

History of Home Computers & Retrocomputing



Shaquana Godwin
Jaeden Souza

First Edition, 2012

ISBN 978-81-323-1277-2

© All rights reserved.

Published by:
College Publishing House
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

Table of Contents

Chapter 1 - Home Computers

Chapter 2 - Acorn Archimedes

Chapter 3 - Acorn Electron

Chapter 4 - Macintosh

Chapter 5 - Amstrad CPC

Chapter 6 - BBC Master

Chapter 7 - Retrocomputing

Chapter 8 - Apple II Series

Chapter 9 - IBM Personal Computer

Chapter 10 - ZX Spectrum

Chapter 1

Home Computers



Children playing Paperboy on an Amstrad CPC 464 in the 1980s



Most home computers, such as this Tandy Color Computer 3, featured a version of the BASIC programming language. The sometimes-sprawling nature of the well-outfitted home computer system is very much in evidence.

Home computers were a class of personal computers entering the market in 1977, and becoming increasingly common during the 1980s. They were marketed to consumers as affordable, accessible personal computers and more capable than video game consoles. These computers typically cost much less than business, scientific or engineering-oriented desktop personal computers of the time, and were generally less powerful in terms of memory and expandability. However, a home computer often had better graphics and sound than contemporary business personal computers. Usually they were bought for education, game play, and personal productivity use such as word processing.

Advertisements for early home computers were rife with possibilities for their use in the home, from cataloging recipes to personal finance to home automation, but these were seldom realized in practice. For example, using a typical 1980s home computer as a home automation appliance would require the computer to be kept powered on at all times and dedicated to this task. Personal finance and database use required tedious data entry. If no packaged software was available for a particular application, the home computer user was required to learn computer programming; a significant time commitment many weren't willing to make. Still, for many the home computer offered the first opportunity to learn to program.

Today the line between 'business' and 'home' computer market segments has blurred or vanished completely, since both categories of computers now typically use the same processor architectures, peripherals, operating systems, and applications. Often the only difference may be the sales outlet through which they are purchased. Another change from the home computer era is that the once-common endeavour of writing one's own software programs has almost vanished from home computer use.



The Commodore PET released in 1977. This model featured a built in Datassette drive.

Background

As early as 1965, some experimental projects such as Jim Sutherland's ECHO IV explored the possible utility of a computer in the home. Computers became affordable for the general public due to the mass production of the microprocessor, with the first commercially successful home computer being the the Altair 8800, whose first programming language was also Microsoft's founding product, Altair BASIC.

Early microcomputers such as the Altair had front-mounted switches and blinkenlights to control and indicate internal system status, and were often sold in kit form to home hobbyists. These kits would contain an empty printed circuit board which the buyer would fill with the integrated circuits, other individual electronic components, wires and connectors, and then hand-solder all the connections.

While two early home computers (Sinclair ZX80, and Acorn Atom) could be bought either in kit form or assembled, most home computers were only sold pre-assembled. They were enclosed in plastic or metal cases similar in appearance to typewriter or hi-fi equipment enclosures, which were more familiar and attractive to consumers and lower cost than the metal card-cage enclosures used by the Altair and similar computers. A keyboard was usually built into the same case as the motherboard. Ports for plug-in peripheral devices such as a video display, cassette tape recorders, joysticks, and (later) disk drives either were built-in or available as add-on cards. Usually the manufacturer would sell peripheral devices designed to be compatible with their computers as extra cost accessories. Often peripherals were not interchangeable between brands of home computer, or even between successive models of the same brand.

To save the cost of a dedicated monitor, the home computer often would connect either directly or through an RF modulator to the family TV set which served as both video display and sound system.

Almost universally, home computers had a version of a BASIC interpreter combined with a line editor in permanent read-only memory with which one could type in BASIC programs and execute them immediately. In direct mode, the BASIC interpreter was also used as the user interface, and given tasks such as loading, saving, managing, and running files. One exception was the Jupiter Ace, which had a Forth interpreter built in. A programming language was seen as a requirement for any computer of the era due to the dearth of commercially-available productivity software as well as the widely varying applications users had in mind for the new devices.

After the success of systems like the RadioShack TRS-80, the Commodore PET and the Apple II in 1977, large numbers of new machines of all types began to appear during the late 1970s and early 1980s. Some home computers sold many units over several years, such as the BBC Micro, Sinclair ZX Spectrum, Atari 800XL and Commodore 64, and attracted third-party software development. By 1982, an estimated 621,000 home computers were in use in the United States, at an average sales price of \$530.

Low-end home computers competed with video game consoles. The markets weren't entirely distinct, as both could be used for games. A common marketing tactic was to show a computer system and console playing games side by side, then emphasizing the computer's greater ability by showing it running user-created programs, education software, word processing, spreadsheet and other applications while the game console showed a blank screen or continued playing the same repetitive game. Books were available for most models of computer with titles along the lines of "64 Amazing BASIC Games for the Commodore 64". These books would include type in program listings and sometimes an mail-in offer to obtain the programs on disk or cassette and were a popular and low-cost means of both learning to program and software distribution. Some video game consoles offered "programming packs", consisting of a version of BASIC in a ROM cartridge. Atari's BASIC Programming for the Atari 2600 was one of these. For the ColecoVision console Coleco even announced an expansion module which would convert it into a full-fledged computer system. This never materialised, but a standalone computer, the Coleco Adam was eventually released. During the peak years of the home computer market, scores of models were produced, usually with little or no thought given to compatibility between different manufacturers or even within product lines of one manufacturer. The concept of a computer platform did not exist, except for the Japanese MSX standard.

Soon after its August 1981 introduction, the IBM Personal Computer would eventually become the standard platform used in business. This was largely due to the system's open architecture, which encouraged production of third-party clones of the design. The Visicalc-running Apple II would be quickly displaced for office use, but Apple Computer's 1984 release of the Apple Macintosh introduced a new model for interacting with the computer to the market, which IBM-compatible computers would eventually

also adopt. Throughout the 1980s, PCs spread through businesses like wildfire, leading, by the end of the decade, to sub-\$1000 IBM PC XT-class white box machines, usually built in Asia and sold by US companies like PCs Limited.

The declining cost of the IBM-compatibles on the one hand, and the greatly increased graphics, sound, and storage abilities of fourth generation video game consoles such as the Sega Genesis and Super Nintendo Entertainment System on the other, combined to cause the market segment for home computers to vanish by the early 1990s in the US. In Europe, the home computer remained a distinct presence for a few years more, with the Amiga and Atari ST lines being the dominant players, but today a computer bought for home use anywhere will be very similar to those used in offices - made by the same manufacturers, with compatible peripherals, operating systems, and application software.

Technology



A Commodore 64c system, showing the basic layout of a typical home computer system of the era. Pictured are the CPU/keyboard unit, floppy disk drive, and dedicated color monitor. Many systems also had a dot matrix printer for producing paper output.



Eastern Bloc computers were often significantly different in appearance from western computers. Pictured is a KC 85/3 with its keyboard placed on top, by VEB Mikroelektronik Mühlhausen released in 1986 and based on an East German Zilog Z80 clone.



The Soviet Elektronika BK0010-01 home computer was based on the K1801BM1 (Soviet LSI-11-compatible CPU) and shared architectural similarities with PDP-11.

Many home computers were superficially similar. Most had a keyboard integrated into the case; sometimes a cheap-to-make membrane or chiclet keyboard in the early days, although full-travel keyboards quickly became universal due to overwhelming consumer preference. Most systems could use an RF modulator to display 20–40 column text output on a home television. Indeed, the use of a television set as a display almost defines the pre-PC home computer. Although dedicated composite or "green screen" computer displays were available for this market segment and offered sharper text display and sometimes increased graphics resolution, a monitor was often a later purchase made only after users had bought a floppy disk drive, printer, modem, and the other pieces of a full system. This "peripherals sold separately" approach is another defining characteristic of the home computer era. Many first time computer buyers brought a base C-64 system home and hooked it up to their TV only to find they needed to buy a disk drive or Datassette before they could make use of it as anything but a game machine.

In the early part of the 1980s, the dominant microprocessors used in home computers were the 8-bit MOS Technology 6502 (Apple, Commodore, Atari) and Zilog Z80 (TRS-80). A notable exception was the TI-99 series, announced in 1979 with a 16-bit TMS9900 CPU.

Processor clock rates were typically 1–2 MHz for 6502 based CPU's and 2–4 MHz for Z80 based systems (yielding roughly equal performance), but this aspect was not emphasized by users or manufacturers, as the systems' limited RAM capacity, graphics abilities and storage options had more of an effect on performance than CPU speed. Clock rate was considered a technical detail of interest only to users needing accurate timing for their own programs. To economize on component cost, often the same crystal used to produce color television compatible signals was also divided down and used for the processor clock. This meant processors rarely operated at their full rated speed, and had the side-effect that European and North American versions of the same home computer operated at slightly different speeds and different video resolution due to different television standards.

Initially, many home computers used the then-ubiquitous compact audio cassettes as a storage mechanism. A rough analogy to how this worked would be to place a recorder on the phone line as a file was uploaded by modem to "save" it, and playing the recording back through the modem to "load". Most cassette implementations were notoriously slow and unreliable, but floppy disk drives as found on more costly business-oriented microcomputers were expensive and used disks eight inches wide at the beginning of the home computer era. Costs declined toward the end of the 1980s as sales of microcomputers increased and mass production of 5.25" drive mechanisms enabled economy of scale. The 5.25" floppy disk drives would remain the standard throughout the 8-bit era. Though external 3.5" drives were made available for most systems toward the latter part of the 1980s, most software sold for 8-bit home computers remained on 5.25" disks; 3.5" drives were used for data storage. Standardization of disk formats was not common; sometimes even different models from the same manufacturer used different disk formats. Toward the end of the home computer era, a few models appeared offering disk-format compatibility with the IBM PC. The disk drives sold with the Commodore

128, Amiga and Atari ST were all able to read and write PC disks, ostensibly to allow users to exchange data between work and home computers.

Various copy protection schemes were developed for floppy disks; most were broken in short order. Many users would only tolerate copy protection for games, as wear and tear on disks was a significant issue in an entirely floppy-based system. The ability to make a "working backup" disk of vital application software was seen as important. Copy programs that advertised their ability to copy or even remove common protection schemes were a common category of utility software in this pre-DMCA era.

In contrast to modern computers, home computers most often had their operating system (OS) stored in ROM chips. This made startup times very fast - no more than a few seconds - but made OS upgrades difficult or impossible without buying a new unit. Usually only the most severe bugs were fixed by issuing new ROMs to replace the old ones at the user's cost. In another defining characteristic of the home computer, instead of a command line, the BASIC interpreter served double duty as a user interface. Coupled to a character-based screen or line editor, BASIC's file management commands could be entered in direct mode. The operating systems provided little other support to application programs, but application programs usually accessed hardware directly to perform a specific task anyway, often switching out the ROM based OS completely to free the address space it occupied and maximize RAM capacity. As multitasking was not common on home computers until late in the '80s, this lack of API support wasn't much of a liability.

In an enduring reflection of their early cassette-oriented nature, most home computers loaded their disk operating system (DOS) separately from the main OS. The DOS was only used to send commands to the floppy disk drive and was not loaded to perform other computing functions. One notable exception was Commodore, whose disk drives actually contained a 6502 processor and Commodore DOS in ROM. Many home computers also had a cartridge interface which accepted ROM-based software. This was occasionally used for expansion or upgrades such as fast loaders. Application software on cartridge did exist, but the vast majority of cartridges were games.

From about 1985, the high end of the home computer market began to be dominated by "next generation" home computers using the 16-bit Motorola 68000 chip, which enabled the greatly increased abilities of the Amiga and Atari ST series. Graphics resolutions approximately doubled, and color palettes increased from dozens to hundreds or thousands of colors available. Stereo sound became standard for the first time. Clock rates on these systems were approximately 8 MHz with RAM capacities of 256 kB (for the base Amiga 1000 system) up to 1024 kB (1 megabyte, a milestone, first seen on the Atari 1040 ST). These systems had built-in 3.5" floppy disks from the beginning but 5.25" drives were made available to facilitate data exchange with the IBM PC compatibles. The Amiga and ST both had GUIs inspired by the Apple Macintosh, but at a list price of \$2495 (over \$5000 in 2007 dollars), the Macintosh itself was too expensive for most households.

Radio frequency interference

After the first wave of computers landed in American homes, the United States Federal Communications Commission (FCC) began receiving complaints of electromagnetic interference to television reception. By 1979 the FCC demanded that home computer makers submit samples for radio frequency interference testing. It was found that "first generation" home computers, which often included their own screens, emitted too much radio frequency noise for household use. Some companies appealed to the FCC to waive the requirements for home computers, while others (with compliant designs) objected to the waiver. Eventually techniques to suppress interference became standardized.

The Home Computer "Revolution"

In the late 1970s and early 1980s, from about 1977 to 1983, it was widely predicted that computers would soon revolutionize many aspects of home and family life as they had business practices in the previous decades. Mothers would keep their recipe catalog in "kitchen computer" databases and turn to a medical database for help with child care, fathers would use the family's computer to manage family finances and track automobile maintenance. Children would use disk-based encyclopedias for school work and would be avid video gamers. Home automation would bring about the intelligent home of the '80s. Using Videotex, NAPLPS or some sort of as-yet unrealized computer technology, television would gain interactivity. The personalized newspaper was a commonly-predicted application. Morning coffee would be brewed automatically under computer control. The same computer would control the house lighting and temperature. Robots would take the garbage out, and be programmable to perform new tasks by the home computer. Electronics were expensive, so it was generally assumed that each home would have only one multitasking computer for the entire family to use in a timesharing arrangement, with interfaces to the various devices it was expected to control.

“ The single most important item in 2008 households is the computer. These electronic brains govern everything from meal preparation and waking up the household to assembling shopping lists and keeping track of the bank balance. Sensors in kitchen ”

appliances,
climatizing units,
communicators,
power supply
and other
household
utilities warn the
computer when
the item is likely
to fail. A
repairman will
show up even
before any
obvious
breakdown
occurs.

Computers also
handle travel
reservations,
relay telephone
messages, keep
track of birthdays
and
anniversaries,
compute taxes
and even figure
the monthly bills
for electricity,
water, telephone
and other
utilities. Not
every family has
its private
computer. Many
families reserve
time on a city or
regional
computer to
serve their needs.
The machine
tallies up its own
services and
submits a bill,
just as it does
with other

utilities.

—Mechanix Illustrated, November
1968 edition

All this was predicted to be commonplace sometime before the end of the decade, but virtually every aspect of the predicted revolution would be delayed or prove entirely impractical. The computers available to consumers of the time period just weren't powerful enough to perform any single task required to realize this vision, much less do them all simultaneously. The home computers of the early 1980s could not multitask. Even if they could, memory capacities were too small to hold entire databases or financial records, floppy disk-based storage was inadequate in both capacity and speed for multimedia work, and the graphics of the systems could only display blocky, unrealistic images and blurry, jagged text. Before long, a backlash set in—computer users were "geeks", "nerds" or worse, "hackers". The North American video game crash of 1983 soured many on home computer technology. The computers that were bought for use in the family room were either forgotten in closets or relegated to basements and children's bedrooms to be used exclusively for games and the occasional book report.

It took another 10 years for technology to mature, for the graphical user interface to make the computer approachable for non-technical users, and for the internet to provide a compelling reason for most people to want a computer in their homes. Predicted aspects of the revolution were left by the wayside or modified in the face of an emerging reality. The cost of electronics dropped precipitously and today many families have a computer for each family member, or a laptop for mom's active lifestyle, a desktop for dad with the kids sharing a computer. Encyclopedias, recipe catalogs and medical databases are kept online and accessed over the world wide web -- not stored locally on floppy disks or CD-ROM. TV has yet to gain substantial interactivity; instead, the web has evolved alongside television, but the HTPC or services like Netflix, Google TV or Apple TV along with internet video sites such as YouTube and Hulu may one day replace traditional broadcast and cable television. Our coffee may be brewed automatically every morning, but the computer is a simple one embedded in the coffee maker, not under external control. As of 2008, robots are just beginning to make an impact in the home, with Roomba and Aibo leading the charge.

This delay wasn't out of keeping with other technologies newly introduced to an unprepared public. Early motorists were widely derided with the cry of "Get a horse!" until the automobile was accepted. Television languished in research labs for decades before regular public broadcasts began. In an example of changing applications for technology, before the invention of radio, the telephone was used to distribute opera and news reports, whose subscribers were denounced as "illiterate, blind, bedridden and incurably lazy people". Likewise, the acceptance of computers into daily life today is a product of continuing refinement of both technology and perception.

Use today

As older computer hardware becomes obsolete (and in some cases nonfunctional), and the supply of replacement parts dwindles, it has become popular among enthusiasts to emulate these machines, their environments on modern hardware. One of the more well-known emulators is the Multiple Emulator Super System which can emulate most of the better known home computers. A more or less complete list of home computer emulators can be found here. Games for many 8 and 16 bit home computers are becoming available for the Wii Virtual Console.

Retrocomputing is gaining in popularity, with many enthusiasts using real Commodore 64 hardware to perform modern tasks such as surfing the web and email. The 64 has also been repackaged as the C-One and C64 Direct-to-TV, both designed by Jeri Ellsworth with modern enhancements. Many enthusiasts have started to collect home computers, with older and rarer systems being much sought after. Sometimes the collections turn into a virtual museum presented on web sites.

As cloud computing develops, future home computer users may opt for the all-in-one simplicity of a console, netbook, nettop or set top box over a standard PC, possibly running a "stripped down" operating system like Chrome OS. This could lead to a new era of home computers as distinct from business computers running a more traditional OS. Game consoles are starting to incorporate most of the most common uses for PCs in the home - in addition to gaming, all of the 2008 console generation feature music playing ability, and the Wii and PlayStation 3 can be used to browse the web. The Xbox 360 also features instant messaging. Through the web browser component, word processing, email and photo editing are available on these consoles using Web applications. Laptops and tablet computers such as the iPad are becoming popular for use in the home, which may redefine the term personal computer itself as a truly personal accessory, similar to a digital audio player or mobile phone and used by an individual in both work and leisure settings.

Notable home computers



The 1977 Apple II with 2 Disk II disk drives and an Apple monitor

The most popular home computers in the USA up to 1985 were: the TRS-80 (1977), various models of the Apple II family (first introduced in 1977), the Atari 400/800 (1979) along with its follow up models the 800XL and 130XE, and the Commodore VIC-20 (1980) and the Commodore 64 (1982). The VIC was the first computer of any type to sell over one million units, and the 64 is still the highest-selling single model of personal computer ever, with over 17 million produced before production stopped in 1994 – a 12-year run with only minor changes.

In Europe the situation was slightly different, as many of the British made systems like Sinclair's ZX81 and Spectrum, and later the Amstrad/Schneider CPC were generally much cheaper in Europe than US systems (such as the Atari and Apple models). The reverse was also true, as popular British systems like the Spectrum never became popular in the US. A few British Sinclair models were sold for low prices in the US by Timex Corporation, such as the Timex Sinclair 1000 and the ill-fated Timex Sinclair 2068. The result was that these British systems were much more popular in Europe than in the USA, the only notable exception being the Commodore 64 (C64), which competed favorably price-wise with the British systems, and was the most popular system in Europe as in the USA.

Until the introduction of the IBM PC in 1981, computers such as the Apple II and TRS 80 also found considerable use in office work.

1970s

Three microcomputers were the prototypes for what would later become the home computer market segment; but when introduced they sold as much to hobbyists and small businesses as to the home.

- June 1977: Apple II (North America), color graphics, eight expansion slots; one of the first computers to use a typewriter-like plastic case design.
- August 1977: Tandy Radio Shack TRS-80 (N. Am.), first home computer for less than US\$600, used a dedicated monitor for U.S. Federal Communications Commission (FCC) rules compliance.
- December 1977: Commodore PET (N. Am.), first all-in-one computer: keyboard/screen/tape storage.

The following computers also introduced significant advancements to the home computer segment:

- 1979: Atari 400/800 (N. Am.), first computer with custom chip set and programmable video chip and built-in audio output.
- 1979: TI-99/4, first home computer with a 16-bit processor.

1980s



No computer has sold more units than the Commodore 64



The East German Robotron KC 85/1 was virtually not available for sale due to huge demand by industrial, educational, and military institutions.

- 1980: Commodore VIC-20 (N. Am.), under US\$300; first computer of any kind to pass one million sold.
- 1980: TRS-80 Color Computer (N. Am.), Motorola 6809, optional OS-9 multi-user multi-tasking.
- June 1981: Texas Instruments TI-99/4A, based on the less successful TI-99/4, first to add sprite graphics.
- 1981: Sinclair ZX81 (Europe), £49.95 in kit form; £69.95 pre-built, released as Timex Sinclair 1000 in US in 1982.
- 1981: BBC Micro (Europe) (premier educational computer in the UK for a decade; advanced BBC BASIC with integrated 6502 machine code assembler, featured a myriad of I/O ports, ~ 1.5 million sold.
- April 1982: Sinclair ZX Spectrum (Europe), best-selling British home computer; catalysed the UK software industry, widely cloned by the Soviet Union.
- June 1982: MicroBee (Australia), initially as a kit, then as a finished unit.
- August 1982: Dragon 32(UK) became, for a short time, the best-selling home micro in the United Kingdom.
- August 1982: Commodore 64 (N. Am.), custom graphic & synthesizer chipset, best-selling computer model of all time: ~ 17 million sold.

- Jan. 1983: Apple IIe, Apple II enhanced. Reduced component count and production costs enabled high-volume production, until 1993.
- Apr. 1984: Apple IIc, Apple II compact. No expansion slots, and built-in ports for pseudo-plug and play ease of use. The Apple II most geared to home use, to complement the Apple IIe's dominant education market share.
- 1983: Acorn Electron A stripped down 'sibling' of the BBC microcomputer with limited functionality. The Electron recovered from a slow start to become one of the more popular home computers of that era in the UK.
- 1983: Coleco Adam, one of the few home computers to be sold as a complete system with storage device and printer; cousin to the ColecoVision game console; one of the first systems to be "orphaned" by its maker, a casualty of the North American video game crash of 1983.
- 1983: MSX (Japan, Korea, Arabia, Europe, N+S. Am.), a computer 'reference design' by ASCII and Microsoft, produced by several companies: ~ 5 million sold.
- 1983: VTech Laser 200, entry level computer aimed at being the cheapest on market, also sold as Salora Fellow, Texet TX8000 & Dick Smith VZ 200.
- 1984: The Apple Macintosh is introduced, providing many consumers their first look at a graphical user interface, which would eventually replace the home computer as it was known.
- 1984: Amstrad/Schneider, CPC, PCW ranges (Europe), British standard before IBM PC; German sales next to C64.
- 1985: Elektronika BK-0010, one of the first 16-bit home computers, and the only "official" home computer in USSR.
- 1985: Robotron KC 85/1 (Europe), one of the few home computers produced by the East German VEB Robotron-Meßelektronik "Otto Schön" Dresden.
- 1985: Atari ST (N. Am.), first with built-in MIDI interface; also 1MB RAM for less than US\$1000; Motorola 68000 processor.
- 1985: Commodore 128 (N. Am.) Final, most advanced 8-bit Commodore, retained full C64 compatibility while adding CP/M in a complex multi-mode architecture
- July 1985: Commodore Amiga (N. Am.), custom chip set for graphics and digital audio; multitasking OS with both GUI and CLI interfaces; Motorola 68000 processor.
- 1987: Acorn Archimedes (Europe), launched with an 8 MHz 32-bit ARM 2 microprocessor, with between 512kB and 4MB of RAM, and an optional 20 or 40MB hard drive.
- 1989: SAM Coupé (Europe), based on 6 MHz Z80 microprocessor; marketed as a logical upgrade from the Sinclair ZX Spectrum.

Chapter 2

Acorn Archimedes

Acorn Archimedes

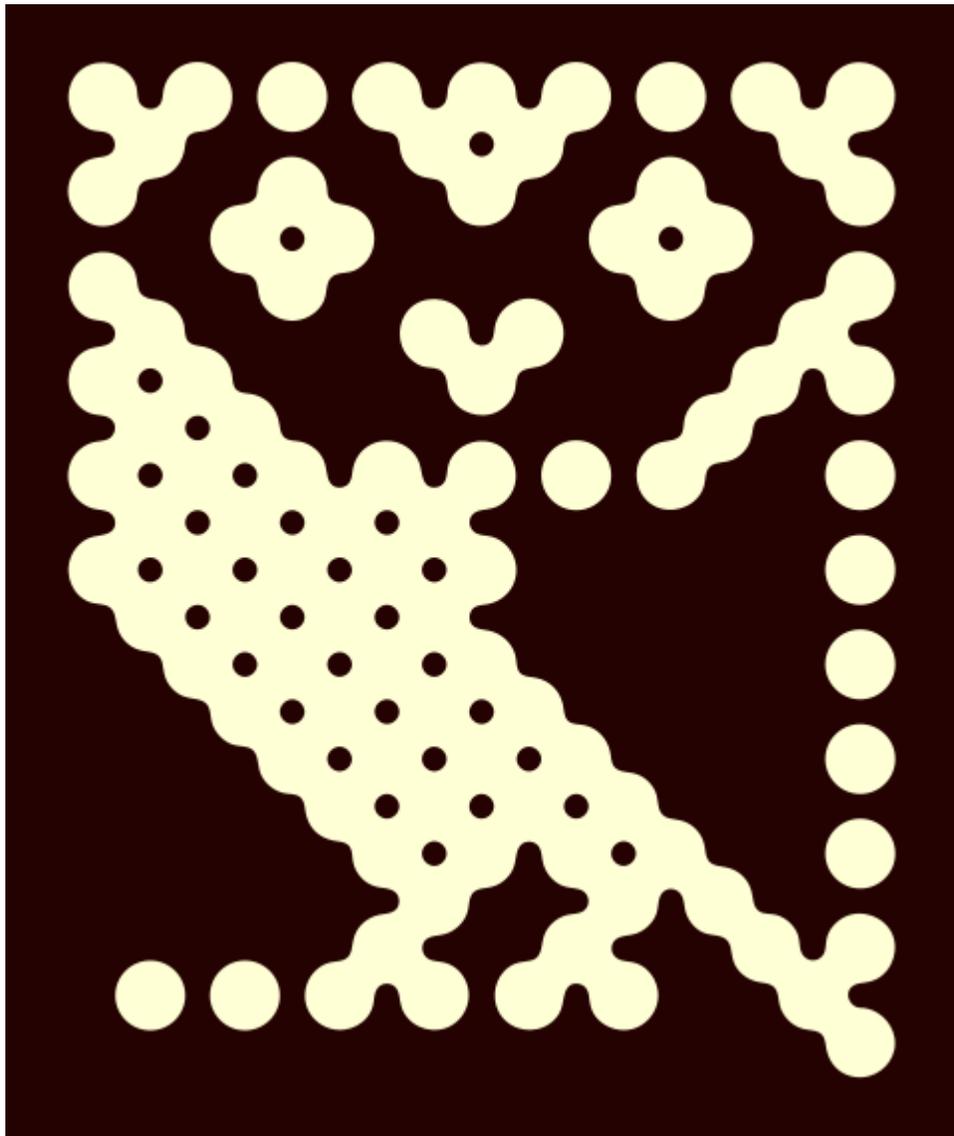


Type	Personal computer or Home computer
Release date	June 1987
Discontinued	mid-1990s
Operating system	RISC OS or RISC iX
CPU	ARM
Memory	512 KB - 16 MB

The **Acorn Archimedes** was Acorn Computers Ltd's first general purpose home computer based on their own 32-bit ARM RISC CPU. The name is also commonly used to describe computers which were based on the same architecture, even where Acorn did not include 'Archimedes' in the official name.

Description and history

Early models



The BBC Computer Literacy Project 'Owl' appeared on the keyboard, above the function keys on the Archimedes 300 series and A3000 keyboards.

The first models were released in June 1987, as the 300 and 400 series. The 400 series included 4 expansion slots (although a 2 slot backplane could be added to the 300 series as an official upgrade, and third parties produced their own 4 slot backplanes) and an ST506 controller for an internal hard drive. Both models included the Arthur OS (later replaced by RISC OS as a paid-for upgrade), BBC BASIC and an emulator for Acorn's earlier BBC Micro, and were mounted in two-part cases with a small central unit, monitor on top, and a separate keyboard and three-button mouse. All models featured onboard 8 channel stereo sound and were capable of displaying 256 colours on screen.

Four models were initially released with different amounts of memory, the A305, A310, A410 and A440. The 300 and 400 were followed by a number of machines with minor changes and upgrades:

A3000 and A5000

Work began on a successor to the Arthur operating system, initially named Arthur 2, but with the release of the Hollywood movie of the same name it was renamed to RISC OS 2 and new computers were shipped with it pre-installed. A number of new machines were introduced along with it, and in May 1989 the 300 series was phased out in favour of the new Acorn A3000 (the 400 series was kept in production). Earlier models which shipped with Arthur could be upgraded to RISC OS 2 by replacing the ROM chips containing the operating system.

The A3000 used an 8 MHz ARM2 and was supplied with 1 MB of RAM. Unlike the previous models, the A3000 came in a single-part case similar to the Amiga 500 and Atari ST computers, with the keyboard integrated in the base unit. This kind of housing consumes a lot of desktop space, a problem that Acorn tried to overcome by offering a monitor stand that attached to the base unit. The new model only sported a single internal expansion slot, which was physically different from that of the earlier models, although electrically similar. An external connector could interface to existing expansion cards, although they really needed to be housed in an external case joined to the main unit.

In 1991, the A5000 was launched. It featured the new 25 MHz ARM3 processor, 2 or 4 MB of RAM, either a 40 MB or an 80 MB hard drive and a more conventional 2U rack pizza box-style two-part case (HxWxD: 100 x 430 x 340 mm). Its enhanced video capabilities allowed the A5000 to comfortably display VGA resolutions of up to 800×600 pixels. It was the first Archimedes to feature a High Density capable floppy disc drive as standard. This supported various formats including DOS and Atari discs. A later version of the A5000 featured a 33 MHz ARM3, 4 or 8 MB of RAM, an 80 or 120 MB hard drive and a revised OS (RISC OS 3.10).

The A5000 ran the new 3.0 version of RISC OS 3.0. As previously, earlier machines were capable of being upgraded to the new RISC OS 3, though some needed help, as well as the ARM3 CPU. Earlier models could also benefit from the video performance of the A5000 via a third party upgrade.

New range and a laptop

In 1992, a new range was produced, the first ARM macrocell: the ARM250 microprocessor. A single chip design including an ARM3 chip without cache, and the IOC1 (Input Output Controller), VIDC1a (VIDEo and sound Controller) and MEMC1 (MEMory Controller) chips all integrated into one chip. The increase in clock frequency, from 8 Mhz to 12 Mhz, gave a performance of 7 MIPS. They run RISC OS 3.10. The A30x0 series had a one-piece design, similar to the A3000 but far smaller, while the A4000 looked like a slightly slimmer A5000. The A3010 model was intended to be a

home computing machine, featuring a TV modulator and joystick ports, while the A3020 targeted the home office and educational markets, featuring a built-in 2.5" hard drive and a dedicated network interface socket . Technically, the A4000 was almost identical to the A3020, only differing in hard disk size (3.5" in the A4000), though it sported a different appearance. All three ARM250-based machines could be upgraded to 4MB with plug-in chips (though the A3010 was designed for 2MB, third party upgrades overcame this) and one "mini-podule" slot as used for internal expansion in the A3000.

Also in 1992, Acorn introduced a laptop computer called A4 that featured an ARM3 processor like the A5000, even though it had a slightly lower clock speed, and a LCD screen capable of displaying a maximum resolution of 640 × 480 pixels in 15 levels of grey. However, it did feature a monitor port which offered the same display capabilities as an A5000. A notable omission from the machine was a built-in pointing device, requiring users to navigate with the cursor keys or attach a conventional Acorn three-button mouse.

The *A7000*, despite its name being reminiscent of the Archimedes naming conventions, was actually more similar to the Risc PC – the line of RISC OS computers that succeeded the Archimedes in 1994. It lacked, however, the DEBI expansion slots and multi-slice case that characterized the RiscPC (though by removing the CDRom, a backplane with one slot could be fitted).

List of models

Model	Memory (RAM)	Hard disk space	Launch date	UK retail price at launch	Notes
BBC Archimedes 305	512 KB (512 KB)	-	July 1987	£899	-
BBC Archimedes 310	1 MB (1 MB)	-	July 1987	£999	-
BBC Archimedes 310M	1 MB	-	July 1987	£	Includes PC emulation software

Acorn Archimedes 410	1 MB	-	July 1987	£1299	-
Acorn Archimedes 440	4 MB	20 MB	July 1987	£1499	-
BBC A3000	1 MB	-	May 1989	£799	This model was the last ever BBC Microcomputer
Acorn Archimedes 410/1	1 MB	- (ST506 interface on motherboard)	June 1989	£999	Improved <i>MEMCIA</i> memory controller over previous 410 model
Acorn Archimedes 420/1	2 MB	20 MB ST506	June 1989	£1099	-
Acorn Archimedes 440/1	4 MB	40 MB ST506	June 1989	£1299	Improved <i>MEMCIA</i> memory controller over previous 440 model
Acorn R140	4 MB	47 MB ST506	June 1989	£3,500	RISC iX workstation
Acorn Archimedes 540	4 MB (max 16Mb)	100 MB SCSI	June 1990	£2499	ARM3 processor
Acorn R225	4 MB	-	July 1990	£3000	ARM3 processor, RISC iX network workstation

Acorn R260	8 MB	100 MB SCSI	July 1990	£5000	ARM3 processor, RISC iX workstation
Acorn A5000	1, 2, 4 or 8 MB	20 MB to 160 MB IDE	September 1991	£999 or £1499	25->33 MHz ARM3 processor, launched with various sub-models
Acorn A4	2 MB or 4 MB	0 MB or 60 MB IDE (2.5")	June 1992	£1399 or £1699	Notebook model with ARM3 processor clocked at 24MHz (1 MHz slower than usual), 640x480 greyscale LCD screen
Acorn A3010	1 MB	-	September 1992	£499	ARM250 processor (early models had an ARM2 mezzanine processor codenamed "Adelaide")
Acorn A3020	2 MB	0 MB - 80 MB IDE (2.5")	September 1992	£799	ARM250 processor
Acorn A4000	2 MB	0 MB - 210 MB IDE	September 1992	£999	ARM250 processor

Also produced, but never sold commercially were:

- A500 - 4 RAM, ST506 interface, Archimedes development machine
- A680 and M4 - 8 MB RAM, SCSI on motherboard, RISC iX development machines

Significance and impact

The Archimedes was one of the most powerful home computers available during the late 1980s and early 1990s; its main CPU was faster than the 68000 microprocessors found in the more popular Commodore Amiga and Atari ST machines. An 8 MHz 68000 had an average performance of roughly 1 MIPS, with peak performance of 2 MIPS for simpler instructions. The 8MHz ARM2 yielded 4.5-4.8 MIPS in repeatable benchmark tests.

The Archimedes won significant market share in the education markets of the UK, Ireland, Australia and New Zealand; the success of the Archimedes in British schools was due partly to its predecessor the BBC Micro and later to the Computers for Schools scheme organised by the Tesco supermarket chain in association with Acorn, and most students and pupils in these countries in the early 90s were exposed to an Archimedes or A-series computer. Despite a technical edge, the Archimedes only ever met a moderate success beyond the education sector, becoming a 'minority' platform outside of certain niche markets. These niche markets included professional work such as radio, medical and railway station management and music publishing.

By the early 1990s, the UK educational market began to turn away from the Archimedes. Apple Macintosh computers or IBM compatible PCs eclipsed the Archimedes in their multimedia capabilities, which led to an erosion of the Archimedes market share. The Tesco Computers for Schools scheme later changed partnership from Acorn to RM plc and many other computer-related suppliers, which also led to the decrease of the Archimedes' educational market share.

Chapter 3

Acorn Electron

Acorn Electron



An Acorn Electron

Developer	Acorn Computers
Type	8-bit microcomputer
Release date	1983
Media	Cassette tape, floppy disk (optional), ROM cartridge (optional)
Operating system	Acorn MOS v2
CPU	MOS Technology 6502A clocked at 2MHz when accessing ROM and 1MHz/0.5897MHz when accessing RAM
Memory	32KB RAM, 32KB ROM
Display	RF modulator, composite video, RGB monitor output
Graphics	160×256 (4 or 16 colours), 320×256 (2 or 4 colours), 640×256 (2 colours),

320×200 (2 colours — spaced display
with two blank horizontal lines
following every 8 pixel lines), 640×200
(2 colours — spaced display)

Input keyboard

The **Acorn Electron** is a budget version of the BBC Micro educational/home computer made by Acorn Computers Ltd. It has 32 kilobytes of RAM, and its ROM includes BBC BASIC along with its operating system.

The Electron was able to save and load programs onto audio cassette via a supplied converter cable that connected it to any standard tape recorder that had the correct sockets. It was capable of basic graphics, and could display onto either a television set, a colour (RGB) monitor or a "green screen" monitor.

At its peak, the Electron was the third best selling micro in the United Kingdom, and total lifetime game sales for the Electron exceeded those of the BBC Micro. There are at least 500 known games for the Electron and the true total is probably in the thousands.

The hardware of the BBC Micro was emulated by a single customized ULA chip designed by Acorn. It had feature limitations such as being unable to output more than one channel of sound where the BBC was capable of three-way polyphony (plus one noise channel) and the inability to provide teletext mode.

The ULA controlled memory access and was able to provide $32K \times 8$ bits of addressable RAM using $4 \times 64K \times 1$ -bit RAM chips (4164). Due to needing two accesses to each chip instead of one, and the complications of the video hardware also needing access, reading or writing RAM was much slower than on the BBC Micro. This meant that although ROM applications ran at the same speed, there was a substantial speed decrease on applications running from RAM.

History

The Electron was developed during 1983 as a cheap sibling for the BBC Micro with the intention of capturing the low cost Christmas sales market for that year. Although Acorn were able to shrink substantially the same functionality as the BBC into just one chip, manufacturing problems meant that very few machines were available for the Christmas period - to the extent that some shops reported eight presales for every delivered machine.

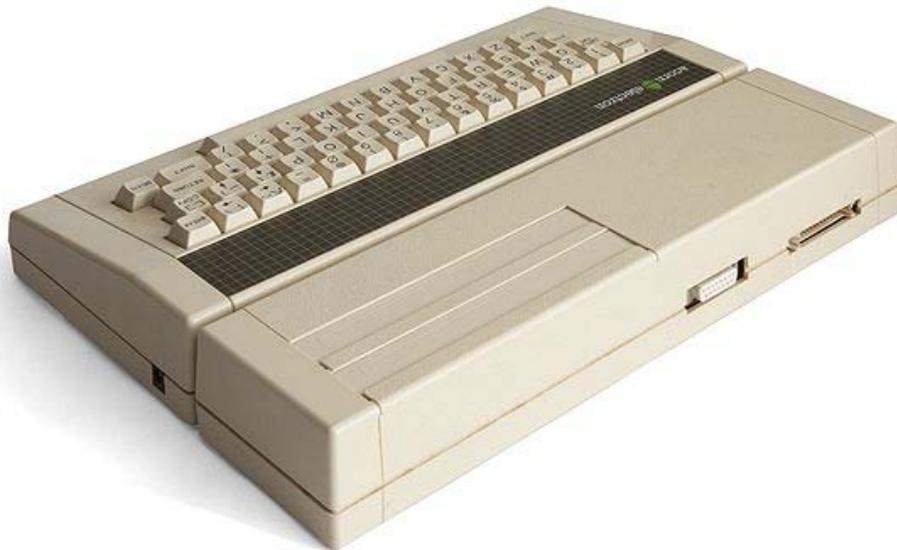
This was a blow from which the machine never fully recovered, although games sales for it would ultimately outstrip those of the BBC Micro. Following Olivetti's 1985 cash injection into Acorn the machine was effectively sidelined.

With hindsight, the machine lacked the RAM (a typical program would need to fit in only around 20 kB once display memory is subtracted) and processing power to take on the prevailing Sinclair ZX Spectrum and Commodore 64. Despite this, several features that would later be associated with BBC Master and Archimedes were first features of Electron expansion units, including ROM cartridge slots and the Advanced Disc Filing System — a hierarchical improvement to the BBC's original Disc Filing System.

Whilst it may not have been as popular as the Spectrum, Commodore 64 or Amstrad CPC, it did sell in sufficient numbers to ensure that new software was being produced right up until the early 1990s. This meant the Electron had a lifespan not much shorter than those more popular micros and much longer than competitors such as the Oric-1 and Dragon 32.

Popular upgrades

Acorn Plus 1



An Acorn Electron with Plus 1 expansion unit attached

The Acorn Plus 1 added two ROM slots, an analogue interface and a parallel port. The analogue interface was normally used for joysticks, the parallel for a printer.

Access to ROM memory occurred at 2 MHz regardless of graphics mode so theoretically programs released on ROM could run at least twice as fast as those released on tape or disc. Despite this all of the games released on ROM were packaged as 'serial ROMS', from which the micro would load programs into main memory in exactly the same way as if it were loading from tape. This meant that programs did not need to be modified for their new memory location but gave no execution speed benefits whatsoever.

Acorn Plus 3

The Acorn Plus 3 was a hardware module that connected independently of the Plus 1 and provided a double-density 3½" disc drive connected through a WD1770 drive controller and an ADFS ROM. Because the WD1770 is capable of single density mode and uses the same IBM360 derived floppy disc format as the Intel 8271 found in the BBC Micro, it was also possible to run a DFS filing system with an alternate ROM.

First Byte Joystick Interface

As a games machine the Electron shared the same failing as the Sinclair Spectrum in not having a joystick port. This was quickly remedied by First Byte Computers who developed an interface and software which allowed a "switched" joystick to be used with the majority of software titles. This interface became very popular and was sold by W.H. Smiths, Boots, Comet and hundreds of independent computer dealers.

P.R.E.S. Advanced Plus 3



The P.R.E.S. Advanced Plus 3 with a 3½" drive

The Advanced Plus 3 was very similar to the Acorn Plus 3 but packaged as a ROM cartridge for the Plus 1 with a disc drive connector at the head. This made it possible to connect a 5¼" floppy disc drive as used by BBC Micro owners or a more common 3½" drive.

Slogger/Elektuur Turbo Board

The Slogger and Elektuur Turbo Boards were born out of a hack initially devised at Acorn. By moving the lowest 8 KB of RAM outside of reach of the ULA, the CPU could always access it at 2 MHz. The tradeoff was that the screen could not be located in that 8 KB. In practice the operating system ROMs always put the screen into the top 24 KB and as a result this probably only broke compatibility with around 2% of software.

The Slogger Turbo Board was a professionally fitted upgrade whereas the Elektuur modification was described in an article in Dutch Electronics magazine *Elektuur* and intended for users to perform at home.

Speeding up the low portion of memory is particularly useful on 6502 derived machines because that processor has a faster addressing mode for the first 256 bytes and so it is

common for software to put any variables involved in time critical sections of program into that region.

If Acorn had thought to include this small modification in the original Electron design it is likely the machine would have had a much greater impact as it would have nearly doubled the amount of motion possible in games and saved modes 0–3 (including the only 16 colour mode) from being nearly useless due to contended memory timings.

Slogger Master RAM Board

A development of the Turbo Board, the Master RAM Board duplicated the Turbo Board functionality and added a further option of running the micro with 32 kB of shadow RAM in addition to the ordinary 32 kB — giving 64 kB total. Some clever program counter catches meant that the ordinary system ROMs and any software using the OS calls could function without significant modification, making substantially more memory available for BASIC, View, Viewsheet and almost every other business application. By providing extra storage this modification also allowed some games and applications intended for the BBC Micro to function on the Electron despite the lack of a native Mode 7.

Applications could not directly address video memory in this mode without modification, so it was incompatible with most games, although there is no inherent reason why a game could not be written to function in shadow mode.

During its decline, Master RAM Boards were added to every Electron in an attempt to increase sales.

Jafa Systems Mode 7 Display Unit

Of the capabilities present in the BBC Micro but absent from the Electron, the teletext style *mode 7* was particularly conspicuous because of the very low memory usage in that mode (just less than 1 kB) and the high number of BBC programs that used it. Jafa Systems provided a number of solutions to redress this deficiency.

The most basic solution was a pure software system supplied on a ROM cartridge that drew a low resolution approximation of the mode 7 display in a graphics mode. Although cheap and effective in enabling use of some software that only used official ROM entry points for text output, this solution proved very slow because the Electron had to be placed into an 80 byte pitch display to be able to get anywhere near to reproducing mode 7 and the CPU spent a lot of time drawing approximations of mode 7 characters and graphics that in a hardware solution would be achieved without any CPU processing. It also used up 20 kB of RAM for the graphics display rather than the 1 kB of a hardware mode 7.

Two solutions with additional hardware were provided. The first used the same graphics processor as the BBC Micro in mode 7 — the SAA5050 — but used software to ensure

that it was fed with the correct graphics data. A software ROM would put the machine into an ordinary 40 byte pitch display. While the ULA would read the display from memory in the usual fashion, the SAA5050 would listen to the data it was reading and produce a mode 7 interpretation of the same information. When necessary the hardware would switch between the graphics output being produced by the micro and that being produced by the add-on.

The disadvantage to this system is that while the SAA5050 would expect to be repeatedly fed the same 40 bytes of data for every display scanline of every character row, the ULA would read a different set of 40 bytes for every display scanline in order to produce a full graphics display. A software ROM worked around this by duplicating the data intended for a mode 7 display in memory. Although this produced a mode 7 that barely impacted upon CPU performance and gave the same visual quality as the BBC Micro, it remained compatible only with software that used the ROM routines for outputting text and graphics and still used 10 kB of memory for the display.

A second version of the hardware add-on corrected these problems. By adding a CRTC6845 to the package, a full hardware solution was created that did not reduce CPU performance and only used 1 kB of memory for the display. A software ROM was still supplied, but this did no more than expand the hardware ROM so that it knew mode 7 now existed and was able to switch into it.

Merlin M2105

An unusual variant of the Electron was sold by British Telecom Business Systems as the BT Merlin M2105 Communications Terminal. This consisted of a de-badged Electron plus a large expansion unit containing 32 KB of RAM, 48 KB of ROM, a Centronics printer port and a modem. The ROM firmware provided dial-up communications facilities. These were used by the Interflora florists network in the UK for over a decade.

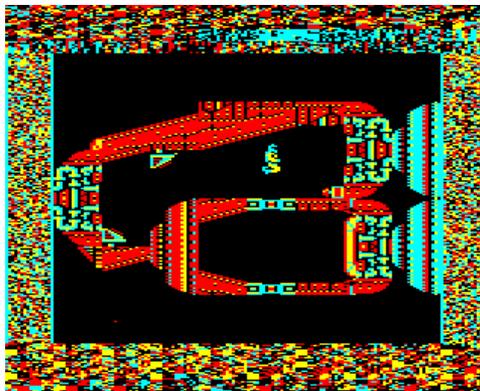
Technical information

Hardware

- CPU: MOS Technology 6502A
- Clock rate: variable. CPU runs at 2 MHz when accessing ROM and 1 MHz or 0.5897 MHz (depending on graphics mode) when accessing RAM due to sharing memory access with the video display circuits. The Electron is widely misquoted as operating at 1.79 MHz after measurements derived from speed testing against the thoroughly 2 MHz BBC Micro for various pieces of 'common software'
- Coprocessor: Ferranti Semiconductor Custom ULA
- RAM: 32 kB
- ROM: 32 kB
- Text modes: 20×32, 40×25, 40×32, 80×25, 80×32 (all text output produced by software in graphics modes)

- Graphics modes: 160×256 (4 or 16 colours), 320×256 (2 or 4 colours), 640×256 (2 colours), 320×200 (2 colours — spaced display with two blank horizontal lines following every 8 pixel lines), 640×200 (2 colours — spaced display)
- Colours: 8 colours (TTL combinations of RGB primaries) + 8 flashing versions of the same colours
- Sound: 1 channel of sound, 7 octaves; built-in speaker. Software emulation of noise channel supported
- Dimensions: 16×34×6.5 cm
- I/O ports: Expansion port, tape recorder connector (1200 baud variation on the Kansas City standard for data encoding), aerial TV connector (RF modulator), composite video and RGB monitor output
- Power supply: External PSU, 18V AC

Quirks



Exile is an example of a game where the developers left non-graphical data visible in the display buffer to gain additional memory space.

Like the BBC Micro, the Electron was constrained by limited memory resources. Of the 32 KB RAM, 3½ KB was allocated to the OS at startup and at least 10 KB was taken up by the display buffer in contiguous display modes.

Due to the timing of interrupts it was possible to disable either the top 100 or bottom 156 lines of the display with palette changes. Many games took advantage of this, gaining storage by leaving non-graphical data in the disabled area.

Other games would load non-graphical data into the display, leaving it visible as regions of apparently randomly coloured pixels.

Although page flipping was a hardware possibility, the limited memory forced most applications to do all their drawing directly to the visible screen, often resulting in graphical flicker or visible redraw. A notable exception is Players' *Joe Blade* series.

Tricks

FireTrack: smooth vertical scrolling

Although programs can alter the position of the screen in memory, the non-linear format of the display means that vertical scrolling can only be done in blocks of 8 pixels without further work.

FireTrack exploits a division in the way the Electron handles its display — of the seven available graphics modes, two are configured so that the final two of every ten scanlines are blank and are not based on the contents of RAM. If 16 scanlines of continuous graphical data are written to a character-block-aligned portion of the screen then they will appear as a continuous block in most modes but in the two non-continuous modes they will be displayed as two blocks of 8 scanlines, separated in the middle by two blank scanlines.

In order to keep track of its position within the display, the Electron maintains an internal display address counter. The same counter is used in both the continuous and non-continuous graphics modes and switching modes mid-frame does not cause any adjustment to the counter.

FireTrack switches from a non-continuous to a continuous graphics mode part way down the display. By using the palette to mask the top area of the display and taking care about when it changes mode it can shift the continuous graphics at the bottom of the display down in two pixel increments because the internal display counter is not incremented on blank scanlines during non-continuous graphics modes.

Exile: sampled speech

Exile turns the Electron's one channel output into a digital speaker for PCM output.

The speaker can be programmatically switched on or off at any time but is permanently attached to a hardware counter so is normally only able to output a square wave. But if set to a frequency outside the human audible range then the ear can't perceive the square wave, only the difference between the speaker being switched on and off. This gives the effect of a simple toggle speaker similar to that seen in the 48 kB Sinclair ZX Spectrum. *Exile* uses this to output 1-bit audio samples.

Chapter 4

Macintosh



The original Macintosh, the first commercially successful personal computer to use a graphical user interface, rather than a command line.



An iMac computer from August 2009, a modern all-in-one Macintosh

The **Macintosh**, or **Mac**, is a series of several lines of personal computers designed, developed, and marketed by Apple Inc. The first Macintosh was introduced on January 24, 1984; it was the first commercially successful personal computer to feature a mouse and a graphical user interface rather than a command-line interface. The company continued to have success through the second half of the 1980s, only to see it dissipate in the 1990s as the personal computer market shifted toward the "Wintel" platform: IBM PC compatible machines running MS-DOS and Microsoft Windows.

Years later, Apple consolidated its multiple consumer-level desktop models into the 1998 iMac all-in-one. This proved to be a sales success and saw the Macintosh brand revitalized, albeit not to the market share level it once had. Current Mac systems are mainly targeted at the home, education, and creative professional markets. They are: the descendants of the original iMac and the entry-level Mac mini desktop models, the Mac Pro tower graphics workstation, the MacBook, MacBook Air and MacBook Pro laptops. The Xserve server was discontinued January 31, 2011.

Production of the Mac is based on a vertical integration model in that Apple facilitates all aspects of its hardware and creates its own operating system that is pre-installed on all Mac computers. This is in contrast to most IBM PC compatibles, where multiple sellers create and integrate hardware intended to run another company's operating software.

Apple exclusively produces Mac hardware, choosing internal systems, designs, and prices. Apple does use third party components, however, such as graphics subsystems from nVidia and ATi. Current Mac CPUs use Intel's x86 architecture; the earliest models (1984–1994) used Motorola's 68k and models from 1994–2006 used the AIM alliance's PowerPC. Apple also develops the operating system for the Mac, currently Mac OS X version 10.6 "Snow Leopard". The modern Mac, like other personal computers, is capable of running alternative operating systems such as Linux, FreeBSD, and, in the case of Intel-based Macs, Microsoft Windows. However, Apple does not license Mac OS X for use on non-Apple computers.

History

1979 to 1984: Development



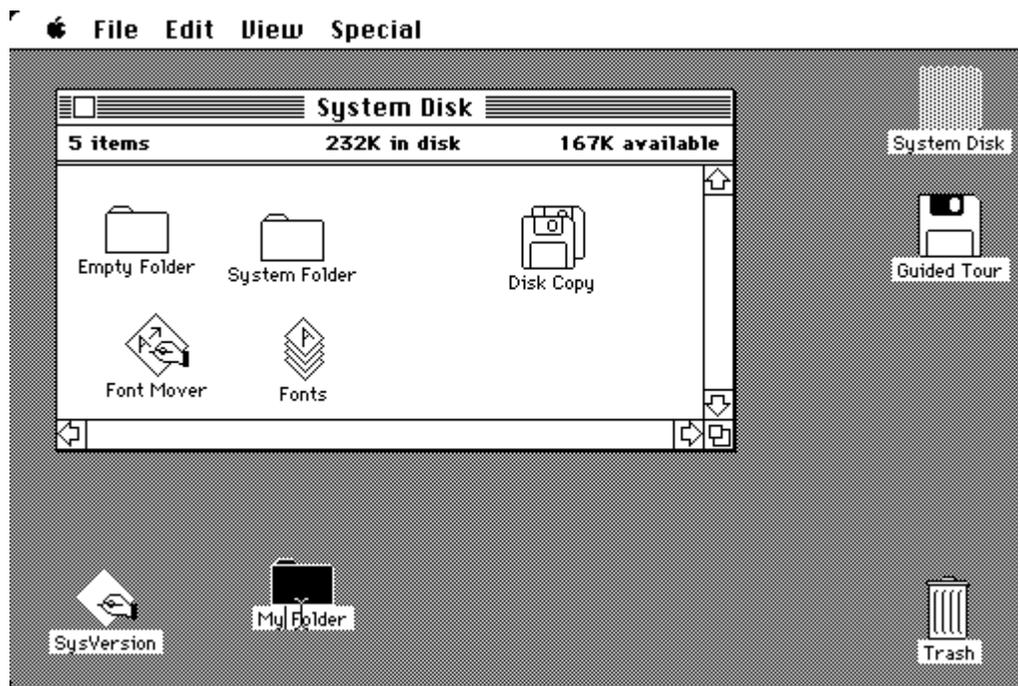
Part of the original Macintosh design team, as seen on the cover of *Revolution in the Valley*.

Left to right: George Crow, Joanna Hoffman, Burrell Smith, Andy Hertzfeld, a Macintosh, Bill Atkinson, Jerry Manock.

The Macintosh project started in the late 1970s with Jef Raskin, an Apple employee, who envisioned an easy-to-use, low-cost computer for the average consumer. He wanted to name the computer after his favorite type of apple, the McIntosh, but the name had to be changed for legal reasons as it was too close, phonetically, to that of the McIntosh audio equipment manufacturer. Steve Jobs requested a release of the name so that Apple could use it, but was denied, forcing Apple to eventually buy the rights to use the name. Raskin was authorized to start hiring for the project in September 1979, and he began to look for an engineer who could put together a prototype. Bill Atkinson, a member of Apple's Lisa team (which was developing a similar but higher-end computer), introduced him to Burrell Smith, a service technician who had been hired earlier that year. Over the years, Raskin assembled a large development team that designed and built the original

Macintosh hardware and software; besides Raskin, Atkinson and Smith, the team included George Crow, Chris Espinosa, Joanna Hoffman, Bruce Horn, Susan Kare, Andy Hertzfeld, Guy Kawasaki, Daniel Kottke, and Jerry Manock.

Smith's first Macintosh board was built to Raskin's design specifications: it had 64 kilobytes (KB) of RAM, used the Motorola 6809E microprocessor, and was capable of supporting a 256×256 pixel black-and-white bitmap display. Bud Tribble, a Macintosh programmer, was interested in running the Lisa's graphical programs on the Macintosh, and asked Smith whether he could incorporate the Lisa's Motorola 68000 microprocessor into the Mac while still keeping the production cost down. By December 1980, Smith had succeeded in designing a board that not only used the 68000, but increased its speed from 5 MHz to 8 MHz; this board also had the capacity to support a 384×256 pixel display. Smith's design used fewer RAM chips than the Lisa, which made production of the board significantly more cost-efficient. The final Mac design was self-contained and had the complete QuickDraw picture language and interpreter in 64 KB of ROM – far more than most other computers; it had 128 KB of RAM, in the form of sixteen 64 kilobit (Kb) RAM chips soldered to the logicboard. Though there were no memory slots, its RAM was expandable to 512 KB by means of soldering sixteen IC sockets to accept 256 Kb RAM chips in place of the factory-installed chips. The final product's screen was a 9-inch, 512x342 pixel monochrome display, exceeding the prototypes.



The original 1984 Mac OS desktop featured a radically new graphical user interface. Users communicated with the computer not through abstract textual commands but rather using a metaphorical desktop that included icons of real life items with which the user was already familiar.

The design caught the attention of Steve Jobs, co-founder of Apple. Realizing that the Macintosh was more marketable than the Lisa, he began to focus his attention on the project. Raskin finally left the Macintosh project in 1981 over a personality conflict with Jobs, and team member Andy Hertzfeld said that the final Macintosh design is closer to Jobs' ideas than Raskin's. After hearing of the pioneering GUI technology being developed at Xerox PARC, Jobs had negotiated a visit to see the Xerox Alto computer and Smalltalk development tools in exchange for Apple stock options. The Lisa and Macintosh user interfaces were partially influenced by technology seen at Xerox PARC and were combined with the Macintosh group's own ideas. Jobs also commissioned industrial designer Hartmut Esslinger to work on the Macintosh line, resulting in the "Snow White" design language; although it came too late for the earliest Macs, it was implemented in most other mid- to late-1980s Apple computers. However, Jobs' leadership at the Macintosh project did not last; after an internal power struggle with new CEO John Sculley, Jobs resigned from Apple in 1985, went on to found NeXT, another computer company, and did not return until 1997 when Apple acquired NeXT.

1984: Introduction



This television commercial, first aired during Super Bowl XVIII, launched the original Macintosh.

The Macintosh 128K was announced to the press in October 1983, followed by an 18-page brochure included with various magazines in December. The Macintosh was introduced by the now famous US\$1.5 million Ridley Scott television commercial, "1984". The commercial most notably aired during the third quarter of Super Bowl XVIII on 22 January 1984 and is now considered a "watershed event" and a "masterpiece." "1984" used an unnamed heroine to represent the coming of the Macintosh (indicated by a Picasso-style picture of Apple's Macintosh computer on her white tank top) as a means of saving humanity from the "conformity" of IBM's attempts to dominate the computer industry. The ad alludes to George Orwell's novel, *Nineteen Eighty-Four*, which described a dystopian future ruled by a televised "Big Brother."

Two days after the 1984 ad aired, the Macintosh went on sale. It came bundled with two applications designed to show off its interface: MacWrite and MacPaint. It was first

demonstrated by Steve Jobs in the first of his famous Mac Keynote speeches, and though the Mac garnered an immediate, enthusiastic following, some labeled it a mere "toy." Because the operating system was designed largely around the GUI, existing text-mode and command-driven applications had to be redesigned and the programming code rewritten. This was a time-consuming task that many software developers chose not to undertake, and could be regarded as a reason for an initial lack of software for the new system. In April 1984 Microsoft's MultiPlan migrated over from MS-DOS, with Microsoft Word following in January 1985. In 1985, Lotus Software introduced Lotus Jazz for the Macintosh platform after the success of Lotus 1-2-3 for the IBM PC, although it was largely a flop. Apple introduced Macintosh Office the same year with the lemmings ad. Infamous for insulting its own potential customers, the ad was not successful.



The Apple Macintosh Plus at the Design Museum in Gothenburg, Sweden

For a special post-election edition of *Newsweek* in November 1984, Apple spent more than US\$2.5 million to buy all 39 of the advertising pages in the issue. Apple also ran a "Test Drive a Macintosh" promotion, in which potential buyers with a credit card could take home a Macintosh for 24 hours and return it to a dealer afterwards. While 200,000 people participated, dealers disliked the promotion, the supply of computers was insufficient for demand, and many were returned in such a bad shape that they could no longer be sold. This marketing campaign caused CEO John Sculley to raise the price from US\$1,995 to US\$2,495 (adjusting for inflation, about \$5,200 in 2010).

1985 to 1989: Desktop publishing era

In 1985, the combination of the Mac, Apple's LaserWriter printer, and Mac-specific software like Boston Software's MacPublisher and Aldus PageMaker enabled users to design, preview, and print page layouts complete with text and graphics—an activity to become known as desktop publishing. Initially, desktop publishing was unique to the Macintosh, but eventually became available for other platforms as well. Later, applications such as Macromedia FreeHand, QuarkXPress, Adobe Photoshop, and Adobe Illustrator strengthened the Mac's position as a graphics computer and helped to expand the emerging desktop publishing market.

The limitations of the first Mac soon became clear: it had very little memory, even compared with other personal computers in 1984, and could not be expanded easily; and it lacked a hard disk drive or the means to attach one easily. Many small companies sprang up to address the memory issue, by upgrading the 128K Mac to 512 KB, by removing the computer's 16 memory chips and replacing them with larger-capacity chips, a tedious operation that was not always successful. In October 1985, Apple increased the Mac's memory to 512 KB, and offered an upgrade for 128K Macs that involved replacing the logic board. In an attempt to improve connectivity, Apple released the Macintosh Plus on January 10, 1986 for US\$2,600. It offered one megabyte of RAM, easily expandable to four by the use of socketed RAM boards, and a SCSI parallel interface, allowing up to seven peripherals—such as hard drives and scanners—to be attached to the machine. Its floppy drive was increased to an 800 KB capacity. The Mac Plus was an immediate success and remained in production, unchanged, until October 15, 1990; on sale for just over four years and ten months, it was the longest-lived Macintosh in Apple's history.



The Macintosh II, one of the first expandable Macintosh models

Updated Motorola CPUs made a faster machine possible, and in 1987 Apple took advantage of the new Motorola technology and introduced the Macintosh II, which used a 16 MHz Motorola 68020 processor. The primary improvement in the Macintosh II was Color QuickDraw in ROM, a color version of the graphics language which was the heart of the machine. Among the many innovations in Color QuickDraw were an ability to handle any display size, any color depth, and multiple monitors.

The Macintosh II marked the start of a new direction for the Macintosh, as now for the first time it had an open architecture with several NuBus expansion slots, support for color graphics and external monitors, and a modular design similar to that of the IBM PC. It had an internal hard drive and a power supply with a fan, which was initially fairly loud. One third-party developer sold a device to regulate fan speed based on a heat sensor, but it voided the warranty. Later Macintosh computers had quieter power supplies and hard drives.

In September 1986, Apple introduced the Macintosh Programmer's Workshop, or MPW that allowed software developers to create software for Macintosh on Macintosh, rather than cross compiling from a Lisa. In August 1987, Apple unveiled HyperCard, and

introduced MultiFinder, which added cooperative multitasking to the Macintosh. Apple began bundling both with every Macintosh.

The Macintosh SE was released at the same time as the Macintosh II, as the first compact Mac with a 20 MB internal hard drive and one expansion slot. The SE's expansion slot was located inside the case along with the CRT, potentially exposing an upgrader to high voltage. For this reason Apple recommended users bring their SE to an authorized Apple dealer to have upgrades performed. The SE also updated Jerry Manock and Terry Oyama's original design and shared the Macintosh II's *Snow White* design language, as well as the new Apple Desktop Bus (ADB) mouse and keyboard that had first appeared on the Apple IIGS some months earlier.

In 1987, Apple spun off its software business as Claris. It was given the code and rights to several applications that had been written within Apple, notably MacWrite, MacPaint, and MacProject. In the late 1980s, Claris released a number of revamped software titles; the result was the "Pro" series, including MacPaint Pro, MacDraw Pro, MacWrite Pro, and FileMaker Pro. To provide a complete office suite, Claris purchased the rights to the Informix Wingz spreadsheet on the Mac, renaming it Claris Resolve, and added the new presentation software Claris Impact. By the early 1990s, Claris applications were shipping with the majority of consumer-level Macintoshes and were extremely popular. In 1991, Claris released ClarisWorks, which soon became their second best-selling application. When Claris was reincorporated back into Apple in 1998, ClarisWorks was renamed AppleWorks beginning with version 5.0.



The Macintosh Portable was Apple's first battery-powered Macintosh. It was available from 1989 to 1991 and could run System 6 and System 7.

In 1988, Apple sued Microsoft and Hewlett-Packard on the grounds that they infringed Apple's copyrighted GUI, citing (among other things) the use of rectangular, overlapping, and resizable windows. After four years, the case was decided against Apple, as were later appeals. Apple's actions were criticized by some in the software community, including the Free Software Foundation (FSF), who felt Apple was trying to monopolize on GUIs in general, and boycotted GNU software for the Macintosh platform for seven years.

With the new Motorola 68030 processor came the Macintosh IIx in 1988, which had benefited from internal improvements, including an on-board MMU. It was followed in 1989 by a more compact version with fewer slots (the Macintosh IIcx) and a version of the Mac SE powered by the 16 MHz 68030, the Macintosh SE/30. Later that year, the Macintosh IIci, running at 25 MHz, was the first Mac to be "32-bit clean," allowing it to natively support more than 8 MB of RAM, unlike its predecessors, which had "32-bit dirty" ROMs (8 of the 32 bits available for addressing were used for OS-level flags). System 7 was the first Macintosh operating system to support 32-bit addressing. Apple

also introduced the Macintosh Portable, a 16 MHz 68000 machine with an active matrix flat panel display that was backlit on some models. The following year the Macintosh IIfx, starting at US\$9,900, was unveiled. Apart from its fast 40 MHz 68030 processor, it had significant internal architectural improvements, including faster memory and two Apple II CPUs dedicated to I/O processing.

1990 to 1998: Growth and decline

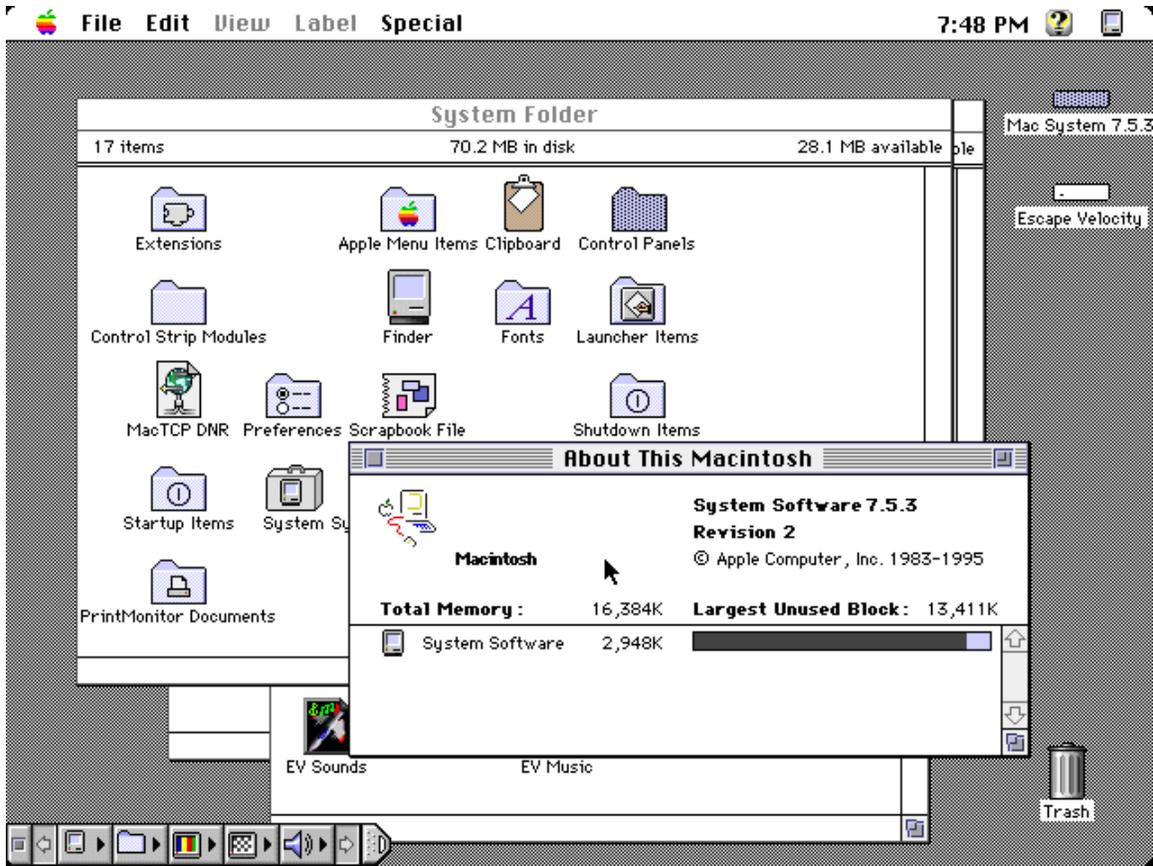


The Macintosh Classic, Apple's early 1990s budget model



The PowerBook 100 (shown here), 140 and 170 introduced a line of professional laptop Macs. They pioneered notebook ergonomics by placing the keyboard behind a palm rest.

Microsoft Windows 3.0, which began to approach the Macintosh operating system in both performance and feature set, was released in May 1990 and was a less expensive alternative to the Macintosh platform. Apple's response was to introduce a range of relatively inexpensive Macs in October 1990. The Macintosh Classic, essentially a less expensive version of the Macintosh Plus, was the least expensive Mac until early 2001. The 68020-powered Macintosh LC, in its distinctive "pizza box" case, offered color graphics and was accompanied by a new, low-cost 512×384 pixel monitor. The Macintosh IIsx was essentially a 20 MHz IIsx with only one expansion slot. All three machines sold well, although Apple's profit margin was considerably lower than on earlier machines.



System 7 was the first major upgrade of the Macintosh operating system



OS 8 was the second major upgrade of the Mac OS. OS 8.6 shown

Apple improved Macintosh computers by introducing models equipped with newly available processors from the 68k lineup. The Macintosh Classic II and Macintosh LC II, which used a 16 MHz 68030 CPU, were joined in 1991 by the Macintosh Quadra 700 and 900, the first Macs to employ the faster Motorola 68040 processor. In 1994, Apple

abandoned Motorola CPUs for the RISC PowerPC architecture developed by the AIM alliance of Apple Computer, IBM, and Motorola. The Power Macintosh line, the first to use the new chips, proved to be highly successful, with over a million PowerPC units sold in nine months.

Apple replaced the Macintosh Portable in 1991 with the first of the PowerBook line: the PowerBook 100, a miniaturized Portable; the 16 MHz 68030 PowerBook 140; and the 25 MHz 68030 PowerBook 170. They were the first portable computers with the keyboard behind a palm rest, and with a built-in pointing device (a trackball) in front of the keyboard. The 1993 PowerBook 165c was Apple's first portable computer to feature a color screen, displaying 256 colors with 640 x 400 pixel resolution. The second-generation of PowerBooks, the 68040-equipped 500 series, introduced the trackpad, integrated stereo speakers and built-in Ethernet to the laptop form factor in 1994.

As for Mac OS, System 7 was a 32-bit rewrite from Pascal to C++ that introduced virtual memory, and improved the handling of color graphics, memory addressing, networking, and co-operative multitasking. Also during this time, the Macintosh began to shed the "Snow White" design language, along with the expensive consulting fees they were paying to Frogdesign, in favor of bringing the work in-house by establishing the Apple Industrial Design Group. They became responsible for crafting a new look to go with the new operating system and all other Apple products.

Despite these technical and commercial successes, Microsoft and Intel began to rapidly lower Apple's market share with the Windows 95 operating system and Pentium processors respectively. These significantly enhanced the multimedia capability and performance of IBM PC compatible computers, and brought Windows still closer to the Mac GUI. Furthermore, Apple had created too many similar models that confused potential buyers. At one point Apple's product lineup was subdivided into Classic, LC, II, Quadra, Performa, and Centris models, with essentially the same computer being sold under a number of different names. These models competed against the Macintosh clones, hardware manufactured by third-parties that ran Apple's System 7. This succeeded in increasing the Macintosh's market share somewhat and provided cheaper hardware for consumers, but hurt Apple financially as existing Apple customers began to buy cheaper clones.

When Steve Jobs returned to Apple in 1997, he ordered that the OS that had been previewed as version 7.7 be branded Mac OS 8 (in place of the never-to-appear Copland OS). Since Apple had licensed only System 7 to third-parties, this move effectively ended the clone line. The decision caused significant financial losses for companies like Motorola, who produced the StarMax, Umax, who produced the SuperMac, and Power Computing Corporation, who offered several lines Mac clones, including PowerWave, PowerTower, and PowerTower Pro. These companies had invested substantial resources in creating their own Mac-compatible hardware. Apple bought out Power Computing's license, but allowed Umax to continue selling Mac clones until their license expired, as they had a sizeable presence in the lower-end segment that Apple did not.

1998 to 2005: New beginnings



The original "Bondi Blue" iMac G3. Introduced in 1998, it led Apple's return to profitability. However, the associated mouse proved to be one of consumers' least favorite Apple products.

In 1998, a year after Steve Jobs had returned to the company, Apple introduced an all-in-one Macintosh called the iMac. Its translucent plastic case, originally Bondi blue and later many other colors, is considered an industrial design landmark of the late 1990s. The iMac did away with most of Apple's standard (and usually proprietary) connections, such as SCSI and ADB, in favor of two USB ports. It also had no internal floppy disk drive and instead included a CD-ROM drive for installing software, but was incapable of writing to CDs or other media without external third-party hardware. The iMac proved to be phenomenally successful, with 800,000 units sold in 139 days, making the company

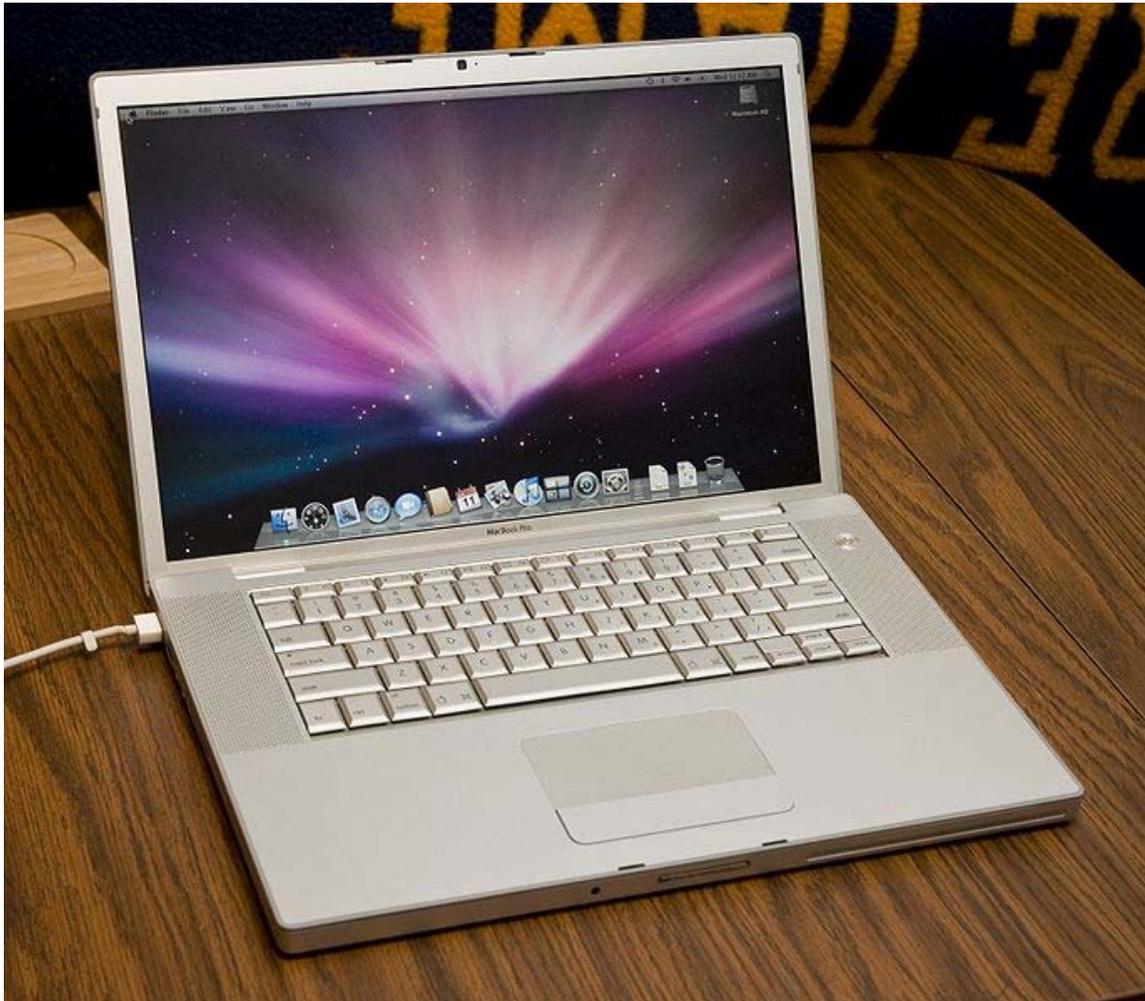
an annual profit of US\$309 million—Apple's first profitable year since Michael Spindler took over as CEO in 1995. The iMacs's "blue and white" aesthetic was applied to the Power Macintosh, and then to a new product, the iBook. Introduced in July 1999, the iBook was Apple's first consumer-level laptop computer, filling in the "missing square" of Apple's four-tiered consumer/professional laptop/desktop product strategy previously announced by Jobs. More than 140,000 pre-orders were placed before it started shipping in September, and by October it was as much a sales hit as the iMac.

In early 2001, Apple began shipping computers with CDRW drives for the first time. Apple had been emphasizing the Mac's ability to play DVDs by including DVD-ROM and DVD-RAM drives as standard. Steve Jobs admitted that Apple had been "late to the party" on writable CD technology but felt that Macs could become a "digital hub" that linked and enabled an "emerging digital lifestyle". Apple would later introduce an update to its iTunes music player software that could burn CDs, along with a controversial "Rip, Mix, Burn" advertising campaign that some felt encouraged media piracy. This accompanied the release of the iPod, Apple's first successful handheld device.

Apple continued to add new products to their lineup, such as the Power Mac G4 Cube, the eMac for the education market and PowerBook G4 laptop for professionals. The original iMac used a G3 processor, but the G4 and then G5 chips were accompanied by successive new designs, dropping the array of colors in favor of white plastic. Current iMacs use aluminum enclosures. On January 11, 2005, Apple announced the release of the Mac Mini priced at US\$499, the least expensive Mac to date.

Mac OS continued to evolve up to version 9.2.2, including retrofits such as the addition of a nanokernel and support for Multiprocessing Services 2.0 in Mac OS 8.6. Ultimately its dated architecture made replacement necessary. Initially developed in the Pascal programming language, it was substantially rewritten in C++ for System 7. From its beginnings on a 128k 8 MHz machine, it had grown to support Apple's latest 1 GHz G4-equipped Macs. But since its architecture was laid down, OS features like preemptive multitasking and protected memory had become feasible on the kind of hardware Apple manufactured - features that were already common on Apple's competition. As such, Apple introduced Mac OS X, a fully overhauled Unix-based successor to Mac OS 9, using Darwin, XNU, and Mach as foundations, and based on NEXTSTEP. Mac OS X was not released to the public until September 2000, as the Mac OS X Public Beta, with a revamped user interface Apple called "Aqua". At US\$29.99, it allowed adventurous Mac users to sample Apple's new operating system and provide feedback for the actual release. The initial release of Mac OS X, 10.0 (nicknamed Cheetah), was released on March 24, 2001. Older Mac OS applications could still run under early Mac OS X versions, using an environment called Classic. Subsequent releases of Mac OS X were 10.1 "Puma" (September 25, 2001), 10.2 "Jaguar" (August 24, 2002), 10.3 "Panther" (October 24, 2003), 10.4 "Tiger" (April 29, 2005), 10.5 "Leopard" (October 26, 2007), 10.6 "Snow Leopard" (August 28, 2009), and 10.7 "Lion" scheduled for 2011. Leopard and Snow Leopard each received certification as a Unix implementation by The Open Group.

2006 onward: Intel era



The MacBook Pro is the first Mac notebook to use an Intel processor. It was released at Macworld 2006.

Apple discontinued the use of PowerPC microprocessors in 2006. At WWDC 2005, Steve Jobs revealed this transition and also noted that Mac OS X was in development to run both on Intel and PowerPC architecture from the very beginning. All new Macs now use x86 processors made by Intel, and some Macs were given new names to signify the switch. Intel-based Macs can run pre-existing software developed for PowerPC using an emulator called Rosetta, although at noticeably slower speeds than native programs, and the Classic environment is unavailable. Intel chips introduced the potential to run the Microsoft Windows operating system natively on Apple hardware, without emulation software such as Virtual PC. In March 2006, a group of hackers announced that they were able to run Windows XP on an Intel-based Mac. The group released their software as open source and has posted it for download on their website. On April 5, 2006, Apple announced the public beta availability of their own Boot Camp software that allows owners of Intel-based Macs to install Windows XP on their machines; later versions

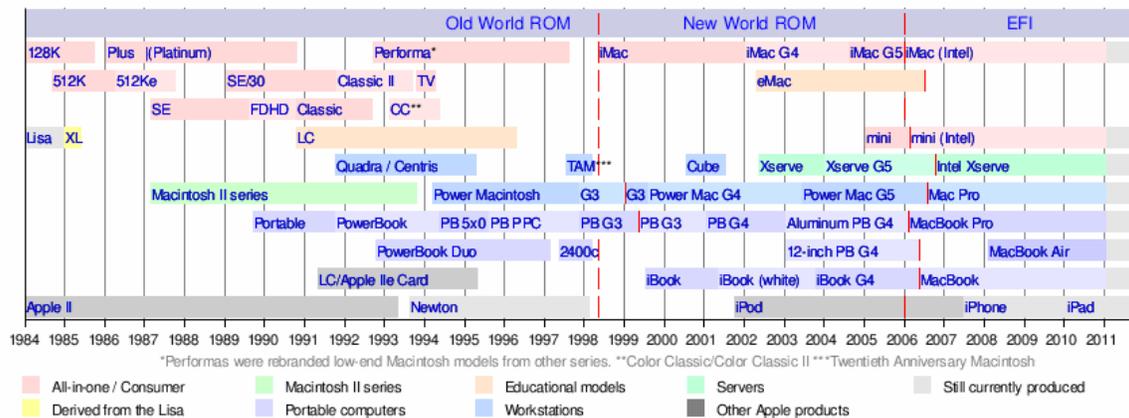
added support for Windows Vista. Boot Camp became a standard feature in Mac OS X 10.5, while support for Classic was dropped from PowerPC Macs.

Apple's recent industrial design has shifted to favor aluminum and glass that is billed as environmentally friendly. The iMac, MacBook Pro and MacBook Air lines use aluminum enclosures, and are now made of a single unibody. Chief designer Jonathan Ive continues to guide products towards a minimalist and simple feel, including the elimination of replaceable batteries in notebooks. Multi-touch gestures from the iPhone's interface have been applied to the Mac line in the form of touch pads on notebooks and the Magic Mouse and Magic Trackpad for desktops.

In recent years, Apple has seen a significant boost in sales of Macs. Many claim that this is due, in part, to the success of the iPod and the iPhone, a halo effect whereby satisfied iPod or iPhone owners purchase more Apple equipment. The inclusion of the Intel chips is also a factor. From 2001 to 2008, Mac sales increased continuously on an annual basis. Apple reported sales of 3.36 million Macs during the 2009 holiday season.

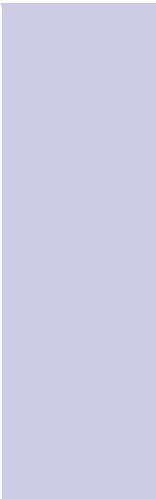
On February 24, 2011, Apple was the first company to bring to market a computer that utilized Intel's new Thunderbolt (codename Light Peak) I/O interface. Using the same physical interface as a minidisplay port, and backwards compatible with that standard, Thunderbolt boasts two-way transfer speeds of 10 Gbps.

Timeline of Macintosh models



Product line

	Compact	Consumer	Professional
	Mac mini	iMac	Mac Pro
Desktop			
	Entry-level; ships without keyboard, mouse, or monitor; uses Intel Core 2	All-in-one;	

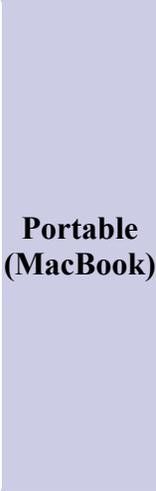


Duo processors

available in 21.5" and 27" screen sizes; uses Intel Core 2 Duo, Intel Core i5, or Intel Core i7 processors



Workstation desktop; highly customizable; uses up to two Intel Xeon 5500 "Gainestown" or Xeon 3500 "Bloomfield" quad-core processors



Portable (MacBook)

MacBook Air



11.6" or 13.3" ultraportable with aluminum casing; uses Intel Core 2 Duo processors

MacBook



13.3" laptop with white polycarbonate casing; uses Intel Core 2 Duo processors

MacBook Pro



13.3", 15.4" or 17" models with aluminum casing; uses Intel Core 2 Duo, Intel Core i5, or Intel Core i7 processors



Server

Mac mini Server



An additional Mac mini configuration without an internal optical drive. Ships with Mac OS X Server installed and two internal 500 GB hard drives for a total of 1 TB of capacity.

Mac Pro Server

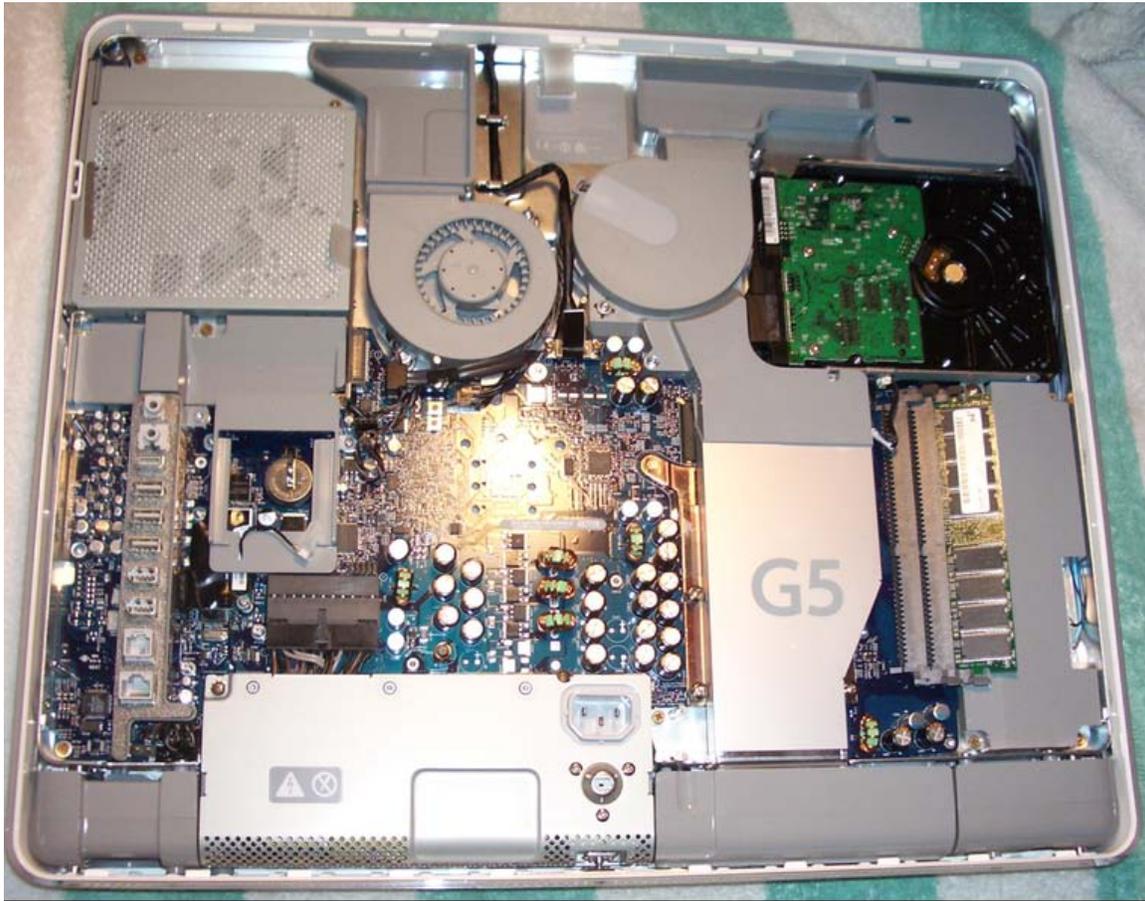


An additional Mac Pro server configuration. Ships with Mac OS X Server installed. 4x2=8 GiB memory, and 2x1=2 TB hard-disk drive space.

Xserve (discontinued January 2011)

Hardware and software

Hardware



The internals of the original 20-inch iMac G5

Apple directly sub-contracts hardware production to Asian original equipment manufacturers such as Asus, maintaining a high degree of control over the end product. By contrast, most other companies (including Microsoft) create software that can be run on hardware produced by a variety of third-parties, like Dell, HP/Compaq, and Lenovo. Consequently, the Macintosh buyer has comparably fewer options.

The current Mac product family uses Intel x86-64 processors. Apple introduced an emulator during the transition from PowerPC chips (called Rosetta), much as it did during the transition from Motorola 68000 architecture a decade earlier. The Macintosh is the only mainstream computer platform to have successfully transitioned to a new CPU architecture, and has done so twice. All current Mac models ship with at least 2 GB RAM as standard. Current Mac computers use ATI Radeon or nVidia GeForce graphics cards. All current Macs (except for the MacBook Air) ship with an optical media drive that includes a dual-function DVD/CD burner, called the SuperDrive. Macs include two standard data transfer ports: USB and FireWire (except for the MacBook Air and

MacBook that do not include FireWire). MacBook Pro computers now also feature the "Thunderbolt" port, which Apple claims can transfer data at speeds up to 10 gigabytes per second. USB was introduced in the 1998 iMac G3 and is ubiquitous today, while FireWire is mainly reserved for high-performance devices such as hard drives or video cameras. Starting with a new iMac G5 released in October 2005, Apple started to include built-in iSight cameras to appropriate models, and a media center interface called Front Row that can be operated by an Apple Remote or keyboard for accessing media stored on the computer.

Apple's Disk Operating System allows for more storage over competing products through the use of 16-sector technology. This allows for nearly 20% more storage over the 13-sector technology used in PCs.

Apple was initially reluctant to embrace mice with multiple buttons and scroll wheels. Macs did not natively support multiple buttons, even from third parties, until Mac OS X arrived in 2001. Apple continued to offer only single button mice, with wired and Bluetooth wireless versions, until August 2005, when it introduced the Mighty Mouse. While it looked like a traditional one-button mouse, it actually had four buttons and a scroll ball, capable of independent *x*- and *y*-axis movement. A Bluetooth version followed in July 2006. In October 2009, Apple introduced the Magic Mouse which uses multi-touch gesture recognition similar to the iPhone instead of a physical scroll wheel or ball. It is available only in Bluetooth, and the Mighty Mouse (re-branded as "Apple Mouse") is available with a cord. Apple also features the "Magic Trackpad" as a means to control Macintosh desktop computers such as the iMac or Mac Pro. This was introduced in 2010.

Software

The original Macintosh was the first successful personal computer to use a graphical user interface devoid of a command line. It used a desktop metaphor, depicting real-world objects like documents and a trashcan as icons onscreen. The *System* software introduced in 1984 with the first Macintosh and renamed *Mac OS* in 1997, continued to evolve until version 9.2.2. In 2001, Apple introduced Mac OS X, based on Darwin and NEXTSTEP; its new features included the Dock and the Aqua user interface. During the transition, Apple included an emulator known as Classic allowing users to run Mac OS 9 applications under Mac OS X, version 10.4 and earlier on PowerPC machines. The most recent version is Mac OS X v10.6 "Snow Leopard." In addition to Snow Leopard, all new Macs are bundled with assorted Apple-produced applications, including iLife, the Safari web browser and the iTunes media player. Apple released Mac OS X 10.7 in 2010, which will be available in the summer of 2011. This operating system features many new features such as: Mission Control, the Mac App Store (available now by software update), and launchpad which is an iPad like way of viewing apps currently installed on Mac. Apple is also releasing a feature known as "resume" which is similar to the hibernate function, found on Microsoft Windows.

Mac OS X enjoys a near-absence of the types of malware and spyware that affect Microsoft Windows users. Mac OS X has a smaller usage share compared to Microsoft

Windows (roughly 5% and 92%, respectively), but it also has secure UNIX roots. Worms as well as potential vulnerabilities were noted in February 2006, that led some industry analysts and anti-virus companies to issue warnings that Apple's Mac OS X is not immune to malware. Apple routinely issues security updates for its software.

Originally, the hardware architecture was so closely tied to the Mac OS operating system that it was impossible to boot an alternative operating system. The most common workaround, used even by Apple for A/UX, was to boot into Mac OS and then to hand over control to a program that took over the system and acted as a boot loader. This technique was no longer necessary with the introduction of Open Firmware-based PCI Macs, though it was formerly used for convenience on many Old World ROM systems due to bugs in the firmware implementation. Now, Mac hardware boots directly from Open Firmware (most PowerPC-based Macs) or EFI (all Intel-based Macs), and Macs are no longer limited to running just Mac OS X.

Following the release of the Intel-based Mac, third-party platform virtualization software such as Parallels Desktop, VMware Fusion, and VirtualBox began to emerge. These programs allow users to run Microsoft Windows or previously Windows-only software on Macs at near native speed. Apple also released Boot Camp and Mac-specific Windows drivers that help users to install Windows XP or Vista and natively dual boot between Mac OS X and Windows. Though not condoned by Apple, it is possible to run the Linux operating system using Boot camp or other virtualization workarounds.

Because Mac OS X is a UNIX system, borrowing heavily from FreeBSD, many applications written for Linux or BSD run on Mac OS X, often using X11. Apple's smaller market share than Microsoft's means that a smaller range of shareware is available, but many popular commercial software applications from large developers such as Microsoft Office and Adobe Photoshop are ported to both Mac OS and Windows. And much of open source software like the Firefox web browser and the OpenOffice.org office suite are cross-platform and run natively.

Advertising

Macintosh advertisements have usually attacked the established market leader, directly or indirectly. They tend to portray the Mac as an alternative to overly complex or unreliable PCs. Apple hyped the introduction of the original Mac with their 1984 commercial that aired during the Super Bowl. It was supplemented by a number of printed pamphlets and other TV ads demonstrating the new interface and emphasizing the mouse. Many more brochures for new models like the Macintosh Plus and the Performa followed. In the 1990s, Apple started the "What's on your PowerBook?" campaign, with print ads and television commercials featuring celebrities describing how the PowerBook helps them in their businesses and everyday lives. In 1995, Apple responded to the introduction of Windows 95 with several print ads and a television commercial demonstrating its disadvantages and lack of innovation. In 1997 the Think Different campaign introduced Apple's new slogan, and in 2002 the Switch campaign followed. The most recent

advertising strategy by Apple is the Get a Mac campaign, with North American, UK and Japanese variants.

Today, Apple introduces new products at "special events" at the Apple Town Hall auditorium, and keynotes at the Apple Worldwide Developers Conference, and (formerly) trade shows like the Apple Expo and the MacWorld Expo. The events typically draw a large gathering of media representatives and spectators, and are preceded by speculation about possible new products. In the past, special events have been used to unveil its desktop and notebook computers such as the iMac and MacBook, and other consumer electronic devices like the iPod, Apple TV, and iPhone, as well as provide updates on sales and market share statistics. Apple has begun to focus its advertising on its retail stores instead of these trade shows; the last MacWorld keynote was in 2009.

Market share and user demographics

Since the introduction of the Macintosh, Apple has struggled to gain a significant share of the personal computer market. At first, the Macintosh 128K suffered from a dearth of available software compared to IBM's PC, resulting in disappointing sales in 1984 and 1985. It took 74 days for 50,000 units to sell. Market share is measured by browser hits, sales and installed base. If using the browser metric, Mac market share has increased substantially in 2007. If measuring market share by installed base, there were more than 20 million Mac users by 1997, compared to an installed base of around 340 million Windows PCs. Statistics from late 2003 indicate that Apple had 2.06 percent of the desktop share in the United States that had increased to 2.88 percent by Q4 2004. As of October 2006, research firms IDC and Gartner reported that Apple's market share in the U.S. had increased to about 6 percent. Figures from December 2006, showing a market share around 6 percent (IDC) and 6.1 percent (Gartner) are based on a more than 30 percent increase in unit sale from 2005 to 2006. The installed base of Mac computers is hard to determine, with numbers ranging from 5% (estimated in 2009) to 16% (estimated in 2005). Mac OS X's share of the OS market increased from 7.31% in December 2007 to 9.63% in December 2008, which is a 32% increase in market share during 2008, compared with a 22% increase during 2007.

As of March 2010, OS X share has increased to 10.9%. Whether the size of the Mac's market share and installed base is relevant, and to whom, is a hotly debated issue. Industry pundits have often called attention to the Mac's relatively small market share to predict Apple's impending doom, particularly in the early and mid 1990s when the company's future seemed bleakest. Others argue that market share is the wrong way to judge the Mac's success. Apple has positioned the Mac as a higher-end personal computer, and so it may be misleading to compare it to a budget PC. Because the overall market for personal computers has grown rapidly, the Mac's increasing sales numbers are effectively swamped by the industry's expanding sales volume as a whole. Apple's small market share, then, gives the impression that fewer people are using Macs than did ten years ago, when exactly the opposite is true. Soaring sales of the iPhone and iPad mean that the portion of Apple's profits represented by the Macintosh has declined in 2010, dropping to 24% from 46% two years earlier. Others try to de-emphasize market share,

citing that it is rarely brought up in other industries. Regardless of the Mac's market share, Apple has remained profitable since Steve Jobs' return and the company's subsequent reorganization. Notably, a report published in the first quarter of 2008 found that Apple had a 14% market share in the personal computer market in the US, including 66% of all computers over \$1,000. Market research indicates that Apple draws its customer base from a higher-income demographic than the mainstream personal computer market.

Chapter 5

Amstrad CPC

Amstrad CPC



Manufacturer	Amstrad
Type	Personal computer
Release date	1984
Discontinued	1990
Media	Cassette tape, 3-inch floppy disks
Operating system	AMSDOS with Locomotive BASIC 1.0 or 1.1; CP/M 2.2 or 3.0
CPU	Zilog Z80A @ 4 MHz
Memory	64 or 128 kB, extendable to 576 kB

The **Amstrad CPC** (short for *Colour Personal Computer*) is a series of 8-bit home computers produced by Amstrad between 1984 and 1990. It was designed to compete in the mid-1980s home computer market dominated by the Commodore 64 and the Sinclair ZX Spectrum, where it successfully established itself primarily in the United Kingdom, France, Spain, and the German-speaking parts of Europe.

The series spawned a total of six distinct models: The *CPC464*, *CPC664*, and *CPC6128* were highly successful competitors in the European home computer market. The later *plus* models, *464plus* and *6128plus*, efforts to prolong the system's lifecycle with

hardware updates, were considerably less successful, as was the attempt to repackage the *plus* hardware into a game console as the *GX4000*.

The CPC models' hardware is based on the Zilog Z80A CPU, complemented with either 64 or 128 kB of memory. Their computer-in-a-keyboard design prominently features an integrated mass storage device, either a compact cassette deck or 3" floppy disk drive. The main units were only sold bundled with a colour or monochrome monitor that doubles as the main unit's power supply. Additionally, a wide range of first and third party hardware extensions such as disk drives (for the CPC464), printers, and memory extensions, was available.

The CPC series was pitched against other home computers primarily used to play video games and enjoyed a strong supply of game software. The comparatively low price for a complete computer system with dedicated monitor, its high resolution monochrome text and graphic capabilities and the possibility to run CP/M software also rendered the system attractive for business users, which is reflected by a wide selection of application software.

During its lifetime, the CPC series sold approximately three million units.



The Schneider CPC6128 was a Schneider-branded version of the Amstrad CPC6128, and very similar in appearance.

Models

The original range

The philosophy behind the CPC series was twofold, firstly the concept was of an “all-in-one” where the computer, keyboard and its data storage device were combined in a single unit, and optionally sold with its own dedicated display monitor. Most home computers at that time such as Sinclair’s ZX- series, the Commodore 64 and the BBC Micro relied on the use of the domestic television set and a separately connected tape recorder or disk drive. In itself, the all-in-one concept was not new, having been seen before on business-oriented machines and the Commodore PET, but in the home computer space, it predated the Apple Macintosh by almost a year.

Secondly, Amstrad founder Alan Sugar wanted the machine to resemble a “real computer, similar to what someone would see being used to check them in at the airport for their holidays”, and for the machine to not look like "a pregnant calculator" – in reference presumably to the Sinclair ZX81 and ZX Spectrum with their low cost, membrane-type keyboards.

CPC464

The CPC464 featured 64 kB RAM and an internal cassette tape deck. It was introduced in June 1984 in the UK. Initial suggested retail prices for the CPC464 were GBP249.00/DM899.00 with a green screen and GBP359.00/DM1398.00 with a colour monitor. Following the introduction of the CPC6128 in late 1985, suggested retail prices for the CPC464 were cut by GBP50.00/DM100.00.

In 1990, the 464plus replaced the CPC464 in the model line-up, and production of the CPC464 was discontinued.

CPC664



A CPC664 main unit (German Schneider-brand variant)

The CPC664 features 64 kB RAM and an internal 3-inch floppy disk drive. It was introduced in May 1985 in the UK. Initial suggested retail prices for the CPC664 were GBP339.00/DM1198.00 with a green screen and GBP449.00/DM1998.00 with a colour monitor.

After the successful release of the CPC464, consumers were constantly asking for two improvements: more memory and an internal disk drive. For Amstrad, the latter was easier to realize first, with a deliberately low-key introduction of the CPC664. It was positioned not only as the lowest cost disc system, but also the lowest cost CP/M 2.2 machine at the time. However, it was not supposed to replace but complement the CPC464 which, upon launch of the CPC664, was neither discontinued nor reduced in price.

Compared to the CPC464, the CPC664's main unit has been significantly redesigned, not only to accommodate the floppy disk drive but also with a redesigned keyboard area. Touted "ergonomic" by Amstrad's promotional material, the keyboard is noticeably tilted to the front with MSX-style cursor keys above the numeric keypad that now carries "function key" labeling. The CPC464's multicoloured keyboard has been quietened to a grey and pale blue colour scheme on the CPC664.

The back of the CPC664 main unit features the same connectors as the CPC464, with the exception of an additional 12V power lead. Unlike the CPC464's cassette tape drive that could be powered off the main unit's 5V voltage, the CPC664's integrated floppy disk drive requires an additional 12V voltage. This voltage had to be separately supplied by an updated version of the bundled green screen/colour monitor (GT-65 and CTM-644 respectively).

The CPC664 was only produced for approximately six months. In late 1985, when the CPC6128 was introduced in Europe, Amstrad decided not to keep three models in the line-up, and production of the CPC664 was discontinued.

CPC6128

The CPC6128 features 128 kB RAM and an internal 3-inch floppy disc drive. Aside from various hardware and firmware improvements, one of the CPC6128's most prominent features is the compatibility with the CP/M+ operating system that rendered it attractive for business uses.

The CPC6128 was released in August 1985 and initially only sold in the USA. Imported and distributed by *Indescomp, Inc. of Chicago*, it was the first Amstrad product to be sold in the United States, a market that at the time was traditionally hostile towards European computer manufacturers. By the end of 1985, it arrived in Europe and replaced the CPC664 in the CPC model line-up. Initial suggested retail prices for the CPC6128 were USD699.00/GBP299.00/DM1598.00 with a green screen and USD799.00/GBP399.00/DM2098.00 with a colour monitor.

In 1990, the 6128plus replaced the CPC6128 in the model line-up, and production of the CPC6128 was discontinued.

The *plus* range

In 1990, confronted with a changing home computer market, Amstrad decided to refresh the CPC model range by introducing a new range variantly labeled *plus* or *PLUS*, *1990*, or *CPC+ range*. The main goals were numerous enhancements to the existing CPC hardware platform, to restyle the casework to provide a contemporary appearance, and to enhance support of cartridge media. The new model palette includes three variants, the *464plus* and *6128plus* computers and the *GX4000* video game console. The "CPC" abbreviation has been dropped from the model names.

The redesign significantly enhanced the CPC hardware, mainly to rectify its previous shortcomings as a gaming platform. The redesigned video hardware allows for hardware sprites and soft scrolling, with a colour palette extended from 17 out of 27 to 32 out of 4096 colours. The enhanced sound hardware offers automatic DMA transfer, allowing more complex sound effects with a significantly reduced processor overhead. Other hardware enhancements include the support of analogue joysticks, 8-bit printers, and ROM cartridges up to 4 Mbits.

The new range of models was intended to be completely backward compatible with the original CPC models. Its enhanced features are only available after a deliberately obscure unlocking mechanism has been triggered, thus preventing existing CPC software from accidentally invoking them.

Despite the significant hardware enhancements, the hardware platform was already outdated at launch and failed to attract both customers and software producers who had already been moving towards 16-bit systems. The plus range was a commercial failure, and production was discontinued shortly after its introduction in 1990.

464plus, 6128plus



A *6128plus* main unit (with Spanish keyboard layout)

The *464plus* and *6128plus* models were intended as "more sophisticated and stylish" replacements of the CPC464 and CPC6128. Based on the redesigned plus hardware platform, they share the same base characteristics as their predecessors: The *464plus* is equipped with 64 kB RAM and a cassette tape drive, the *6128plus* features 128 kB RAM and a 3" floppy disk drive. Both models share a common case layout with a keyboard taken over from the CPC6128 model, and the respective mass storage drive inserted in a case breakout.

In order to simplify the EMC screening process, the edge connectors of the previous models have been replaced with micro-ribbon connectors as previously used on the German Schneider CPC6128. As a result, a wide range of extensions for the original CPC range is connector-incompatible with the *464plus* and *6128plus*. In addition, the *6128plus* does not have a tape socket for an external tape drive.

The plus range is not equipped with an on-board ROM, and thus the *464plus* and the *6128plus* do not contain a firmware. Instead, Amstrad provided the firmware for both models via the ROM extension facility, contained on the included *Burnin' Rubber and Locomotive BASIC* cartridge. This resulted in reduced hardware localization cost (only

some select key caps and case labels had to be localized) with the added benefit of a rudimentary copy protection mechanism (without a firmware present, the machine itself could not copy a game cartridge's content). As the enhanced *V4* firmware's structural differences causes problems with some CPC software directly calling firmware functions by their memory addresses, Amstrad separately sold a cartridge containing the original CPC6128's *V3* firmware.

Both the 464plus and the 6128plus were introduced to the public in September 1990. Initial suggested retail prices were FRF1990 with a green screen and FRF2990 with a colour monitor for the 464plus, and FRF2990 with a green screen and FRF3990 with a colour monitor for the 6128plus.

GX4000



The Amstrad GX4000

Developed as part of the *plus range*, the GX4000 is Amstrad's short-lived attempt to enter the market. Sharing the plus range's hardware characteristics, it represents the bare minimum variant of the range without a keyboard or support for mass storage devices.

Special models and clones

CPC472

The *CPC472* is a modified CPC464 model, created and only distributed in Spain by Amstrad's Spanish distributor *Indescomp* (later to become *Amstrad Spain*). Its only difference to the CPC464 is the inclusion of an add-on board containing 8 kB of memory. The additional memory is not available to the CPU, its sole purpose was to increase the machine's total memory to 72 kB, thus circumventing a Spanish tax on computers with 64 kB memory or less that were not localized to the Spanish language. Soon after the *CPC472*'s release in 1984, this tax was extended to all computers, regardless of their memory size. CPC models with a Spanish keyboard became available, including a remaining stock of *CPC472*.

KC Compact



The Kleincomputer KC Compact

The *Kleincomputer KC Compact* ("Kleincomputer" being a rather literal German translation of the English "microcomputer") is a clone of the Amstrad CPC built by East Germany's *VEB Mikroelektronik Mühlhausen* in 1989. Although the machine included various substitutes and emulations of an Amstrad CPC's hardware, the machine is largely compatible with Amstrad CPC software. It is equipped with 64 kB memory and a CPC6128's firmware customized to the modified hardware, including an unmodified copy of Locomotive BASIC 1.1. The KC Compact is the last 8-bit computer produced in East Germany.

Hardware

Processor

The entire CPC series is based on the Zilog Z80A processor, clocked at 4 MHz.

In order to avoid conflicts resulting from the CPU and the video circuits both accessing the shared main memory ("snowing"), CPU memory access is constrained to occur on microsecond boundaries, effectively padding every CPU instruction to a multiple of four

CPU cycles. As typical Z80 instructions require only three or four CPU cycles, the resulting loss of processing power is minor, reducing the effective clock rate to approximately 3.3 MHz.

Memory

Amstrad CPCs are equipped with either 64 (CPC464, CPC664, 464plus, GX4000) or 128 (CPC6128, 6128plus) kB of RAM. This base memory can be extended by up to 512 kB using memory expansions sold by third-party manufacturers, and by up to 4096 kB using experimental methods developed by hardware enthusiasts. Because the Z80 processor is only able to directly address 64 kB of memory, additional memory from the 128 kB models and memory expansions is made available using the bank switching technique

Video

Underlying a CPC's video output is the unusual pairing of a CRTIC (Motorola 6845 or compatible) with a custom-designed gate array to generate a pixel display output. CPC6128s later in production as well as the models from the plus range integrate both the CRTIC and the gate array's functions with the system's ASIC.

Three built-in display resolutions are available: 160×200 pixels with 16 colours ("Mode 0", 20 text columns), 320×200 pixels with 4 colours ("Mode 1", 40 text columns), and 640×200 pixels with 2 colours ("Mode 2", 80 text columns). Increased screen size can be achieved by reprogramming the CRTIC.

The original CPC video hardware supports a colour palette of 27 colours, generated from RGB colour space with each colour component assigned as either off, half on, or on. The plus range extended the palette to 4096 colours, also generated from RGB with 4 bits each for red, green and blue.

With the exception of the GX4000, all CPC models lack an RF television or composite video output and instead shipped with a proprietary 6-pin DIN connector intended for use solely with the supplied Amstrad monitor. It delivers a PAL frequency 1v p-p analogue RGB with composite sync signal that, if wired correctly, can drive a SCART television. External adapters for RF television were available as a first-party hardware accessory.

Audio

The CPC uses the General Instrument AY-3-8912 sound chip, providing three channels, each configurable to generate square waves, white noise or both. A small array of hardware volume envelopes are available.

Output is provided in mono by a small (4 cm) built-in loudspeaker with volume control, driven by an internal amplifier. Stereo output is provided through a 3.5 mm headphones jack.

It is possible to playback digital sound samples at a resolution of approximately 5-bit by sending a stream of values to the sound chip. This technique is very processor-intensive and hard to combine with any other processing. Examples are the title screens or other non-playable scenes of games like *Chase H.Q.*, *Meltdown*, and *RoboCop*.

Floppy disk drive



3" floppy discs used on CPC machines

Amstrad's choice of Hitachi's 3" floppy disk drive, when the rest of the PC industry was moving to Sony's 3.5" format, is often wrongly claimed to be due to Amstrad bulk-buying a large consignment of 3" drive units in Asia; the units were custom-made by Panasonic. The chosen drive (built-in for later models) is a single-sided 40-track unit that requires the user to physically remove and flip the disk to access the other side. Each side has its own independent write-protect switch. The sides are termed "A" and "B", with each one commonly formatted to 180 kB (in AMSDOS format, comprising 2 kB directory and 178 kB storage) for a total of 360 kB per disc.

The interface with the drives is a NEC 765 FDC, used for the same purpose in the IBM PC/XT, PC/AT and PS/2 machines. Its features are not fully used in order to cut costs, namely DMA transfers and support for single density disks; they were formatted as double density using modified frequency modulation.

Disks were shipped in a paper sleeve or a hard plastic case resembling a compact disc "jewel" case. The casing is thicker and more rigid than that of 3.5" diskettes, and

designed to be mailed without any additional packaging. A sliding metal cover to protect the media surface is internal to the casing and latched, unlike the simple external sliding cover of Sony's version. They were significantly more expensive than both 5.25" and 3.5" alternatives. This, combined with their low nominal capacities and their essentially proprietary nature, led to the format being discontinued shortly after the CPC itself was discontinued.

Apart from Amstrad's other 3" machines (the PCW and the ZX Spectrum +3), the few other computer systems to use them included the Sega SF-7000 and CP/M systems such as the Tatung Einstein and Osborne machines. They also found use on embedded systems.

The Shugart-standard interface means that Amstrad CPC machines are able to use standard 3", 3½" or 5¼" drives as their second drive. Programs such as ROMDOS and ParaDOS extend the standard AMSDOS system to provide support for double-sided, 80-track formats, enabling up to 800k to be stored on a single disk.

The 3" disks themselves are usually known as "discs" on the CPC, following the spelling on the machine's plastic casing and conventional non-American spelling.

Expansion

The hardware and firmware was designed to be able to access software provided on external ROMs. Each ROM has to be a 16k block and was switched in and out of the memory space shared with the video RAM. The Amstrad firmware is deliberately designed so that new software could be easily accessed from these ROMs with minimum of fuss. Popular applications were marketed on ROM, particularly word processing and programming utility software (examples are Protext and Brunword of the former, and the MAXAM assembler of the latter type).

Such extra ROM chips do not plug directly into the CPC itself, but into extra plug-in "rom boxes" which contain sockets for the ROM chips and a minimal amount of decoding circuitry for the main machine to be able to switch between them. These boxes were either marketed commercially or could be built by competent hobbyists and they attached to the main expansion port at the back of the machine. Software on ROM loads much faster than from disc or tape and the machine's boot-up sequence was designed to evaluate ROMs it found and optionally hand over control of the machine to them. This allows significant customization of the functionality of the machine, something that enthusiasts exploited for various purposes. However, the typical user would probably not be aware of this added ROM functionality unless they read the CPC press, as it is not described in the user manual and was hardly ever mentioned in marketing literature. It is, however, documented in the official Amstrad firmware manual.

The machines also feature a 9-pin Atari-style joystick socket that will either directly take one joystick, or two joysticks by use of a splitter cable.

Peripherals

RS232 Serial Adapters

Amstrad issued two RS-232-C D25 serial interfaces, attached to the expansion connector on the rear of the machine, with a through-connector for the CPC464 disk drive or other peripherals.

The original interface came with a *Book of Spells* for facilitating data transfer between other systems using a proprietary protocol in the device's own ROM, as well as terminal software to connect to British Telecom's Prestel service. A separate version of the ROM was created for the U.S. market due to the use of the commands "|SUCK" and "|BLOW", which were considered unacceptable there.

Software and hardware limitations in this interface led to its replacement with an Amstrad-branded version of a compatible alternative by Pace. Serial interfaces were also available from third-party vendors such as KDS Electronics and Cirkit.

Software

BASIC and operating system



Locomotive BASIC on the Amstrad CPC 464

Like most home computers at the time, the CPC has its OS and a BASIC interpreter built in as ROM. It uses Locomotive BASIC - an improved version of Locomotive Software's Z80 BASIC for the BBC Microcomputer co-processor board. It is particularly notable for providing easy access to the machine's video and audio resources in contrast to the arcane POKE commands required on generic Microsoft implementations. Other unusual features include timed event handling with the AFTER and EVERY commands, and text-based windowing.

CP/M

Digital Research's CP/M operating system was supplied with the 664 and 6128 disk-based systems, and the DDI-1 disk expansion unit for the 464. 64k machines shipped with CP/M 2.2 alone, while the 128k machines also include CP/M 3.1. The compact CP/M 2.2 implementation is largely stored on the boot sectors of a 3" disk in what was called "System format"; typing |CPM from Locomotive BASIC would load code from these sectors, making it a popular choice for custom game loading routines. The CP/M 3.1 implementation is largely in a separate file which is in turn loaded from the boot sector. Much public domain CP/M software was made available for the CPC, from word-processors such as VDE to complete bulletin board systems such as ROS.

Other languages

Although it was possible to obtain compilers for Locomotive BASIC, C and Pascal, the majority of the CPC's software was written in native Z80 assembly language. Popular assemblers were Hisoft's Devpac, Arnor's Maxam, and (in France) DAMS. Disk-based CPC (not Plus) systems shipped with an interpreter for the educational language LOGO, booted from CP/M 2.2 but largely CPC-specific with much code resident in the AMSDOS ROM; 6128 machines also include a CP/M 3.1, non-ROM version. A C compiler was also written and made available for the European market through Tandy Europe, by Micro Business products.

Roland

In an attempt to give the CPC a recognizable mascot, a number of games by Amstrad's in-house software publisher Amsoft have been tagged with the *Roland* name. However, as the games had not been designed around the Roland character and only had the branding added later, the character design varies immensely, from a spiky-haired blonde teenager (*Roland Goes Digging*) to a white cube with legs (*Roland Goes Square Bashing*) or a mutant flea (*Roland In The Caves*). The only two games with similar gameplay and main character design are *Roland in Time* and its sequel *Roland in Space*. The Roland character has been named after Roland Perry, one of the lead designers of the original CPC range.

Schneider Computer Division



Schneider Computer Division logo

In order to market its computers in Germany, Austria, and Switzerland where Amstrad did not have any distribution structures, Amstrad entered a partnership with *Schneider*, a German company that - very much like Amstrad itself - was previously only known for value-priced audio products. In 1984, Schneider's *Schneider Computer Division* daughter company was created specifically for the task, and the complete Amstrad CPC line-up was branded and sold as *Schneider CPC*.

Although they are based on the same hardware, the Schneider CPC models differ from the Amstrad CPC models in several details. Most prominently, the Schneider CPC464 and CPC664 keyboards featured gray instead of coloured keys, but still in the original British keyboard layout. To achieve a German "QUERTZ" keyboard layout, Schneider marketed a small software to reassign the keys as well as sticker labels for the keys. In order to conform with stricter German EMC regulations, the complete Schneider CPC line-up is equipped with an internal metal shielding. For the same reason, the Schneider CPC6128 features micro ribbon type connectors instead of edge connectors. Both the greyscale keyboard and the micro ribbon connectors found their way up into the design of later Amstrad CPC models.

In 1988, after Schneider refused to market Amstrad's AT-compatible computer line, the cooperation ended. Schneider went on to sell the remaining stock of Schneider CPC models and used their now well-established market position to introduce its own PC designs. With the formation of its German daughter company *Amstrad GmbH* to distribute its product lines including the CPC464 and CPC6128, Amstrad attempted but ultimately failed to establish their own brand in the German-speaking parts of Europe.

Community

The Amstrad CPC enjoyed a strong and long lifetime, mainly due to the machines use for businesses as well as gaming. Dedicated programmers continued working on the CPC range, even producing Graphical User Interface (GUI) operating systems such as FutureOS and SymbOS. Internet sites devoted to the CPC have appeared from around the world featuring forums, news, hardware, software, programming and games. CPC Magazines appeared during the 1980s including publications in countries such as Britain,

France, Spain, Germany, Denmark, Australia, and Greece. Titles included the official Amstrad Computer User publication, as well as independent titles like *Amstrad Action*, *Amtix!*, *Computing with the Amstrad CPC*, *CPC Attack*, Australia's *The Amstrad User*, France's *Amstrad Cent Pour Cent* and *Amstar*. Following the CPCs end of production, Amstrad gave permission for the CPC ROMs to be distributed freely as long as the copyright message is not changed and that it is acknowledged that Amstrad still holds copyright, giving emulator authors the possibility to ship the CPC firmware with their programs.

Influence on other Amstrad machines

Amstrad followed their success with the CPC 464 by launching the Amstrad PCW word-processor range, another Z80-based machine with a 3" disk drive and software by Locomotive Software. The PCW was originally developed to be partly compatible with an improved version of the CPC (*ANT*, or Arnold Number Two - the CPC's development codename was Arnold). However, Amstrad decided to focus on the PCW, and the ANT project never came to market.

On 7 April 1986 Amstrad announced it had bought from Sinclair Research "...the worldwide rights to sell and manufacture all existing and future Sinclair computers and computer products, together with the Sinclair brand name and those intellectual property rights where they relate to computers and computer related products." which included the ZX Spectrum, for £5 million. This included Sinclair's unsold stock of Sinclair QLs and Spectrums. Amstrad made more than £5 million on selling these surplus machines alone. Amstrad launched two new variants of the Spectrum: the ZX Spectrum +2, based on the ZX Spectrum 128, with a built-in tape drive (like the CPC 464) and, the following year, the ZX Spectrum +3, with a built-in floppy disk drive (similar to the CPC 664 and 6128), taking the 3" disks that Amstrad CPC machines used.

Chapter 6

BBC Master

BBC Master Series



	Acorn's BBC Master
Type	8-bit Microcomputer
Release date	Early 1986
Discontinued	1994
Operating system	Acorn MOS, optional DOS Plus
CPU	MOS Technology 65SC12, optional Intel 80186 or 65C102 depending on model
Memory	128 kB–512 kB

The **BBC Master** was a home computer released by Acorn Computers in early 1986. It was designed and built for the British Broadcasting Corporation (BBC) and was the successor to the BBC Micro Model B. The Master 128 remained in production until 1993.

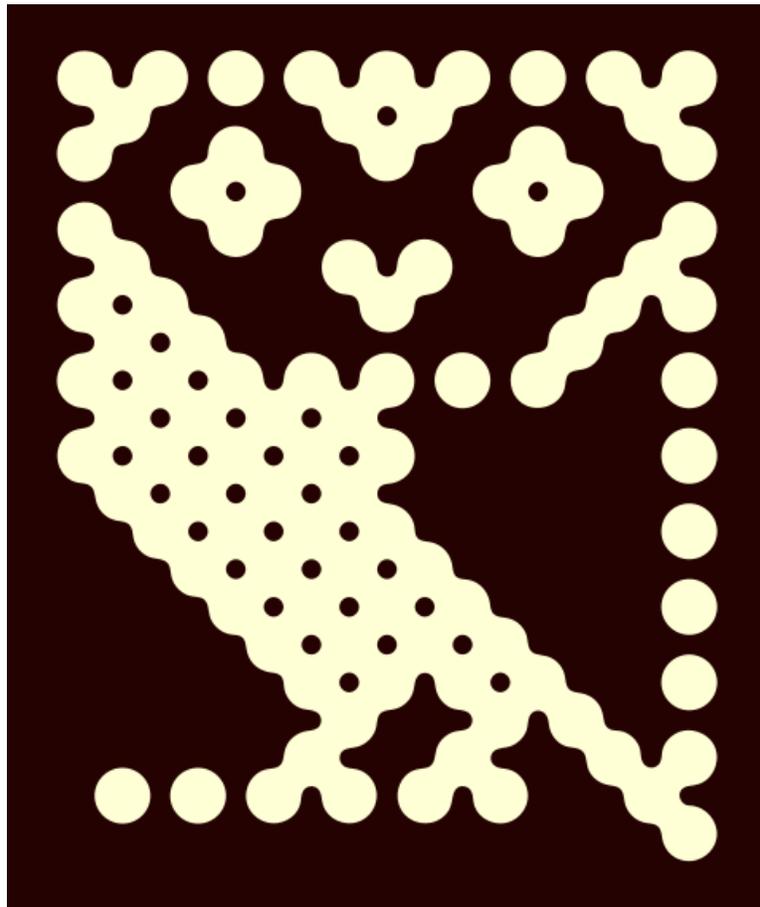
Design

The Master featured several improvements on its predecessor. The systems had 128 kB RAM as standard, alleviating the shortage of available RAM which had amongst other

things discouraged use of the best graphics modes in the original design, and had two cartridge slots mounted above the new numerical keypad. Rather than the MOS Technology 6502 microprocessor used by the Model B it ran on the slightly improved 65SC12: the cost of this CPU compatibility with the Model B was that the address bus was still only 16 bits, meaning that only 64 kB could be directly addressed at any one time and the remaining memory had to be paged in as required. However the 65SC12's extra instructions allowed a little more to be shoehorned into the OS and BBC BASIC ROMs, limited by the memory architecture to 16 kB each.

Although the Master was intended to be compatible with "legally written" software for the older models, there were some problems running older programs, particularly games. Conversely, although few programs were ever targeted specifically at Master series machines (except the Master 512), many later BBC games (and Master versions of earlier classics such as *Elite*) included enhanced features which took advantage of the extra memory.

Models



The BBC Computer Literacy Project Owl appeared on the bottom left of the keyboard on both standard and Master Compact cases.

The Master was available in several different models.

Master 128

This was the standard issue computer. The 128 in the name referred to its 128 kB of RAM, though it also featured 128 kB ROM.

Master Turbo

This was a Master with 4 MHz 65C102 coprocessor card (which could be either bought with the machine or added to an existing Master 128).

Master AIV



The BBC Master as part of a BBC Domesday System

The Master AIV (Advanced Interactive Videodisc) was essentially a Master Turbo model with a SCSI interface and a VFS (Videodisc Filing System) ROM added, and formed the basis of the BBC Domesday System. Although normally supplied as part of a Domesday System, with LaserVision player, Domesday videodiscs, monitor and trackerball included, an upgrade kit was also available to turn a normal BBC Master into a Domesday System.

Master ET

The ET (Econet Terminal) system was designed for use in a network and as such had no interfaces except RGB and Composite video, plus an Econet interface module and ANFS fitted as standard (it was usually an option). It used the same main circuit board as the Master 128, but the components for missing interfaces were simply not fitted (though there was nothing stopping them being added later by someone with appropriate soldering skills). The internal ROM also contained much less software than that of the Master 128.

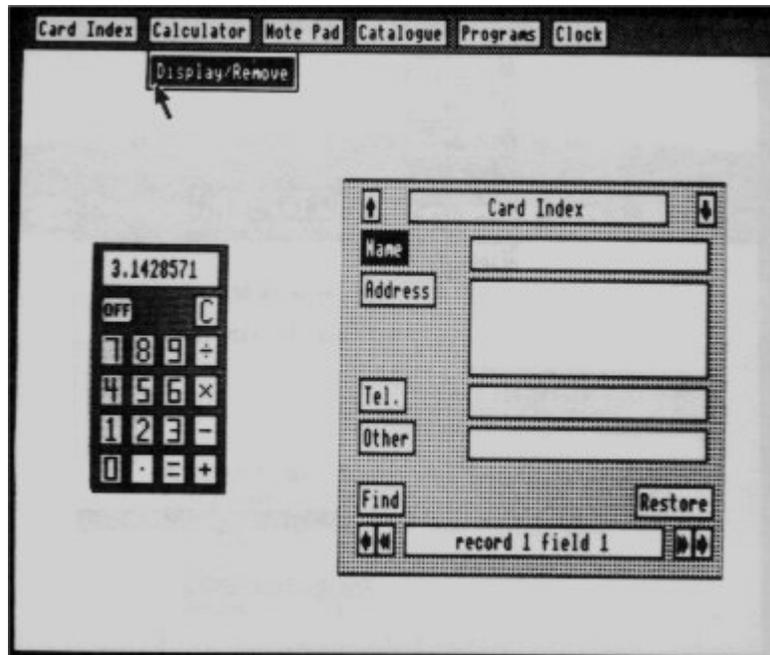
Master 512

This system boasted a coprocessor card with a 10 MHz Intel 80186 and 512 kB memory. It also had the ability to run DOS+ and the GEM graphical user interface.

Master Scientific

The Master Scientific was announced at the time of the BBC Master's launch, but was not produced. It was to have an 8 MHz 32016 coprocessor with 32081 floating point processor and 512 kB of RAM, running the PANOS operating system. This was similar to the previous external 32016 Second Processor.

Master Compact



The Master Compact GUI

This model separated the keyboard from another unit which could be placed under the monitor. Only the ADFS filing system was supplied as standard, though it is possible to

load a 1770 DFS ROM into sideways RAM, or to insert a ROM or EPROM containing it. The Compact also utilised a limited re-burn EEPROM, instead of the battery backed clock plus CMOS memory found in the other models, and hence had no real time clock of its own (the time could be fetched via Econet where available).

The unit under the monitor housed a 3½” floppy disk drive and the system power supply. The remainder of the system was housed in the same unit as the keyboard, much like a conventional Master 128. The cartridge and cassette ports were removed as a space saving measure, and RS-232 hardware not populated on the circuit board as standard. A multifunction mouse and joystick port was provided as a 9 pin D type with its function configured in software.

Software for the Compact became very expensive (typically £20 for a game) due to the much lower demand for the 3½” disk format (5¼” was the de facto standard for the Master and earlier BBC Micro).

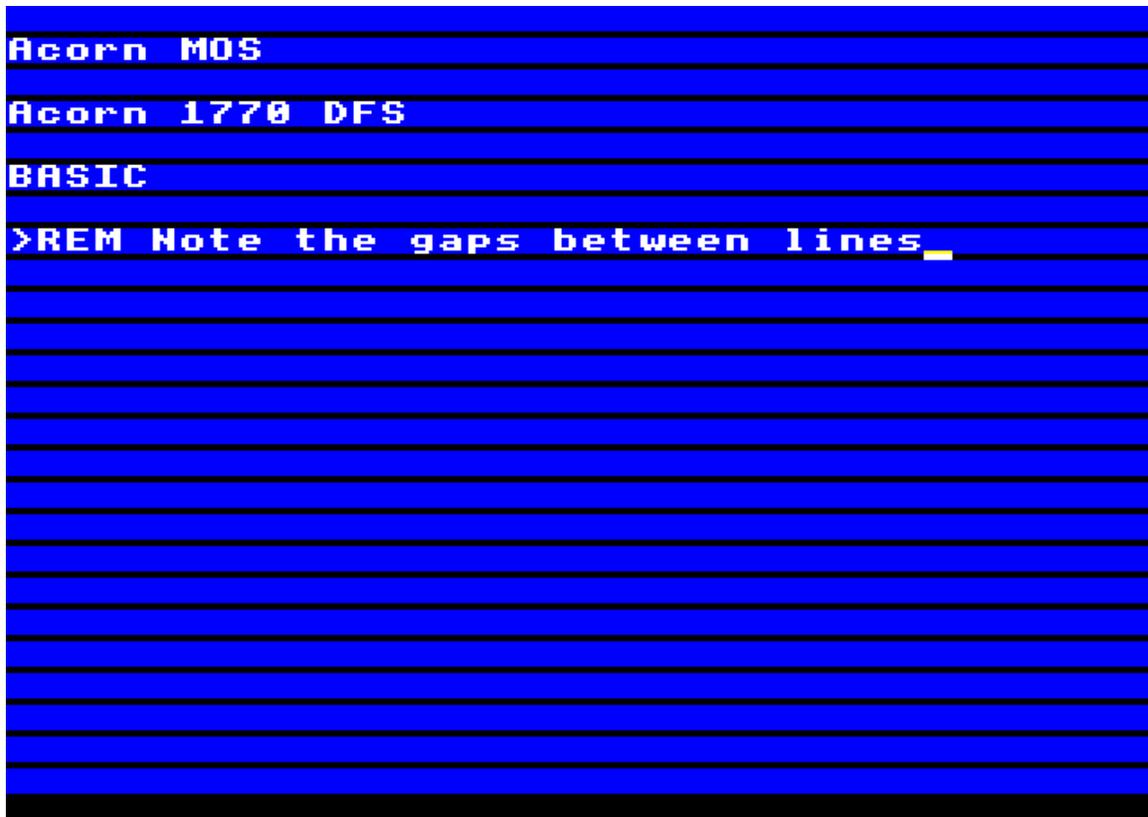
The Compact included Acorn's first public GUI. Little commercial software, beyond that included on the Welcome disk, was ever made available for the system.

Specifications



Internal shot of Master 128 showing Vine Micro Romboard4 fitted - also cooling fan added by owner

- 2 MHz Rockwell R65SC12 processor
- 128 kB ROM in the Master 128, Master Turbo, and Master 512. Comprising a 16 kB MOS (Machine Operating System), always accessible, and seven 16 kB sideways ROMs, any one of which could be paged into memory at a time:
 - 16 kB Terminal emulator and MOS extras (such as the cassette filing system) in paged ROM 15
 - 16 kB Acornsoft View (word processor) in paged ROM 14
 - 16 kB Advanced Disk Filing System in paged ROM 13
 - 16 kB BBC BASIC in paged ROM 12
 - 16 kB Acorn Screen Editor AKA Edit (text/BBC BASIC editor) in paged ROM 11
 - 16 kB ViewSheet (spreadsheet) in paged ROM 10
 - 16 kB Disk Filing System and Sideways RAM utilities in paged ROM 9
- 64 kB ROM in the Master ET. Comprising a 16 kB MOS (Machine Operating System), always accessible, and three 16 kB sideways ROMs, any one of which could be paged into memory at a time:
 - 16 kB MOS extras (such as the cassette filing system and Sideways RAM utilities) in paged ROM 15
 - 16 kB Advanced Network Filing System in paged ROM 14
 - 16 kB BBC BASIC in paged ROM 13
- 128 kB RAM, comprising:
 - 32 kB main user program/data storage
 - 20 kB "shadow" video memory (paged over main user RAM)
 - 12 kB OS workspace (paged over ROM)
 - 64 kB workspace accessible to user machine code applications (divided into up to four 16 kB regions to act like volatile paged ROMs)
- Full-travel keyboard with a top row of ten red-orange function keys $f_0 - f_9$ and AT-style numeric keypad. The 'BREAK' reset key could be physically disabled by rotating a small plastic cam, particularly useful in educational environments
- Highly configurable graphics display based on the Motorola 6845. Unlike on the original BBC Micro, separate video RAM was used so that choosing a high-resolution mode did not reduce the amount of available user RAM. (However, user RAM could still be used as the video buffer if required, in order to allow effects such as double buffering.) Eight graphics modes were provided by the system ROM:
 - Modes 0 to 6 could display a choice of colours from a logical palette of sixteen, though only eight physical colours could really be generated by the hardware; the eight RGB colours (black, red, green, yellow, blue, magenta, cyan, white) and said colours in a flashing state;



Screen mode 6 with a blue background, showing the filler lines

Modes 3 and 6 were special software (framebuffer) text modes. To save RAM, the count of lines was reduced from 32 to 25. As this would reduce the height of the frame, filler rows were created between each line of text when the frame was output, where no pixels were read from the framebuffer. This creates characteristic black lines between the rows of text when a different background colour is set, and a blank gap at the bottom of the display with the left-over pixels. The screen mode is otherwise held in memory as a regular graphics mode.

- Mode 7's Teletext capability was provided by a Mullard SAA5050 Teletext chip.

Graphics mode	Resolution (X×Y)		Hardware colours	Video RAM used		Type
	Char cells	Pixels		(KB)	map	
0	80 × 32	640 × 256	2	20	3000–7FFF	Graphics
1	40 × 32	320 × 256	4	20	3000–7FFF	Graphics
2	20 × 32	160 × 256	8	20	3000–7FFF	Graphics

3	80 × 25	640 × 200	2	16	4000– 7FFF	Text
4	40 × 32	320 × 256	2	10	5800– 7FFF	Graphics
5	20 × 32	160 × 256	4	10	5800– 7FFF	Graphics
6	40 × 25	320 × 200	2	8	6000– 7FFF	Text
7 (Teletext)	40 × 25	480 × 500	8	1	7C00– 7FFF	Text

- Four independent sound channels (one noise and 3 melodic) using the Texas Instruments SN76489 sound chip
- Built-in hardware support included:
 - pluggable ROMs, directly or via cartridge slots
 - floppy disk drives (both DFS and the newer ADFS supported) with WD1770 disk controller
 - tape interface (with motor control), using a variation of the Kansas City standard data encoding scheme
 - parallel printer port (Centronics compatible)
 - serial communication (using RS-423, a superset of RS-232)
 - display output for TV, RGB or 1v p-p video monitor
 - a 15 pin 'D shaped' port with four analogue inputs (suitable for two joysticks, four digital/contact ports (for buttons) and a special Light pen input
 - proprietary "Tube" interface for internal or external second CPU (in the Master 512 model, an 80186 was used; other options included a 3 MHz extra 6502, a Zilog Z80 for e.g. CP/M, an NS32016, an ARM1, and others)
 - a 16 pin IDC style "user port" consisting of 8 general purpose digital I/O pins (and two special handshaking ones) mapped directly into the 6522 VIA
 - generic expansion through the "1 MHz bus", and
 - Econet interface, installed by adding a module board and the ANFS ROM (fitted as standard to the Master ET machine)

Several of the inputs were directly wired to specific registers in order to allow the hardware to do some of the heavy lifting. For example the light-pen input would directly halt a counter which was started by the start of the vertical sweep of each display refresh, making calculation of where the lightpen was touching the screen little more than a simple divide/remainder operation. Likewise, the motor control relay for the audio cassette tape was controlled by a simple command and could be readily used in numerous control applications.

Chapter 7

Retrocomputing



The 1977 Apple II, popular amongst hobbyists in retrocomputing

Retrocomputing (a portmanteau of retro and computing) is the use of early computer hardware and software today. Retrocomputing is usually classed as a hobby and recreation rather than a practical application of technology; enthusiasts often collect rare and valuable hardware and software for sentimental reasons. However some do make use of it. Retrocomputing often gets its start when a computer user realizes that formerly expensive fantasy systems like IBM Mainframes, DEC Superminis, SGI workstations and Cray Supercomputers have become affordable on the used computer market, usually in a relatively short time after the computers' era of use.

Many people have personal computer museums, with collections of working vintage computers such as Apple IIs, IBM PCs, ZX Spectrums, Atari, Commodore, Amigas and BBC Micros. Early personal computers based on the S-100 bus are also very popular among collectors, as well as a wide variety of machines running the CP/M operating system, such as Kaypro and Osbornes. However, many users use emulation software on more modern computers rather than using real hardware, in order to enjoy the experience, while preserving the aging electronics of the original. This is not considered to be retrocomputing by some, as it is rather an application of modern computer hardware. A third option is the use of home computer remakes, dedicated appliances, which do the emulation using dedicated hardware.

Historical retrocomputing

A more serious line of retrocomputing is part of the history of computer hardware. It can be seen as the analogue of experimental archaeology in computing. Some notable examples include the reconstruction of Babbage's Difference engine (more than a century after its design) and the implementation of Plankalkül in 2000 (more than half a century since its inception).

"Homebrew" computers

Some retrocomputing enthusiasts also consider the 'Homebrewing' (designing and building of retro- and retro-styled computers or kits), to be an important aspect of the hobby, giving new enthusiasts an opportunity to experience more fully what the early years of hobby computing were like. There are several different approaches to this end. Some are exact replicas of older systems, and some are newer designs based on the principals of retrocomputing, while others combine the two, with old and new features in the same package. One such example is offered by IMSAI, a modern, updated, yet backward-compatible version and replica of the original IMSAI 8080, one of the most popular early personal systems. Several Apple 1 replicas and kits have been sold in limited quantities in recent years, by different builders, such as the "Replica 1", from Briel Computers: . A currently ongoing project that uses old technology in a new design is the Z80-based N8VEM.

Vintage computers



Some old computers from Commodore International. Amiga 500 (top left), Commodore 128 (top right) and three different models of Commodore 64.

The personal computer has been around since approximately 1976. But in that time, numerous technological revolutions have left generations of obsolete computing equipment on the junk heap. Nevertheless, in that time, these otherwise useless computers have spawned a sub-culture of vintage computer collectors, who often spend large sums to acquire the rarest of these items, not only to display but restore to their fully functioning glory, including active software development and adaptation to modern uses. This often includes so-called hackers who add-on, update and create hybrid composites from new and old computers for uses for which they were otherwise never intended. Most of this hobby centers on those computers manufactured after 1960, though there are collectors who specialize in pre-1960 computers as well.

Apple Inc.

The earliest of the Apple Inc. personal computers are among some of the most collectible. They are relatively easy to maintain in an operational state thanks to Apple's use of readily available over-the-counter parts.

- **Apple II:** The Apple II series of computers are some of the easiest to adapt, thanks to the original expansion architecture designed into them. New peripheral cards are still being designed by an avid community that still thrives, thanks to the longevity of this platform, manufactured from 1976 through 1993. Numerous websites exist to support not only the legacy users, but new adopters who weren't even born when the Apple II was discontinued by Apple.
- **Macintosh:** Perhaps because of its friendly design and first commercially successful graphical user interface as well as its enduring Finder application that persists on the most current Macs, the Macintosh is one of the most collected and used of the vintage computers. With dozens of websites around the world, old Macintosh hardware and software is put into daily use. Many maintain vast collections of functional and non-functional systems, which are lovingly maintained and discussed on worldwide user forums.

IBM

- **IBM 1130** computing system from 1966 which still has a following of interested users, albeit mostly via an emulator rather than the actual machine.
- The IBM 5100 also has an avid collector and fan base.
- The IBM PC series (PC, PC/XT, PC/AT) has become very popular in recent years, with the earliest models (PC) being considered the most collectible.

BBC Micro

- The BBC Micro was a very popular computer in the 1980s with home and educational users. It was possible to use 100K 5 1/4 inch disks and it had many expansion ports.

Robotron

- The Robotron Z1013 was an East German home computer produced by VEB Robotron. It had a U880 processor, 16 kByte RAM and a membrane keyboard.
- The KC 85 series of computers was a modular 8 bit computer system used in East German schools

Internet

There are a number of sites on the Internet catering to vintage computer hobbyists, including web pages, mailing lists, newsgroups, discussion forums, etc. Some are dedicated to certain specific systems while others are more generic and cover many different systems. Erik Klein's Vintage Computer Forum is one example of a discussion page covering all aspects of the hobby.

cctech, also known as the "*Classic Computers Discussion List*", is an electronic mailing list about old computer technology, and is run by the Classic Computing organization.

Chapter 8

Apple II Series



The 1977 Apple II, shown here with Disk II floppy disk drives and a 1980s-era Apple Monitor II. The Apple II featured an integrated keyboard, sound, a plastic case, and eight internal expansion slots.

The **Apple II** (often rendered **Apple][** or **Apple //**) was an 8-bit home computer, one of the first highly successful mass-produced microcomputer products, designed primarily by Steve Wozniak, manufactured by Apple Computer (now Apple Inc.) and introduced in 1977. In terms of ease of use, features and expandability the Apple II was a major

technological advancement over its predecessor, the Apple I, a limited-production bare circuit board computer for electronics hobbyists which pioneered many features that made the Apple II a commercial success. Introduced at the West Coast Computer Faire in 1977, the Apple II was among the first successful personal computers; it launched the Apple company into a successful business (and allowed several related companies to start). Throughout the years, a number of models were sold, with the most popular model remaining relatively little changed into the 1990s. By the end of production in 1993, somewhere between five and six million Apple II series computers (including about 1.25 million Apple IIGS models) had been produced.

The Apple II became one of the most recognizable and successful computers during the 1980s and early 1990s. It was aggressively marketed through volume discounts and manufacturing arrangements to educational institutions which made it the first computer in widespread use in American secondary schools. The effort to develop educational and business software for the Apple II, including the 1979 release of the popular VisiCalc spreadsheet, made the computer especially popular with business users and families.

The original Apple II operating system was contained in ROM along with Integer BASIC. Programs were entered, then saved and loaded on cassette tape. When the Disk II was implemented in 1978 by Steve Wozniak, a Disk Operating System or DOS was commissioned. The final and most popular version of this software was Apple DOS 3.3. Some commercial Apple II software booted directly and did not use standard DOS formats. This discouraged the copying or modifying of the software on the disks and improved loading speed. Apple DOS was superseded by ProDOS, which supported a hierarchical filesystem and larger storage devices. With an optional third-party Z80-based expansion card the Apple II could boot into the CP/M operating system and run WordStar, dBase II, and other CP/M software. At the height of its evolution, towards the late 1980s, the platform had the graphical look of a hybrid of the Apple II and Macintosh with the introduction of the Apple IIGS. By 1992, the platform had 16-bit processing capabilities, a mouse-driven Graphical User Interface, and graphics and sound capabilities far beyond the original.

Despite the introduction of the Motorola 68000-based Apple Lisa system in 1983, and its more successful cousin the Macintosh in 1984, the relatively unsophisticated Apple II series was Apple's primary revenue source for most of the following decade. At its peak, it was a billion-dollar-a-year industry with its associated community of third-party developers and retailers. The Apple IIGS was sold until the end of 1992; the last II-series Apple in production, the IIfx, was discontinued on October 15, 1993.

Design

The Apple II was designed to look more like a home appliance than a piece of electronic equipment. The lid popped off the beige plastic case without the use of tools, allowing access to the computer's internals, including the motherboard with eight expansion slots, and an array of random access memory (RAM) sockets that could hold up to 48 kilobytes worth of memory chips.

The Apple II had color and high-resolution graphics modes, sound capabilities and one of two built-in BASIC programming languages (initially Integer BASIC, later Applesoft BASIC). The Apple II was targeted for the masses rather than just hobbyists and engineers; it also influenced most of the microcomputers that followed it. Unlike preceding home microcomputers, it was sold as a finished consumer appliance rather than as a kit (unassembled or preassembled). *VanLOVEs Apple Handbook* and *The Apple Educators Guide* by Gerald VanDiver and Rolland Love reviewed more than 1,500 software programs that the Apple II series could use. The Apple dealer network used this book to emphasize the growing software developer base in education and personal use.

The Apple II series had a keyboard built into the motherboard shell, with the exception of the Apple IIGS which featured an external keyboard. An upgrade kit was sold later to house the motherboard of an Apple IIGS in an Apple IIe case.

Models

Early II-series models were usually designated "Apple]["; later models "Apple //", plus a letter suffix.

Apple II



An Apple II computer with an external modem

The first Apple II computers went on sale on June 5, 1977 with a MOS Technology 6502 microprocessor running at 1 MHz, 4 KB of RAM, an audio cassette interface for loading programs and storing data, and the Integer BASIC programming language built into the ROMs. The video controller displayed 24 lines by 40 columns of monochrome, upper-case-only (the original character set matches ASCII characters 0x20 to 0x5F) text on the

screen, with NTSC composite video output suitable for display on a TV monitor, or on a regular TV set by way of a separate RF modulator. The original retail price of the computer was US\$1298 (with 4 kB of RAM) and US\$2638 (with the maximum 48 kB of RAM). To reflect the computer's color graphics capability, the Apple logo on the casing was represented using rainbow stripes, which remained a part of Apple's corporate logo until early 1998. The earliest Apple II's were assembled in Silicon Valley, and later in Texas; printed circuit boards were manufactured in Ireland and Singapore.

An external 5¼-inch floppy disk drive, the Disk II, attached via a controller card that plugged into one of the computer's expansion slots (usually slot 6), was used for data storage and retrieval to replace cassettes. The Disk II interface, created by Steve Wozniak, was regarded as an engineering masterpiece for its economy of electronic components. While other controllers had dozens of chips for synchronizing data I/O with disk rotation, seeking the head to the appropriate track, and encoding the data into magnetic pulses, Wozniak's controller card had few chips; instead, the Apple DOS used software to perform these functions. The Group Code Recording used by the controller was simpler and easier to implement in software than the more common MFM. In the end, the low chip count of the controller helped make Apple's Disk II the first affordable floppy drive for personal computers. As a side effect, Wozniak's scheme made it easy for proprietary software developers to copy-protect the media on which their software shipped by changing the low-level sector format or stepping the drive's head between the tracks; inevitably, other companies eventually sold software to foil this protection. Another Wozniak optimization allowed him to omit Shugart's Track-0 sensor. When the Operating System wants to go to track 0, the controller simply moves 40 times toward the next-lower-numbered track, relying on the mechanical stop to prevent it going any further down than track 0. This process, called "recalibration", made a loud buzzing (rapid mechanical chattering) sound that often frightened Apple novices.

The approach taken in the Disk II controller was typical of Wozniak's design sensibility. The Apple II used several engineering shortcuts to save hardware and reduce costs. For example, taking advantage of the way that 6502 instructions only access memory every other clock cycle, the video generation circuitry's memory access on the otherwise unused cycles avoided memory contention issues and also eliminated the need for a separate refresh circuit for the DRAM chips. Rather than use a complex analog-to-digital circuit to read the outputs of the game controller, Wozniak used a simple timer circuit whose period was proportional to the resistance of the game controller, and used a software loop to measure the timer.

The text and graphics screens had a complex arrangement (the scanlines were not stored in sequential areas of memory) which was reputedly due to Wozniak's realization that doing it that way would save a chip; it was less expensive to have software calculate or look up the address of the required scanline than to include the extra hardware. Similarly, in the high-resolution graphics mode, color was determined by pixel position and could thus be implemented in software, saving Wozniak the chips needed to convert bit patterns to colors. This also allowed for sub-pixel font rendering since orange and blue pixels appeared half a pixel-width further to the right on the screen than green and purple pixels.

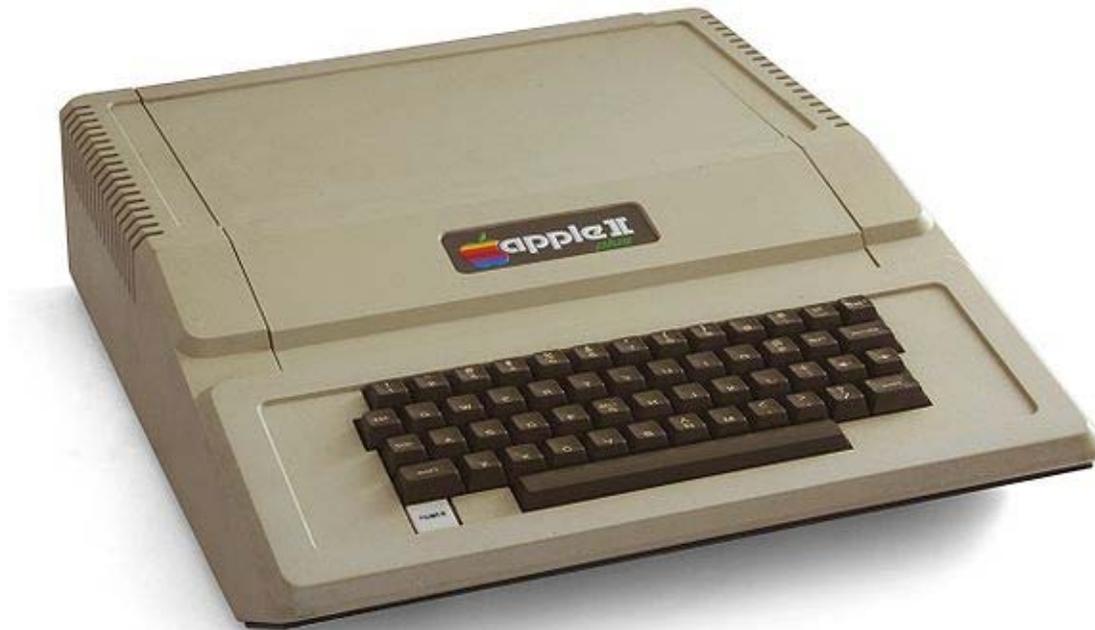
Color on the Apple II series took advantage of a quirk of the NTSC television signal standard, which made color display relatively easy and inexpensive to implement. The original NTSC television signal specification was black-and-white. Color was tacked on later by adding a 3.58-MHz subcarrier signal that was partially ignored by B&W TV sets. Color is encoded based on the *phase* of this signal in relation to a reference *color burst* signal. The result is that the position, size, and intensity of a series of pulses define color information. These pulses can translate into *pixels* on the computer screen.

The Apple II display provided two pixels per subcarrier cycle. When the color burst reference signal was turned on and the computer attached to a color display, it could display green by showing one alternating pattern of pixels, magenta with an opposite pattern of alternating pixels, and white by placing two pixels next to each other. Later, blue and orange became available by tweaking the offset of the pixels by half a pixel-width in relation to the colorburst signal. The high-resolution display offered more colors simply by compressing more, narrower pixels into each subcarrier cycle. The coarse, low-resolution graphics display mode worked differently, as it could output a short burst of high-frequency signal per pixel to offer more color options.

The epitome of the Apple II design philosophy was the Apple II sound circuitry. Rather than having a dedicated sound-synthesis chip, the Apple II had a toggle circuit that could only emit a click through a built-in speaker or a line out jack; all other sounds (including two, three and, eventually, four-voice music and playback of audio samples and speech synthesis) were generated entirely by software that clicked the speaker at just the right times. Not for nearly a decade would an Apple II be released with a dedicated sound chip (though with 6 expansion slots, users could add sound functionality via a soundcard like the Mockingboard). Similar techniques were used for cassette storage: the cassette output worked the same as the speaker, and the input was a simple zero-crossing detector that served as a relatively crude (1-bit) audio digitizer. Routines in the ROM were used to encode and decode data in frequency-shift keying for the cassette.

Wozniak's open design and the Apple II's multiple expansion slots permitted a wide variety of third-party devices, including Apple II peripheral cards such as Serial controllers, display controllers, memory boards, hard disks, and networking components. There were plug-in expansion cards — such as the *Z80-card* — that permitted the Apple to use the Z80 processor and run a multitude of programs developed under the CP/M operating system, including the dBase II database and the WordStar word processor. There was also a third-party 6809 card that would allow OS-9 Level One to be run. The Mockingboard sound card greatly improved audio capabilities, allowing simple music synthesis and text-to-speech functions. Eventually, Apple II accelerator cards were created to double or quadruple the computer's speed.

Apple II Plus



Apple II Plus

The **Apple II Plus**, introduced in June 1979, included the Applesoft BASIC programming language in ROM. This Microsoft-authored dialect of BASIC, which was previously available as an upgrade, supported floating-point arithmetic, and became the standard BASIC dialect on the Apple II series (though it ran at a noticeably slower speed than Steve Wozniak's Integer BASIC).

The Apple II Plus was otherwise identical to the original Apple II. The smaller memory sizes were no longer available, so the II Plus always had a total of 48 kB of RAM, expandable to 64 kB by means of the "language card", a 16 kB RAM expansion card that could be installed in the computer's slot 0. The Apple's 6502 microprocessor could support up to 64 kB of memory, and a machine with 48 kB RAM reached this limit

because of the additional 12 kB of read-only memory and 4 kB of I/O addresses. For this reason, the extra RAM in the language card was bank-switched over the machine's built-in ROM, allowing code loaded into the additional memory to be used as if it actually were ROM. Users could thus load Integer BASIC into the language card from disk and switch between the Integer and Applesoft dialects of BASIC with DOS 3.3's INT and FP commands just as if they had the BASIC ROM expansion card. The language card was also required to use the UCSD Pascal and FORTRAN 77 compilers, which were released by Apple at about the same time. These ran under the UCSD p-System operating system, which had its own disk format and emitted code for a "virtual machine" rather than the actual 6502 processor. The UCSD P-system had a curious approach to memory management, which became even more curious on the Apple III.

A TEMPEST approved version of the Apple II Plus called the Microfix was developed in 1980 by the Georgia Tech Research Institute for U.S. Army FORSCOM. Fielded in 1982, the Microfix system was the first tactical system using video disk (Laserdisk) map technology providing zoom and scroll over map imagery coupled with a point database of intelligence data such as order of battle, airfields, roadways, and bridges.

Apple II Europlus and J-Plus

After the success of the first Apple II in the United States, Apple expanded its market to include Europe, Australia and the Far East in 1978, with the **Apple II Europlus** (Europe, Australia) and the **Apple II J-Plus** (Japan). In these models, Apple made the necessary hardware, software and firmware changes in order to comply to standards outside of the U.S. The power supply was modified to accept the local voltage, and in the European and Australian model the video output signal was changed from color NTSC to monochrome PAL — an extra video card was needed for color PAL graphics, since the simple tricks Wozniak had used to generate a pseudo-NTSC signal with minimal hardware did not carry over to the more complex PAL system. In the Japanese version of the international Apple, the keyboard layout was changed to allow for Katakana writing (full Kanji support was clearly beyond the capabilities of the machine), but in most other countries the international Apple was sold with an unmodified American keyboard; thus the German model still lacked the umlauts, for example. For the most part, the Apple II Europlus and J-Plus were identical to the Apple II Plus. Production of the Europlus ended in 1983.

Apple IIe



An Apple IIe with DuoDisk and Monitor //.

The Apple II Plus was followed in 1983 by the **Apple IIe**, a cost-reduced yet more powerful machine that used newer chips to reduce the component count and add new features, such as the display of upper and lowercase letters and a standard 64 kB of RAM.

The IIe RAM was configured as if it were a 48 kB Apple II Plus with a language card; the machine had no slot 0, but instead had an auxiliary slot that for most practical purposes took the place of slot 3, the most commonly used slot for 80-column cards in the II Plus.

The auxiliary slot could accept a 1 kB memory card to enable the 80-column display. This card contained only RAM; the hardware and firmware for the 80-column display was built into the Apple IIe, remaining fairly compatible with the older Videx-style cards, even though the low-level details were very different. An "extended 80-column card" with more memory expanded the machine's RAM to 128 kB.

As with the language card, the memory in the 80-column card was bank-switched over the machine's main RAM; this made the memory better suited to data storage than to running software, and in fact the ProDOS operating system, which was introduced with the Apple IIe, would automatically configure this memory as a RAM disk upon booting.

Third-party aux-slot memory cards later allowed expansion up to 1 MB. The 1 K 80-column card also enabled one new graphics mode, Double Lo-Res (80×48 pixels). The extended 80-column card enabled two, Double Lo-Res and Double Hi-Res (560×192 pixels). Both modes doubled the horizontal resolution in comparison to the standard Lo-Res (40×48) and Hi-Res (280×192) Modes; in the case of Double Hi-Res, the number of available colors was increased as well, from 6 to 15. Apple IIe's from the very first production run cannot use Double Hi-Res. Neither of these modes was directly supported by the built-in BASIC, however, so the user had to resort to the use of lots of POKE and CALL commands in BASIC, or assembly language programming, or one of a number of software Toolkits to exploit these modes.

While it was possible for software to switch out the 80-column firmware, making the firmware of a card in slot 3 available with a card in the auxiliary slot, it was not a common thing to do. However, even with the 80-column firmware enabled, slot 3's I/O memory range was still usable, giving it approximately the capability of slot 0 on a II or II plus. This meant that it actually was possible to use slot 3 for things, such as coprocessor cards and language cards, that did not use slot firmware space.

Introduced with the IIe was the DuoDisk, essentially two Disk II 5.25-inch drives in a single enclosure designed to stack between the computer and the monitor, and a new controller card to run it. This controller was (by design) functionally identical to the original Disk II controller but used a different connector, allowing a single cable to control both drives in the DuoDisk. The DuoDisk was plagued by reliability problems, however, and did not catch on as well as the Apple IIe itself.

The Apple IIe was the most popular Apple II ever built and was widely considered the "workhorse" of the line. It also has the distinction of being the longest-lived Apple computer of all time — it was manufactured and sold with only minor changes for nearly eleven years. In that time, following the original, two important variations were introduced known as the Enhanced IIe (four new replacement chips to give it some of the features of the later model Apple IIc, including an upgraded processor called the 65C02) and the Platinum IIe (a modernized new look for the case color to match other Apple products of the era, along with the addition of a built-in numeric keypad). An Enhanced IIe with 128 kB of RAM can be considered the minimum requirement for running most Apple II software released after about 1988.

Two and a half years before the Apple IIe, Apple had produced and marketed a computer called the *Apple III* for business users. This product was not a success, and Steve Wozniak has been quoted as saying that the Apple III had a 100% failure rate — every single machine manufactured had some kind of fault (a famous Apple technical bulletin recommended dropping the machine vertically onto a table to re-seat the DIP chips in their loose sockets). Still, many of its features were carried over in the design of the Apple IIe, without the manufacturing flaws that led to failures in the Apple III. Among them was the ProDOS operating system, which was based on Apple III's Sophisticated Operating System (SOS).

Apple IIc



The Apple IIc was Apple's first compact and portable computer

Apple released the **Apple IIc** in April 1984, billing it as a portable Apple II, because it could be easily carried, though unlike modern portables it lacked a built-in display and battery. The IIc even sported a carrying handle that folded down to prop the machine up into a typing position. It was the first of three Apple II models to be made in the Snow White design language, and the only one that used its unique creamy off-white color. (The other Snow White computers from the Apple II series, the IIGS and the IIc Plus, were light gray, called "Platinum" by Apple.)

The Apple IIc was the first Apple II to use the 65C02 low-power variant of the 6502 processor, and featured a built-in 5.25-inch floppy drive and 128 kB RAM, with a built-in disk controller that could control external drives, composite video (NTSC or PAL), serial interfaces for modem and printer, and a port usable by either a joystick or mouse. Unlike previous Apple II models, the IIc had no internal expansion slots at all, this being the means by which its compact size was attained. Third parties did eventually figure out how to wedge up to 1 MB of additional memory and a real-time clock into the machine, and a later revision of the motherboard provided an expansion slot that could accept an Apple memory card bearing up to 1 MB of RAM. The disk port, originally intended for a second 5.25-inch floppy drive, eventually was able to interface to 3½-inch disk drives and (via third parties) even hard disks.

To play up the portability, two different monochrome LCD displays were sold for use with the IIc's video expansion port, although both were short-lived due to high cost and poor legibility. (An Apple IIc with the smaller of these displays appeared briefly in the film *2010*.) The IIc had an external power supply that converted AC power to 12 V DC, allowing third parties to offer battery packs and automobile power adapters that connected in place of the supplied AC adapter.

The Apple IIc (in its American version) was the first microcomputer to include support for the Dvorak Simplified Keyboard, which was activated using a switch above the keyboard. This feature was also later found in late-model American Apple IIe computers (though the switch was inside the computer) and in the Apple IIGS (accessible via the built-in control panel). The international models used the same mechanism to switch between the localized and the American keyboard layouts, but did not offer Dvorak.

Apple IIGS



The Apple IIGS, the most powerful Apple II, featuring a true 16-bit CPU, 4096 colors, Ensoniq synthesizer, a Mac-like GUI and a mouse.



The Apple IIGS setup, with keyboard and mouse shown

The next member of the line was the **Apple IIGS** computer, released in September 15, 1986. A radical departure from the existing Apple II line, the IIGS featured a true 16-bit microprocessor, the 65C816, operating at 2.8 MHz with 24-bit addressing, allowing expansion up to 8 MB of RAM without the bank-switching hassles of the earlier machines (RAM cards with more than 4 MB were never directly supported by Apple). It introduced two completely new graphic modes sporting higher resolutions and a palette of 4,096 colors; however, only 4 (at 640×200 resolution) or 16 (at 320×200 resolution) colors could be used on a single line at a time, although a technique known as *dithering* was often employed in software to increase the number of perceived colors.

In a departure from earlier Apple II graphics modes, the new modes laid out the scanlines sequentially in memory. However, programmers in search of a graphics challenge could always turn to 3200-color mode, which involved precisely swapping in a different 16-color palette for each of the screen's 200 scanlines as the monitor's electron beam traced the screen line by line. This exotic technique did not leave many CPU cycles available for other processing, so this "mode" was best suited to displaying static images.

The Apple IIGS stood out from any previous (or future) Apple II models, evolving and advancing the platform into the next generation of computing while still maintaining near-complete backward compatibility. The secret of the Apple IIGS's compatibility was a

single chip called the Mega II, which contained the functional equivalent of an entire Apple IIe computer (sans processor). This, combined with the flawless 65C02 emulation mode of the 65C816 processor, provided full support for legacy software.

The computer also included a 32-voice Ensoniq 5503, 'wavetable' sample-based music synthesizer chip with 64 kB dedicated RAM, 256 kB of standard RAM, built-in peripheral ports (switchable between IIe-style card slots and IIc-style onboard controllers for disk drives, mouse, RGB video, and serial devices), built-in AppleTalk networking, and a ROM toolbox that supported a graphical user interface derived from the Macintosh toolbox. The computer could run existing 8-bit Apple II software (including software written for the very first Apple II in Integer BASIC), but also supported 16-bit software running under a new OS first called ProDOS 16 and later called GS/OS. The new OS eventually included a Finder that could be used for managing disks and files and opening documents and applications, along with desk accessories — just like the Macintosh. The 16-bit operating system would automatically switch to the text display and downshift to 8-bit mode to run legacy software, while offering a consistent, Macintosh-like graphical interface for native 16-bit applications. Eventually, the IIGS gained the ability to read and write Macintosh disks and, through third-party software, even multitasking (both cooperative and preemptive, the latter in the form of a Unix-type shell), outline TrueType font support, and in one case, even real-time 3D gaming using texture mapping.

The first 50,000 Apple IIGS computers came with Steve Wozniak's "*Woz*" signature silkscreened on the front and were referred to as the "*Woz Limited Edition*". These machines are not functionally different from machines from the same time period without the signature.

Apple IIc Plus



The Apple IIc Plus, an 8-bit revision of the original portable but with faster CPU, 3.5-inch floppy and built-in power supply. It was the last introduced of the Apple II line.

The final Apple II model was the **Apple IIc Plus** introduced in 1988. It was the same size and shape as the IIc that came before it, but the 5.25-inch floppy drive had been replaced with a 3½-inch drive, the power supply was moved inside (gone was the IIc's "brick on a leash" power supply), and the processor was a fast 4 MHz 65C02 processor that actually ran 8-bit Apple II software faster than the IIGS. (Third-party accelerators for other models could, however, go as fast as 10 MHz, and IIGS accelerators would eventually reach 16 MHz.) The IIc Plus's accelerator was derived from a design licensed from Zip Technologies, a third-party maker of accelerators for the Apple II, though Apple used separate chips instead of combining the processor, cache, and supporting logic on a multi-chip module as did Zip. Like later models of the original Apple IIc, the IIc Plus included a memory expansion slot that would accept a daughter-card carrying up to a megabyte of RAM. The IIc Plus also featured a new keyboard layout that matched the Platinum IIe and IIGS. Unlike the IIe, IIc and IIGS, the IIc Plus came only in one version (American) and was not officially sold anywhere outside the USA.

Many perceived the IIc Plus as Apple's attempt to compete with the Laser 128EX/2, a popular third party Apple-compatible machine that also had an accelerated processor and

a built-in 3.5-inch drive. There were few other rational explanations for Apple expending resources on the continued development of a new 8-bit Apple II model rather than furthering the 16-bit Apple IIGS. However, with its 3.5-inch drive and speedy processor, it was an excellent, compact machine for running the AppleWorks integrated productivity package, especially with the 1 MB memory upgrade.

Apple IIe Card

Although not an extension of the Apple II line, in 1990 the **Apple IIe Card**, an expansion card for the LC line of Macintosh computers, was released. Essentially a miniaturized Apple IIe computer on a card (using the Mega II chip from the Apple IIGS), it allowed the Macintosh to run 8-bit Apple IIe software through hardware emulation (although video was emulated in software and was slower at times than a IIe). Many of the LC's built-in Macintosh peripherals could be "borrowed" by the card when in Apple II mode (i.e. extra RAM, 3.5-inch floppy, AppleTalk networking, hard disk). The IIe card could not, however, run software intended for the 16-bit Apple IIGS. The Macintosh LC with IIe Card was intended to replace the Apple IIGS in schools and homes and was presumably the reason a new model Apple IIGS that was confirmed by insiders to be in development at one point was cancelled and never released.

Final years

Apple's Macintosh product line finally eclipsed the Apple II in the early 1990s. Even after the Macintosh's introduction, the Apple II had remained the company's primary revenue source for years. The computer was the first to attract a loyal user community and many outspoken Apple II fans were bitter that the company had invested its Apple II profits into the Macintosh rather than using them to further the Apple II series.

Apple continued to sell Apple II systems alongside the Macintosh until terminating the IIGS in December, 1992 and the IIe in November, 1993.

Advertising, marketing, and packaging

Mike Markkula, a retired Intel salesman who provided early critical funding for Apple Computer, was keen on marketing. From 1977-1981, Apple used the Regis McKenna agency for its advertisements and marketing. In 1981, Chiat-Day acquired Regis McKenna's advertising operations and Apple used Chiat-Day. At Regis McKenna Advertising, the team assigned to launch the Apple II consisted of Rob Janoff, art director, Chip Schafer, copywriter and Bill Kelley, account executive. Janoff came up with the Apple logo with a bite out of it. The design was originally an olive green with matching company logotype all in lower case. Steve Jobs insisted on promoting the color capability of the Apple II by putting rainbow stripes on the Apple logo. In its letterhead and business card implementation, the rounded "a" of the logotype echoed the "bite" in the logo. This logo was developed simultaneously with an advertisement and a brochure; the latter being produced for distribution initially at the first West Coast Computer Faire. Ever since the original Apple II, Apple has paid high attention to its quality of packaging,

partly because of Steve Jobs' personal preferences and opinions on packaging and final product appearance. All of Apple's packaging for the Apple II series looked similar, featuring lots of clean white space and showing the Apple rainbow logo prominently. For several years up until the late 1980s, Apple used the Motter Tekkura font for packaging, until changing to the Apple Garamond font.

Apple ran the first advertisement for the Apple II in the July 1977 edition of *Byte* — a two page spread ad titled "Introducing the Apple II" and followed by a third page that was an order form. The first brochure, was entitled "Simplicity" and the copy in both the ad and brochure pioneered "demystifying" language intended to make the new idea of a home computer more "personal." The Apple II introduction ad was later run in the September 1977 issue of *Scientific American*.

For the Apple IIc, Apple wanted an advertisement to demonstrate the power of the machine despite its small size; they ran a memorable television commercial featuring a high-rise office building in which they claimed with words and images that the IIc had all the power necessary to run a large building, suggesting that it had more than enough power for the home user. (This ad, along with the 1984 Macintosh ad, was featured in a Marketing telecourse run on PBS.)

Apple later aired eight television commercials for the Apple IIGS, emphasizing its benefits to education and students, along with some print ads.

Towards the end of 1982, art director Brent Thomas and Steve Hayden came up with the idea of doing an advertising campaign based on the timely tagline "Why 1984 will not be like 1984". Chiat-Day shopped it around to a number of clients, including Apple, where it was proposed to be used for a print ad in the Wall Street Journal promoting the Apple II. However, Apple did not go for it, and the idea was filed away until the spring of 1983, when they met with the Macintosh marketing team to start working on the launch, which was scheduled for January 1984. The idea eventually became the famous 1984 commercial which aired during the third quarter at Super Bowl XVIII.

Clones



The Jiama (嘉馬) SPS-109, a Taiwanese clone of the Apple II, looks almost identical to the Apple II and II+, including an identical case, color and keyboard layout. The only noticeable physical difference is the label above the keyboard.

The Apple II was frequently cloned, both in the United States and abroad — similar cloning of the IBM PC later occurred. According to some sources (see below), more than 190 different models of Apple II clones were manufactured. Many of these had "fruit" names (e.g. "Pineapple") to indicate to the initiated that they were Apple II clones. Well-known in the Soviet Bloc were the Agat, an oversized Russian Apple II clone with a Cyrillic character set, and Bulgarian Pravetz series 8, a close Apple II replica with Cyrillic support.

Basis, a German company, created the Basis 108, a clone for the Apple II that included both a 6502 processor and the Zilog Z80, allowing it to run the CP/M operating system as well as most Apple II software. This machine was unusual in that it was housed in a heavy cast-iron chassis. The Basis 108 was equipped with built-in Centronics (parallel) and RS232c (serial) ports, as well as the standard six Apple II compatible slots. Unlike the Apple II it came with a detached full-stroke keyboard (AZERTY/QWERTY) of 100 keys plus 15 functions keys and separate numeric and editing keypads.

A Bosnian (at the time part of communist Yugoslavia) company named IRIS Computers (sub company of biggest electric company in Bosnia and Herzegovina and Yugoslavia ENERGOINVEST) has produced Apple II clones since the early 1980s. Their official brand name was IRIS 8. They were very expensive and hard to obtain and were produced primarily for usage in early computerized digital telephone systems and for education. Their usage in offices of the state companies, R&D labs and in the Yugoslav army was also reported. IRIS 8 had looks of early IBM PCs — separate central unit with cooling system and two 5.25-inch disks, monitor and keyboard. Compatibility with original Apple II was complete. Elite high schools in Yugoslavia and especially Bosnia and Herzegovina were equipped with clusters of 8, 16 or 32 IRIS 8 computers connected in local network administrated by IRIS 16 PC clone. The number of IRIS 8's produced could be as many as a couple of tens of thousands.

An Australian-produced clone of the Apple II was the Medfly, named after the Mediterranean fruit fly that attacks apples. The Medfly computer featured a faster processor, more memory, detached keyboard, lower and upper case characters and a built-in disk controller.

Unitron, a Brazilian company, produced another clone, named ApII. Unitron used a copy of the Apple's ROM translated to Portuguese. The operating system was Apple's DOS 3.3 translated to Portuguese. During this period, it was illegal to import microcomputers in Brazil, and buying those (illegal) clones was the only way to have a microcomputer. Unitron stopped manufacturing the ApII a few years after the introduction of IBM PC clones in Brazil.

The Ace clones from Franklin Computer Corporation are the best known and had the most lasting impact, as Franklin copied Apple's ROMs and software and freely admitted to doing so. Franklin's argument: a computer's ROM was simply a pattern of switches locked into a fixed position, and one cannot copyright a pattern of switches. Apple fought Franklin in court for about five years to get its clones off the market, and was ultimately successful when a court ruled that software stored in ROM was in fact copyrightable in the U.S. Franklin later released non-infringing but less-compatible clones; these could run ProDOS and AppleWorks and had an Applesoft-like BASIC, but compatibility with other software was hit-or-miss.

Apple also challenged VTech's Laser 128, an enhanced clone of the Apple IIc first released in 1984, in court. This suit proved less fruitful for Apple, because VTech had reverse-engineered the Monitor ROM rather than copying it and had licensed Applesoft BASIC from its creator, Microsoft. Apple had neglected to obtain exclusive rights to the Applesoft dialect of BASIC from Microsoft; VTech was the first cloner to license it. The Laser 128 proved popular and remained on the market for many years, both in its original form and in accelerated versions that ran faster than 1 MHz. Although it was not 100% compatible with the Apple II, it was close, and its popularity ensured that most major developers tested their software on a Laser as well as on genuine Apple machines. Because it was frequently sold via mail order and mass-market retailers such as Sears, the

Laser 128 may have cut into the sales of low-cost competitors such as Commodore Business Machines as much as it did Apple's.

While the first Apple II clones were generally exact copies of their Apple counterparts that competed mainly on price, many clones had extra capabilities too. A Franklin model, the Ace 1000, sported a numeric keypad and lower-case long before these features were added to the Apple II line. The Laser 128 series is sometimes credited with spurring Apple to release the Apple IIc Plus; the built-in 3½-inch drive and accelerated processor were features Laser had pioneered. The Laser 128 also had a IIe-style expansion slot on the side that could be used to add peripheral cards.

Bell & Howell, an audiovisual equipment manufacturer whose products (particularly film projectors) were ubiquitous in American schools, offered what appeared at first glance to be an Apple II Plus clone in a distinctive black plastic case. However, these were in fact real Apple II Plus units manufactured by Apple for B&H for a brief period of time. Many schools had a few of these Black Apple or Black "Darth Vader" Apples in their labs.

ITT created an Apple II Plus-compatible for the European market called the ITT 2020 (Europlus). This machine was built under license from Apple. It has the same shape as the Apple II but a different color (matte silver), and is not an exact copy functionally.

Syscom 2 Inc (from Carson City, NV) created the Syscom 2 Apple II+ clone. The case looked nearly identical. They had 48 k RAM and the normal expansion capabilities. These clones also supported lower case characters, toggled with a ^O keystroke.

An unknown company produced a clone called the RX-8800. One new feature it had was a numeric keypad.

Although not technically a clone, Quadram produced an add-in ISA card, called the Quadlink, that provided hardware emulation of an Apple II+ for the IBM PC. The card had its own 6502 CPU and dedicated 80 K RAM (64 K for applications, plus 16 K to hold a reverse-engineered Apple ROM image, loaded at boot-time), and installed "between" the PC and its floppy drive(s), color display, and speaker, in a pass-through configuration. This allowed the PC to operate in a dual-boot fashion: when booted through the Quadlink, the PC could run the majority of II software, and read and write Apple-formatted floppies through the standard PC floppy drive. Because it had a dedicated processor, rather than any form of software emulation, this system ran at nearly the same speed as an equivalent Apple machine. Another company, Diamond Computer Systems, produced a similar card called the Trackstar, that had both a 6502 and a Z80, allowing use of software for both Apple DOS and Apple CP/M. The Trackstar also had a connector allowing use of an actual Apple floppy drive, which enhanced its compatibility with software that took advantage of Apple hardware for copy-protection.

General

Data storage

Originally the Apple II used audio cassette tapes for program and data storage. A dedicated tape recorder along the lines of the Commodore Datasette was never produced; Apple recommended using the Panasonic RQ309 in some of its early printed documentation. Apple and many third-party developers made software available on tape at first, but after the Disk II became available, tape-based Apple II software essentially disappeared from the market.

The Disk II floppy drive used 5.25-inch floppy disks. The first disk operating systems for the Apple II were DOS 3.1 and DOS 3.2, which stored 113.75 kB on each disk, organized into 35 tracks of thirteen 256-byte sectors each. After about two years, DOS 3.3 was introduced, storing 140 kB thanks to a minor firmware change on the disk controller that allowed it to store 16 sectors per track. (This upgrade was user-installable on older controllers.) After the release of DOS 3.3, the user community discontinued use of DOS 3.2 except for running legacy software. Programs that required DOS 3.2 were fairly rare; however, as DOS 3.3 was not a major architectural change aside from the number of sectors per track, a program called MUFFIN was provided with DOS 3.3 to allow users to copy files from DOS 3.2 disks to DOS 3.3 disks.

On a DOS 3.x disk, tracks 0, 1, and most of track 2 were reserved to store the operating system. (It was possible, with a special utility, to reclaim most of this space for data if a disk did not need to be bootable.) A short ROM program on the disk controller had the ability to seek to track zero — which it did without regard for the read/write head's current position, resulting in the characteristic "chattering" sound of a Disk II boot, which was the read/write head hitting the rubber stop block at the end of the rail — and read and execute code from sector 0. The code contained in there would then pull in the rest of the operating system. DOS stored the disk's directory on track 17, smack in the middle of the 35-track disks, in order to reduce the average seek time to the frequently-used directory track. The directory was fixed in size and could hold a maximum of 105 files. Subdirectories were not supported.

Most game publishers did not include DOS on their floppy disks, since they needed the memory it occupied more than its capabilities; instead, they often wrote their own boot loaders and read-only file systems. This also served to discourage "crackers" from snooping around in the game's copy-protection code, since the data on the disk was not in files that could be accessed easily.

Some third-party manufacturers produced floppy drives that could write 40 tracks to most 5.25-inch disks, yielding 160 kB of storage per disk, but the format did not catch on widely, and no known software was published on 40-track media. Most drives, even Disk IIs, could write 36 tracks; simple modifications to DOS for formatting the extra track were common.

Incidentally, although the Apple Disk II stored 140 kB on single-sided, "single-density" floppy disks, it was very common for Apple II users to extend the capacity of a floppy disk to 280 kB — by cutting out a second write-protect notch on the side of the disk using a "disk notcher" (although a simple hole puncher would do) and inserting the disk flipped over. Early on, diskette manufacturers routinely warned that this technique would damage the read/write head of the drives or wear out the disk faster, and these warnings were frequently repeated in magazines of the day. In practice, however, this method was an inexpensive way to store twice as much data for the same amount of money, and was widely used for commercially released floppies as well.

Later, Apple IIs were able to use 3.5-inch disks with a total capacity of 800 kB and hard disks. DOS 3.3 did not support these drives natively; third-party software was required, and disks larger than about 400 kB had to be split up into multiple "virtual disk volumes." ProDOS, a 1983 descendent of the Apple ///'s SOS, became the Apple II operating system of choice for users with these larger disks thanks to its native support of volumes up to 32 MB in size and the fact that AppleWorks required it.

Renditions of the "II" name

The "II" portion of the Apple II name was rendered in a variety of creative ways using stylized characters which resembled punctuation symbols on the front lids of the computers, and most printed material followed this lead. The II and II+ were labeled][and][plus. The IIGS and IIc Plus were rendered in small caps. The Apple ///, IIc, and IIe models used slashes: ///, //c and //e. There have been some errors in the Apple II's name due to the numerous variations and forms on the "II".

Legacy

Today, emulators for various Apple II models are available to run Apple II software on Mac OS X, Linux, Microsoft Windows, homebrew enabled Nintendo DS and other operating systems. Numerous disk images of Apple II software are available free over the Internet for use with these emulators. AppleWin and MESS are among the best emulators compatible with most Apple II images. The MESS emulator supports recording and playing back of Apple II emulation sessions. The Home Action Replay Page (aka HARP) allows Apple II users to archive their favorite play sessions of the Apple II system and its games. However, many emulators cannot run software on copy-protected media, or can run only software employing fairly simple protection schemes, unless it is "cracked" (copy restrictions removed). Cracked software was widely pirated in the Apple II's heyday (with commercial cracking software such as the popular Copy II+ program being sold in stores with the purpose of creating legitimate back-ups of protected software). Although creating back-ups was legitimate under copyright law of the time, the use of such software today is of questionable legality in the U.S. For those who prefer to obtain their old software legally, the Lost Classics Project has the goal of convincing copyright holders of classic Apple II software to officially allow unrestricted free distribution of their software and has "freed" a number of programs.

In addition, an active retrocomputing community of vintage Apple II collectors and users, continue to restore, maintain and develop hardware and software for daily use of these original computers. Numerous websites and support groups exist for these enthusiasts who engage in the trade and purchase for their collections, increasingly rare parts and systems. Hardly a dead platform, the Apple II has a worldwide network of kindred spirits actively engaged in preserving this otherwise outdated technology and indeed regularly attracts, new younger members who continue to keep the platform alive long after it was discontinued by Apple. There is still a small annual convention, KansasFest, dedicated to the platform.

Industry impact

The Apple II series of computers had an enormous impact on the technology industry and on everyday life. The Apple II was the first personal computer many people ever saw, and its price was within the reach of many middle-class families. By the end of 1980 Apple had already sold over 100,000 Apple IIs Its popularity bootstrapped the entire computer game and educational software markets and began the boom in the word processor and computer printer markets. The first microcomputer "killer app" for business was VisiCalc, the earliest spreadsheet, and it ran first on the Apple II; many businesses bought Apple II's just to run VisiCalc, because it was the only spreadsheet available at the time. Apple's success in the home market inspired competitive home computers such as the VIC-20 (1980) and Commodore 64 (1982, with estimated sales between 17 and 25 million units). Through their significantly lower price point, these models introduced the computer to several tens of millions more home users.

The success of the Apple II in business spurred IBM to create the IBM PC, which was then purchased by middle managers in all lines of business to run spreadsheet and word processing software, at first ported from Apple II versions; later, whole new application software dynasties would be founded on the PC. The popularity of these PCs and their clones then transformed business again with LAN applications such as e-mail and later Internet applications such as Usenet and the WWW.

One valuable lesson from the Apple II was the importance of an open architecture to the success of a computer platform. The first Apple II's shipped with an *Apple II Reference Manual* containing a complete schematic of the entire computer's circuitry and a complete source listing of the "Monitor" ROM firmware that served as the machine's BIOS (later this guide had to be purchased separately, and in the case of the Apple IIGS, the full technical documentation ran to several volumes). The Apple II's slots, allowing any peripheral card to take control of the bus and directly access memory, enabled an independent industry of card manufacturers who together created a flood of hardware products that let users build systems that were far more powerful and useful (at a lower cost) than any competing system, most of which were not nearly as expandable and were universally proprietary. Even the game port was unusually powerful and could be used for digital and analog input and output; one hacker (Don Lancaster) used it to drive a LaserWriter printer.

Apple decided not to create an open architecture with the initial Macintosh models, and this is widely seen as having hobbled its success. It wasn't until the advent of the open architecture Macintosh II that the platform took off. However, the IBM PC provides an object lesson that success for the platform does not necessarily equate to success for the company that invented it. In the end, the IBM PC's off-the-shelf, open architecture allowed clones to be manufactured by startup competitors such as Compaq, Dell and Gateway, leading to a Pyrrhic victory for IBM. In December 2004, IBM confirmed it had sold its personal computer division including all computer models and technology to Lenovo in the People's Republic of China for US\$1.75 billion.

Chapter 9

IBM Personal Computer

IBM PC (model 5150)



IBM 5150 PC

Type	Personal computer
Release date	August 12, 1981
Discontinued	April 2, 1987

	IBM BASIC / PC-DOS 1.0
Operating system	CP/M-86 UCSD p-System
CPU	Intel 8088 @ 4.77 MHz
Memory	16 kiB ~ 256 kiB
Sound	1-channel PWM

The **IBM Personal Computer**, commonly known as the **IBM PC**, is the original version and progenitor of the IBM PC compatible hardware platform. It is IBM model number **5150**, and was introduced on August 12, 1981. It was created by a team of engineers and designers under the direction of Don Estridge of the IBM Entry Systems Division in Boca Raton, Florida.

Alongside "microcomputer" and "home computer", the term "personal computer" was already in use before 1981. It was used as early as 1972 to characterize Xerox PARC's Alto. However, because of the success of the IBM Personal Computer, the term *PC* came to mean more specifically a microcomputer compatible with IBM's PC products.

Origins

The original line of PCs were part of an IBM strategy to get into the small computer market then dominated by the Commodore PET, Atari 8-bit family, Apple II and Tandy Corporation's TRS-80s, and various CP/M machines. IBM's first desktop microcomputer was the IBM 5100, introduced in 1975. It was a complete system, with a built-in monitor, keyboard, and data storage. It was also very expensive — up to \$20,000 USD. It was specifically designed for professional and scientific problem-solvers, not business users or hobbyists. When the PC was introduced in 1981, it was originally designated as the IBM 5150, putting it in the "5100" series, though its architecture was not directly descended from the IBM 5100.



Don Estridge, the Development Director

Rather than going through the usual IBM design process, a special team was assembled with authorization to bypass normal company restrictions and get something to market rapidly. This project was given the code name *Project Chess* at the IBM Entry Systems

Division in Boca Raton, Florida. The team consisted of twelve people directed by Don Estridge with Chief Scientist Larry Potter and Chief Systems Architect Lewis Eggebrecht. They developed the PC in about a year. To achieve this they first decided to build the machine with "off-the-shelf" parts from a variety of different original equipment manufacturers (OEMs) and countries. Previously IBM had always developed their own components. Secondly for scheduling and cost reasons, rather than developing unique IBM PC monitor and printer designs, project management decided to utilize an existing "off-the-shelf" IBM monitor developed earlier in IBM Japan as well as an existing Epson printer model. Consequently, the unique IBM PC industrial design elements were relegated to the system unit and keyboard. They also decided on an open architecture, so that other manufacturers could produce and sell peripheral components and compatible software without purchasing licenses. IBM also sold an *IBM PC Technical Reference Manual* which included complete circuit schematics, a listing of the ROM BIOS source code, and other engineering and programming information. IBM announced the PC on August 12, 1981. Six weeks later at COMDEX Fall, Tecmar had 20 PC products available for sale. These products included memory expansion, IEEE-488, data acquisition and PC Expansion chassis . Pricing for the IBM PC started at \$1,565 for a bare-bones configuration without disk drives.

At the time, Don Estridge and his team considered using the IBM 801 processor (an early RISC CPU) and its operating system that had been developed at the Thomas J. Watson Research Center in Yorktown Heights, New York. The 801 was at least an order of magnitude more powerful than the Intel 8088, and the operating system many years more advanced than the DOS operating system from Microsoft, that was finally selected. Ruling out an in-house solution made the team's job much easier and may have avoided a delay in the schedule, but the ultimate consequences of this decision for IBM were far-reaching. IBM had recently developed the Datamaster business microcomputer which used an Intel processor and peripheral ICs; familiarity with these chips and the availability of the Intel 8088 processor was a deciding factor in the choice of processor for the new product. Even the 62-pin expansion bus slots were designed to be similar to the Datamaster slots. Delays due to in-house development of the Datamaster software also influenced the design team to a fast track development process for the PC, with publicly available technical information to encourage third-party developers.

Other manufacturers soon reverse engineered the BIOS to produce their own non-infringing functional copies. Columbia Data Products introduced the first IBM-PC compatible computer in June 1982. In November 1982, Compaq Computer Corporation announced the *Compaq Portable*, the first portable IBM PC compatible. The first models were shipped in March 1983.

Once the *IBM PC* became a commercial success, the product came back under the more usual tight IBM management control. IBM's tradition of "rationalizing" their product lines, deliberately restricting the performance of lower-priced models in order to prevent them from "cannibalizing" profits from higher-priced models, worked against them.

IBM PC as standard

The success of the IBM computer led other companies to develop *IBM Compatibles*, which in turn led to brandings like diskettes being in IBM format, or systems complaining about no ROM-BASIC on booting. In essence, during the bulk of the 1980s and early 1990s, the main machines that were talked about in the press and in how-to guides, were IBM ones.

To a great extent one could build an IBM clone with off-the-shelf parts, but the BIOS required some reverse-engineering. Companies like American Megatrends, Award, and others achieved workable clones of this, allowing companies like DELL, Compaq, HP *et al*, to manufacture PCs that worked like IBM ones. These did not have a ROM-BASIC, so when ROM-Basic was expected to load in the absence of a boot device, a message might appear saying no ROM BASIC was found.

Third-party distribution

ComputerLand and Sears Roebuck partnered with IBM from the beginning of development. IBM's head of sales and marketing, H.L. ('Sparky') Sparks, relied on these retail partners for important knowledge of the marketplace.

As a natural progression, Computerland and Sears became the main outlets for the new product. More than 190 Computerland stores already existed, while Sears was in the process of creating a handful of in-store computer centers for sale of the new product. This guaranteed IBM widespread distribution across the U.S.

Targeting the new PC at the home market, Sears Roebuck sales failed to live up to expectations. This unfavourable outcome revealed that the strategy of targeting the office market was the key to higher sales.

Models

The IBM PC range

Model name	Model #	Introduced	CPU	Features
PC	5150	August 1981	8088	Floppy disk or cassette system
XT	5160	March 1983	8088	First IBM PC to come with an internal hard drive as standard.
XT/370	5160/588	October 1983	8088	5160 with XT/370 Option Kit and 3278/79 Emulation Adapter
3270 PC	5271	October 1983	8088	With 3270 terminal emulation
PCjr	4860	November 1983	8088	Floppy-based home computer

Portable	5155	February 1984	8088	Floppy-based portable
AT	5170	August 1984	80286	Medium-speed hard disk
AT/370	5170/599	October 1984	80286	5170 with AT/370 Option Kit and 3278/79 Emulation Adapter
3270 AT	5281	June 1985	80286	With 3270 terminal emulation
Convertible	5140	April 1986	8088	Microfloppy laptop portable
XT 286	5162	September 1986	80286	Slow hard disk, but zero wait state memory on the motherboard. This 6 MHz machine was actually faster than the 8 MHz ATs (when using planar memory) because of the zero wait states

All IBM personal computers are software backwards-compatible with each other in general, but not every program will work in every machine. Some programs are time sensitive to a particular speed class. Older programs will not take advantage of newer higher-resolution display standards.

PC

The original PC had a version of Microsoft BASIC — IBM Cassette BASIC — in ROM. The CGA (Color Graphics Adapter) video card could use a standard television set or an RGBI monitor for display; IBM's RGBI monitor was their display model 5153. The other option that was offered by IBM was an MDA (Monochrome Display Adapter) and their monochrome display model 5151. It was possible to install both an MDA and a CGA card and use both monitors concurrently, if supported by the application program. For example, AutoCAD allowed use of a CGA card for graphics and a separate monochrome board for text menus. Some model 5150 PCs with CGA monitors and a printer port also included the MDA adapter by default, because IBM provided the MDA port and printer port on the same adapter card; it was in fact an MDA/printer port combo card.

The most commonly used storage medium was the floppy disk, though cassette tape was originally envisioned by IBM as a low-budget alternative. Accordingly, the IBM 5150 PC was available with one or two floppy drives or without any drives or storage medium; in the latter case IBM intended for a user to connect their own cassette recorder via the 5150's cassette jack. The cassette tape port was mechanically identical to, and located next to, the keyboard port on the 5150's mainboard. A hard disk could not be installed into the 5150's system unit without retrofitting a stronger power supply, but an "Expansion Unit", a.k.a. the "IBM 5161 Expansion Chassis" was available, which came with one 10 MB hard disk and also allowed the installation of a second hard disk. The system unit had five expansion slots; the expansion unit had eight; however, one of the system unit's slots and one of the expansion unit's slots had to be occupied by the Extender Card and Receiver Card, respectively, which were needed to connect the expansion unit to the system unit and make the expansion unit's other slots available, for

a total of 11 slots. A working configuration required that some of the slots be occupied by display, disk, and I/O adapters, as none of these were built in to the 5150's motherboard; the only on-board external connectors were the keyboard and cassette ports; the simple PC speaker sound hardware was also on-board. The original PC's maximum memory using IBM parts was 256 kiB, 64 kiB on the main board and three 64 kiB expansion cards. The processor was an Intel 8088 (early 1978 version, later were 1978/81/2 versions of intel chip; second-sourced AMDs were used after 1983) running at 4.77 MHz (4/3 the standard NTSC color burst frequency of 3.579545 MHz). Some owners replaced the 8088 with an NEC V20 for a slight increase in processing speed. An Intel 8087 co-processor could also be added for hardware floating-point arithmetic. IBM sold the PC in configurations with 16 or 64 kiB of RAM preinstalled using either nine or thirty-six 16-kibit DRAM chips. (The ninth bit was used for parity checking of memory.)

Although the TV-compatible video board, cassette port and Federal Communications Commission Class B certification were all aimed at making it a home computer, the original PC proved too expensive for the home market. At introduction, a PC with 64 kiB of RAM and a single 5.25-inch floppy drive and monitor sold for 3005 US\$, while the cheapest configuration (1565 US\$) that had no floppy drives, only 16 kiB RAM, and no monitor (again, under the expectation that users would connect their existing TV sets and cassette recorders) proved too unattractive and low-spec, even for its time (cf. footnotes to the above IBM PC range table). While the 5150 did not become a top selling home computer, its floppy-based configuration became an unexpectedly large success with businesses.

XT

The "IBM Personal Computer XT", IBM's model 5160, was an enhanced machine that was designed for diskette and hard drive storage introduced two years after the introduction of the "IBM Personal Computer". It had eight expansion slots and a 10 MB hard disk (later versions 20 MB). Unlike the model 5150 PC, the model 5160 XT no longer had a cassette jack. The XT could take 256 kiB of memory on the main board (using 64 kibit DRAM); later models were expandable to 640 kiB. (The 384 kiB of BIOS ROM, video RAM, and adapter ROM and RAM space filled the rest of the one megabyte address space of the 8088 CPU.) It was usually sold with a Monochrome Display Adapter (MDA) video card. The processor was a 4.77 MHz Intel 8088 and the expansion bus 8-bit Industry Standard Architecture (ISA) with XT bus architecture. The XT's expansion slots were placed closer together than with the original PC; this rendered the XT's case and mainboard incompatible with the model 5150's case and mainboard. The slots themselves and the peripheral cards however were compatible, unless a rare card designed for the PC happened to use the extra width of the 5150's slots. The XT's expansion slot spacing was identical to the one that was later used in the IBM PC AT and is still used as of 2010, though with different actual slots and bus standards.

AT

The "IBM Personal Computer/AT" (model 5170), announced August 1984, used an Intel 80286 processor, originally running at 6 MHz. It had a 16-bit ISA bus and 20 MB hard drive. A faster model, running at 8 MHz, housing a 30-megabyte hard disk was introduced in 1986.

IBM made some attempt at marketing it as a multi-user machine, but it sold mainly as a faster PC for power users. Early PC/ATs were plagued with reliability problems, in part because of some software and hardware incompatibilities, but mostly related to the internal 20 MB hard disk.

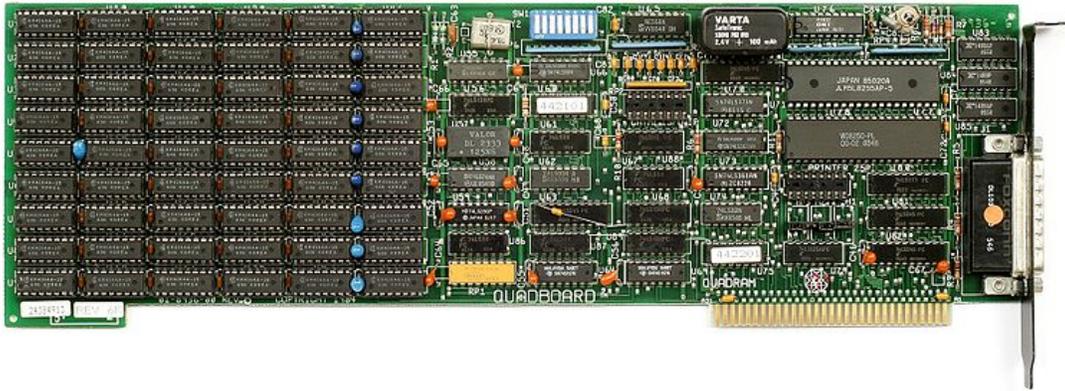
While some people blamed IBM's hard disk controller card and others blamed the hard disk manufacturer Computer Memories Inc. (CMI), the IBM controller card worked fine with other drives, including CMI's 33-MB model. The problems introduced doubt about the computer and, for a while, even about the 286 architecture in general, but after IBM replaced the 20 MB CMI drives, the PC/AT proved reliable and became a lasting industry standard.

Technology

Electronics

The main circuit board in an IBM PC is called the motherboard (IBM terminology calls it a *planar*). This mainly carries the CPU and RAM, and it has a bus with slots for expansion cards. On the motherboard are also the ROM subsystem, DMA and IRQ controllers, coprocessor socket, sound (PC speaker, tone generation) circuitry, and keyboard interface.

The bus used in the original PC became very popular, and it was subsequently named ISA. While it was popular, it was more commonly known as the PC-bus or XT-bus; the term *ISA* arose later when industry leaders chose to continue manufacturing machines based on the IBM PC AT architecture rather than license the PS/2 architecture and its MCA bus from IBM. The XT-bus was then retroactively named *8-bit ISA* or *XT ISA*, while the unqualified term *ISA* usually refers to the 16-bit AT-bus (as better defined in the ISA specifications.) The AT-bus is an extension of the PC-/XT-bus and is in use to this day in computers for industrial use.



Quadram Quadboard

A monitor and any floppy or hard disk drives are connected to the motherboard through cables connected to graphics adapter and disk controller cards, respectively, installed in expansion slots. Memory expansion beyond the amount installable on the motherboard was also done with boards installed in expansion slots, and I/O devices such as parallel, serial, or network ports were likewise installed as individual expansion boards. For this reason, it was easy to fill the five expansion slots of the PC, or even the eight slots of the XT, even without installing any special hardware. Companies like Quadram and AST addressed this with their popular multi-I/O cards which combined several peripherals on one adapter card that uses only one slot; Quadram offered the QuadBoard and AST the SixPak.

Intel 8086 and 8088-based PCs require expanded memory (EMS) boards to work with more than 640 kiB of memory. (Though the 8088 can address one megabyte of memory, the last 384 kiB of that is used or reserved for the BIOS ROM, BASIC ROM, extension ROMs installed on adapter cards, and memory address space used by devices including display adapter RAM and even the 64 kiB EMS page frame itself.) The original IBM PC AT used an Intel 80286 processor which can access up to 16 MiB of memory (though standard DOS applications cannot use more than one megabyte without using additional APIs.) Intel 80286-based computers running under OS/2 can work with the maximum memory.

Keyboard



The original keyboard for the IBM 5150

The original 1981 IBM PC's keyboard at the time was an extremely reliable and high quality electronic keyboard originally developed in North Carolina for the Datamaster system. Each key was rated to be reliable to over 100 million keystrokes. For the IBM PC, a separate keyboard housing was designed with a novel usability feature that allowed users to adjust the keyboard angle for personal comfort. Compared with the keyboards of other small computers at the time, the IBM PC keyboard was far superior and played a significant role in establishing a high quality impression. For example, the industrial design of the keyboard, together with the system unit, was recognized with a major design award. *Byte* magazine in the fall of 1981 went so far as to state that the keyboard was 50% of the reason to buy an IBM PC. The importance of the keyboard was definitely established when the 1983 IBM PCjr flopped, in very large part for having a much different and mediocre Chiclet keyboard that made a poor impression on customers. Oddly enough, the same thing almost happened to the original IBM PC when in early 1981 management seriously considered substituting a cheaper and lower quality keyboard. This mistake was narrowly avoided on the advice of one of the original development engineers.

However, the original 1981 IBM PC 84-key keyboard was criticized by typists for its non-standard placement of the `Return` and left `Shift` keys, and because it did not have

separate cursor and numeric pads that were popular on the pre-PC DEC VT100 series mainframe data terminals. In 1982, Key Tronic introduced the now standard 101-key PC keyboard. In 1984, IBM corrected the Return and left Shift keys on its AT keyboard, but shortened the 'backspace' key, making it harder to reach. In 1986, IBM changed to the 101 key enhanced keyboard, which added the separate cursor and numeric key pads, relocated all the function keys and the `Ctrl` keys, and the `Esc` key was also relocated to the opposite side of the keyboard.

Another criticism of the original keyboard was the relatively loud "clack" sound each key made when pressed. Since typewriter users were accustomed to keeping their eyes on the hardcopy they were typing from and had come to rely on the mechanical sound that was made as each character was typed onto the paper to ensure that they had pressed the key hard enough (and only once), the PC keyboard electronic "clack" feature was intended to provide that same reassurance. However, it proved to be very noisy and annoying, especially if many PCs were in use in the same room, and later keyboards were significantly quieter.

On the technical side, the IBM PC keyboard is very robust and flexible. At the electrical and low-level interface level, every key is equal in basic capability: each key sends a signal when it is pressed and another signal when it is released. An integrated microcontroller in the keyboard manages electrical scanning of the keyboard and encodes a "scan code" and "release code" for each key as it is pressed and released separately. Therefore, any key can be used as a shift key, and a large number of keys can be held down simultaneously and separately sensed. The controller in the keyboard handles typematic operation, issuing periodic repeat scan codes for a depressed key and then a single release code when the key is finally released.

An "IBM PC compatible" may have a keyboard that does not recognize every key combination a true IBM PC does, such as shifted cursor keys. In addition, the "compatible" vendors sometimes used proprietary keyboard interfaces, preventing the keyboard from being replaced.

Although the PC/XT and AT used the same style of keyboard connector, the low-level protocol for reading the keyboard was different between these two series. The AT keyboard uses a bidirectional interface which allows the computer to send commands to the keyboard. An AT keyboard could not be used in an XT, nor the reverse. Third-party keyboard manufacturers provided a switch on some of their keyboards to select either AT-style or XT-style protocol for the keyboard.

Serial port addresses and interrupts

The serial port is an 8250 or a derivative (such as the 16450 or 16550), mapped to eight consecutive IO addresses and one interrupt request line.

COM Port IRQ Base port address [Hex]

COM1 IRQ4 3F8

COM2	IRQ3 2F8
COM3	IRQ4 3E8
COM4	IRQ3 2E8

Only COM1: and COM2: addresses were defined by the original PC. Attempts to share IRQ 3 and IRQ4 to use additional ports require special measures in hardware and software, since shared IRQs were not defined in the original PC design.

Character set

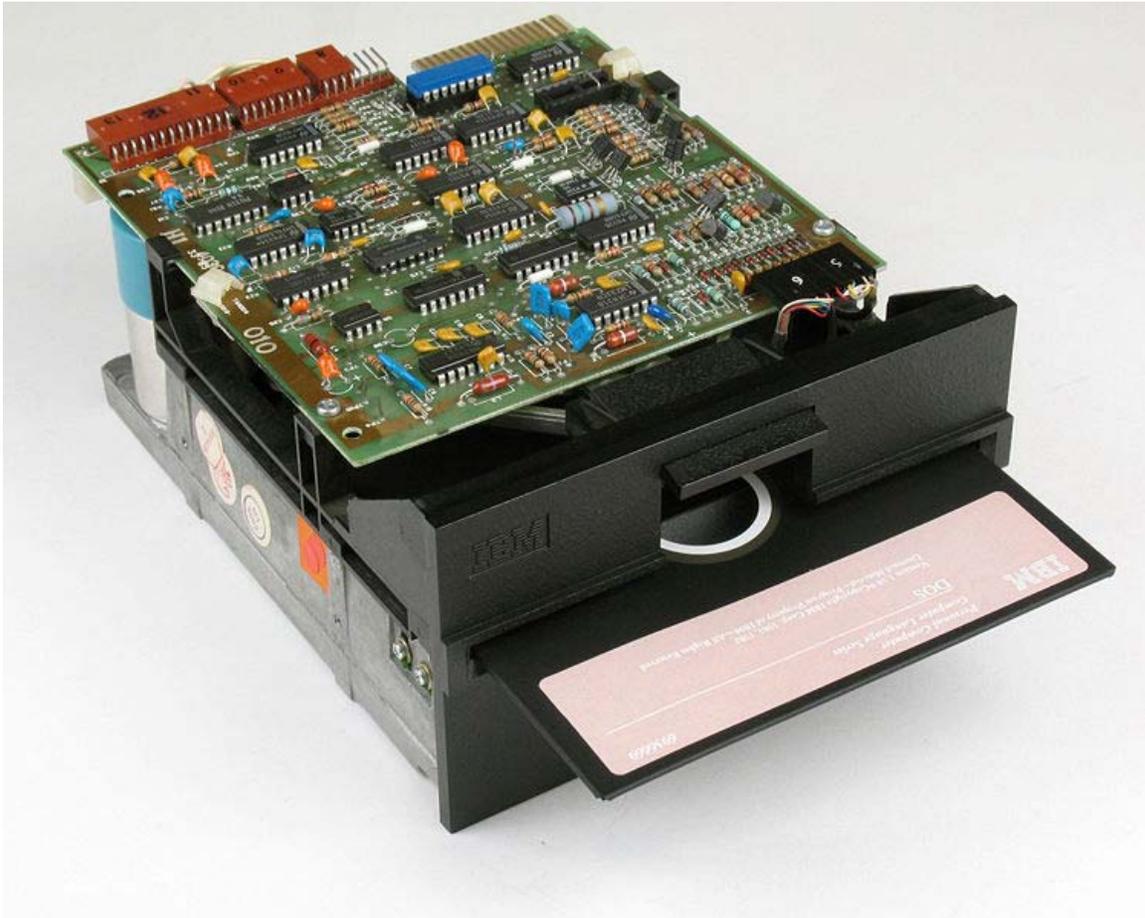
The original IBM PC used the 7-bit ASCII alphabet as its basis, but extended it to 8 bits with nonstandard character codes. This character set was not suitable for some international applications, and soon a veritable cottage industry emerged providing variants of the original character set in various national variants. In IBM tradition, these variants were called code pages. These codings are now obsolete, having been replaced by more systematic and standardized forms of character coding, such as ISO 8859-1, Windows-1251 and Unicode. The original character set is known as code page 437.

Storage media

Cassette tape

As mentioned above, IBM equipped the model 5150 with a cassette port for connecting a cassette drive, and originally intended compact cassettes to become the 5150's most common storage medium. However, adoption of the floppy- and monitor-less configuration was low; few (if any) IBM PCs left the factory without a floppy disk drive installed. Also, DOS was not available on cassette tape, only on floppy disks (hence "Disk Operating System"). 5150s with just external cassette recorders for storage could only use the built-in ROM BASIC as their operating system. As DOS saw increasing adoption, the incompatibility of DOS programs with PCs that used only cassettes for storage made this configuration even less attractive. The ROM BIOS supported cassette operations.

Floppy diskettes



Tandon 5.25-inch Diskette Drive with a partially inserted double-density diskette containing DOS 1.1.

Most or all 5150 PCs had one or two 5.25-inch floppy disk drives. These floppy drives were either single-sided double-density drives (SS/DD, a.k.a. SSDD), or double-sided double-density drives (DS/DD, a.k.a. DSDD). The IBM PC never used single density floppy drives. The drives and disks were commonly referred to by capacity, e.g. "160KB floppy disk" or "360KB floppy drive", but because this is not entirely unambiguous, they are here referred to using the less commonly used but more accurate SSDD and DSDD terminology. DSDD drives were backwards compatible; they could read and write SSDD floppies. The same type of physical diskette could be used for both drives, however to convert a 5.25-inch SSDD disk to a DSDD disk, it needed to be reformatted, at which point SSDD drives could no longer read it.

The disks were Modified Frequency Modulation (MFM) coded in 512-byte sectors, and were soft-sectored. They contained 40 tracks per side at the 48 track per inch (TPI) density, and initially were formatted to contain eight sectors per track. This meant that SSDD disks initially had a formatted capacity of 160 kiB, while DSDD disks had a capacity of 320 kiB. However, the DOS operating system was later updated to allow

formatting the disks with nine sectors per track. This yielded a formatted capacity of 180 kiB with SSDD disks/drives, and 360 kiB with DSDD disks/drives. The *unformatted* capacity of the floppy disks was advertised as "250KB" for SSDD and "500KB" for DSDD ("KB" ambiguously referring to either 1000 or 1024 bytes; essentially the same for rounded-off values), however these "raw" 250/500 kB were not the same thing as the usable formatted capacity; under DOS, the maximum capacity for SSDD and DSDD disks was 180 kiB and 360 kiB, respectively. Regardless of type, the file system of all floppy disks (under DOS) was FAT12.

While the SSDD drives initially were the only floppy drives available for the model 5150 PC, IBM later switched to DSDD drives, and the majority of 5150 PCs sold eventually shipped with one or two DSDD drives. The 5150's successor, the model 5160 IBM XT, never shipped with SSDD drives; it generally had one double-sided 360 kiB drive (next to its internal hard disk). While it was technically possible to retrofit more advanced floppy drives such as the high-density drive (released in 1984) into the original IBM PC, this was not an option offered by IBM for the 5150 model, and the move to high-density 5.25-inch floppies in particular was notoriously fraught with disk compatibility problems.

IBM's original floppy disk controller card also included an external 37-pin D-shell connector. This allowed users to connect additional external floppy drives by third party vendors. IBM themselves did not offer external floppy drives.

Fixed disks



20MB Seagate ST-225 with a controller card by Western Digital

The 5150 could not itself power hard drives without retrofitting a stronger power supply, but IBM later offered the 5161 Expansion Unit, which not only provided more expansion slots, but also included a 10 MB (later 20 MB) hard drive powered by the 5161's own separate 130-watt power supply.

The first IBM PC that shipped with an internal, fixed, non-removable hard disk was IBM's model 5160, the XT. As other IBM-compatible PCs started to appear, hard disks with larger storage capacities also became available. Space permitting, these could be installed into either the IBM PC's Expansion Unit, into PSU-upgraded PCs or into XTs. Adding a third-party hard disk sometimes required plugging in a new controller board, because some of these hard drives were not compatible with the existing disk controller. Some third party hard disks for IBM PCs were sold as kits including a controller card and replacement power supply. Finally, some hard disks were integrated with their controller into a single expansion card, commonly called a "Hard Card".

OS support

The IBM PC's ROM BASIC and BIOS supported cassette tape storage. DOS itself did not support cassette tape storage. PC-DOS version 1.00 supported only 160 kiB SSDD floppies, but version 1.1, which was released nine months after the PC's introduction, supported 160 kiB SSDD and 320 kiB DSDD floppies. Support for the slightly larger nine sector per track 180 kiB and 360 kiB formats arrived 10 further months later in March 1983. In addition to PC-DOS, buyers could choose either CP/M-86 or UCSD p-System as operating systems. Due to their higher prices, they never became very popular and PC-DOS (a.k.a. IBM-DOS) or MS-DOS came to be the dominant operating system.

Original software

All IBM PCs include a relatively small piece of software stored in ROM. The original IBM PC 40 kiB ROM included 8 kiB for power-on self-test (POST) and basic input/output system (BIOS) functions plus 32 kiB BASIC in ROM (Cassette BASIC). The 40 kiB of ROM was present in five 8 kiB ROM DIP chip packages installed in sockets. (A sixth empty socket was provided for a customer's own custom ROM, and some vendors resold special-purpose PC units with the BASIC ROMs and even the BIOS ROM replaced with specialized custom ROMs.) While small compared to the maximum and even the common RAM size, the 40 kiB of ROM was large compared to subsequent PC clones, which omitted the ROM BASIC and provided only the POST and BIOS ROM programs. The ROM BASIC interpreter was the default user interface if no DOS boot disk was present. BASICA was distributed on floppy disk and provided a way to run the ROM BASIC under PC-DOS control.

Longevity

While the IBM PC technology is largely obsolete by today's standards, many are still in service. As of June 2006, IBM PC and XT models were still in use at the majority of U.S. National Weather Service upper-air observing sites. The computers were used to process

data as it is returned from the ascending radiosonde, attached to a weather balloon. They were phased out over a several year period, replaced by the Radiosonde Replacement System. Factors that have contributed to the 5150 PC's longevity are its flexible modular design, open technical standard making information needed to adapt, modify, and repair it readily available, use of few special nonstandard parts, and rugged high-standard IBM manufacturing, the last of which provided for exceptional long-term reliability and durability. Most newer PCs, by contrast, use special-purpose chips (ASICs) implementing trend-driven technology which becomes obsolete in a few years—after which the parts become unavailable.

Chapter 10

ZX Spectrum

ZX Spectrum



An original 1982 ZX Spectrum

Type	8-bit Home computer
Release date	23 April 1982
Discontinued	1992
Media	Cassette tape
Operating system	Sinclair BASIC
CPU	Z80 @ 3.5 MHz and equivalent
Memory	16 KB / 48 KB / 128 KB

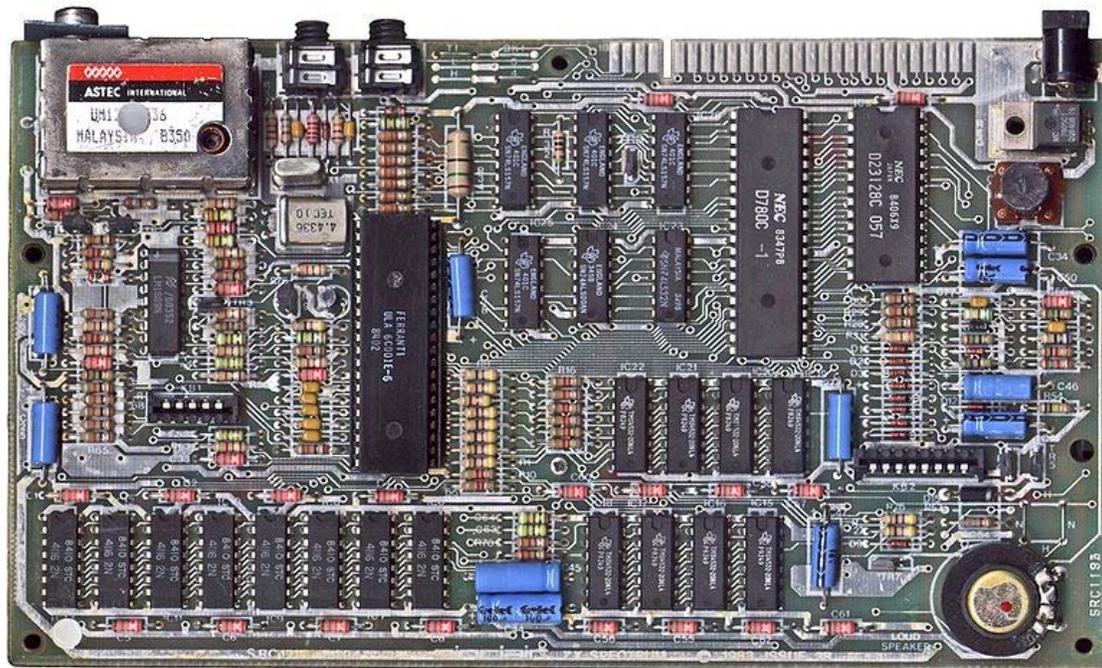
The **ZX Spectrum** (*Pronounced "Zed Ecks Spec-trum" in its original British English branding*) is an 8-bit personal home computer released in the United Kingdom in 1982 by Sinclair Research Ltd. Referred to during development as the *ZX81 Colour* and *ZX82*, the machine was launched as the *ZX Spectrum* by Sinclair to highlight the machine's colour

display, compared with the black-and-white of its predecessor, the Sinclair ZX81. The Spectrum was released in eight different models, ranging from the entry level model with 16 KB RAM released in 1982 to the ZX Spectrum +3 with 128 KB RAM and built in floppy disk drive in 1987, together they sold in excess of 5 million units worldwide

The Spectrum was among the first mainstream audience home computers in the UK, similar in significance to the Commodore 64 in the USA. The introduction of the ZX Spectrum led to a boom in companies producing software and hardware for the machine, the effects of which are still seen; some credit it as the machine which launched the UK IT industry. Licensing deals and clones followed, and earned Clive Sinclair a knighthood for "services to British industry".

The Commodore 64, BBC Microcomputer and later the Amstrad CPC range were major rivals to the Spectrum in the UK market during the early 1980s. The ZX Spectrum has enjoyed a resurgence in popularity thanks to the accessibility of ZX Spectrum emulators, allowing 1980s video game enthusiasts to enjoy classic titles without the long loading times associated with data cassettes. Over 20,000 titles have been released since the Spectrum's launch and new titles continue to be released, with over 60 new ones in 2009.

Hardware



ZX Spectrum 48K motherboard (Issue 3B — 1983, heat sink removed)

The Spectrum is based on a Zilog Z80A CPU running at 3.5 MHz (or NEC D780C-1 clone). The original model Spectrum has 16 KB (16×1024 bytes) of ROM and either 16 KB or 48 KB of RAM. Hardware design was by Richard Altwasser of Sinclair

Research, and the machine's outward appearance was designed by Sinclair's industrial designer Rick Dickinson.

Video output is through an RF modulator and was designed for use with contemporary portable television sets, for a simple colour graphic display. Text can be displayed using 32 columns × 24 rows of characters from the ZX Spectrum character set or from a set provided within an application, from a palette of 15 shades: seven colours at two levels of brightness each, plus black. The image resolution is 256×192 with the same colour limitations. To conserve memory, colour is stored separate from the pixel bitmap in a low resolution, 32×24 grid overlay, corresponding to the character cells. Altwasser received a patent for this design.

An "attribute" consists of a foreground and a background colour, a brightness level (normal or bright) and a flashing "flag" which, when set, causes the two colours to swap at regular intervals. Unfortunately, this scheme leads to what was dubbed *colour clash* or *attribute clash* with some bizarre effects in the animated graphics of arcade style games. This problem became a distinctive feature of the Spectrum and an in-joke among Spectrum users, as well as a point of derision by advocates of other systems. Other machines available around the same time, for example the Amstrad CPC, did not suffer from this limitation. The Commodore 64 used colour attributes in a similar way, but a special multicolour mode, hardware sprites and hardware scrolling were used to avoid attribute clash.

Sound output is through a beeper on the machine itself. This is capable of producing one channel with 10 octaves. The machine also includes an expansion bus edge connector and audio in/out ports for the connection of a cassette recorder for loading and saving programs and data.

Firmware

The machine's Sinclair BASIC interpreter is stored in ROM (along with fundamental system-routines) and was written by Steve Vickers on contract from Nine Tiles Ltd. The Spectrum's chiclet keyboard (on top of a membrane, similar to calculator keys) is marked with BASIC keywords, so that, for example, pressing "G" when in programming mode would insert the BASIC command GO TO.

The BASIC was developed from that used on the ZX81 and a ZX81 BASIC program can be typed into a Spectrum largely unmodified, but Spectrum BASIC included many extra features making it easier to use. It also featured a full ASCII character set, missing from the ZX81 which did not feature lower-case letters. Spectrum BASIC included extra keywords for the more advanced display and sound, and also supported multi-statement lines. The cassette interface was also much more advanced, saving and loading around four times faster than the ZX81, and much more reliably. As well as being able to save programs, the Spectrum could in addition save the contents of arrays, the contents of the screen memory, and the contents of any defined range of memory addresses.

Sinclair Research models

Pre-production designs

Rick Dickinson came up with a number of designs for the "ZX82" project before the final ZX Spectrum design. A number of the keyboard legends changed during the design phase including *ARC* becoming *CIRCLE*, *FORE* becoming *INK* and *BACK* becoming *PAPER*.

ZX Spectrum 16K/48K



ZX Spectrum 16K/48K (Dimensions (mm): 233x144x30 (WxHxD) @ ~552 grams)

The original ZX Spectrum is remembered for its rubber keyboard, diminutive size and distinctive rainbow motif. It was originally released in 1982 with 16 KB of RAM for £125 Sterling or with 48 KB for £175; these prices were later reduced to £99 and £129 respectively. Owners of the 16 KB model could purchase an internal 32 KB RAM upgrade, which for early "Issue 1" machines consisted of a daughterboard. Later issue machines required the fitting of 8 dynamic RAM chips and a few TTL chips. Users could mail their 16K Spectrums to Sinclair to be upgraded to 48 KB versions. To reduce the price, the 32 KB extension used eight faulty 64 kilobit chips with only one half of their capacity working and/or available. External 32 KB RAM packs that mounted in the rear expansion slot were also available from third parties. Both machines had 16 KB of onboard ROM.

About 60,000 "Issue 1" ZX Spectrums were manufactured; they can be distinguished from later models by the colour of the keys (light grey for Issue 1, blue-grey for later models).

ZX Spectrum+



ZX Spectrum+ (Dimensions (mm): 319x149x38 (WxHxD))

Planning of the **ZX Spectrum+** started in June 1984, and the machine was released in October the same year. This 48 KB Spectrum (development code-name *TB*) introduced a new QL-style case with an injection-moulded keyboard and a reset button. Electronically, it was identical to the previous 48 KB model. It retailed for £179.95. A DIY conversion-kit for older machines was also available. Early on, the machine outsold the rubber-key model 2:1; however, some retailers reported a failure rate of up to 30%, compared with a more usual 5-6%.

ZX Spectrum 128



ZX Spectrum 128

Sinclair developed the **ZX Spectrum 128** (code-named *Derby*) in conjunction with their Spanish distributor Investrónica. Investrónica had helped adapt the ZX Spectrum+ to the Spanish market after the Spanish government introduced a special tax on all computers with 64 KB RAM or less which did not support the Spanish alphabet (such as ñ) and show messages in Spanish.

New features included 128 KB RAM, three-channel audio via the AY-3-8912 chip, MIDI compatibility, an RS-232 serial port, an RGB monitor port, 32 KB of ROM including an improved BASIC editor, and an external keypad.

The machine was simultaneously presented for the first time and launched in September 1985 at the SIMO '85 trade show in Spain, with a price of 44,250 pesetas. Because of the large number of unsold Spectrum+ models, Sinclair decided not to start selling in the UK until January 1986 at a price of £179.95. No external keypad was available for the UK release, although the ROM routines to use it and the port itself, which was hastily renamed "AUX", remained.

The Z80 processor used in the Spectrum has a 16-bit address bus, which means only 64 KB of memory can be directly addressed. To facilitate the extra 80 KB of RAM the designers used bank switching so that the new memory would be available as eight pages of 16 KB at the top of the address space. The same technique was also used to page

between the new 16 KB editor ROM and the original 16 KB BASIC ROM at the bottom of the address space.

The new sound chip and MIDI out abilities were exposed to the BASIC programming language with the command *PLAY* and a new command *SPECTRUM* was added to switch the machine into 48K mode, keeping the current BASIC program intact (although there is no way to switch back to 128K mode). To enable BASIC programmers to access the additional memory, a RAM disk was created where files could be stored in the additional 80 KB of RAM. The new commands took the place of two existing user-defined-character spaces causing compatibility problems with some BASIC programs.

The Spanish version had the "128K" logo in white while the English one had the same logo in red.

Amstrad models



ZX Spectrum +2

ZX Spectrum +2

The **ZX Spectrum +2** was Amstrad's first Spectrum, coming shortly after their purchase of the Spectrum range and "Sinclair" brand in 1986. The machine featured an all-new grey case featuring a spring-loaded keyboard, dual joystick ports, and a built-in cassette recorder dubbed the "Datacoder" (like the Amstrad CPC 464), but was in most respects identical to the ZX Spectrum 128. The main menu screen lacked the Spectrum 128's "Tape Test" option, and the ROM was altered to account for a new 1986 Amstrad copyright message. These changes resulted in minor incompatibility problems with software that accessed ROM routines at certain addresses. Production costs had been reduced and the retail price dropped to £139–£149.

The new keyboard did not include the BASIC keyword markings that were found on earlier Spectrums, except for the keywords *LOAD*, *CODE* and *RUN* which were useful for loading software. This was not a major issue however, as the +2 boasted a menu system, almost identical to the ZX Spectrum 128, where one could switch between 48k

BASIC programming with the keywords, and 128k BASIC programming in which all words (keywords and otherwise) must be typed out in full (although the keywords are still stored internally as one character each). Despite these changes, the layout remained identical to that of the 128.

ZX Spectrum +2A



ZX Spectrum +2A

The **ZX Spectrum +2A** was produced to homogenise Amstrad's range in 1987. Although the case reads "ZX Spectrum +2", the +2A/B is easily distinguishable from the original +2 as the case was restored to the standard Spectrum black.

The +2A was derived from Amstrad's +3 4.1 ROM model, using a new motherboard which vastly reduced the chip count, integrating many of them into a new ASIC. The +2A replaced the +3's disk drive and associated hardware with a tape drive, as in the original +2. Originally, Amstrad planned to introduce an additional disk interface, but this never appeared. If an external disk drive was added, the "+2A" on the system OS menu would change to a +3. As with the ZX Spectrum +3, some older 48K, and a few older 128K, games were incompatible with the machine.

ZX Spectrum +2B

The **ZX Spectrum +2B** signified a manufacturing move from Hong Kong to Taiwan later in 1987.

The +3 was the final official model of the Spectrum to be manufactured, remaining in production until December 1990. Although still accounting for one third of all home computer sales in the UK at the time, production of the model was ceased by Amstrad at that point.

Clones



Didaktik M

Sinclair licensed the Spectrum design to Timex Corporation in the United States. An enhanced version of the Spectrum with better sound, graphics and other modifications was marketed in the USA by Timex as the Timex Sinclair 2068. Timex's derivatives were largely incompatible with Sinclair systems. However, some of the Timex innovations were later adopted by Sinclair Research. A case in point was the abortive *Pandora* portable Spectrum, whose ULA had the high resolution video mode pioneered in the TS2068. *Pandora* had a flat-screen monitor and Microdrives and was intended to be Sinclair's business portable. When Alan Sugar bought the computer side of Sinclair it got ditched (a conversation with UK computer journalist Guy Kewney went thus: AS: "Have you seen it?" GK: "Yes" AS: "Well then.").

In the UK, Spectrum peripheral vendor Miles Gordon Technology (MGT) released the SAM Coupé as a potential successor with some Spectrum compatibility. However, by this point, the Commodore Amiga and Atari ST had taken hold of the market, leaving MGT in eventual receivership.

Many unofficial Spectrum clones were produced, especially in the former Eastern Bloc countries (e.g. in Romania, several models were produced (Tim-S, HC85, HC91, Cobra, Junior, CIP, CIP 3, Jet) , some featuring CP/M and a 5.25"/3.5" floppy disk) and South America (e.g. Microdigital TK 90X and TK 95). In the Soviet Union, ZX Spectrum clones were assembled by thousands of small start-ups and distributed through poster ads and street stalls. Over 50 such clone models existed. Some of them are still being produced, such as the *Pentagon* and *ATM Turbo*. In India, Decibells Electronics introduced a licensed version of the Spectrum+ in 1986. Dubbed the "db Spectrum+", it

did reasonably well in the Indian market and sold quite a few thousand until 1990 when the market died away.

Peripherals

Several peripherals for the Spectrum were marketed by Sinclair: the ZX Printer was already on the market, as the ZX Spectrum expansion bus was backwards-compatible with that of the ZX81.

The ZX Interface 1 add-on module included 8 KB of ROM, an RS-232 serial port, a proprietary LAN interface (called ZX Net), and an interface for the connection of up to eight ZX Microdrives – somewhat unreliable but speedy tape-loop cartridge storage devices released in July 1983. These were later used in a revised version on the Sinclair QL, whose storage format was electrically compatible but logically incompatible with the Spectrum's. Sinclair also released the ZX Interface 2 which added two joystick ports and a ROM cartridge port.

There were also a plethora of third-party hardware addons. The better known of these included the Kempston joystick interface, the Morex Peripherals Centronics/RS-232 interface, the Currah Microspeech unit (speech synthesis), Videoface Digitiser, RAM pack, the Cheetah Marketing SpecDrum, a drum machine, and the Multiface, a snapshot and disassembly tool from Romantic Robot. Keyboards were especially popular in view of the original's notorious "dead flesh" feel.



ZX Interface 1



ZX Printer



ZX Interface 2



ZX Microdrive



Kempston joystick interface

There were numerous disk drive interfaces, including the Abbeydale Designers/Watford Electronics SPDOS, Abbeydale Designers/Kempston KDOS and Opus Discovery. The SPDOS and KDOS interfaces were the first to come bundled with Office productivity software (*Tasword* Word Processor, *Masterfile* database and *OmniCalc* spreadsheet). This bundle, together with OCP's Stock Control, Finance and Payroll systems, introduced many small businesses to a streamlined, computerised operation. The most popular floppy disk systems (except in East Europe) were the DISCiPLE and +D systems released by Miles Gordon Technology in 1987 and 1988 respectively. Both systems had the ability to store memory images onto disk *snapshots* could later be used to restore the Spectrum to its exact previous state. They were also both compatible with the Microdrive command syntax, which made porting existing software much simpler.

During the mid-1980s, Telemap Group Ltd launched a fee-based service allowing users to connect their ZX Spectrums via a Prism Micro Products VTX5000 modem to a viewdata service known as Micronet 800, hosted by Prestel. This service pre-dated the web, but offered many of the services now considered commonplace.

Software



A screenshot from *Rebelstar*, a well-known Spectrum game

The Spectrum enjoys a vibrant, dedicated fan-base. Since it was cheap and simple to learn to use and program, the Spectrum was the starting point for many programmers. The hardware limitations of the Spectrum imposed a special level of creativity on game designers, and so many Spectrum games are very creative and playable even by today's standards. The early Spectrum models' great success as a games platform came in spite of its lack of built-in joystick ports, primitive sound generation, and colour support that was optimised for text display.

The Spectrum family enjoys a very large software library of more than 20,000 titles which is still increasing. While most of these are games, the library is very diverse, including programming language implementations, databases (e.g. *VU-File*), word processors (e.g. *Tasword II*), spreadsheets (e.g. *VU-Calc*), drawing and painting tools (e.g. *OCP Art Studio*), and even 3D-modelling (e.g. *VU-3D*) and archaeology software amongst many other types.

Distribution

Most Spectrum software was originally distributed on audio cassette tapes. The Spectrum was intended to work with a normal domestic cassette recorder, and despite differences in audio reproduction fidelity, the software loading process was quite reliable, if somewhat slow (by today's standards).

Although the ZX Microdrive was initially greeted with good reviews, it never took off as a distribution method due to worries about the quality of the cartridges and piracy. Hence the main use became to complement tape releases, usually utilities and niche products like the *Tasword* word processing software and *Trans Express*, (a tape to microdrive copying utility). No games are known to be exclusively released on Microdrive.

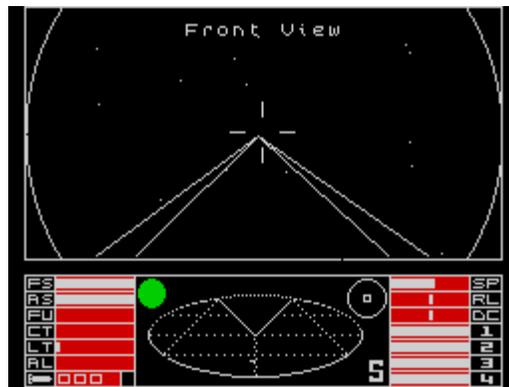
Despite the popularity of the DISCiPLE and +D systems, most software released for them took the form of utility software. The ZX Spectrum +3 enjoyed much more success

when it came to commercial software releases on floppy disk. More than 700 titles were released on 3-inch disk from 1987 to 1997.

Software was also distributed through print media; magazines and books. The reader would type the Sinclair BASIC program listing into the computer by hand, run it, and could save it to tape for later use. The software distributed in this way was in general simpler and slower than its assembly language counterparts. Magazines also printed long lists of checksummed hexadecimal digits with machine code games or tools.

Another software distribution method was to broadcast the audio stream from the cassette on another medium and have users record it onto an audio cassette themselves. In radio or television shows in many European countries, the host would describe a program, instruct the audience to connect a cassette tape recorder to the radio or TV and then broadcast the program over the airwaves in audio format. Some magazines distributed 7" 33⅓ rpm *flexidisc* records, a variant of regular vinyl records which could be played on a standard record player. These disks were known as *floppy ROMs*.

Copying and backup software



A screenshot from *Elite* game

Many copiers—utilities to copy programs from audio tape to another tape, microdrive tapes, and later on diskettes—were available for the Spectrum. As a response to this, publishers introduced copy protection measures to their software, including different loading schemes. Other methods for copy prevention were also used including asking for a particular word from the documentation included with the game—often a novella like in Silicon Dreams trilogy—or another physical device distributed with the software—e.g. Lenslok as used in Elite. Special hardware, such as Romantic Robot's Multiface, was able to dump a copy of the ZX Spectrum RAM to disk/tape at the press of a button, entirely circumventing the copy protection systems.

Most Spectrum software has, in recent years, been converted to current media and is available for download. One popular program for converting Spectrum files from tape is *Taper*; it allows connecting a cassette tape player to the line in port of a sound card, or—through a simple home-built device—to the parallel port of a PC. Once in files on a host

machine, the software can be executed on one of many emulators, on virtually any platform available today.

The largest on-line archive of ZX Spectrum software is World of Spectrum, with more than 21,000 titles. The legality of this practice is still in question and while a number of copyright holders have explicitly objected to the posting of their software, others have given their permission for their games to be archived as part of the preservation project.

Notable developers

A number of current leading games developers and development companies began their careers on the ZX Spectrum, including David Perry of Shiny Entertainment, and Tim and Chris Stamper (founders of Ultimate Play The Game, now known as Rare, maker of many famous titles for Nintendo and Microsoft game consoles). Other prominent games developers include Julian Gollop (*Chaos, Rebelstar, X-COM* series), Matthew Smith (*Manic Miner, Jet Set Willy*), Jon Ritman (*Match Day, Head Over Heels*), The Oliver Twins (the *Dizzy* series), Clive Townsend (*Saboteur*), Pete Cooke (*Tau Ceti*), Mike Singleton (*The Lords of Midnight, War In Middle Earth*), and Alan Cox. Although the Spectrum's audio hardware was not as capable as that of the Commodore 64, computer musicians David Whittaker and Tim Follin produced notable multi-channel music for the machine.

Jeff Minter ported some of his Commodore VIC-20 games for the ZX Spectrum.

Community

The ZX Spectrum enjoyed a very strong community early on. Several dedicated magazines were released including *Sinclair User* (1982), *Your Sinclair* (1983) and *CRASH* (1984). Early on they were very technically oriented with type-in programs and machine code tutorials. Later on they became almost completely game-oriented. Several general contemporary computer magazines covered the ZX Spectrum in more or less detail. They included *Computer Gamer*, *Computer and Video Games*, *Computing Today*, *Popular Computing Weekly*, *Your Computer* and *The Games Machine*.

The Spectrum is affectionately known as the *Speccy* by elements of its fan following.

More than 80 electronic magazines existed, many in Russian. Most notable of them were AlchNews (UK), ZX-Format (Russia), and Spectrofon (Russia).