Graphing Calculator Devices and Models

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Chapter 1

Graphing Calculator

A typical graphing calculator by Texas Instruments

A **graphing calculator** (also **graphics calculator**) typically refers to a class of handheld calculators that are capable of plotting graphs, solving simultaneous equations, and performing numerous other tasks with variables. Most popular graphing calculators are also programmable, allowing the user to create customized programs, typically for scientific/engineering and education applications. Due to their large displays intended for graphing, they can also accommodate several lines of text and calculations at a time. Some graphing calculators also have colour displays, and others even include 3D graphing.

Many graphing calculators can be attached to devices like electronic thermometers, pH gauges, weather instruments, decibel and light meters, accelerometers, and other sensors and therefore function as data loggers.

Since graphing calculators are readily user-programmable, such calculators are also widely used for gaming purposes, with a sizable body of user-created game software on most popular platforms.

There is also computer software available to emulate or perform the functions of a graphing calculator. One such example is Grapher for Mac OS X and is a basic software graphics calculator.

History
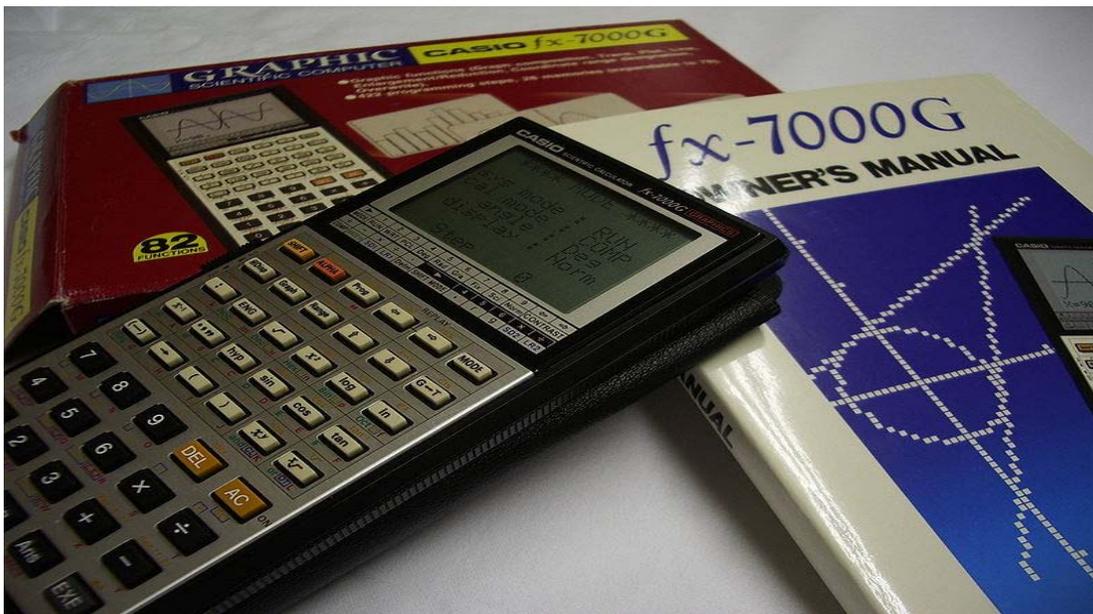

Casio fx-7000G; The world's first graphing calculator

Casio produced the world's first graphics calculator, the fx-7000G, in 1985. After Casio, Hewlett Packard followed shortly in the form of the HP-28C. This was followed by the HP-28S (1988), HP-48SX (1990), HP-48S (1991), and many other models. Recent models like the current HP 50g (2006), feature a computer algebra system (CAS) capable

of manipulating symbolic expressions and analytic solving. The HP-28 and -48 range were primarily meant for the professional science/engineering markets; the HP-38/39/40 were sold in the high school/college educational market; while the HP-49 series cater to both educational and professional customers of all levels. The HP series of graphing calculators is best known for its Reverse Polish notation interface, although the HP-49 introduced a standard expression entry interface as well.

Texas Instruments has produced graphing calculators since 1990, the oldest of which was the TI-81. Some of the newer calculators are similar, with the addition of more memory, faster processors, and USB connection such as the TI-82, TI-83 series, and TI-84 series. Other models, designed to be appropriate for students 10–14 years of age, are the TI-80 and TI-73. Other TI graphing calculators have been designed to be appropriate for calculus, namely the TI-85, TI-86, TI-89 series, and TI-92 series (TI-92, TI-92 Plus, and Voyage 200). TI offers a CAS on the TI-89, TI-Nspire CAS and TI-92 series models with the TI-92 series featuring a QWERTY keypad. TI calculators are targeted specifically to the educational market, but are also widely available to the general public.

Graphing calculators are also manufactured by Sharp but they do not have the online communities, user-websites and collections of programs like the other brands.

Graphing calculators in schools
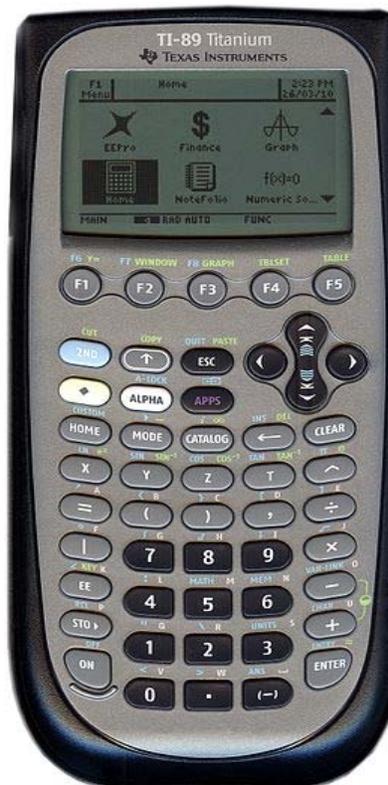
TI-89 Titanium, capable of doing Symbolic Manipulation, Computer Algebra System (CAS)

- **North America** – high school mathematics teachers allow and even encourage their students to use graphing calculators in class. In some cases (especially in calculus courses) they are *required*. Some of them are banned in certain classes such as chemistry or physics due to their capacity to contain full periodic tables.
- **United Kingdom** – a graphics calculator is required for most A-level maths courses, the use of such devices is both taught and tested. However, for GCSE maths exams, a limited number of calculator models are allowed, none of which are capable of graphic operations (although they are capable of scientific and statistical operations).
- **Finland and Slovenia** – and certain other countries, it is forbidden to use calculators with symbolic calculation (CAS) or 3D graphics features in the matriculation exam.
- **Norway** – calculators with wireless communication capabilities, such as IR links, have been banned at some technical universities.
- **College Board of the United States** – permits the use of most graphing or CAS calculators that do not have a QWERTY-style keyboard for parts of its AP and SAT exams, but IB schools do not permit the use of calculators with computer algebra systems on its exams.
- **Australia** – policies vary from state to state.
- **Victoria, Australia** – the VCE specifies approved calculators as applicable for its mathematics exams. For Further Mathematics an approved graphics calculator (for example TI-83/84, Casio 9860, HP-39G) or CAS (for example TI-89, Classpad 300, HP-40G) can be used. Mathematical Methods and Mathematical Methods CAS have a common technology free examination consisting of short answer and some extended answer questions. They also each have a technology assumed access examination consisting of extended response and multiple choice questions: a graphics calculator is the assumed technology for Mathematical Methods and a CAS for Mathematical Methods CAS. These two exams have substantial material in common but also some distinctive questions. Specialist Mathematics has a technology free examination and a technology assumed access examination where either an approved graphics calculator or CAS may be used. Calculator memories are not required to be cleared. In subjects like Physics and Chemistry, students are only allowed a standard scientific calculator.
- **Western Australia** – all tertiary entrance examinations in Mathematics involve a calculator section which assume the student has a graphics calculator; CAS enabled calculators are also permitted. In subjects such as Physics, Chemistry and Accounting only non programmable calculators are permitted.
- **New South Wales** – graphics calculators are allowed for the General Mathematics Higher School Certificate exam, but disallowed in the higher level Mathematics courses.
- **New Zealand** – calculators identified as having high-level algebraic manipulation capability are prohibited in NCEA examinations unless specifically allowed by a standard or subject prescription. This includes calculators such as the TI-89 series .
- **Turkey** – any type of calculator whatsoever is prohibited in all primary and high schools except the IB and American schools.

- **Singapore** – graphing calculators are used in junior colleges; it is required in the Mathematics paper of the GCE 'A' Levels, and most schools use the TI-84 Plus or TI-84 Plus Silver Edition.
- **Netherlands** – high school students are obliged to use graphing calculators during tests and exams in their final three years. Most students use the TI-83 Plus or TI-84 Plus, but other graphing calculators are allowed, including the Casio CFX-9860G and HP-39G.

Programming

Most graphing calculators, as well as some non-graphing scientific and programmer's calculators (e.g. the Radio Shack PC-7 and other machines in that series, which use a full-blown Basic variant) can be programmed to automate complex and frequently used series of calculations and those inaccessible from the keyboard.

The actual programming can often be done on a computer then later uploaded to the calculators. The most common tools for this include the PC link cable and software for the given calculator, configurable text editors like TextPad, and specialised programming tools such as the below-mentioned implementation of various languages on the computer side and Hackman, a hex editor which also includes syntax highlighting and other tools for assembly programming on more than a dozen processor types as well as a disassembler, macro and scripting facilities, programmers' calculator application, source code management and code snippet library functions and the ability to edit various types of media like clusters and File Allocation Tables on a disc.

Earlier calculators stored programmes on magnetic cards and the like; increased memory capacity has made storage on the calculator the most common implementation. More of the newer machines also can use memory cards as well.

Many calculators, such as earlier TI graphing and scientific calculators. will tokenise the code for a programme or function, using ISO 8859 type character codes for the statements and other programming elements. The TI-92 Plus and many HP calculators read the code much like computers do and they have functions such as Chr$, Chr, Char, Asc, and the like in Basic (sometimes renamed) in addition to using somewhat modified or unmodified versions of 7-bit, 8-bit or 9-bit ISO 8859-derived character sets and other character sets running from of values of 0 to 127 (07F hex), 255 (0FF hex), or 511 (1FF hex) -- and many of them have a tool similar to the Character Map on Windows.

The official sites of the manufacturers and of other people like professors & teachers, students, statisticians, scientists, and organisations like university business and computer science departments, SourceForge, and the 27. November Spreadsheet Macro Programming Club are also useful. A broad array of third-party software including 3-D function graphing tools, web browsers, chat, email and NNTP clients, telnet/SSH, spreadsheets, word processors, sound & graphics tools, network tools, and programming tools can be located on the internet.

A cable and/or IrDA transceiver connecting the calculator to a computer make the process easier and expands other possibilities such as on-board spreadsheet, database, graphics, and word processing programmes. The second option is being able to code the programmes on board the calculator itself. This option is facilitated by the inclusion of full-screen text editors and other programming tools in the default feature set of the calculator or as optional items. Some calculators have QWERTY keyboards and others can be attached to an external keyboard which can be close to the size of a regular 102-key computer keyboard. Programming is a major use for the software and cables used to connect calculators to computers, other calculators &c.

The most common programming languages used for calculators are similar to keystroke-macro languages and variants of Basic. The latter can have a large feature set -- approaching that of Basic as found in computers -- including character and string manipulation, advanced conditional and branching statements, sound, graphics, and more including, of course, the huge spectrum of mathematical, string, bit-manipulation, number base, I/O, and graphics functions built into the machine.

Languages for programming calculators fall into all of the main groups, i.e. machine code, low-level, mid-level, high-level languages for systems and application programming, scripting, macro, and glue languages, procedural, functional, imperative &. Object-Oriented Programming can be achieved in some cases.

Nearly all calculators capable to being connected to a computer can be programmed in assembly language and machine code. The most common assembly and machine languages are for the purpose-designed, TMS9900, Zilog Z-80, and various Motorola chips (e.g. the modified 68000) which serve as the Central Processing Units of the machines. At least one machine in development may have a conventional 80*86 series, RISC, or purpose-built Intel chip. All of the above chips are modified to some extent from their use elsewhere. Some manufacturers do not document and even mildly discourage the assembly language programming of their machines because they must programmed in this way by putting together the programme on the PC and then forcing it into the calculator by various improvised methods, but more current models are set up for greater ease of assembly programming and more official documentation is available.

Other on-board programming languages include purpose-made languages, variants of Eiffel, Forth, and Lisp, and Command Script facilities which are similar in function to batch/shell programming and other glue languages on computers but generally not as full featured. Ports of other languages like BBC Basic and development of on-board interpreters for Fortran, Rexx, Awk, Perl, Unix shells (ksh, sh, bash, csh, zsh, tcsh &c.), other shells (DOS/Win95, OS/2, and WinNT/2000 shells as well as the related 4Dos, 4NT and 4OS2 as well as DCL), Cobol, C, Python, Tcl, Pascal, Delphi, ALGOL, and other languages are at various levels of development.

Some calculators, especially those with other PDA-like functions have actual operating systems including the TI proprietary OS for its more recent machines, MS-DOS, Windows CE, and rarely Windows NT 4.0 Embedded et seq, and Linux. Experiments

with the TI-89, 92, 92+ and Voyager machines show the possibility of installing some variants of other systems such as a chopped-down variant of CP/M, an operating system which has been used for portable devices in the past.

Tools which allow for programming the calculators in C/C++ and possibly Fortran and assembly language are used on the computer side, such as HPgcc, TIgcc and others. Flash memory is another means of conveyance of information to and from the calculator.

The on-board Basic variants in TI graphing calculators and the languages available on HP 48 type calculators can be used for rapid prototyping by developers, professors, and students, often when a computer is not close at hand.

Most graphing calculators have on-board spreadsheets which usually integrate with Microsoft Excel on the computer side. At this time, spreadsheets with macro and other automation facilities on the calculator side are not on the market. In some cases, the list, matrix, and data grid facilities can be combined with the native programming language of the calculator to have the effect of a macro and scripting enabled spreadsheet.

Chapter 2

Casio 9850 Series and Casio 9860 Series

Casio 9850 series

Casio 9850 series

Black model of the CFX-9850GB PLUS with protective slide cover, showing the menu-based interface on its screen.

Type	Programmable Graphing
Manufacturer	Casio
Introduced	1996

Calculator	
Entry mode	Infix
Display Type	LCD Dot-matrix
Display Size	128×64 dots
Programming	
Programming language(s)	BASIC-like
User Memory	32 kibibyte
Other	
Power supply	four AAA alkaline batteries
Weight	190 gram

The **Casio 9850 series** (sometimes called **9x50 series**) is a series of Casio graphic calculators.

Overview

First made in the year 1996, there have been numerous variations of the CFX-9850G. The 9850 series models have 3-colour screens apart from the **9750** versions which are black and white. The **9950G** has 64k memory compared to the 32k of the original 9850G. The **9970G** has symbolic algebra. Later versions such as Ga, GB and GC models fixed some bugs from the original G model and added some stats and finance features. The GB models have a built-in software library.

There are french versions where the ab/c and EXP buttons are labelled differently. (French versions: 9750=Graph 30,35,fx-8930GT; 9850,9950=Graph 60,65,CFX-9930GT,9940,9960; 9970=Graph 80)

The calculators weigh about 190 grams including batteries, and measure about 19.7 mm x 83 mm x 176 mm. Features include scientific calculations, including calculus, graphing and programming, statistics and matrix operations.

Power

The back of the device shows a slightly protruding battery case cover, which slides out to reveal the compartment for the four AAA alkaline batteries used for primary power, and a CR2032 lithium button cell used for memory backup when primary power is down or being changed. The device consumes power at the rate of 0.06W, and turns itself off automatically after about 6 minutes of time spent without any keypad activity. Battery life for the primary power cells ranges from 240 hours to 150 hours, depending on the kind of battery being used. Backup cells last up to about 2 years each.

Display
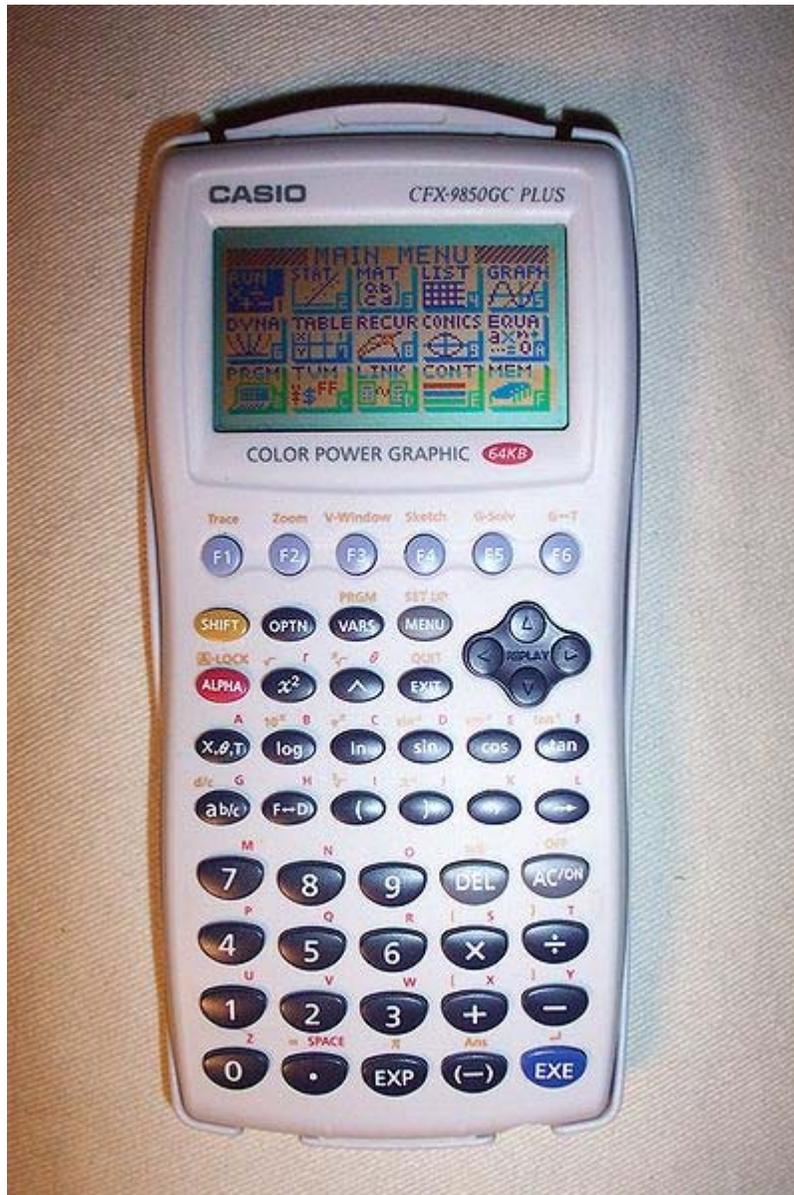
Casio CFX-9850GC Plus
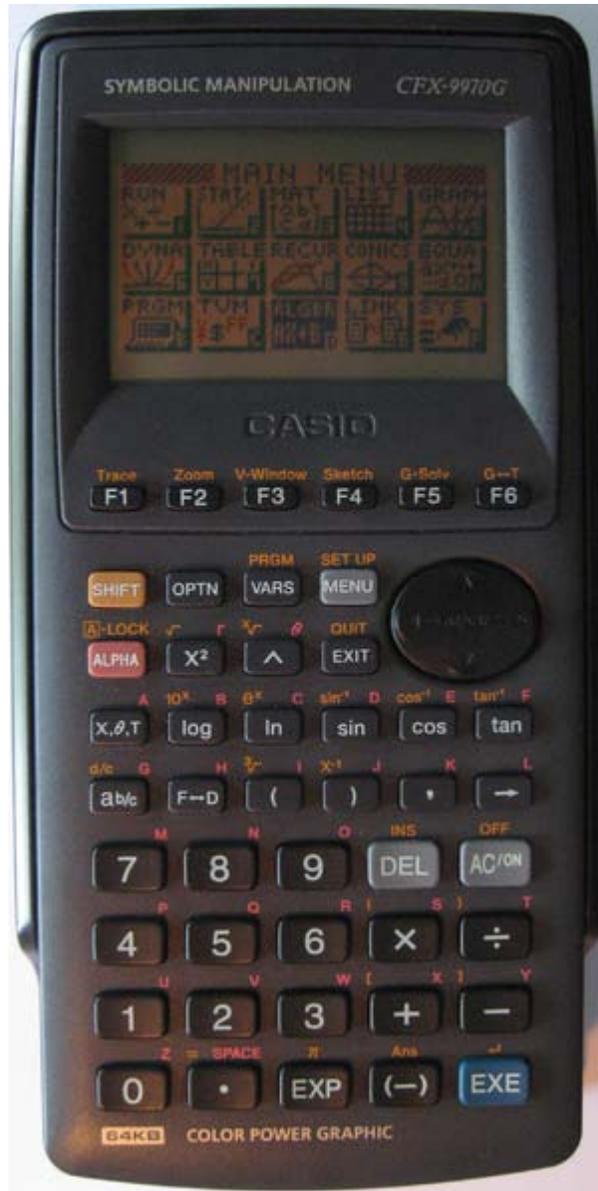
Casio CFX-9970G

The screen's graphics resolution is 128 dots by 64 dots (the first row and column of dots are unusable in graphing), and its character resolution is 21 columns by 8 lines. The bottom line is reserved for function key menu tips, and the rest is available for the graphics and character display. The screen is capable of three colors: orange, blue and green, apart from the 9750 models which have a black and white display.

Memory

The calculators come with 32 or 64 kibibytes of inbuilt memory depending on the model. This is flexibly divided among storage blocks for programs, statistics, matrices, lists, static and dynamic graphs and their associated settings, functions, recursions, equations,

financial data, and variables (all of which are global). These can be cleared individually or completely in the MEM menu.

Communications

The device can link up via specialized cables to a computer (FA-122 interface unit and cables) or to another calculator (SB-62 cable) to transfer data, such as programs, equations, graphs etc. It can also connect to a Casio label printer (SB-62 cable). Transmission speed is stated as 9600 byte/s.

The serial link cable was designed and U.S. patented by Purple Computing and manufactured by Traveling Software (AKA Laplink.com) and later by Purple Computing for Casio. The common name for the cable used by the companies was "PC-Link". It has a 2.5mm stereo phono plug on one end, the patented electronic circuit inside the plastic bump and a DB9F (standard 9 pin serial plug) on the other for connecting to the serial port of a PC. The circuit converts low voltage low power signals of the handheld device to be compatible with the levels and power of a PC's RS232 serial port. Versions of the circuit were used by many companies from the early 1990s to bridge the RS232/TTL voltage/power gap.

Software Library

The CFX-9850GB PLUS and CFX-9950GB PLUS models have a built-in software library, consisting of programs that perform complicated calculations and data processing. For example, operations on differential equations, digital caliper measurements, capacitor charge curves, figure rotations and Riemann sums. These are organized into six sub-libraries, five of them for mathematical computations, and one for scientific instrumentation.

Graphing

Graphs can be drawn with split-screen viewing of graphs as well as tables or zooms. Graphed areas can be shaded in customizable colors. The graph viewport can be resized and shifted (these settings can be saved for later retrieval), and points along the graph curves can be traced. Graph solver tools can also be used to find useful points, such as maxima/minima and intersection points. The calculator also has a special section for advanced conic section graphing. Dynamic graphing provides all the functionality of regular graphing, but allows the binding of a variable in the graph equation to time over a value range.

Lists and tables

Up to 36 lists can be stored and manipulated in various ways in the list manager. The lists can be also be used to feed data into inbuilt statistics operations, producing various statistical figures, performing regression analysis, and generating graphs like scatter and

box and whisker plots, among others. Tables can be generated from functions, recursive series can be generated, and equations can be solved - both simultaneous and polynomial.

Financial calculations

A number of financial operations such as interest compounding and amortization are also provided.

Casio 9860 series

CASIO fx-9860G
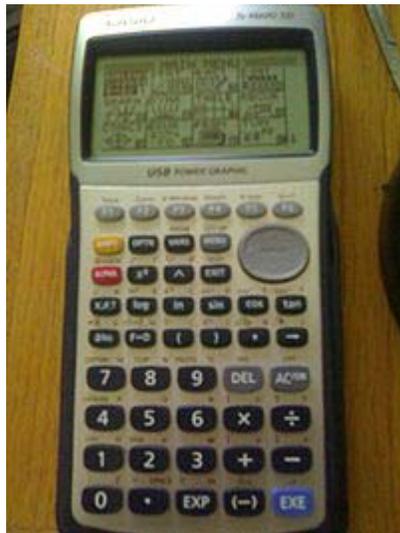
Casio fx-9860G SD

Introduced	2005
Calculator	
Entry mode	Infix, Natural display
Display Type	LCD Dot matrix monochrome
Display Size	128 x 64 pixels
CPU	
Processor	SuperH 3
Frequency	29 MHz
Programming	
User Memory	64 KiB

Firmware Memory	Flash memory, 1.5 MiB (800 KiB for AU version)
External Memory	Up to 2GB for SD version with an SD memory card

The **9860 series** are CASIO manufactured graphing calculators. Some of the improvements compared to older models are: Natural Display, a USB port, flash memory, upgradeable OS (through ROM updates) and a high contrast display LCD.

Variants

There are several versions of the fx-9860G; the standard fx-9860G, often referred to as the 'vanilla' flavor, and the SD, AU and Slim versions.

- The AU version limits the amount of internal flash memory available to 800 KiB to meet Australian school regulations.
- The SD variant comes with an SD expansion card slot, allowing read and write access to up to 1GiB of memory on a SD memory card.
- The Slim version has a backlit display, on-board help, and is designed as a clamshell to minimize its size.
- The fx-9860GII and fx-9860GII SD were announced recently and will be available in May 2009. These calculators have backlit displays and the Geometry (in user mem) and ECON2 apps preinstalled. They also have new mathematical functions.

The usual fx-9860G and fx-9860G SD are marketed in France as *Graph85* and *Graph85 SD*.

The french versions of the GII models are the Graph 75 and Graph 95. The Australian version of the GII is the fx-9860G AU PLUS.

Programming

The calculators can be programmed through a couple of ways. The fx-9860G's come with a built-in BASIC-like interpreter, allowing the user to create simple programs, using built-in functionality.

The other method is to create an add-in. Add-ins are binary programs, executing directly on the calculators CPU. CASIO has released two official add-ins, GEOMETRY and PHYSIUM. An SDK was released by CASIO in 2006, allowing users to create their own add-ins, though no support is provided for this by CASIO. The add-ins and the SDK are available for registered users at CASIO's website.

Add-ins and the SDK allowed more powerful applications to be developed, and has been used to create an interpreter for the popular Multi-Platform Language for Calculators.

Chapter 3

Casio ClassPad 300 and Casio fx-7000G

Casio ClassPad 300

Casio ClassPad 300

Type	Programmable Graphing
Manufacturer	Casio
Calculator	
Entry mode	V.P.A.M.
Display Type	LCD Dot-matrix
Display Size	160×240 dots

Programming	
Programming language(s)	BASIC-like

The Casio ClassPad 300 is the first and only (apart from the unsuccessful Sharp models EL-9650 and EL-9600c) stylus based calculator. HP worked on a pen based calculator called the HP-Xpander, as did Texas Instruments under their PET Project, yet both projects were cancelled before they were released to the market. The ClassPad comes with a collection of applications that support self-study, like 3D Graph, Geometry, eActivity, Spreadsheet, etc. A large 160x240 pixel LCD touch screen enables stylus-based operation. There is a strong resemblance between the ClassPad and the older Pocket Viewer line.

The ClassPad 300 allows input of expressions, and displays them as they appear in a textbook. Factorization of expressions, calculation of limit values of functions, and other operations can be performed while viewing the results on a large LCD screen. The ClassPad 300 comes with graphing tools for 3D graphing and drawing of geometric figures.

The user interface of the ClassPad 300 uses a pull-down menu format. Solutions, expressions, and other items can be selected with the tap of the stylus. The ClassPad 300 also supports drag and drop, copy and paste, and other pen-based operations.

An eActivity application allows the creation of eActivities that can include figures, expressions, and explanations.

Product lines

ClassPad 300

This is the first ClassPad series with only 4.5 MB of flash memory.

ClassPad 300 Plus

The Plus series is equipped with a high contrast display, 5.4 MB of flash memory and comes with a standardized Mini-USB port.

ClassPad 330

This series is almost identical to the ClassPad 300 Plus except that the preinstalled firmware has been updated to at least OS 3.02.

ClassPad 330-A

The A series was reported to be a version of ClassPad 330 with preinstalled OS 3.03.

History

During 1996, CASIO worked on the CAS (Computer Algebra System) and studying Geometry. The CAS was first used in the Casio CFX-9970G then the Casio Algebra FX 2.0, and later formed the core math system for the ClassPad.

In 1999, with the help of many teachers and friends, the idea of the eActivity emerged. It would allow all applications to interact from within one application, and display information in a textbook style.

In 2000 CASIO opened a new office, the CASIO Education Technology M.R.D. Center in Portland, Oregon, USA. They hired engineers familiar with programming PCs and specialists from the education field. Ideas from around the world were now being implemented into the ClassPad by Tokyo R&D and Portland MRD Team.

In 2002 CASIO completed a prototype for the ClassPad. Before the prototype was complete, an emulator was used for testing. The emulator was so good that CASIO decided to include the emulator in the software that was being developed for data transfer. The data transfer and emulator software merged into one product called the ClassPad Manager.

In 2003 CASIO finally released the ClassPad 300.

In 2005 CASIO released the ClassPad 300 Plus featuring more flash memory, a better display and standardized Mini-USB.

In 2007 CASIO released the ClassPad 330 featuring a preinstalled version of OS 3.02 or OS 3.03.

ClassPad OS 3.0

ClassPad Manager 3.0 Software

In 2006 CASIO released OS 3.0 for the ClassPad. OS 3.0 featured Laplace and Fourier transform, differential equation graphs, financial functions, AP statistics and parameterized 3D graphs. Subsequent releases were only available for users with OS 3.0 or later.

In 2006 CASIO released OS 3.01 for the ClassPad. OS 3.01 concentrated solely on bug fixing.

In 2007 CASIO released OS 3.02 for the ClassPad. OS 3.02 concentrated solely on bug fixing.

In 2008 CASIO released OS 3.03 for the ClassPad. OS 3.03 featured new probability distribution functions, an extended numeric solver and several user interface improvements.

In 2009 CASIO released OS 3.04 for the ClassPad. OS 3.04 featured an updated spreadsheet application, stat function enhancements and several user interface improvements. Also, there were two hotfix releases for OS 3.04.3000 - namely: OS 3.04.4000 and OS 3.04.5000

In 2010 CASIO released OS 3.05 for the ClassPad. OS 3.05 featured new financial functions and an 'on data' option for quartile calculation.

Casio fx-7000G

fx-7000G
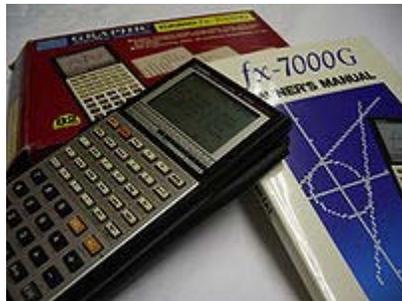
Introduced	October 1985
Calculator	
Entry mode	Infix
Precision	13 digits
Display Type	LCD Dot matrix
Display Size	96×64 pixels/8 * 16 characters
Programming	
Memory Register	78(26) numbers
Program Steps	422 bytes
Other	
Power supply	3×"CR-2032" Lithium
Dimensions	6.5" x 3.5" x 0.6"

The **Casio fx-7000G** is notable for being the world's first graphing calculator.

It came with 422 bytes of memory and it was possible to store up to ten programs in 10 program slots. 422 bytes is not much by today's standards but with its heavily tokenised programming language, programs performing fairly large tasks could be written.
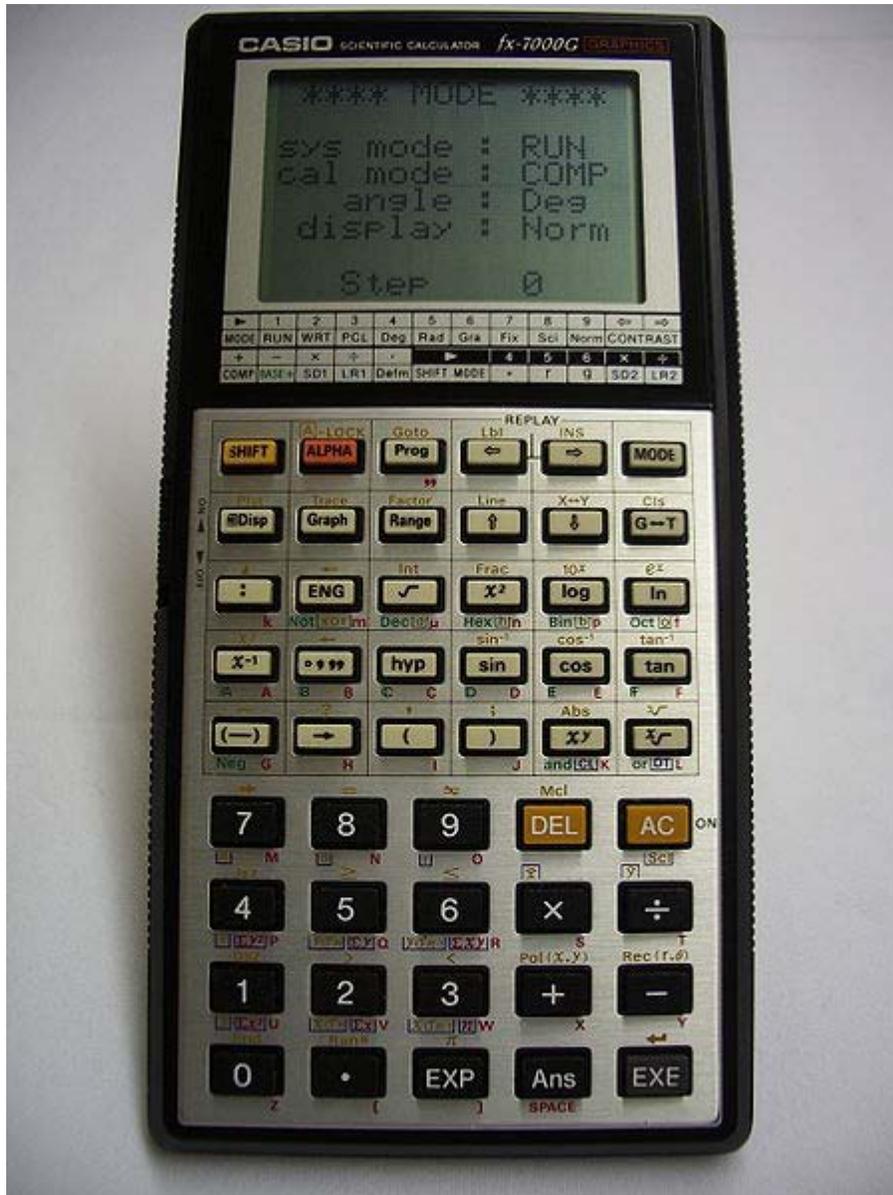
The power-on switch is a small slider half-way up the left-hand side.
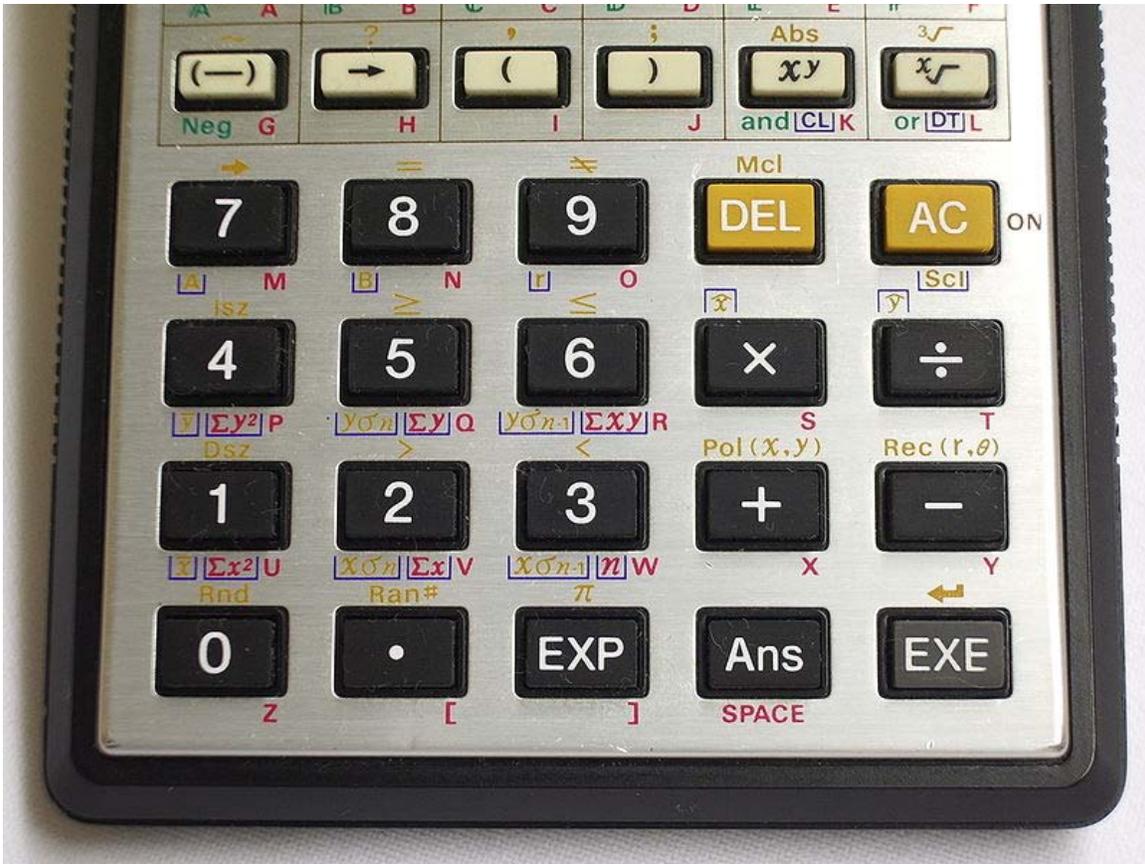
The lower keys have the traditional Casio layout. The EXE key would execute the sum on the keyboard. The Ans key could be used to represent the last answer; simple iterative functions could be built up.

The upper keyboard has the main function keys. The SHIFT and ALPHA keys are used to access the many different functions each key could be.

The power-on screen displays system mode, calculation mode, angle unit and rounding. These could be changed by pressing the MODE button, or SHIFT then MODE buttons, as shown on the writing below the screen.

Chapter 4

Casio Graphic Calculators

Casio Algebra FX 2.0 Plus
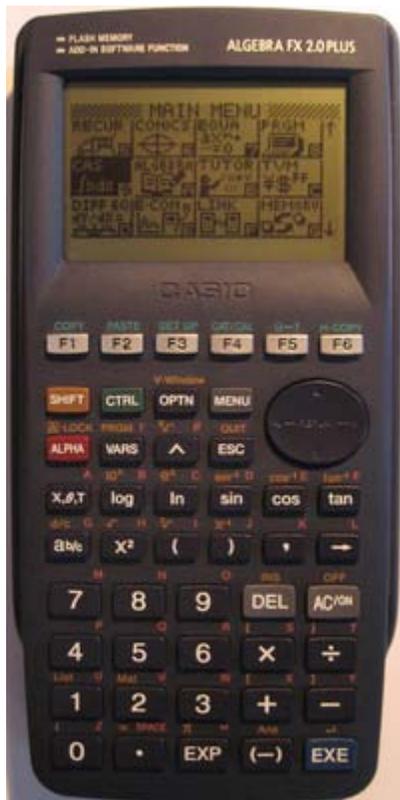
A graphic calculator from Casio, the Casio Algebra
FX 2.0 Plus

Type	Programmable Graphing
Manufacturer	Casio
Introduced	2001
	Calculator
Entry mode	Infix

Display Type	LCD Dot-matrix
Display Size	128×64 dots

Programming

Programming language(s)	BASIC-like
User Memory	144 kibibyte RAM, 768 kibibyte Flash

Other

Power supply	four AAA alkaline batteries
Weight	213 gram

Graphic calculators made by Casio include the touchscreen Classpad 300 as well as the models with traditional buttons which can be divided into two main generations listed below. Casio produced the world's first graphing calculator, the fx-7000G.

2nd Generation

Prizm fx-CG series

Announced for January 2011, these models have a high-resolution color display (384×216 pixels with 2^{16} colors), a USB 2.0 port, 16 MB of flash memory and a feature called Picture Plot.

Models: fx-CG10 (North America only), fx-CG20

9860 G/GII series

First made in the year 2005, the 9860 G/GII models are much faster than previous models and can be programmed in C/C++ using the official software development kit. Newer models like the fx-9860G Slim and fx-9860GII also have a backlight display.

The fx-9750GII and fx-7400GII are low-budget versions with restricted OS functionality. Also, the fx-7400GII does not have a USB 1.1 port.

Models: fx-9860G, fx-9860G SD, fx-9860G Slim, fx-9860GII, fx-9860GII SD, fx-9750GII, fx-7400GII (French versions: Graph 85, Graph 85 SD, Graph 85 Slim, Graph 75, Graph 95, Graph 35+ USB, Graph 25+ Pro)

Australia only: fx-9860G AU, fx-9860G AU Plus

Algebra FX series

First made in the year 1999, these have flash memory which provides larger capacity than previous models, however due to the short lifespan of the original flash memory used, these calculators stop working after a few years. Casio has stated that this problem has been fixed. The Algebra FX 2.0 versions have symbolic algebra, while the FX 1.0 versions do not. There are community written tools for accessing the ROM-DOS operating system thus allowing C and Pascal compilers to be used.

Models: Algebra FX 2.0, FX 1.0, Algebra FX 2.0 Plus, FX 1.0 Plus (French versions: Graph 100, Graph 100+)

9850 series (9750/9850/9950/9970)

Casio CFX-9850GB Plus

Casio CFX-9850GB Plus

Type	Programmable Graphing
Manufacturer	Casio
Introduced	1998
Calculator	
Entry mode	Infix
Display Type	LCD Dot-matrix

Display Size	128×64 dots

Programming

Programming language(s)	BASIC-like
User Memory	32 kibibyte

Other

Power supply	four AAA alkaline batteries
Weight	190 gram

First made in the year 1996, there have been numerous variations of the CFX-9850G. The 9850 series models have 3-colour screens apart from the fx-9750G which is black and white. The 9950G has 64k memory compared to the 32k of the original 9850G. The 9970G has symbolic algebra. Later versions such as Ga, GB and GC models fixed some bugs from the original G model and added some stats and finance features. The GB models have a built-in software library.

(French versions: 9750=Graph 30,35,fx-8930GT; 9850,9950=Graph 60,65,CFX-9930GT,9940,9960; 9970=Graph 80)

7400 Series

First made in the year 1996, this series is like a cut-down version of the 9850 series. For instance it does not have the commands Getkey,Locate,Text or matrices or complex numbers, and the screen is smaller.

Models: fx-7400G, fx-7400G Plus, fx-7450G, fx-7400G Plus GY (French versions: fx-6910G, Graph 20, Graph 25)

1st Generation

Icon Menu Power Graphic series (1993)

Around 1993, the Icon Menu Power Graphic series introduced: An icon-driven menu interface, further increasing ease of use, numerical differentiation; matrices in programs; and an equation solver. Models: fx-7700GE, later renamed fx-7700GH. (French version: fx-7900GC)

Additionally there were models with 24K memory which introduced: dynamic graphing; complex numbers; table mode; more advanced equation solver; larger matrices (255x255); sigma calculations; graph solver for roots, intercepts, max and mins. These include the fx-9700GE, later renamed fx-9700GH (wider screen) and the CFX-9800G (3-color screen). (French versions: fx-9900GC, CFX-9900GC)

Also made with an icon menu but none of the above features was the fx-7300G (french: fx-6900G).

Power Graphic Series (1990)

Around 1990, the Power Graphic series introduced: F1 through F6 shortcut keys which enabled significantly greater ease of use, polar, parametric and inequality graphs; box and factor zoom; multiple graph scrolling; range initialization; integration; matrix mode; fractions; permutations; combinations; normal probabilities; SI unit symbols; Models: fx-7700G, fx-7700GB, fx-8700G, fx-8700GB. The GB models have a communications port. (French versions: fx-7800G, fx-7800GC, fx-8800G, fx-8800GC).

Also made was the low-end fx-6300G (french: fx-6800G) with a smaller screen and less features, and the fx-6200G which didn't have any programming facility.

Original series

First produced in 1985, these include the fx-7000G, fx-6000G, fx-6500G, fx-7200G, fx-7500G, fx-8000G, fx-8500G.

Programming

Casio graphic calculators use a BASIC-like programming language but variable names are restricted to single letters A-Z which are shared by all programs including subroutines which are stored as separate programs. This means there are no local variables, they are all global. These variables are also shared by other functions of the calculator. For example, drawing a graph will overwrite the X and Y values.

1st Generation Programming Language

Loops are constructed by incrementing or decrementing the value of a variable with the *Isz* and *Dsz* commands in conjunction with the *Lbl* and *Goto* commands, rather than using simpler *For* or *While* commands. Arrays are achieved by overwriting other letters, for example A[0]=A, A=B, A=C. The available space for arrays can be extended with the *Defm* command so that Z, Z etc can be used depending on how much unused memory capacity is available.

2nd Generation Programming Language

Compared to the first generation models these have many more commands including: For and While Loops, If.. Then structures and the ability for real-time user interaction with the Getkey command and the ability to place characters anywhere on the screen with the Locate and Text commands. Also the method for using array variables was changed to using lists and matrices.

HP-28 Series and HP-39g Series

HP-28 series

HP-28S

The **HP-28C** and **HP-28S** were two graphing calculators produced by Hewlett-Packard from 1986 to 1992. The HP-28 was the first calculator capable of solving equations symbolically. They were replaced by the HP-48 series of calculators, which grew from the menu-driven RPL programming language interface first introduced in the HP-28 series.

The HP-28 calculators shared a flip-open (book style) case. On the left side of the flip, there is an alphabetic keyboard (in alphabetic order). On the right was a typical scientific keyboard layout. The display was a 137x32 LCD matrix, usually displaying four lines of information (3 stack/command lines, plus one softkey label line).

Two models were produced, the HP-28C came first in 1987 with two kilobytes of usable RAM, and was the first calculator with a Computer Algebra System. A year later, the more common HP-28S was released with 32k of RAM and a directory system for filing variables, functions, and programs. The HP-28C used a single Saturn processor at 640 kHz whereas the HP-28S used a custom chip containing an improved Saturn processor core at 1 MHz (the HP-48S, the replacement for the 28, used the HP-28S CPU core at 2 MHz).

The HP-28C was the last HP model introduced with the suffix **"C"** in its model designation – a practice which HP had started with the HP-25C back in 1976. The **"C"** had distinguished those models as having continuous memory. However by 1988 that capability had become so common on calculators that it was no longer a feature of distinction, as it was an assumed characteristic of all serious scientific and business calculators. So beginning with the HP-28S, HP-17B, HP-19B, and HP-27S, the feature suffix **"C"** was replaced with a class suffix which was more meaningful in the market: **"S"** for Scientific, **"B"** for Business, and later (in 1993) **"G"** for Graphic.

Among the drawbacks of the HP-28 was the lack of a computer interface. This meant that stored information could only be entered through the keypad and not backed up.

The plastic of the case around the battery cover is prone to breaking, surviving examples of this calculator frequently have tape over the cover to hold it in place.

One of the interesting side notes for this calculator was its ability to store significant amounts of information including formulas thereby enabling students to "cheat" on tests.

HP-39g series

HP-39g series calculators are the successors of HP-38G.

There are five calculators in the 39 series of HP graphing calculators. These calculators have algebraic entry modes, and can perform numeric analysis together with varying degrees of symbolic calculation. All calculators in this series are aimed at high school level students and are characterised by their ability to download (via cable or infra-red) APLETs or E-lessons. These are programs of varying complexity which are generally

intended to be used in the classroom to enhance the learning of mathematics by the graphical and/or numerical exploration of concepts. Some hundreds of these can be found on various websites.

HP-39G

HP-39g was released in 2000.

Basic characteristics

- CPU: 4 MHz SATURN (Yorke)
- Communication: Proprietary infrared, Serial RS-232 (Serial port).
- Memory: 256 KB
- Screen resolution: 131×64 pixels
- Includes a hard cover
- Limited symbolic equation functionality.

HP-40G

HP-40g was released in 2000 in parallel with the HP-39g. The HP-40G's operating system is identical to the HP-39G. Differences detected in hardware during start-up trigger the differences in software functionality.

Basic characteristics

- Identical to HP-39G except:
- Communication: No infrared communication, Serial RS-232 (Serial port).
- Software: Includes an equation writer and advanced CAS.

HP-39g+

HP 39g+

HP-39g+ was released in September, 2003.

Basic characteristics

- CPU: 75 MHz ARM9
- Communication: USB port (using the Kermit or XModem protocols), IrDA (infrared).
- Memory: 256 KB
- Power: 3*AAA as main power, CR2032 for memory backup

- Screen resolution: 131×64 pixels
- Does not come with a hard cover
- Limited symbolic equation functionality.

Note: Although an ARM processor is used in this model, the operating system is substantially the same as that of the 39G, with the Saturn chip being emulated on the ARM at a higher speed than was possible for the 39G. The CAS component of the HP-40G's operating system appears to have been totally removed, rather than simply being hidden at start-up.

HP-39gs

HP-39gs was released in Jun, 2006.

Basic characteristics

- CPU: 75 MHz ARM9
- Communication: USB port (using the Kermit or XModem protocols), IrDA (infrared), 4-pin asynchronous Serial port (not RS232 voltage levels) using a serial cable with a 4-pin mini-USB connector.
- Power: 4*AAA as main power, CR2032 for memory backup
- Screen resolution: 131×64 pixels
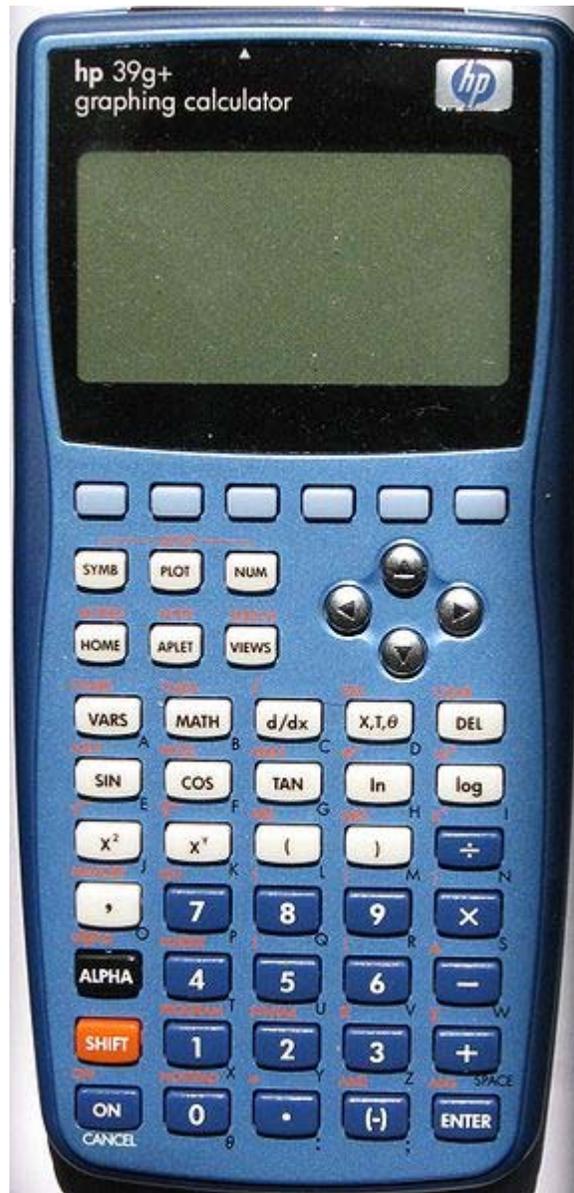- Includes a hard cover
- Limited symbolic equation functionality.
- Flash memory to allow potential future upgrades/bug fixes.

Note: Although an ARM processor is used in this model the operating system is substantially the same as that of the 39G, with the Saturn chip being emulated on the ARM at a higher speed than was possible for the 39G.

HP-40gs

HP-40gs was released in mid-2006.

Basic characteristics

- Identical to HP-39gs except:
- Communication: No infrared communication.
- Software: Includes an equation writer and advanced CAS.
- Memory: Flash memory is larger. This is necessary to accommodate the CAS software.

Chapter 6

HP-48 Series

HP 48GX

HP 48GX

Type	graphing calculator
	Calculator
Entry mode	RPN
	CPU
Processor	Saturn

The **HP-48** is a series of graphing calculators using Reverse Polish notation (RPN) and the RPL programming language, produced by Hewlett-Packard (HP) from 1990 until 2003. The series include the **HP-48S**, **HP-48SX**, **HP-48G**, **HP-48GX**, and **HP-48G+**, the G models being expanded and improved versions of the S models. The models with an **X** suffix are expandable via special RAM (memory expansion) and ROM (software application) cards. In particular, the GX models have more onboard memory than the G

models. The G+ models have more onboard memory only. The SX and S models have the same amount of onboard memory.

Note that the similarly named HP-48GII (2004) is not really a member of the series, but rather much more closely related to the HP-49G and HP-49G+.

The hardware architecture developed for the HP-48 series became the basis for the HP-38G, with a simplified user interface and an infix input method, and the HP-49G with various software enhancements. Likewise, the hardware and software design of the HP-48 calculators are themselves strongly influenced by other calculators in the HP line, most of all by the HP-18C and the HP-28 series.

Specifications

The HP-48 series' Saturn microprocessor is a hybrid 64-bit / 20-bit CPU hardware-wise but acts like a 4-bit processor in that it presents nibble-based data to programs and uses a nibble-based addressing system. The main registers A, B, C, D, along with temp registers R0, R1, R2, R3, and R4 are a full 64-bits wide, but the data registers D0 & D1 are only 20-bit. External logical data fetches are transparently converted to 8-bit physical fetches. The processor has a 20-bit address bus available to code but due to the presence of the high/low nibble selection bit, only 19 bits are available externally.

In both the HP-48S/SX and G/GX series, the *Saturn* CPU core is integrated as part of a more complex integrated circuit (IC) package. These packages have codenames inspired by the members of the Lewis and Clark Expedition. The codename of the IC is *Clarke* in the S/SX, after William Clark, and *Yorke* in the G/GX, after Clark's manservant. The previous series of Saturn-based ICs were codenamed *Lewis*, after Meriwether Lewis.

Common for all models

- CPU architecture: Saturn
- Screen resolution: 131×64 pixels
- Communication Ports: 4-pin RS-232 (Serial port) or Infrared port (not IrDA)
- Data bus width: 8-bit (external)
- Maximum 4-bit-cell address width: 20 bits (leading to the address space shown next)
- Logical address space: 512 kB
- Maximum register size: 64 bit (both working and scratch registers)
- Available expansion card ports on X models: 2
- Expansion card pins: 40

HP-48S/SX specific

- CPU clock frequency: 2 MHz
- Memory clock frequency: 2 MHz
- CPU codename: Clarke

- Communication Protocol(s): Serial Transfers: Kermit (protocol); Infrared Transfers: proprietary
- On-board ROM: 256 KB
- On-board RAM: 32 KB
- Maximum additional memory per expansion card: 128 KB (SX only)
- ROM versions: A, B, C, D, E, J

HP-48G/GX specific

Hewlett-Packard 48GX Scientific Graphing Calculator

- CPU clock frequency: 3.7 to 4 MHz
    - Some claim that the frequency varies according to temperature
    - According to one of the engineers on the design team of the HP48G series (Dave Arnett), the yields for 4MHz CPUs were essentially separated into two parts: the ones closest to spec, generally near 3.93-3.94MHz, were reserved for the expandable models (GX), and those just slightly under spec were used for the non-expandable units (G). Eventually the yields improved and the CPUs which clocked closer to 4MHz were installed in the non-expandable units as well. The effects of (non-extreme) temperatures are almost negligible.
- Memory clock frequency: 2 MHz
- CPU codename: Yorke
- Communication Protocol(s): Serial Transfers: Kermit (protocol) or Xmodem; Infrared Transfers: proprietary

- On-board ROM: 512 kB
- On-board RAM: 32 kB (G) or 128 kB (G+/GX)
- Maximum additional memory for expansion card port 1: 128 kB
- Maximum additional memory for expansion card port 2: 4 MB (128 kB addressable at any given time via bank switching)
- Other communication protocols: XModem
- ROM versions: K, L, M, P, R

Programming

The HP-48 series of calculators support a stack-based programming language named Reverse Polish Lisp (RPL), a combination of Reverse Polish Notation (RPN) and Lisp. RPL adds the concepts of lists and functions to stack-based programming, allowing the programmer to pass unevaluated code as arguments to functions, or return unevaluated code from a function by leaving it on the stack. In spite of the name, RPL resembles Forth more closely than Lisp.

RPL comes in two flavors: User RPL and System RPL. User RPL is the language that a user can program directly on the calculator. System RPL requires an external compiler; this may be done on the calculator with a third-party utility, or on another machine. The two languages vary mainly in the number of low-level operations available to them. User RPL does not expose any commands that do not check their arguments. Consequently, User RPL programs cannot normally crash the calculator (and are therefore slower than System RPL programs), whereas a System RPL program that invokes a command with incorrect arguments will almost certainly leave the calculator in a state which requires a full memory reset (occasionally referred to as a three-finger salute because it requires pressing the ON, the A, and the F keys on the calculator at the same time).

It is also possible to program the HP48 directly in Machine Language code. Books are available on this subject and some of them are freely available on the web.

Programmers working in System RPL or machine language most commonly work on an HP48 emulator because it is much quicker and easier to restore the state of a crashed emulator than to restore a crashed calculator.

Chapter 7

HP-49 Series

HP-49g
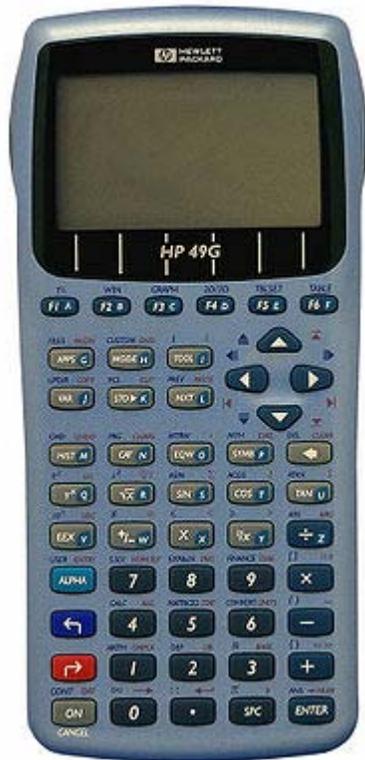
HP 49G graphing calculator

Calculator

Entry mode	RPN
Display Size	131×64 pixels

CPU

Processor	4 MHz Saturn

Programming	
User Memory	2 MiB flash memory and 512 KiB RAM
Interfaces	
Ports	RS232 (using the Kermit or XModem protocols, 10 pin proprietary connector)

The **HP 49G** series are Hewlett-Packard (HP) manufactured graphing calculators. They are the successors of the popular HP-48 series.

There are four calculators in the 49 series of HP graphing calculators. These calculators have both algebraic and RPN entry modes, and can perform numeric and symbolic calculations using the built-in Computer Algebra System (CAS), which is an improved ALG48 and Erable combination from the HP-48 series.

Because these calculators features CAS, none of the 49 series are permitted for use in the ACT, the PLAN and some classrooms, though it may be used on all of College Board's calculator-permitted tests, including the SAT, some SAT Subject Tests and the AP Calculus, Chemistry, Physics, and Statistics exams.

HP 49G

Released in August 1999, this calculator was the first HP unit to break from the more traditional subdued coloration. In addition to having a metallic blue color, the keyboard material was rubber and did not have the traditional HP calculator hinged keyboard feel. In addition, it lacked a large ENTER key which was seen by many as the defining sign of an HP calculator. These changes were disliked by many traditional HP calculator users.

The 49G incorporated many of the most powerful interface and mathematics tools available on the HP-48 series into the firmware of the new 49G, including the ability to easily decompile and compile both SysRPL and Saturn assembly code on the unit.

The 49G was the first HP calculator to use flash memory and have an upgradable ROM. In addition, it had a hard sliding case as opposed to the soft pouches supplied with the HP-48 series. The last officially supported ROM update for this calculator was 1.18, but several unofficial ROMs were released by the developers. The final ROM version was 1.19-6.

In 2003, the CAS source code of the 49G ROM was released under the LGPL. In addition, this release included an interactive geometry program and some commands to allow compatibility with certain programs written for the newer 49g+ calculator. Due to licensing restrictions, the recompiled ROM cannot be redistributed.

Issues, bugs and criticism

The major criticisms of the 49G calculator dealt with the new rubber keyboard design and strange blue coloration. Users reported that some of the rubber keys could easily disconnect from the plastic structure. In addition, many felt that the 49G was based on outdated hardware that was surpassed by the TI-89's faster processor and higher resolution screen.

In using a 4MHz Saturn processor the designers were able to easily reuse old code from the HP-48 series, but there was not the great advance in technology that many users were expecting.

Documentation of new features was poor, making learning difficult for new users.

HP 49g+

HP-49g+
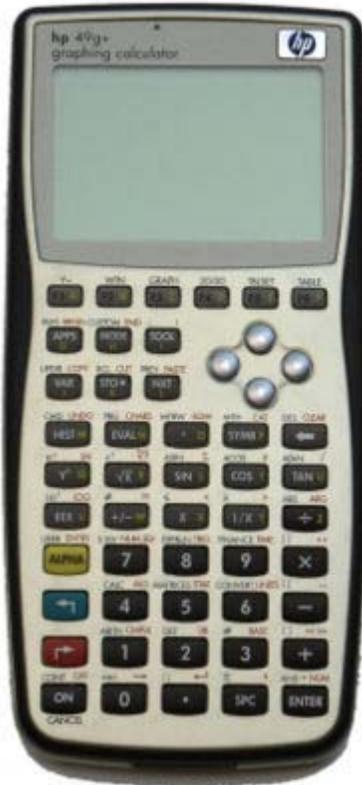
HP 49g+ graphing calculator

Calculator

Entry mode RPN

Display Size 131×80 pixels

CPU

Processor	203 MHz ARM version ARMv4T (clocked at 75 MHz by default, but can be overclocked by certain user programs)

Programming	
User Memory	2 MiB flash memory (~768 KiB user accessible), 512 KiB RAM (~380 KiB user accessible)
External Memory	SD memory card (up to 2 GB)

Interfaces	
Ports	USB port (using the Kermit or XModem protocols), IrDA (infrared)

In August 2003, HP released the 49g+. This unit had metallic gold coloration and was backward compatible with the HP 49G. Instead of the rubber keyboard found on the HP 49G, this calculator's keyboard had plastic hinges intended to return the feel of older HP calculators, and also included a pouch to protect the unit, similar to those included with older HP models. It was designed and manufactured by Kinpo Electronics for HP.

This calculator featured an entirely new processor architecture, USB and IrDA (infrared) communication, memory expansion via an SD card, and a slightly larger screen, as well as other improvements over the previous model.

The calculator system did not run directly on the new ARM processor, but rather on an emulation layer for the older Saturn processors found in previous HP calculators. This allowed the 49g+ to maintain binary-level compatibility with most of the programs written for the HP 49G calculator, as well as source code-level compatibility with many written for the HP 48 series.

Despite the emulation, the 49g+ was still much faster than any older model of HP calculator. The speed increase over the HP 49G is around 3-7 times depending on the task. It is even possible to run programs written for the ARM processor thus bypassing the emulation layer completely. A port of the GNU C compiler is also available.

Issues, bugs and criticism

The 49g+ has been criticized more than any other HP calculators in the past.

The keyboard design caused a hollow clunking noise when pressed, and many users began reporting frequent physical key failures. Because of their unproven design, the keys would frequently register twice from one keypress. They would often break internally as well, losing the physical feedback that made them unique in the first place.

The housing components are made of low grade plastics, which would often crack or discolor over time causing an unsightly look. These physical defects and design defects caused many users to seek new units under warranty from HP. Some users have reported receiving three or more replacement units and experiencing the same problems.

In addition to physical problems, many software issues plagued the initial launch. Despite having a larger screen, the software did not take advantage of it with applications such as plotting. Many keystrokes were often missed or even doubled, resulting in further problems with data entry. The screen would flicker with usage, and even sometimes experience an unsightly display issue dubbed the "earthquake effect".

For this reason, many internet reviews have been unfavorable. For example, on Amazon the average rating for a HP 49g+ is 3.04 on a scale of 1 to 5, versus 4.47 for its predecessor HP 48GX and 4.55 for its successor, the HP 50g. Its competitors, the TI-89 and the TI-84, have been rated 4.56 and 4.35, respectively. Used HP 48GX calculators are 2–3 times more expensive than a new 49g+, and whilst the HP 49G/g+ is decreasing in price, the used 48GX's are actually increasing in value.

While HP has made no official response to these criticisms, there have been changes attempting to rectify the problems. Software updates fixed most problems experienced with previous ROM revisions, and the new keyboard introduced with the 49g+ has undergone several revisions that seem to be improving its reliability with each change.

The latest 49g+ model, with serial numbers CNA6XXXXXXX and above, has the latest keyboard design found on the new 39gs, 40gs and 50g calculators. Many have reported a dramatic improvement between the feel of the keyboards found on these newer 49g+ models and the older 39/49g+ models. The new keyboards appear to be much more durable than previous generations.

HP 48gII

	HP 48gII
	Calculator
Entry mode	RPN
Display Size	131×64 pixels
	CPU
Processor	203 MHz ARM version ARMv4T (clocked at 48 MHz by default, but can be overclocked by certain user programs)
	Programming
User Memory	128 KiB RAM (~80 KiB user accessible)

Interfaces

Ports	RS-232 port (using the Kermit or XModem protocols, non-standard -- must use included cable), and IrDA (infrared); or USB port, IrDA, and asynchronous serial.

The HP 48gII was not a replacement for the HP 48G series as its name suggested. Rather it was a 49g+, also with an ARM processor (unlike the 48g), but with reduced memory, no expansion via an SD memory card, lower clock speed, and a smaller screen. This calculator seems to target users that desire mathematical capability, but have no desire to install many programs.

Issues, bugs and criticism

In its original release (prior to the advent of the HP 50g), the HP 48gII suffered from similar problems to the 49g+, including a keyboard perceived by longtime HP users as suboptimal. As early units did not allow ROM updates, a general recall had to be issued when a problem with battery life was discovered in early 2004.

Additionally, some users have complained about the non-standard RS-232 communications used by the unit. Early units came with a special RS-232 serial cable with a built in converter - unfortunately, even with this cable, the units still do not function properly with most RS-232 equipment. For this reason, the main advantage the 48gII had over the 49g+ (the ability to communicate with instrumentation using the RS-232 communication protocol) is essentially moot.

Following the release of the 50g, HP put out a revised version of the 48gII (without changing its model number). This version addresses many of the most serious criticisms of the original 48gII, most notably giving it an improved keyboard, ROM updatability, use of four AAA-cell batteries, and similar USB and serial ports to the 50g. Despite this, the 48gII is still looked at by many veteran users of the original HP 48 line as an inferior successor.

The 48gII will run most 49g+ compatible programs, provided there is enough memory available.

HP 50g

HP-50g

HP50g graphing calculator, with the Equation Editor being used

Calculator

Entry mode RPN

Display Size 131×80 pixels

CPU

Processor 203 MHz ARM version ARMv4T (clocked at 75 MHz by default, but can be adjusted by certain user programs)

Programming

User Memory 2 MiB flash memory (~768 KiB user accessible), 512 KiB RAM (~380 KiB user accessible)

External Memory SD memory card (up to 2 GB)

The HP 50g is the latest calculator in the "49" series. The most apparent change is a revised color scheme, returning the unit to a more traditional HP calculator appearance.

Using dark black plastic for the entire body, white, orange and yellow are used for function shift keys. The back shell is textured more deeply than the 49g+ to provide a more secure grip.

The form and size of the calculator shell is identical to the current 49g+ series, but four AAA batteries are used as opposed to three in previous models. In addition to all the features of the 49g+, the 50g also includes the full equation library found in the 48G series (also available for the 49g+ with ROM 2.06 and above) and has an asynchronous serial port in addition to IrDA and USB ports of the 49g+. Like the 49g+, the range of the infrared port has been limited to about 10 cm (4 inches).

The new asynchronous serial port is not a true RS-232 port as it uses different voltage levels and a non-standard connector. An external converter/adapter is required to interface with RS-232 equipment.

The keyboard, the most often criticized feature of the 49g+ calculators, has been redesigned to eliminate previous problems.

A worldwide announcement regarding the availability of this calculator was made by HP in August 2006, and official details are available on the HP calculators webpage.

Issues, bugs and criticism

While the operating system still lacks true support for languages other than English, additional software is available which allows one to operate the 49g+/50g in French, Spanish, Italian and German thus allowing easier use of the calculator for non native English speakers.

The Conn4x software used to connect the HP 50g to a PC to exchange files and complete other tasks is not compatible with Windows Vista, and unless the user knows that they must manually run the Conn4x setup program with Administrator rights, the Setup program silently exits without even attempting to install the Conn4x software.

Conn4x Windows 7 (Vista?) Workaround

Default installation of the Conn4x and HP USB framework on windows 7 does not yield a working communication path between computer and calculator, but there seems to be a workaround. Installing the HP USB connectivity framework from their Windows Vista / 7 download page will install a driver that does not seem to work with the Windows XP version of Conn4x.

However, installing the HP Conn4x package as distributed for Windows XP **without** installing the HP USB framework will install several drivers as well as the Conn4x program. These drivers do not appear in an on-connect driver scan on Windows 7, but instructing the computer to use the driver found in C:\Program Files\Hewlett-Packard\Conn4x\USBDriver (default install path) results in functional communication

between an HP50G and Windows 7 using Conn4x. This result should extend to Windows Vista and the 49G series, although it has only been tested to-date using a 50G and Windows 7. Drag and drop may not work for transfer to the calculator, but copy and paste do work as expected. On Windows Vista and Windows 7 Conn4x installer should be run with administrative permissions.

Programming

The HP 49 series of calculators support both algebraic (HP-Basic) and a stack-based programming language named RPL (ROM Procedural Language or Reverse Polish Lisp), a combination of Reverse Polish Notation (RPN) and Lisp. RPL adds the concepts of lists and functions to stack-based programming, allowing the programmer to pass unevaluated code as arguments to functions, or return unevaluated code from a function by leaving it on the stack.

The highest level language is User RPL, consisting of sequences of built-in postfix operations, optionally including loops and conditionals. Every User RPL command checks the stack for its particular arguments and returns an error if they are incorrect or not present. Below User RPL is System RPL (SysRPL). Most System RPL commands lack argument checking and are defined only for specific argument types (e.g. short integer vs. long integer), making System RPL programs run dramatically faster than equivalent User RPL ones. In addition, System RPL includes many advanced functions that are not available in User RPL. System RPL programs can be created without the use of PC software (although it is available), thanks to the calculator's builtin compiler, MASD. MASD also can compile Saturn assembly language and, with the latest ROM revision for the 49g+/50g, ARM assembly language on the calculator itself. Many tools exist to assist programmers and make the calculator a powerful programming environment.

Saturn assembly, and, on the 49g+/50g, ARM assembly and C, are also programmable using desktop based compilers.

HPGCC for the 49g+/50g

HPGCC is an implementation of the GCC compiler, released under the GNU GPL. It is now mainly targeted at the ARM based 49g+/50g calculator. Previous versions of HPGCC supported the other ARM based calculator models (the 48gII, and the 39g+/39gs/40gs), but this was removed due to lack of interest and compatibility issues. Formally, HPGCC is a cross-compiler; it compiles code for the ARM-based HP calculators, but runs on a PC rather than the target system.

The latest version of HPGCC offers many enhancements from earlier versions. Most notably, the compiled code is now in ARM Thumb mode by default, resulting in great reduction in code size with little performance hit. Besides implementing most of ANSI C, there are device-specific libraries that allow access to things like the calculator's RPN stack, memory and piezoelectric buzzer. The GCC compiler itself is the property of the

Free Software Foundation, and they state that its use does not impose any particular licensing restrictions on any of its output. However, the libraries included with HPGCC, including routines necessary to actually invoke any HPGCC-compiled program on an actual calculator, are released under a modified GPL license, contrary to GCC on many other platforms which use a more permissive license for their libraries. Thus any programs that link against them can only be distributed if they are also released under the GPL (with an exception for "non-profit" software).

Linux, Windows, and Mac OS X versions are available for download. The Windows version also includes a version of Programmer's Notepad for a basic IDE.

Emulators for the 49 series

There are several emulators available for the HP 49G calculator. A version of Emu48 is available in the Debug4x IDE that allows emulation of most of the features of the 49g+/50g but will not execute any ARM-based code.

An ARM-based emulator, x49gp, has been released and allows the true emulation of the 49g+/50g ARM processor and successfully runs HPGCC 2 and 3 compiled programs. At this time the emulator is only available for Linux and Mac OS X and must be compiled from the source.

An emulator for Microsoft Windows Mobile (PPC, smartphones) is available.

ROM Updates

The 49 series allows the user to update the ROM to gain enhanced features or bug fixes. To retrieve the ROM version, one must execute the command VERSION. This will return two strings to the stack which should look similar to this:

```
"Version HP49-C Revision #2.09"
"Copyright HP 2006"
```

A current ROM and installation instructions can be found at HP's 49g+ homepage.

It is important to note that there are several unofficial ROMs available for download. These are not officially supported, but it is recommended by users to use the latest ROM possible. Unofficial ROMs are best found on hpcalc.org where they are released by the ROM maintainers.

Chapter 8

TI-73 Series, TI-80 and TI-81

TI-73 series

TI-73 series

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1998
Predecessor	TI-80
Calculator	
Entry mode	D.A.L.
CPU	
Processor	Zilog Z80
Frequency	6 MHz
Programming	
Programming language(s)	TI-BASIC
User Memory	25 KB RAM 64 KB flash ROM
Firmware Memory	512 KB
Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

TI-73 series are graphing calculators made by Texas Instruments.

The original TI-73 was originally designed in 1998 as a replacement for the TI-80 for use at a middle school level (grades 6-9). Its primary advantage over the TI-80 is its 512 KB

of flash memory, which holds the calculator's operating system and thereby allows the calculator to be upgraded. Other advantages over the TI-80 are the TI-73's standard sized screen (as opposed to the TI-80's smaller screen), the addition of a link port, 25 KB of RAM (as compared to the TI-80's 7 KB of RAM), and a faster 6 MHz Zilog Z80 processor (as compared with the TI-80's 980 kHz proprietary processor). The TI-73 also uses the standard 4 AAA batteries with a lithium backup battery (instead of the TI-80's 2 CR2032 lithium batteries).

In 2003, the **TI-73** was redesigned with a sleek new body shape and redesignated the **TI-73 Explorer** to indicate its currently intended use as a bridge between the TI-15 Explorer and similar calculators and the TI-83 Plus, TI-84 Plus, and similar calculators.

Due to lack of demand in middle schools, the TI-73 and TI-73 Explorer have not been huge sellers for TI and are not carried by most retail stores. Most American upper-level middle school algebra courses generally tend to use the TI-83 or TI-84 families instead of the TI-73 or TI-73 Explorer, while most basic middle school math courses generally do not use graphing calculators, instead opting for scientific calculators such as the TI-30 or TI-34 families.

Originally the TI-73 could only run programs written in TI-BASIC, although that has changed in recent years. In 2005 an assembly shell called **Mallard** was released for the TI-73. Mallard allows the user to run programs written in assembly language. As with the TI-82 and the TI-85 before, a hacked backup file is downloaded containing the assembly shell.

Released in early 2009, the Windows utility Chameleon allows a user to load the TI-73 Explorer with a slightly modified TI-83+ firmware, giving it nearly equivalent functionality.

Technical specifications

CPU
> Zilog Z80 CPU, 6 MHz

Flash ROM
> 512 KB with 128 KB available for Flash Applications

RAM
> 32 KB with 25 KB available to the user

Display
> Text: 16×8 characters
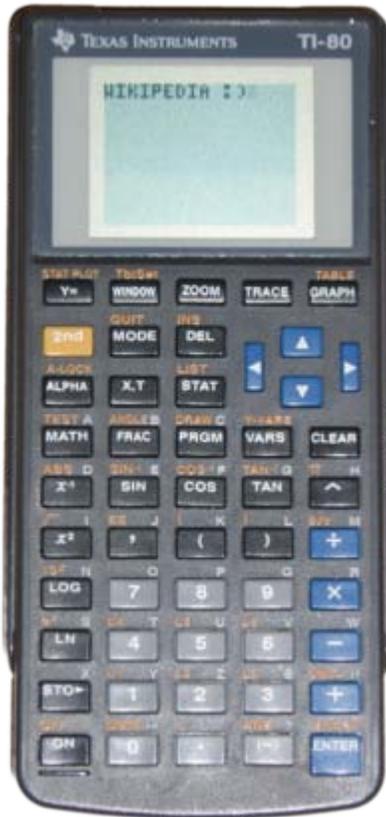
I/O
> Link port
> 50 button built-in interface

Power
> 4 AAA batteries plus 1 lithium battery for backup

Integrated programming languages
> TI-BASIC

TI-80

TI-80

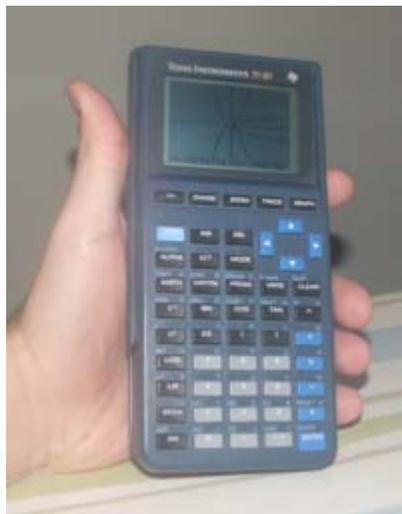| Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1995
Discontinued	1998
Successor	TI-73 series
Calculator	
Entry mode	D.A.L.
Display Size	64×48 pixels, 16×8 characters
CPU	
Processor	proprietary
Frequency	980 kHz
Programming	
User Memory	7 KB of RAM
Other	

Power supply   2 CR2032 batteries

TI-80 is a graphing calculator made by Texas Instruments. It was originally designed in 1995 to be used at a middle school level (grades 6-9).

The TI-80 featured the smallest screen and slowest processor (980 kHz proprietary) of any TI graphing calculator. In comparison, the TI-81, released in 1990, featured a 2 MHz Zilog Z80 processor. However, the TI-80 did feature 7 KB of RAM (compared with the TI-81's 2.4 KB). The TI-80 also had more built-in functions than the TI-81 (such as list and table functions, as well as fraction and decimal conversions). Like the TI-81, the TI-80 did not feature a link port. The TI-80 was also the only graphing calculator to use 2 CR2032 lithium batteries (instead of the standard 4 AAA batteries with a lithium backup battery).

Since its release, it has been superseded by the superior TI-73 and TI-73 Explorer. The TI-80 has been discontinued.

TI-81

TI-81

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1990
Successor	TI-82

Calculator

Entry mode	D.A.L.
Display Size	96×64 pixels, 16×8 characters
CPU	
Processor	Zilog Z80
Frequency	2 MHz
Programming	
User Memory	2400 bytes of RAM
Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

The **TI-81** is the first graphing calculator made by Texas Instruments. It was designed in 1990 for use in algebra and precalculus courses. Since its original release, it has been superseded several times by newer calculators - the TI-82, the TI-83, the TI-83 Plus, TI-83 Plus Silver Edition, the TI-84 Plus, the TI-84 Plus Silver Edition, and most recently the TI-Nspire and TI-Nspire CAS; most of these share the original feature set and 96×64-pixel display that began with this calculator.

Features of the TI-81

The TI-81 is powered by a Zilog Z80 microprocessor, like those used in almost every other Texas Instruments graphing calculator (except the TI-80, TI-89, TI-89 Titanium, TI-92, TI-92 Plus, and Voyage 200). However, the processor runs at only 2 MHz whereas the other Z80-powered Texas Instruments calculators run at a speed of at least 6 MHz (the TI-83 Plus Silver Edition, TI-84 Plus, and TI-84 Plus Silver Edition run at 15 MHz). It contained 2.4 KB of RAM.

The TI-81's user interactions are provided by its so-called Equation Operation System. This is comparable to the interface provided by the more recent TI-82, TI-83, and so on. This system is capable of such tasks as two-dimensional parametric graphing (in addition to standard two-dimensional function graphing), trigonometric calculations in units of either degrees or radians, simple drawing capabilities, creation and manipulation of matrices up to 6x6 in size, and programming in Texas Instruments' native TI-BASIC programming language.

In early 2010, an exploit was found that can be used to execute machine code on the TI-81, which is impressive as the calculator had no link port. Programs can be written and assembled using a toolset called Unity, which will output the machine code that the user must manually input on the calculator.

As with its successors, the TI-81 is powered by four AAA batteries and one CR1616 or CR1620 lithium backup battery (to ensure programs are kept when the AAA batteries are being changed).

Texas Instruments distributes software which emulates the TI-81 and its Equation Operating System on a desktop computer.

Chapter 9

TI-82 and TI-83 Series

TI-82

TI-82

TI-82, original design

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1993
Predecessor	TI-81
Successor	TI-83
	Calculator
Entry mode	D.A.L.
Display Size	96×64 pixels, 16×8 characters

CPU	
Processor	Zilog Z80
Frequency	6 MHz
Programming	
User Memory	28 kB of RAM
Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

The **TI-82** is a graphing calculator made by Texas Instruments. The TI-82 was designed in 1993 as a stripped down, more user friendly version of the TI-85, and as a replacement for the TI-81. It was the direct predecessor of the TI-83. It shares with the TI-85 a 6 MHz Zilog Z80 microprocessor. Like the TI-81, the TI-82 features a 96x64 pixel display, and the core feature set of the TI-81 with many new features.

Features of the TI-82

The TI-82 is powered by the same processor that powered its cousin, the TI-85, a 6 MHz Zilog Z80 microprocessor. This was an improvement over the TI-81's 2 MHz Z80 processor. In addition, the available RAM was increased more than tenfold — from 2.4 KB to 28 KB (the same amount as the TI-85).

Some of the more notable improvements of the TI-82 over the TI-81 include the following: the addition of a link port to enable programs and other data to be transferred between two calculators or between a calculator and a computer; the addition of two new graphing types—polar and sequence, the addition of a new type of data — the list, the expansion of the size limit of matrices to 50x50, and the (unintentional) addition of the ability to program the calculator in assembly language. The last of these provided a significant boost in interest in the programmability of the calculator, as the use of assembly language (as opposed to Texas Instruments' own TI-BASIC) enabled significantly more performance and flexibility with the programs able to be used on the calculator.

Carried over from the TI-81 is the TI-82's power source — four AAA batteries and one CR1616 or CR1620 lithium backup battery (to ensure programs are kept when the AAA batteries are being changed).

Design changes

The TI-82 was redesigned twice, first in 1999 and again in 2001. The 1999 redesign introduced a design very similar to the TI-73 and TI-83 Plus, introducing a more contoured body, and eliminating the sloped screen that has been common on TI graphing calculators since the TI-81. The 2001 redesign (nicknamed the TI-82 "Parcus")

introduced a slightly different shape to the calculator, eliminated the glossy screen border, and reduced cost by streamlining the printed circuit board to four units.

Technical specifications

CPU
> Zilog Z80 CPU, 6 MHz

RAM
> 28 KB

Display
> Text: 8 Rows × 16 characters
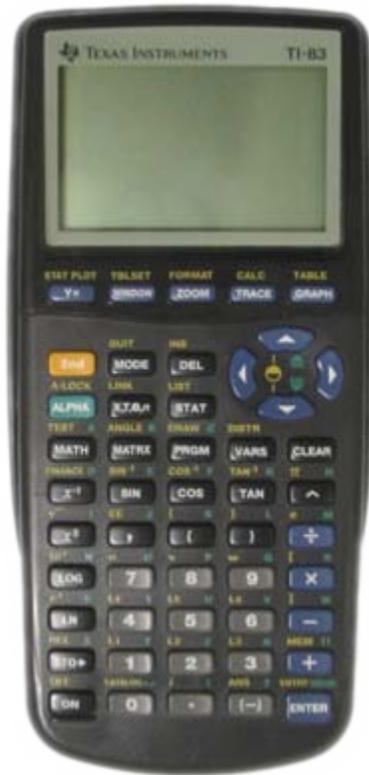> Graphics: 96×64 pixels, monochrome

I/O
> Link port

Power
> 4 AAA batteries plus 1 CR1616/CR1620 lithium battery for backup

Integrated programming languages
> TI-BASIC, Assembly(hacked memory backups)

TI-83 series

TI-83

TI-83, original design

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1996
Discontinued	2004
Successor	TI-83 Plus

Calculator

Entry mode	D.A.L.

CPU

Processor	Zilog Z80
Frequency	6 MHz

Programming

Programming language(s)	TI-BASIC,Assembly
User Memory	32 KB RAM

Other

| **Power supply** | 4 AAAs,
1 CR1616 or CR1620 |

The **TI-83 series** of graphing calculators is manufactured by Texas Instruments. The original TI-83 is itself an upgraded version of the TI-82. Released in 1996, it is one of the most used graphing calculators for students. In addition to the functions present on normal scientific calculators, the TI-83 includes many features, including function graphing, polar/parametric/sequence graphing modes, statistics, trigonometric, and algebraic functions. Although it does not include as many calculus functions, applications and programs can be downloaded from certain websites, or written on the calculator.

TI replaced the TI-83 with the **TI-83 Plus** calculator in 1999, which included flash memory, enabling the device's operating system to be updated if needed, or for large new Flash Applications to be stored, accessible through a new Apps key. The Flash memory can also be used to store user programs and data. In 2001, the TI-83 Plus Silver Edition was released, which featured approximately nine times the available Flash memory, and over twice the processing speed (15 MHz) of a standard TI-83 Plus, all in a translucent "sparkle" grey case.

The TI-83 was the first calculator in the TI series to have built in assembly language support. The TI-92, TI-85, and TI-82 were capable of running assembly language programs, but only after sending a specially constructed (hacked) memory backup. The support on the TI-83 could be accessed through a hidden feature of the calculator. Users would write their assembly (ASM) program on their computer, assemble it, and send it to their calculator as a program. The user would then execute the command "Send (9prgm*XXX*" (where *XXX* is the name of the program), and it would execute the program. Successors of the TI-83 replaced the Send() backdoor with a less-hidden Asm() command.

The TI-83 was redesigned twice, first in 1999 and again in 2001. The 1999 redesign introduced a design very similar to the TI-73 and TI-83 Plus, eliminating the sloped screen that has been common on TI graphing calculators since the TI-81. The 2001 redesign (nicknamed the TI-83 "Parcus") introduced a slightly different shape to the calculator, eliminated the glossy screen border, and reduced cost by streamlining the printed circuit board to four units.

TI-83 Plus

TI-83+
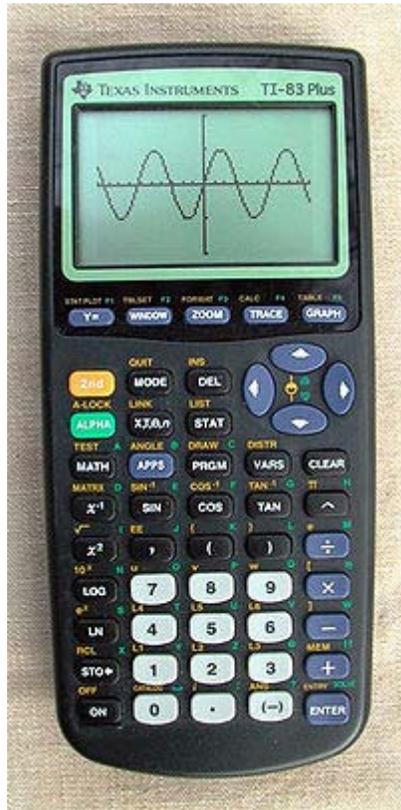
The TI-83 Plus (second version of TI-83)

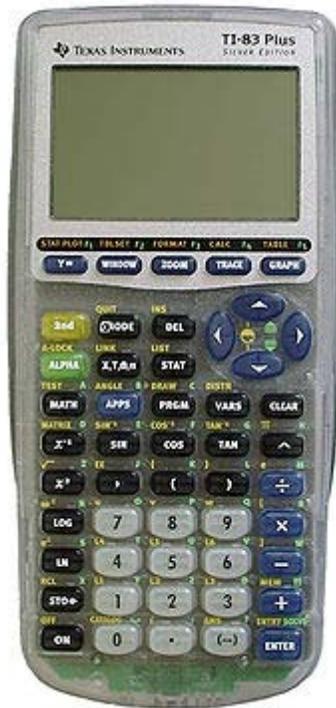|	
Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1999
Predecessor	TI-83
Successor	TI-84 Plus
Calculator	
Entry mode	D.A.L.
CPU	
Processor	Zilog Z80
Frequency	6 MHz
Programming	
Programming language(s)	TI-BASIC Assembly
User Memory	27 KB RAM 160 KB flash ROM
Firmware Memory	512 KB

Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

The **TI-83 Plus** is a graphing calculator made by Texas Instruments, designed in 1999 as an upgrade to the TI-83. The TI-83 Plus is one of TI's most popular calculators. It uses a Zilog Z80 microprocessor running at 6 MHz, a 96×64 monochrome LCD screen, and 4 AAA batteries as well as backup CR1616 or CR1620 battery. A link port is also built into the calculator in the form of a 2.5mm jack. The main improvement over the TI-83, however, is the addition of 512 KB of Flash ROM, which allows for OS upgrades and applications to be installed. Most of the Flash memory is used by the OS, with 160 KB available for user files and applications. Another development is the ability to install Flash Applications, which allows the user to add functionality to the calculator. Such applications have been made for math and science, text editing, organizers and day planners, editing spread sheets, games, and many other uses.

Designed for use by high school students, though now used by middle school students in some public school systems, it contains all the features of a scientific calculator as well as function, parametric, polar, and sequential graphing capabilities; an environment for financial calculations; matrix operations; on-calculator programming; and more. Symbolic manipulation (differentiation, algebra) is not built into the TI-83 Plus. It can be programmed using a language called TI-BASIC, which is similar to the BASIC computer language. Programming may also be done in TI Assembly, made up of Z80 assembly and a collection of TI provided system calls. Assembly programs run much faster, but are more difficult to write. Thus, the writing of Assembly programs is often done on the computer.

TI-83 Plus Silver Edition

TI-83+SE

TI-83 Plus Silver Edition

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	2001 (83+SE)
Discontinued	2004
Successor	TI-84 Plus Silver Edition
Calculator	
Entry mode	D.A.L.
CPU	
Processor	Zilog Z80
Frequency	15 MHz (83+SE)
Programming	
Programming language(s)	TI-BASIC Assembly
User Memory	128 KB RAM 1.5 MB flash ROM

Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

The **TI-83 Plus Silver Edition** is a newer version of the TI-83 Plus calculator, released in 2001. Its enhancements are 1.5 MB of Flash memory, a dual-speed 6/15 MHz processor, 96 KB of additional RAM (but TI has yet to code support for the entire RAM into an OS), an improved link transfer hardware, a translucent silver case, and more applications preinstalled. It also includes a USB link cable in the box. It is almost completely compatible with the TI-83 Plus; the only problems that may arise are with programs (i.e. games) that may run too quickly on the Silver Edition or with some programs which have problems with the link hardware. The key layout is the same. The TI-83 Plus Silver Edition is listed on the Texas Instruments website as "discontinued."

In April 2004, the TI-83 Plus Silver Edition was replaced by the TI-84 Plus Silver Edition. They feature the same processor and the same amount of Flash memory, but the TI-84 Plus Silver Edition features a built in USB port, clock, and changeable faceplates.

TI-84 Plus series

The TI-84 Plus series was introduced in April 2004 as a further update to the TI-83 line. Despite the new appearance, they are not vastly superior to the TI-83 Plus series. The main improvements of the TI-84 Plus and TI-84 Plus Silver Edition are: a modernized case design, changeable faceplates (Silver Edition only), new built in functions, more speed and memory over the TI-83 and TI-83 Plus, a built-in clock, and built-in USB port connectivity. The Ti-84 Plus also has a brighter screen with more contrast, and the keys feel crisper, though they are smaller than the ones on the Ti-83. The TI-84 Plus has 3 times the memory of the TI-83 Plus, and the TI-84 Plus Silver Edition has 9 times the memory of the TI-83 Plus. They both have 2.5 times the speed of the TI-83 Plus. The operating system and math functionality remain essentially the same, as does the standard link port for connecting with the rest of the TI Calculator series.

Technical specifications

CPU
> Zilog Z80 CPU, 6 MHz (TI-83, 83+), or 15 MHz (Silver Edition), or Inventec 6S1837 (TI-83+ revision A)

ROM
> 24 KB ROM (TI-83)

Flash ROM
> 512 KB with 163 KB available for user data and programs (83+) or 2 MB (Silver Edition)

RAM
> 32 KB RAM with 24 KB available for user data and programs (128 KB on Silver Edition, however the extra 96 KB is *not* user accessible by default, this extra

memory is used in some Applications such as Omnicalc for a RAM recovery feature and a *virtual calc*)

84 series expandable via special software to use up disk space on a USB memory drive.

Display

Text: 16×8 characters (normal font)

Graphics: 96×64 pixels, monochrome

I/O

Link port, 9.6 kbit/s

50 button built-in keypad

Power

4 AAA batteries plus 1 CR 1616 or CR 1620 for backup

Integrated programming languages

TI-BASIC, Assembly language and machine code. C requires a computer with a Z80 cross-compiler or an on-calc assembler.

Cryptographic Keys

In 2009, a group of enthusiasts used brute force and distributed methods to find all of the cryptographic signing keys for the calculator firmwares, allowing users to directly flash their own operating systems to the devices. The key for the TI-83 calculator was first published by someone at the unitedti.org forum. They needed several months to crack it. The other keys were found after a few weeks by the unitedti.org community through a distributed computing project. Texas Instruments then began sending out DMCA take-down requests to a variety of different websites mirroring the keys, including unitedTI and reddit.com. They then became subject to the Streisand effect and were mirrored on a number of different sites.

Chapter 10

TI-83&4 Series
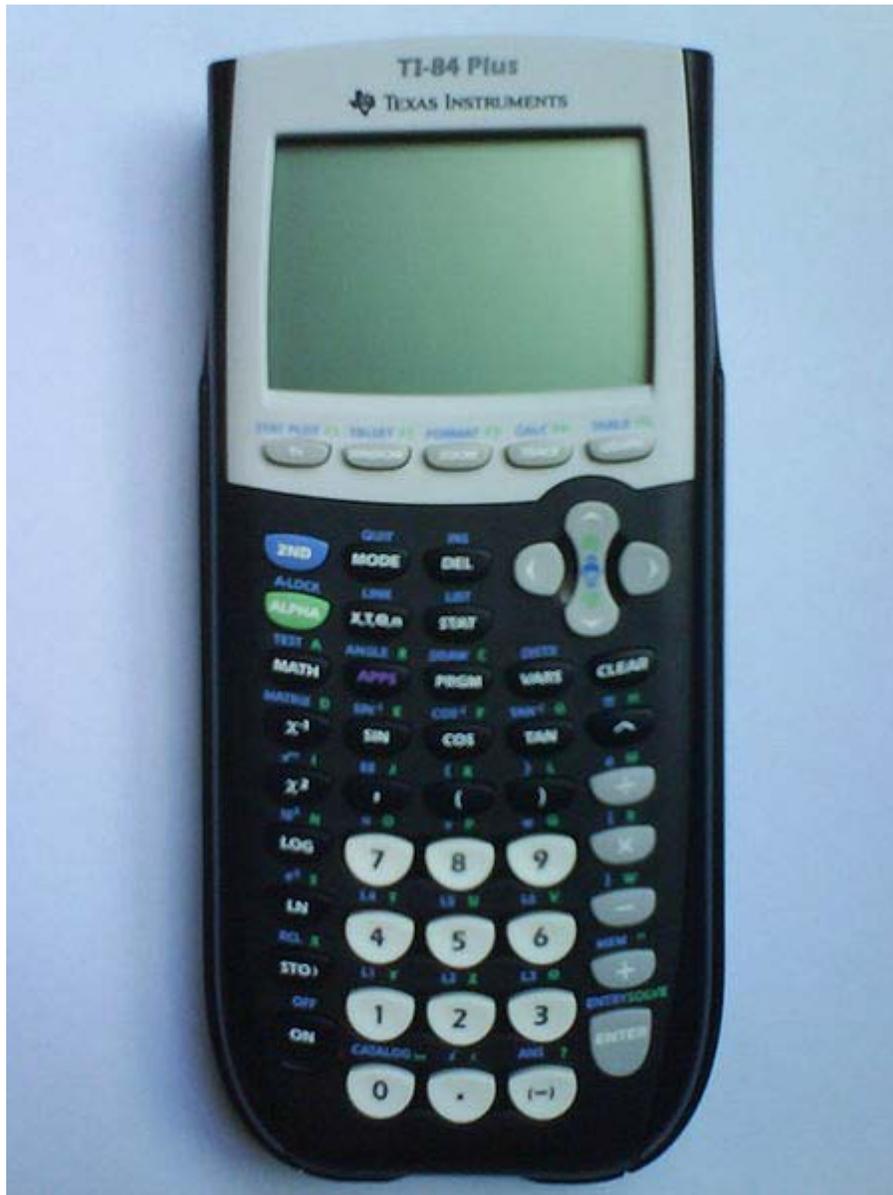
TI-84 Plus
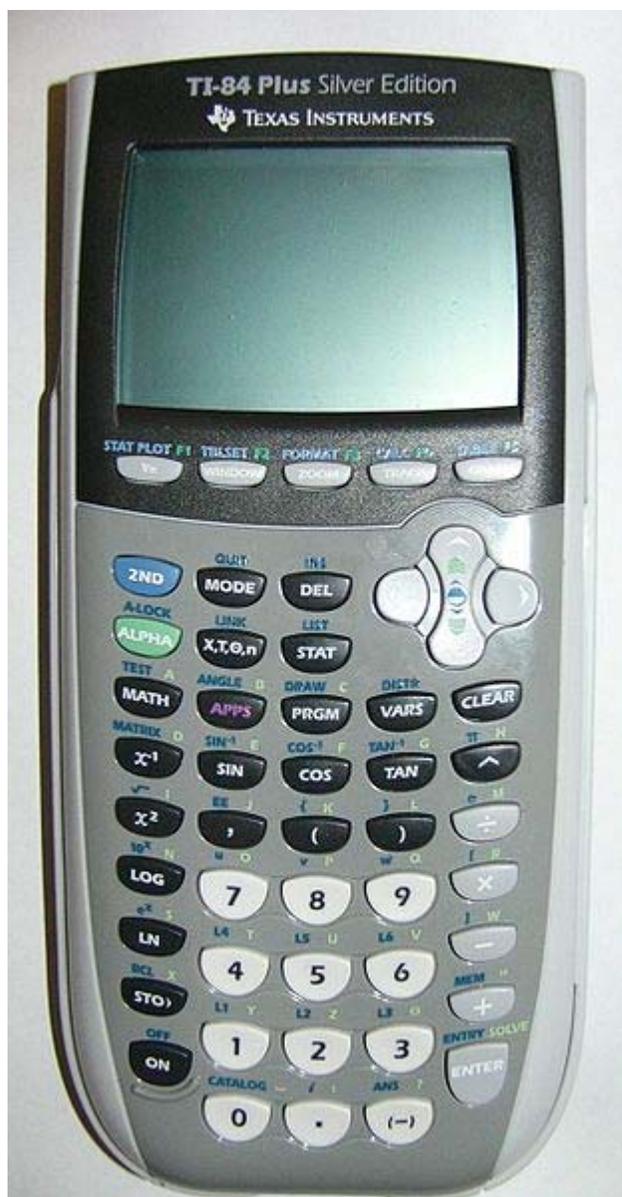
TI-84 Plus Silver Edition

The **TI-84 Plus** is a graphing calculator made by Texas Instruments which was released in early 2004. There is no original TI-84, only the TI-84 Plus and TI-84 Plus Silver Edition models. It is an enhanced version of the TI-83 Plus. The key-by-key correspondence is relatively the same, but the 84 features some improved hardware. The memory is about 3 times as large, and CPU about 2.5 times as fast (over the TI-83 and TI-83 Plus). A USB port and built-in clock functionality were also added. (if set correctly, it will tell the actual time). It is merely a slightly enhanced version of the TI-83 Plus Silver Edition, as it retains many of the same system specs. The USB port on the TI-84 Plus series is USB On-The-Go compliant, similar to the next generation TI-Nspire calculator, which supports connecting to USB based data collection devices and probes, and supports device to device transfers over USB rather than the via Link port. Although

graphing calculators have been called inexpensive in education reform research, the TI-84 Plus Silver Edition was $129.99 in 2008 on the TI online store.

The **TI-84 Plus Silver Edition** was released in 2004 as an upgrade to the TI-83 Plus Silver Edition. Like the TI-83 Plus Silver Edition, it features a 15 MHz Zilog Z80 processor, 24 kB user available RAM (the actual chip is 128 kB, but TI has yet to code support for the entire RAM into an OS), and 1.5 MB Flash ROM. Like the standard TI-84 Plus, the Silver Edition includes a built-in USB port, a built-in clock, and assembly support. It uses 4 AAA batteries and a backup button cell battery. If you take out the batteries while the TI-84 is running, it clears the RAM. TI offers yellow versions of this calculator to schools. Owners can buy other interchangeable colored face-plates and slide-cases online. A kickstand-style slide case and other accessories are also available. The **TI-84 Plus Silver Edition** comes preloaded with a variety of programs, including App4Math, an interface upgrade that allows students to input math problems exactly as they appear in the textbook.

There are three different types of programs which can be downloaded or programmed into it: TI-BASIC, Z80 assembly language, and Flash (applications). There are a wide range of applications that this produces, from science classes, to games, to calculus to note taking (when put together with a separately sold keyboard). The TI-84 Plus Series is exactly like its predecessor in that it can be used on the SAT and ACT examinations as well as International Baccalaureate examinations. However in some cases those administering the exam may reset the calculator's memory beforehand to prevent cheating through the use of built in programs or other data.

When OS 2.30 was initially released, users noticed the speed of graphing was greatly reduced. The explanation was that the update added asymptote checking in graphing.

In January 2006, Texas Instruments released v 2.40 operating system for the TI-84 plus series. The most noticeable addition to the new OS was the teacher key, allowing the teacher to disable any programs installed on the calculator, so they cannot be used on tests, etc. OS version 2.41 for the TI-84 plus series was released in May 2006.

The current OS version is 2.53MP which was released in February 2010. This OS update added prettyprinting as an option which could be toggled on and off.

Assembly Language

Z80 assembly language gives a programmer much more power over the calculator than the built-in language, TI-BASIC. On the downside, Z80 assembly is much more difficult to learn than TI-BASIC and very cumbersome for coding large programs. Z80 assembly language can be programmed on the computer and sent to the calculator via a USB port, written by hand directly into the program editor (using the hexadecimal equivalents to the opcodes) or compiled using third party compiler programs. Programs written in assembly are much faster and more efficient than those using TI-BASIC, as it is the processor's

native language, and does not have to be interpreted like TI-BASIC. An example program that displays "Hello World" on the screen:

```
  B_CALL ClrLCD            ; Clears the screen
  B_CALL HomeUp            ; Moves the cursor to the top-left corner of
the screen
  ld hl,Hello              ; Loads the address that points to "Hello
World" into register hl (16-bit)
  B_CALL PutS              ; Displays "Hello World" on the screen in the
top left corner
  ret                      ; pops off the last data pushed onto the stack.
                           ; May be used to end the program depending on
what's
                           ; on the stack
  Hello:                   ; Label, that has an equate address in memory.
The hex values of
                           ;"Hello World" are stored at the start of
label, Hello
  .db "Hello World!",0  ;defines a series of bytes in memory which
start at the label Hello
```

TI-BASIC

TI-BASIC is the built in language for TI-84 Plus series calculators, as well as many other TI graphing calculators. TI-BASIC is a non-structured programming language, meaning it is arranged sequentially, without the use of methods or organized blocks of code. Because it is so simple and easy to use many programmers start their careers with this. Below is an example of a Hello World program equivalent to the assembly language example.

```
ClrHome              ; Clears the screen and moves the cursor to the top
left corner
Disp "Hello World"  ; Displays "Hello World" on the screen in the top
left corner
```

Technical specifications

CPU
      Zilog Z80 15 MHz, with 6 MHz compatibility mode.

Flash ROM
      Plus Edition: 480 KB user accessible of 1 MB
      Silver Edition: 1.5 MB user accessible of 2 MB

RAM
      24 KB RAM user accessible of 128KB
      Third-party software permits usage of USB drives

Display
      Text: 16×8 characters (normal font)
      Graphics: 96×64 pixels, monochrome

I/O
      Link port, 9.6 kbit/s
      50 button built-in keypad

USB

Power

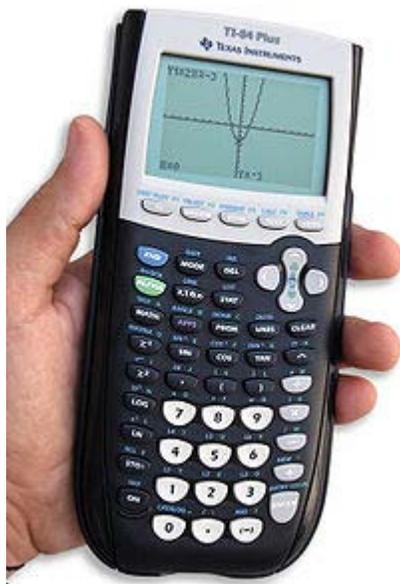   4 AAA batteries plus 1 SR44SW or 303 silver oxide battery for backup

Integrated programming languages

    TI-BASIC and machine code. Assembly and C require a computer with a Z80 cross-compiler or an on-calc assembler.
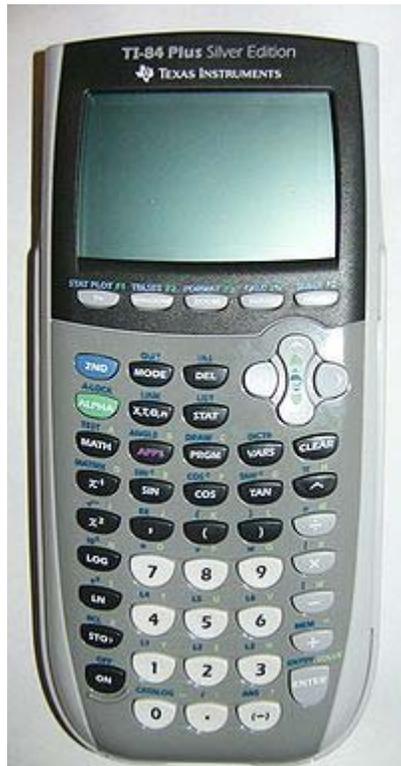
Chapter 11

TI-84 Plus Series

TI-84+

TI-84 Plus

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	2004
Predecessor	TI-83 Plus

Calculator

Entry mode	D.A.L.

CPU

Processor	Zilog Z80
Frequency	15 MHz

Programming

Programming	TI-BASIC, Z80

language(s)

| **User Memory** | 128 KB RAM (48 KB on newer models) of which 24 KB are user accessible. |
| **Firmware Memory** | 2 MB Flash ROM (1.5 MB user-accessible) (Silver Edition) |

Other

| **Power supply** | 4 AAA's, 1 SR44 button cell |

TI-84+SE

TI-84 Plus Silver Edition

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	2004
Predecessor	TI-83 Plus Silver Edition

Calculator

| **Entry mode** | D.A.L. |

CPU

| **Processor** | Zilog Z80 |

Frequency	15 MHz
	Programming
Programming language(s)	TI-BASIC, Z80
User Memory	128 KB RAM (48 KB on newer models) of which 24 KB are user accessible.
Firmware Memory	2 MB Flash ROM (1.5 MB user-accessible)
	Other
Power supply	4 AAA's, 1 SR44 button cell

The **TI-84 Plus** is a graphing calculator made by Texas Instruments which was released in early 2004. There is no original TI-84, only the TI-84 Plus and TI-84 Plus Silver Edition models. It is an enhanced version of the TI-83 Plus. The key-by-key correspondence is relatively the same, but the 84 features some improved hardware. The memory is about 3 times as large, and CPU about 2.5 times as fast (over the TI-83 and TI-83 Plus). A USB port and built-in clock functionality were also added. It is merely a slightly enhanced version of the TI-83 Plus Silver Edition, as it retains many of the same system specs. The USB port on the TI-84 Plus series is USB On-The-Go compliant, similar to the next generation TI-Nspire calculator, which supports connecting to USB based data collection devices and probes, and supports device to device transfers over USB rather than over the Link port.

The **TI-84 Plus Silver Edition** was released in 2004 as an upgrade to the TI-83 Plus Silver Edition. Like the TI-83 Plus Silver Edition, it features a 15 MHz Zilog Z80 processor, 24 kB user available RAM (the actual chip is 128 kB, but TI has yet to code support for the entire RAM into an OS), and 1.5 MB Flash ROM. Like the standard TI-84 Plus, the Silver Edition includes a built-in USB port, a built-in clock, and assembly support. It uses 4 AAA batteries and a backup button cell battery. TI offers a special yellow version of the TI-84 Plus, inscribed with the words "School Property", for schools to loan out to students. This special design was produced in effort to combat theft.. Owners can buy other interchangeable colored face-plates and slide-cases online. A kickstand-style slide case and other accessories are also available. The **TI-84 Plus Silver Edition** comes preloaded with a variety of programs, including App4Math,an interface upgrade that allows students to input math problems exactly as they appear in the textbook,and Chip's Challenge, which is in fact, a video game. Although graphing calculators have been called inexpensive in education reform research, the TI-84 Plus Silver Edition was $129.99 in 2008 on the TI online store.

There are three different types of programs which can be downloaded or programmed into it: TI-BASIC, Z80 assembly language, and Flash (applications). There are a wide range of applications that this produces, from science classes, to games, to calculus to

note taking (when put together with a separately sold keyboard). The TI-84 Plus Series is exactly like its predecessor in that it can be used on the SAT and ACT examinations as well as International Baccalaureate examinations. However in some cases those administering the exam may reset the calculator's memory beforehand to prevent cheating through the use of built in programs or other data.

When OS 2.30 was initially released, users noticed the speed of graphing was greatly reduced. The explanation was that the update added asymptote checking in graphing.

In January 2006, Texas Instruments released v 2.40 operating system for the TI-84 plus series. The most noticeable addition to the new OS was the teacher key, allowing the teacher to disable any programs installed on the calculator, so they cannot be used on tests, etc. OS version 2.41 for the TI-84 plus series was released in May 2006. As of OS version 2.53MP which was released in February 2010, support was added for prettyprinted expressions . The current OS version is 2.55MP which was released in January 2011.

In July 2009, a community-made patch now allows user-made operating systems to be easily uploaded onto the TI-84 plus series.

All calculators with the letter H or later as the last letter in the serial code have fewer ram pages causing some programs to fail.

Assembly Language

Z80 assembly language gives a programmer much more power over the calculator than the built-in language, TI-BASIC. On the downside, Z80 assembly is much more difficult to learn than TI-BASIC and very cumbersome for coding large programs. Z80 assembly language can be programmed on the computer and sent to the calculator via USB port, written by hand directly into the program editor (using the hexadecimal equivalents to the op-codes) or compiled using third party compiler programs. Programs written in assembly are much faster and more efficient than those using TI-BASIC, as it is the processor's native language, and does not have to be interpreted like TI-BASIC. An example program that displays "Hello World" on the screen:

```
.nolist
#include "ti83plus.inc"
.list
.org $9D95 - 2
  .db t2ByteTok, tAsmComp
Main:
  b_call(_ClrLCDFull);  ; Clears the screen
  b_call(_HomeUp);      ; Moves the cursor to the top-left corner of
the screen
  ld hl,Hello;          ; Loads the address that points to "Hello
World" into register hl (16-bit)
  b_call(_PutS);        ; Displays "Hello World" on the screen in the
top left corner
  ret                   ; pops off the last data pushed onto the stack.
```

```
                         ; May be used to end the program depending on
what's
                         ; on the stack
Hello:                   ; Label, that has an equate address in memory.
The hex values of
                         ;"Hello World" are stored at the start of
label, Hello
  .db "Hello World!",0  ;defines a series of bytes in memory which
start at the label Hello
.end                     ; Marks the end of a file
.end                     ; Two .ends must be used because of a bug in
the standard compiler
```

TI-BASIC

TI-BASIC is the built in language for TI-84 Plus series calculators, as well as many other TI graphing calculators. TI-BASIC is a non-structured programming language, meaning it is arranged sequentially, without the use of methods or organized blocks of code. Due to its simplicity and the ubiquity of TI calculators in school curricula, for many students it is their first experience with programming. Below is an example of a Hello World program equivalent to the assembly language example.

```
ClrHome                ; Clears the screen
Disp "Hello World"  ; Displays "Hello World" on the screen in the top
left corner
```

Technical specifications

CPU
> Zilog Z80 15 MHz, with 6 MHz compatibility mode.

Flash ROM
> Plus Edition: 480 KB user accessible of 1 MB
> Silver Edition: 1.5 MB user accessible of 2 MB
> Third-party software permits usage of FAT16-formatted USB drives

RAM
> 24 KB RAM user accessible of 128KB (48KB on newer models)

Display
> Text: 16×8 characters (normal font)
> Graphics: 96 (0-94) ×64 (0-62) pixels, monochrome (software grayscale can be used, with up to 16 shades)

I/O
> Link port, 9.6 kbit/s
> 50 button built-in keypad

USB

Power
> 4 AAA batteries plus 1 SR44SW or 303 silver oxide battery for backup
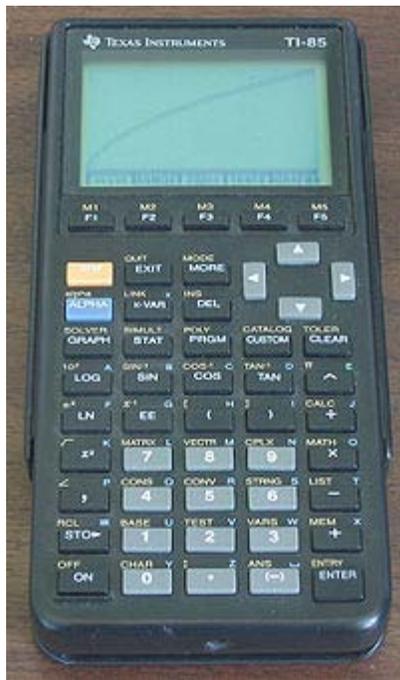
Integrated programming languages
> TI-BASIC and machine code. Assembly and C require a computer with a Z80 cross-compiler or an on-calc assembler.

Chapter 12

TI-85, TI-86 and TI-89 Series

TI-85

TI-85

Type	Graphing calculator
Manufacturer	Texas Instruments
Introduced	1993
Discontinued	1997
Successor	TI-86
Calculator	
Entry mode	D.A.L.
Display Size	128×64 pixels, 21×8 characters
CPU	

Processor	Zilog Z80
Frequency	6 MHz
	Programming
User Memory	28 kB of RAM
	Other
Power supply	4 AAA's, 1 CR1616 or CR1620

The **TI-85** was a graphing calculator made by Texas Instruments based around the Zilog Z80 microprocessor. Designed in 1992 as TI's second graphing calculator (the first was the TI-81), it has since been replaced by the TI-86, which has also been discontinued.

The TI-85 was significantly more powerful than the TI-81, as it was designed as a calculator primarily for use in engineering and calculus courses. Texas Instruments had included a version of BASIC on the device to allow programming. Each calculator came with a cable to connect calculators (simply a three-conductor cable with 2.5 mm jack plugs on each end). Another cable known as the TI-Graph Link was also sold, along with appropriate software, to connect the calculator to a personal computer. These cables made it possible to save programs and make backups.

Assembly programs

Enthusiasts analyzed memory backups and discovered that entries in the calculator's CUSTOM menu pointed at specific memory locations. With this knowledge, a hack was devised where a special string could be inserted into the backup at the proper location to allow the calculator to execute assembly language programs. These programs could run much faster than their BASIC counterparts, and could be much more efficient in terms of memory usage. This development made the TI-85 the first TI graphing calculator that could execute assembly programs.

Programs written in assembly would be stored as string expressions and accessed via the CUSTOM menu. Games such as *Tetris* and *Boulder Dash* are available, as are programs with more practical uses, such as versions of the periodic table. The use of these programs was limited by the scarce RAM memory available on the TI-85. Total memory capacity was about 28 kilobytes, with 25 to 26 kB available for use.

The assembly language shell ZShell is also available for the TI-85, with the most famous version still unreleased on Magnus Hagander's TI-85 . Probably in response to the widespread use of assembly programs, TI officially introduced assembly access in later models, such as the TI-83 and TI-86, along with expanded memory. The TI-86 is very similar to the TI-85, sharing the same display resolution (128×64), processor, and processor speed (6 MHz).

Technical specifications

CPU
  Zilog Z80 CPU, 6 MHz
RAM
  32 KB, (28 KB user-available)
ROM
  128 KB non-upgradeable
Display
  Text: 21×8 characters
  Graphics: 128×64 pixels, monochrome
Link capability
  2.5 mm I/O port
Power
  4×AAA, 1×CR1616 or CR1620
Programming language(s)
  TI-BASIC, Z80 Assembly (hacked)

TI-86

TI-86
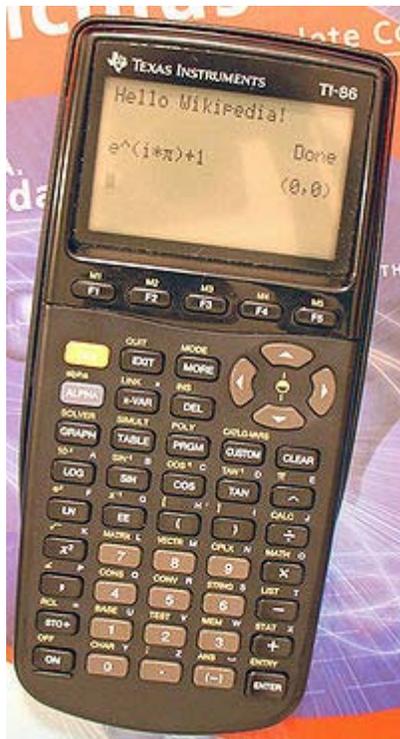
Type Graphing calculator

Manufacturer	Texas Instruments
Introduced	1997
Discontinued	2004
Predecessor	TI-85
Calculator	
Entry mode	D.A.L.
Display Size	128×64 pixels, 21×8 characters
CPU	
Processor	Zilog Z80
Frequency	6 MHz
Programming	
User Memory	96 kB of RAM
Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

The **TI-86** is a programmable graphing calculator introduced in 1997 and produced by Texas Instruments. The TI-86 uses the Zilog Z80 microprocessor. It is partially backwards-compatible with its predecessor, the TI-85.

The TI-86 can be thought of as the tier among various Texas Instruments calculators directly above the TI-83 and TI-84 line. In addition to having a larger screen than the TI-83, the TI-86 also allows the user to type in lower case and Greek letters and features five softkeys, which improve menu navigation and can be programmed by the user for quick access to common operations such as decimal-to-fraction conversion. The calculator also handles vectors, matrices and complex numbers better than the TI-83. One drawback, however, is that the statistics package on the TI-83 range doesn't come preloaded on the TI-86. However, it can be downloaded from the Texas Instruments program archive and installed on the calculator using the link cable.

The TI-86 has been discontinued.

Specifications

- **CPU:** Zilog Z80 6 MHz
- **RAM:** 128 KB, 96 KB user-accessible
- **ROM:** 256 KB non-upgradable
- **Display:** 128×64 pixels high-contrast monochrome LCD
- **Data Communication:** Serial link port; allows two TI-86 calculators to be connected to each other, or one TI-86 to be connected to a PC, for data transfer via a special link cable

- **Programming Languages:** TI-BASIC, Z80 Assembly (ASM)

TI-89 series

TI-89
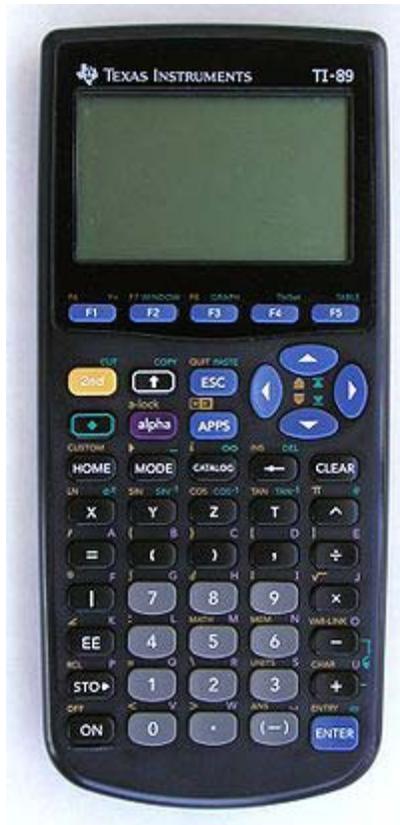
A TI-89

Type	Programmable Graphing
Manufacturer	Texas Instruments
Introduced	1998
Discontinued	2004
Successor	TI-89 Titanium
	Calculator
Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	160x100

	Programming
User Memory	188 kB RAM
Firmware Memory	639 kB flash memory
	Other
Power supply	4 AAA batteries, 1 CR1616 or CR1620

The **TI-89** and the **TI-89 Titanium** are graphing calculators developed by Texas Instruments. They are differentiated from most other TI graphing calculators by their computer algebra system, which allows symbolic manipulation of algebraic expressions. For example, equations can be solved in terms of variables; the TI-83/84 series can only give a numeric result.

TI-89

The **TI-89** is a graphing calculator developed by Texas Instruments (TI) in 1998. The unit features a 160×100 pixel resolution LCD screen and a large amount of flash memory, and includes TI's *Advanced Mathematics Software*. The TI-89 one of the highest model line in TI's calculator products, along with the TI-Nspire, which lacks 3D functions and other high power capabilities. In the summer of 2004, the standard TI-89 was replaced by the TI-89 Titanium.

The TI-89 runs on a 32-bit microprocessor, the Motorola 68000, which nominally runs at 10, 12, or 16 MHz, depending on the calculator's hardware version. Texas Instruments has allocated 256 kB of the total RAM for the unit (190 kB of which are available to the user) and 2 MB of flash memory (700 kB of which is available to the user). The RAM and Flash ROM are used to store expressions, variables, programs, tables, text files, and lists.

The TI-89 is essentially a TI-92 Plus with a limited keyboard and smaller screen. It was created partially in response to the fact that while calculators are allowed on many standardized tests, the TI-92 was considered a computer due to the QWERTY layout of its keyboard. Additionally, some people found the TI-92 unwieldy and overly large. The TI-89 is significantly smaller—about the same size as most other graphing calculators. It has a flash ROM, a feature present on the TI-92 Plus but not on the original TI-92. The TI-89 is not permitted on the ACT or the National Fundamentals of Engineering exam, although it is permitted on the SAT examinations.

User features

The major advantage of the TI-89 over lower-model TI calculators is its built-in computer algebra system, or CAS. The calculator can evaluate and simplify algebraic expressions symbolically. For example, entering `(x^3-x^2-8x+12)/(x+3)` returns $x^2 - 4x + 4$. The answer is pretty printed by default; that is, it is displayed as it would be

written on paper, as opposed to `x^2-4x+4` returned by calculators which are incapable of displaying superscripts or subscripts. The TI-89's abilities include:

- Algebraic factoring of expressions, including partial fraction decomposition.
- Algebraic simplification; for example, the CAS can combine multiple terms into one fraction by finding a common denominator.
- Evaluation of trigonometric expressions to exact values. For example, $\sin(60°)$ returns $\dfrac{\sqrt{3}}{2}$ instead of 0.86603.
- Solving equations for a certain variable. The CAS can solve for one variable in terms of others; it can also solve systems of equations. For equations such as quadratics where there are multiple solutions, it returns all of them. Equations with infinitely many solutions are solved by introducing arbitrary constants: `solve(tan(x+2)=0,x)` returns $x=@n1\pi-2$, with the @n1 representing any integer.
- Finding limits of functions, including infinite limits and limits from one direction.
- Symbolic differentiation and integration. Derivatives and definite integrals are evaluated exactly when possible, and approximately otherwise.

In addition to the standard two-dimensional function plots, it can also produce graphs of parametric equations, polar equations, sequence plots, differential equation fields, and three-dimensional (two independent variable) functions.

Programming

The TI-89 is directly programmable in a language called TI-BASIC, TI's derivative of BASIC for calculators. With the use of a PC, it is also possible to develop more complex programs in Motorola 68000 assembly language or C, translate them to machine language, and copy them to the calculator. Two software development kits for C programming are available; one is TI Flash Studio, the official TI SDK, and the other is TIGCC, a third-party SDK based on GCC.

Since the TI-89's release in 1998, thousands of programs for math, science, or entertainment have been developed. Many available games are generic clones of *Tetris*, *Minesweeper*, and other classic games, but some programs are more advanced—for example, a ZX Spectrum emulator, a chess-playing program, and a clone of *Link's Awakening*. One of the most popular and well-known games is Phoenix. Many calculator games and other useful programs can be found on TI-program sharing sites. Ticalc.org is a major one that offers thousands of calculator programs.

Hardware versions

There are four hardware versions of the TI-89. These versions are normally referred to as HW1, HW2, HW3, and HW4 (released in May 2006). Entering the key sequence **[F1] [A]** displays the hardware version. Older OS versions (before 2.00) don't display anything about the hardware version unless the calculator is HW2 or later. The

differences in the hardware versions are not well documented by Texas Instruments. HW1 and HW2 correspond to the original TI-89; HW3 and HW4 are only present in the TI-89 Titanium.

The most significant difference between HW1 and HW2 is in the way the calculator handles the display. In HW1 calculators there is a video buffer that stores all of the information that should be displayed on the screen, and every time the screen is refreshed the calculator accesses this buffer and flushes it to the display (direct memory access). In HW2 and later calculators, a region of memory is directly aliased to the display controller (memory-mapped I/O). This allows for slightly faster memory access, as the HW1's DMA controller used about 10% of the bus bandwidth. However, it interferes with a trick some programs use to implement grayscale graphics by rapidly switching between two or more displays (page-flipping). On the HW1, the DMA controller's base address can be changed (a single write into a memory-mapped hardware register) and the screen will automatically use a new section of memory at the beginning of the next frame. In HW2, the new page must be written to the screen by software. The effect of this is to cause increased flickering in grayscale mode, enough to make the 7-level grayscale supported on the HW1 unusable (although 4-level grayscale works on both calculators).

HW2 calculators are slightly faster because TI increased the nominal speed of the processor from 10 MHz to 12 MHz. It is believed that TI increased the speed of HW4 calculators to 16 MHz, though many users disagree about this finding.

Another difference between HW1 and HW2 calculators is assembly program size limitations. The size limitation on HW2 calculators has varied with the AMS version of the calculator. As of AMS 2.09 the limit is 24k. Some earlier versions limited assembly programs to 8k, and the earliest AMS versions had no limit. HW1 calculators have no hardware to enforce the limits, so it is easy to bypass them in software. There are unofficial patches and kernels that can be installed on HW2 calculators to remove the limitations.

TI-89 Titanium

TI-89 Titanium
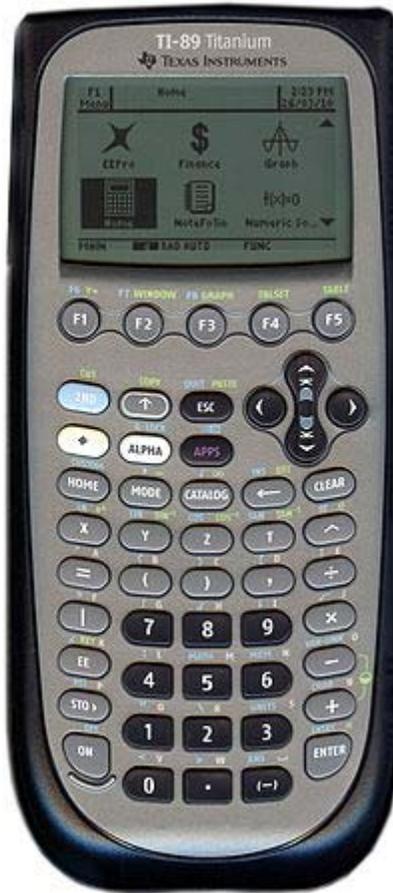
A TI-89 Titanium with Computer Algebra System

Type	Programmable Graphing
Introduced	2004
Predecessor	TI-89
Calculator	
Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	160x100
Programming	
Memory Register	188 kB RAM 2.7 MB flash memory
Other	
Power supply	4 AAA's, 1 SR44

The **TI-89 Titanium** was released in the summer of 2004, and is positioned as a replacement for the popular classic TI-89. The TI-89 Titanium is referred to as HW3 and uses the corresponding AMS 3.x. In 2006, new calculators were upgraded to HW4 which was supposed to offer increases in RAM and speeds up to 16 MHz, but some benchmarks made by users reported speeds between 13–14 MHz.

The touted advantages of the TI-89 Titanium over the original TI-89 include four times the available flash memory (with over three times as much available to the user). The TI-89 Titanium is essentially a Voyage 200, except it doesn't have an integrated keyboard. The TI-89 Titanium also has a USB On-The-Go port, for connectivity to other TI-89 Titanium calculators, or to a computer (to store programs or update the operating system). The TI-89 Titanium also features some pre-loaded applications, such as "CellSheet", a spreadsheet program also offered with other TI calculators. The Titanium has a slightly updated CAS, which adds a few more mathematical functions, most notably implicit differentiation. The Titanium also has a slightly differing case design from that of the TI-89 (the Titanium's case design is similar to that of the TI-84 Plus).

There are some minor compatibility issues with C and assembly programs developed for the original TI-89. Some have to be recompiled to work on the Titanium due to various small hardware changes, though in most cases the problems can be fixed by using a utility such as GhostBuster, by Olivier Armand and Kevin Kofler. This option is usually the best as it requires no knowledge of the program, works without the need of the program's source code, is automated, and doesn't require additional computer software. In some cases, only one character needs to be changed (the ROM base on TI-89 is at 0x200000, whereas the TI-89 Titanium is at 0x800000) by hand or by patcher. Most, if not all, of these problems are caused by the Ghost Space or lack thereof.

From a usability and functionality standpoint (preloaded spreadsheet, text editor, day-planner, calendar etc), the TI-89 is beginning to resemble quite closely the portable, battery-powered, BASIC-programmable microcomputers of the mid-1980s, such as the Amstrad Notepad NC100, Laser PC5, Tandy TRS-80 Model 100, Kyocera 85 and so forth. Due to the advanced processing capabilities and simplified user input methods, the TI-89 is considered by some to be a fully featured portable computer.

Use in schools

United States

In the United States, the TI-89 is allowed by the College Board on all calculator-permitted tests, including the SAT, some SAT Subject Tests and the AP Calculus, Chemistry, Physics, and Statistics exams. However, the calculator is banned from use on the ACT, the PLAN, and in some classrooms. In many testing situations, the TI-89 and TI-89 Titanium, along with the HP-49 series, are the most powerful and function-rich graphing calculators that are permitted: the TI-92 series, with otherwise comparable features, have QWERTY keyboards that result in them being classified as computer devices rather than calculators.

Chapter 13

TI-92 Series

TI-92

The original TI–92

Type	Programmable Graphing
Introduced	1995
Discontinued	1998
Successor	TI-92 Plus
Calculator	
Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	240x128
Programming	
Memory Register	68 kB RAM (128 kB on TI-92 II)
Other	
Power supply	4 AA's, 1 CR1616 or CR1620
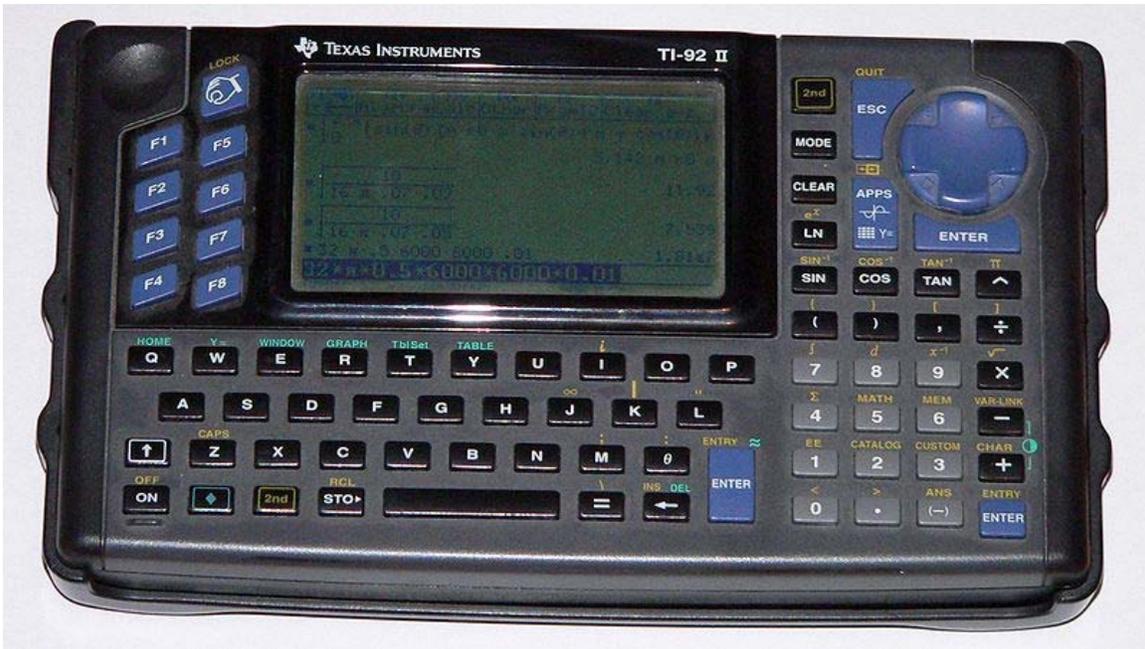
TI-92 II, a slightly upgraded version of the *TI-92*, with double the RAM

The **TI-92 series** of graphing calculators are a line of calculators produced by Texas Instruments. They include: the **TI-92** (1995), the **TI-92 Plus** (1998,1999), and the **Voyage 200** (2002). The design of these relatively large calculators includes a QWERTY keyboard. Because of this keyboard, it was given the status of a "computer" rather than "calculator" by American testing facilities and cannot be used on tests such as the SAT or AP Exams while the similar TI-89 can be.

TI-92

The **TI-92** was originally released in 1995, and was the first symbolic calculator made by Texas Instruments. It came with a computer algebra system (CAS) based on Derive, and was one of the first calculators to offer 3D graphing. The TI-92 was not allowed on most standardized tests due mostly to its QWERTY keyboard. Its larger size was also rather cumbersome compared to other graphing calculators. In response to these concerns, Texas Instruments introduced the TI-89 which is functionally similar to the original TI-92, but featured Flash ROM and 188 KB RAM, and a smaller design without the QWERTY keyboard. The TI-92 was then replaced by the TI-92 Plus, which was essentially a TI-89 with the larger QWERTY keyboard design of the TI-92. Eventually, TI released the Voyage 200, which is a smaller, lighter version of the TI-92 Plus with a QWERTY keyboard and more Flash ROM. The TI-92 is no longer sold through TI or its dealers, and is very hard to come by in stores.

TI-92 Plus

TI-92 Plus

Type	Programmable Graphing
Introduced	1998
Discontinued	2006
Predecessor	TI-92/TI-92 II
Successor	Voyage 200
Calculator	
Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	240x128
Programming	
Memory Register	188 kB RAM 384 kB flash memory
Other	
Power supply	4 AA's, 1 CR1616 or CR1620

The **TI-92 Plus** (or **TI-92+**) was released in 1998, slightly after the creation of the almost-identical (in terms of software) TI-89, while physically looking exactly as its predecessor, the TI-92 (which lacked flash memory). Besides increased memory over its predecessor, the TI-92 Plus also featured a sharper "black" screen, which had first appeared on the TI-89 and which eases viewing.

The TI-92 Plus was available both as a stand-alone product, and as a user-installable Plus module which could be added to original TI-92 units to gain most of the feature improvements, most notably Flash Memory. A stand-alone TI-92 Plus calculator was functionally similar to the HW2 TI-89, while a module-upgraded TI-92 was functionally similar to the HW1 TI-89. Both versions could run the same releases of operating system software.

As of 2002, the TI-92 Plus was succeeded by the Voyage 200 and is no longer sold through TI or its dealers.

Voyage 200

Voyage 200

Type	Programmable Graphing
Introduced	2002
Predecessor	TI-92 Plus
Calculator	
Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	240x128
Programming	
Memory Register	188 kB RAM 2.7 MB flash memory
Other	
Power supply	4 AAA's, 1 CR1616 or CR1620

Voyage 200 (also **V200** and **Voyage 200 PLT**) was released in 2002, being the replacement for the TI-92 Plus, with its only hardware upgrade over that calculator being an increase in the amount of flash memory available (2.7 megabytes for the Voyage 200 vs. 702 kilobytes for the TI-92 Plus). It also features a somewhat smaller and more rounded case design.

Like its predecessor, Voyage 200 is an advanced calculator that supports plotting multiple functions on the same graph, parametric, polar, 3D, and differential equation graphing as well as sequence representations. Its symbolic calculation system is based on a trimmed version of the calculation software Derive. In addition to its algebra and calculus capabilities, the Voyage 200 is packaged with list, spreadsheet, and data processing applications and can perform curve fitting to a number of standard functions and other statistical analysis operations. The calculator can also run most programs written for the TI-89 and TI-92 as well as programs specifically written for it. A large number of applications, ranging from games to interactive periodic tables can be found online.

The V200 is easily mistaken for a PDA or a small computer because of its massive enclosure and its full QWERTY keyboard — a feature which disqualifies the calculator for use in many tests and examinations, including the American ACT and SAT. The TI-89 Titanium offers exactly the same functionality in a smaller format that is also legal on the SAT test, but not the ACT test.

## *Features*

Technical specifications

	TI-92 TI-92II	TI-92 Plus	Voyage 200
Display	240×128 pixels	240×128 pixels	240×128 pixels
CPU	Motorola MC68000 10 MHz	Motorola MC68000 12 MHz	Motorola MC68000 12 MHz
RAM	128 KB 70 KB user-available(TI-92) 256 KB 136 KB user-available(TI-92II)	256 KB (188 KB user-available)	256 KB (188 KB user-available)
Flash ROM	1 MB ROM, (non-upgradeable)	2 MB, (702 KB user-available)	4 MB, (2.7 MB user-available)
Link capability	2.5 mm I/O port	2.5 mm I/O port	2.5 mm I/O port
Power	4×AA, 1×CR2032	4×AA, 1×CR2032	4×AAA, 1×CR1616
Release	1995(TI-92) 1996(TI-92II)	1998,1999	2002

Note. Official page specifies user-available ROM amount for TI-92 Plus as 702K , but other sources specify it as 388K . This is due to the TI-92+ coming with The Geometer's Sketchpad pre-installed, which uses the 314 KB difference.

Chapter 14

TI-Nspire

TI-Nspire with Touchpad
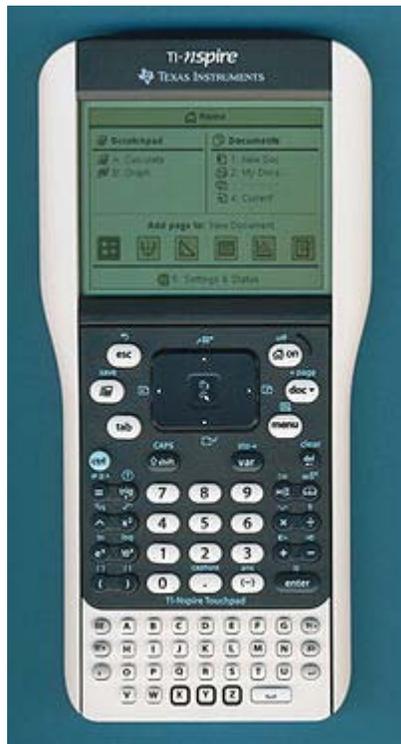
A TI-Nspire calculator with Touchpad

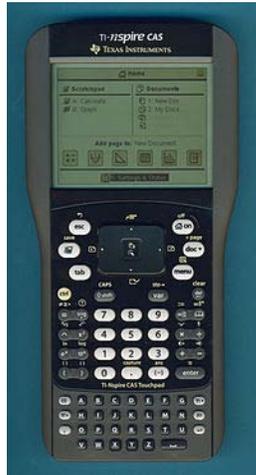|	
Type	Programmable, Graphing
Manufacturer	Texas Instruments
Introduced	2010
Calculator	
Entry mode	D.A.L.
Display Type	LCD Dot-matrix

Display Size 320x240

Programming

Programming language(s) TI-Nspire BASIC

Other

TI-Nspire CAS with Touchpad

A TI-Nspire CAS calculator with Touchpad

Type Programmable, Graphing, Symbolic

Manufacturer Texas Instruments

Introduced 2010

Calculator

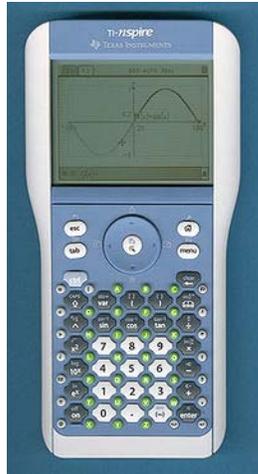**Entry mode** D.A.L.

Display Type LCD Dot-matrix

Display Size 320x240

Programming

Programming language(s) TI-Nspire BASIC

Other

TI-Nspire with Clickpad

A TI-Nspire calculator with Clickpad

Type	Programmable, Graphing
Manufacturer	Texas Instruments
Introduced	2007
Discontinued	2010

Calculator

Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	320x240

Programming

Programming language(s)	TI-Nspire BASIC

Other

TI-Nspire CAS with Clickpad

A TI-Nspire CAS calculator with Clickpad

Type	Programmable, Graphing, Symbolic
Manufacturer	Texas Instruments
Introduced	2007
Discontinued	2010
Calculator	
Entry mode	D.A.L.
Display Type	LCD Dot-matrix
Display Size	320x240
Programming	
Programming language(s)	TI-Nspire BASIC

The **TI-Nspire** product line is a series of graphing calculators developed by Texas Instruments. This line currently includes the *TI-Nspire* and *TI-Nspire CAS*. It is available as a handheld and also as software for Windows and Mac OS X. In 2010, Texas Instruments updated the calculators to the Touchpad versions which come with the Nspire or Nspire CAS computer software and optional rechargeable batteries.

Handhelds

The TI-Nspire line of handhelds have greatly improved hardware compared to older TI graphing calculators running Derive Software. The new LCD screen has a higher resolution (320x240 pixels) and is capable of displaying sixteen shades of gray. The TI-Nspire and TI-Nspire CAS both use a TI-NS2006A controller clocked at 90 MHz.

The TI-Nspire line features the ability to display dynamically linked variables from application to application. For example, a calculator application with an equation stored in the variable x might be displayed alongside a graphing application which would graph the shared variable. Changes made to variables made in one application will affect the others in real time.

In addition to dynamic variable linking, the TI-Nspire also displays mathematical expressions in pretty-print, making it possible to enter and display mathematical expressions the way they would be written on paper.

TI-Nspire

The standard *TI-Nspire* calculator is comparable to the TI-84 Plus in features and functionality. It features a **TI-84 mode** by way of a replaceable snap-in keypad (included) and contains a TI-84 Plus emulator. The likely target of this is secondary schools that make use of the TI-84 Plus currently or have textbooks that cover the TI-83 (Plus) and TI-84 Plus lines, and to allow them to transition to the TI-Nspire line more easily.

Since the TI-Nspire lacks a QWERTY keyboard, it is acceptable for use on the PSAT, SAT, SAT II, ACT, AP, and IB Exams.

The TI-Nspire also features a "testing mode" LED indicator, designed to stop potential cheating, informing test supervisors that the calculator is still denying access to saved files and possibly restricting geometry features on the handheld during the test. It also features a timer. At the end of a test, the supervisor is required to check the calculator's timer to see if it has not been removed out of "testing mode."

Version 2.0 of the firmware also contains some improvements, most notable the Scratchpad which can be used to perform quick graphs and operations, and support for a newer keypad that contains a touchpad.

TI-Nspire CAS

The *TI-Nspire CAS* calculator is capable of displaying and evaluating values symbolically, not just as floating-point numbers. It includes algebraic functions such as a symbolic differential equation solver: **deSolve(...)**, the complex eigenvectors of a matrix: **eigVc(...)**, as well as calculus based functions, including limits, derivatives, and integrals. For this reason, the TI-Nspire CAS is more comparable to the TI-89 Titanium and

Voyage 200 than to other calculators. Its likely targets are college students and universities.

Unlike the TI-Nspire, it is not compatible with the snap-in TI-84 Plus keypad. It has a "testing mode" including a similar LED notification system to the standard TI-Nspire model that flashes green when Press to Test is in use. It is accepted in the SAT and AP exams but not in the ACT or IB.

The current *TI-Nspire CAS* calculator is now running the OS version 2.1.0.631, released on July 14, 2010. The operating system has been updated frequently since 2007 (due to bugs and missing functions), one year after its release in 2006. Version 2.0.0.1188 and later of the operating system adds the following new features:

- Scratchpad (Easily and quickly use a calculator and graph)
- New, more organized home screen
- Calculator application changes
  - Solving of systems of equations (linear or non-linear)
  - Complex and real roots of polynomials
  - Derivative at a point
  - Remainder, quotient, coefficients, and degree of polynomials
  - Greatest common divisor
  - Central difference quotient with steps
  - Creation of a zero matrix
- New programming capabilities
  - Ability to separate a programming page from a calculator page
  - Request and RequestStr I/O functions
  - Output text
- Graphs application changes
  - Can toggle table of values
  - Can hide object selection guides
  - Custom sequence graphs
  - Zoom to decimal
  - Analyze Graph menu
    - Zero
    - Minimum
    - Maximum
    - Intersection
    - Inflection
    - dy/dx
    - Integral
- New geometry application is simply a graphing application that can only make shapes
- Data and Statistics application changes
  - Ability to add X and Y variables with frequency
- Notes application changes
  - Calculations in the Notes application,

- New graph settings page

TI-Nspire CX and TI-Nspire CX CAS

The upcoming CX series features a color screen, as well as 3D graphing. Both models have 64MB of RAM. TI-Nspire CX models are not capable of using AAA batteries and instead rely exclusively on a rechargeable battery. The manufacturer's suggested retail price has been announced at $165.

Memory

Both calculators have 32 MB of NAND Flash, 32 MB of SDRAM, and 512 KB of NOR Flash. The NAND Flash contains the Operating system and saved documents and is not executable. The SDRAM likely contains an uncompressed version of the OS, and a copy of all active documents. The NOR Flash contains boot instructions for loading the operating system.

The NSpire family does not contain a backup battery (like all previous models) so when a battery is removed, the SDRAM is deleted, hence the need to load the operating system and file structure from the NAND Flash to the SDRAM.

Other features

One feature includes a periodic table with the TI-84 keyboard, or using a program-like document with the Nspire keyboard, useful for chemistry classes. As with some other TI calculators, the TI-Nspire can be used with sensors to deal with the real world (data acquisition) such as Vernier EasyTemp, Vernier Go! Motion, Vernier Go! Temp, or Texas Instruments CBR2 motion detector. In addition, it has been hacked to run homebrew software, though doing so is not officially supported (and in fact fought against by Texas Instruments). The exploit, Ndless, is made by Geoffrey Anneheim (geogeo) and Olivier Armand (ExtendeD). Although the original version of Ndless only worked on the first operating system, version 1.1, it has been updated to support more recent operating systems, including versions 1.3, 1.4, and notably 1.7. Several programs have been released, one of the most popular being a Game Boy Color emulator.

Recently a team of developers from the popular calculator forum Omnimaga have ported a modified version of the classic FPS shooter DOOM to the TI-Nspire and have plans to release a fully functioning version to the public soon.