architecture.
- In some systems there is no distinction between the system and graphics memory, and in any case the two are addressed identically.

Integrated display processor



- Integrated systems may be slower due to the relatively low speeds of the system bus and the greater demands placed on it, however from a programming point of view they are much neater, since all the memory can be addressed from both processors.

Summary

- Having finished this lecture you should:
  - be aware of the issues raised by hardware constraints – pixelated displays;
  - contrast CRT and LCD technologies;
  - compare the merits of different graphics system architectures.
- Hardware forms the lowest level we explore (briefly) in the graphics course – providing a background to what we have learnt.