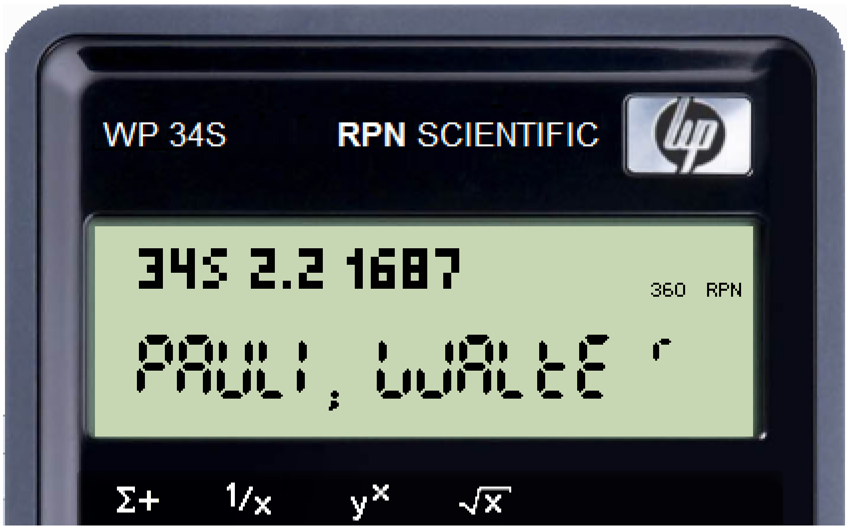
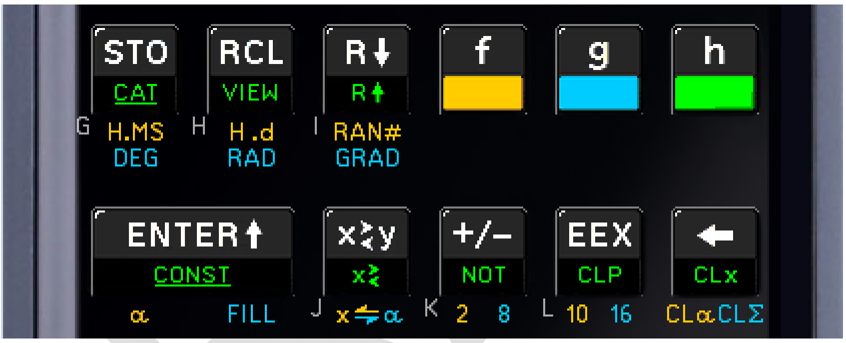



# OWNER’S MANUAL




This file is part of WP 34S.



First aid for those complaining about getting trapped in an unexpected or unwanted calculator mode while playing around before reading: H.d (i.e. f RCL ) will bring you back to floating point mode.

For those who don’t even read this: Sorry, we can’t help you.

**TABLE OF CONTENTS**

**JUST IN CASE …**

... you still have your *HP-20b Business Consultant* or your *HP-30b Business Professional* sitting on your desk unchanged as produced by HP, please turn to [Appendix A](#) for some instructions how to convert it into a full fledge WP 34S yourself. Alternatively, if you don't want to bother with cables on your desk connecting it to your computer, with flashing the calculator firmware and attaching a sticky overlay, you may purchase e.g. a *HP-30b*-based WP 34S readily in the internet:

http://www.thecalculatorstore.com/epages/eb9376.sf/en_GB/?ObjectPath=/Shops/eb9376/Products/%22WP34s%20Pack%22
(We apologize for the small font – it allowed this hyperlink fitting into one print line).

The first way may just cost your time, the second will cost you some money at the store. If you choose buying your WP 34S at the address mentioned, we (the developers) will get a modest fraction of the price. Both ways, however, are proven to work – it is your choice.

For the following, we assume the flashing is done and you hold a WP 34S in your hands.

# WELCOME

Dear user, now you have got it: your own WP 34S. It uses the mechanics and hardware of the *HP-20b Business Consultant* or the new *HP-30b Business Professional*, so you benefit from their unexcelled processor speed. And with the *HP-30b* you get the famous rotate-and-click keys in addition, giving the tactile feedback appreciated in vintage *Hewlett-Packard* calculators for decades.

On the other hand, the firmware and user interface of the WP 34S were thoroughly thought through and discussed by us, newly designed and written from scratch, loaded with functions, pressed into the little memory provided, and tested over and over again to give you **a fast and compact <u>scientific</u> calculator like you have never had before.**

The WP 34S function set is based on the famous *HP-42S RPN Scientific*, the most powerful programmable RPN calculator built so far [1]. We expanded this set, incorporating the functionality of the renowned programmer's calculator *HP-16C*, the fraction mode of the *HP-32SII*, probability distributions as featured by the *HP-21S*, and added **many more useful functions for mathematics, statistics, physics, engineering, programming etc.** like

- Euler's Beta function, Fibonacci numbers, Lambert's W (all of these in real and complex domains), the error function, incomplete regularized Beta and Gamma, Riemann's Zeta, the most 'popular' orthogonal polynomials, testing for primality,
- many statistical distributions and their inverses like Poisson, Binomial, Geometric as well as Cauchy-Lorentz, Exponential, Logistic, Weibull for reliability analysis, Lognormal and Gaussian with arbitrary means and standard deviations,
- programmable sums and products, first and second derivatives,
- extended date and time calculations based on a real time clock,

[1] Though the *HP-42S* was sold in 1988 already, this statement holds still. – Due to hardware restrictions, the matrix math of the *HP-42S* cannot be supported by the WP 34S. Matrices are covered, however, by a package of basic commands (see far below).

- integer computing in arbitrary bases from binary to hexadecimal,
- financial operations like mean rate of return and margin calculations,
- 80 conversions, mainly between universal SI and old Imperial units,
- 50 fundamental physical constants as precise as known today by national standards institutes like NIST or PTB, plus some more out of mathematics, astronomy, and surveying,
- complete Greek and extended Latin letter fonts covering many languages on this planet (upper and lower case in two font sizes each).

**The WP 34S is the first RPN calculator overcoming the limits of a 4-level stack** – forget worries about stack overflow in calculations. It features a choice of two stack sizes expanded by a complex LASTx register: traditional four stack levels for HP compatibility, eight levels for convenient calculations in complex domain, advanced real calculus, vector algebra, or for whatever application you have in your mind. You find a full set of commands for stack handling and navigation in either size.

Furthermore, your WP 34S features over 100 general purpose registers, 104 user flags, 506 program steps in working memory, more than 4000 in flash, a 31 byte alpha register for message generation, and 4 programmable hotkeys for your favorite functions or routines. And you may backup your work in battery-fail-safe memory.

Your WP 34S is the result of a long range collaboration of two individuals, an Australian and a German. We did this in our free time, so you may call it our hobby (though some people close to us found different names for this). From its very beginning, our project was discussed on the forum of the *Museum of HP Calculators* (www.hpmuseum.org), so we want to express our gratitude to all the international contributors there who taught us a lot and brought their ideas and support in several stages of our project. Special thanks go to Marcus von Cube (Germany) supporting us in bringing the WP 34S to life, starting with an emulator for v1.14, allowing widespread use and convenient testing. From v1.17 on, the software runs on the real hardware as well. A very useful assembler / disassembler is supplied by Neil Hamilton (Canada) since v1.18 and even a symbolic preprocessor was added with v2.1.

We baptized our baby WP 34S in honor of one of the most powerful LED pocket calculators, the *HP-34C* of 1979. The WP 34S is our humble approach – with the hardware given – to a future 43S we can only dream of becoming the successor of the *HP-42S* once. May the WP 34S help in convincing those having access to more resources than us: covering the market of serious scientific instruments is worthwhile.

Firmware-wise, we have carefully checked everything we could think of to our best knowledge, so our hope may be justified the WP 34S is free of bugs. Anyway, we promise we will continue improving the WP 34S whenever it turns out being necessary – so if you discover any strange result, please report it to us, and if it is revealed to be an internal error we will provide you with an update as soon as we have got one ourselves. We did show short response times so far, and we will continue this way.

Enjoy!

*Paul Dale and Walter Bonin*

## PRINT CONVENTIONS

Please note:

- Throughout this manual, standard font is Arial. *Specific terms, names or titles* are printed in italics. *Hyperlinks* are underlined. Bold italic letters like ***n*** are used for variables. Calculator commands – e.g. ENTER – are generally called by their names, printed in capitals for easy recognition. Each and every command featured is listed in the *Index of Operations* below.
- This CPX font is taken for explicit references to keys.
- Register addresses are printed using **bold Times New Roman**, while lower case italic letters of this font are employed for register contents. So, for example, ***y*** lives in stack level **Y**, ***r45*** in general purpose register **R45**, and ***alpha*** in the alpha register, respectively.

All this holds unless stated otherwise explicitly.

## GETTING STARTED

**If you know how to deal with a good old HP RPN scientific calculator, you can start with your WP 34S right away. Use the following as a reference manual.**

Else we recommend you get an *HP-42S Owner's Manual*. It is available at low cost on the DVD distributed by the *Museum of Hewlett-Packard Calculators* (*www.hpmuseum.org*). There are also other sources in the internet.

Please read Part 1 of said manual as a starter. This part includes an excellent introduction to RPN. This RPN is a very effective method making (, ), [, ], {, } and = keys obsolete in calculations. Once you got used to it you will most probably never employ a calculator featuring = again.

Part 2 of said manual will support you when you are heading for programming your WP 34S for easy handling of repeated or iterative computations. Further documentation, also about the other calculators mentioned above and in the following text, will add valuable information – it is all readily accessible on a single DVD from said source.

Most "old" commands on your WP 34S will work as they did on the *HP-42S*. This little manual here is meant as a supplement showing you all the new features. It contains all the necessary information including some formulas and technical explanations but is not intended to replace textbooks about mathematics, statistics, physics, programming, or the like.

The following text starts presenting the keyboard as it will be active in various modes, so you know where to find what you are looking for. It continues explaining the memory, addressing items therein, the display and indicators used to give you feedback what is going on. Then the major part of this booklet is taken by the index of all the operations, catalog contents, constants and conversions featured. It closes with a list of messages the WP 34S will display if special conditions prevent it from executing your command as expected.

## WHAT'S ON THE KEYBOARD AND HOW TO ACCESS IT?

Let us investigate your WP 34S in default state. Take off the battery cover, locate the little RESET hole between the batteries, and use a paper clip to reset. This will erase all user contents and give you a fresh start.

As usual, white labels execute the *default primary function* of the respective key. There are further (secondary) functions provided for almost all keys. Their labels are printed next to the white ones in golden, blue, green or grey color.


Green labels are placed on the slanted faces of most keys. Golden and blue labels are printed below of the respective key on the top face of the WP 34S, i.e. on the *key plate*. Grey letters are put bottom left of most keys.

Labels underlined open *catalogs*.

To access a golden, blue, or green label, use the *prefix* f, g, or h, respectively.

E.g. the key 5 preceded by

- f will calculate the arithmetic mean values of the data accumulated in the statistic registers via x̄ ,
- g will return the standard deviations for the same data via s ,
- h will open a catalog of supplementary statistic functions via STAT .
- The grey letter **R** will become relevant in *alpha mode*.

These prefixes allow for easily accessing a multiple of the 37 primary functions the keyboard can take. You may keep the respective prefix pressed if you want to call several functions in sequence showing the same label color. Any numeric entry will just fill the display and is interpreted when completed, not earlier.

Time for a small example. Please take your WP 34S and press

ON (i.e. the bottom left key) to turn your calculator on. You will get


In the following, we shall quote the numeric results only, i.e. 0. here.

Now let us assume you want to fence a little patch of land 40 feet long and 30 feet wide. You have set the first corner post (A) already, and also the second (B) in a distance of 30 feet from A. Where do you place the third post (C) to be sure setting up the fence forming a proper rectangle? Simply enter:

| | | |
|---|---|---|
| 4 0 | 40 | |
| ENTER↑ | 40. | (this key is for separating two numbers in input here) |
| 3 0 | 30 | |
| →P | 50. | ( →P is reached via g and → ) |

So, just take a 90 feet rope, nail its one end on post A and the other one on B, fetch the loose loop and walk 40 feet away. As soon as both parts of the rope are tightly stretched, stop and place post C there. You may set the fourth post the same way.

This method works for arbitrary rectangles. Your WP 34S does the calculation of $\sqrt{40^2 + 30^2}$ (or whatever lengths apply for you) automatically. You just care for the land, the rope, hammer and nails. And it will be up to you to set the posts!

As in this example, we will generally refer to shifted functions like →P by just printing the colored label in this text and omit the prefix key of corresponding color, since redundant.

By the way, by pressing →P the function →POL is called. Most labels on your WP 34S simply call operations carrying the same name as the respective label. There are, however, also a number of cases like →P. Let us introduce them, starting top left on the keyboard:

- A, B, C, and D are called *hotkeys*, since they immediately call the user programs carrying these labels if defined. If the respective labels are not (yet) defined, these keys act as Σ+, 1/x, $y^x$, or $\sqrt{x}$, respectively.

- ➡ is the prefix for direct conversions: ➡ trailed by H.MS, H.d, DEG, RAD, or GRAD will convert $x$ , i.e. the value currently displayed. The respective function names all begin with →.
- CPX is employed as a prefix for calling complex operations. See the respective paragraph *below* for more.
- HYP is the prefix for hyperbolic functions, as $HYP^{-1}$ is for their inverses (see SINH, COSH, TANH, ASINH, ACOSH, and ATANH). In analogy, $SIN^{-1}$ stands for ASIN, etc.
- R← calls →REC, so the pair R←→P takes care of the two classic coordinate transformations.
- a b/c and d/c enter the fraction mode for proper and improper fractions, respectively (see PROFRC and IMPFRC).
- H.d stands for decimal hours, but also for floating point numbers in general (see DECM).
- ! calls x!, and |x| calls ABS.

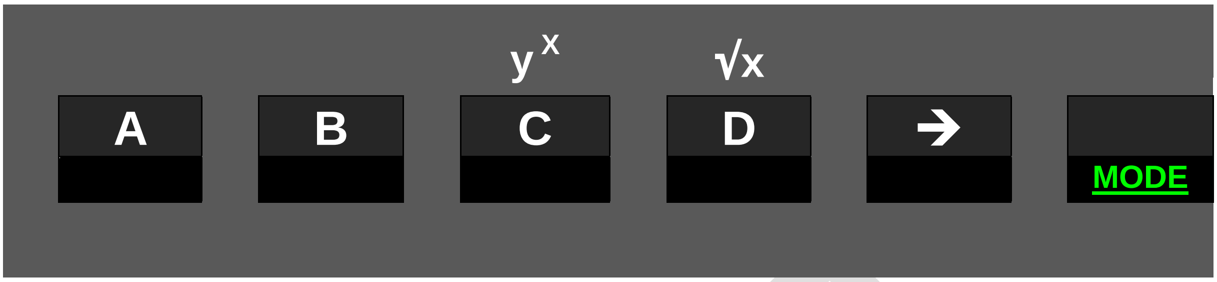
You will find each and every command provided on your WP 34S in the *index of operations* below for your reference, together with the necessary individual explanation.

In four decades of pocket calculators, a wealth of nice to sophisticated application examples were invented and described by different authors – more and better than we can ever create ourselves. Also it is not our intention to copy these old examples. Instead, we recommend the DVD mentioned *above* once more: it contains all the user guides, handbooks, and manuals of vintage Hewlett Packard calculators. Be assured that almost everything described there for any scientific calculator can be done on your WP 34S as well, just significantly faster.

Returning to our introductory example:

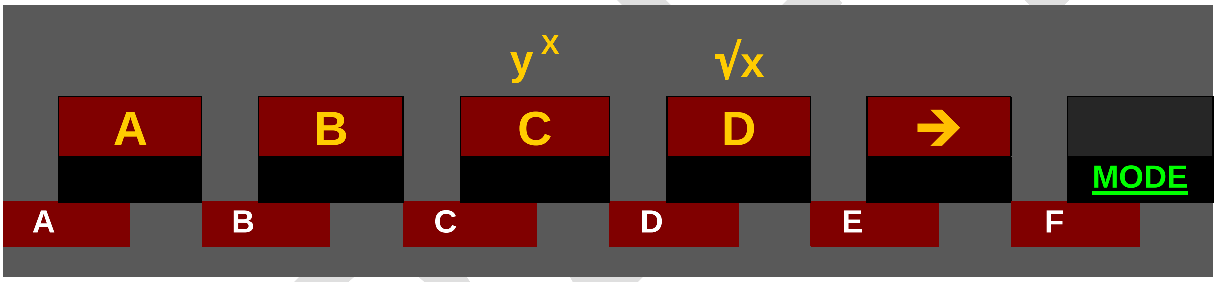
Although we entered integer numbers only for both sides of our little ground, the calculation was executed in default *floating point mode* of your WP 34S. This calculator mode allows for decimal fractions of e.g. feet in input and output as well. Before you suffer from feet fractions, however, we want to briefly show you some additional modes your WP 34S features (you will find a complete list of all modes provided in a separate chapter further below).

**Integer modes** are meant to deal with integers only – in input, output, and calculations. This is useful for computer logic and similar applications. In these modes, operations like SIN don't make sense for obvious reasons. Thus, for integer bases up to ten, the top row of keys on your WP 34S will work as shown here:




→ is used exclusively in addressing here (see *addressing tables* below).

In hexadecimal integer mode, primary functions of these top keys will change to become numeric input, so f is used for accessing their default primary functions:



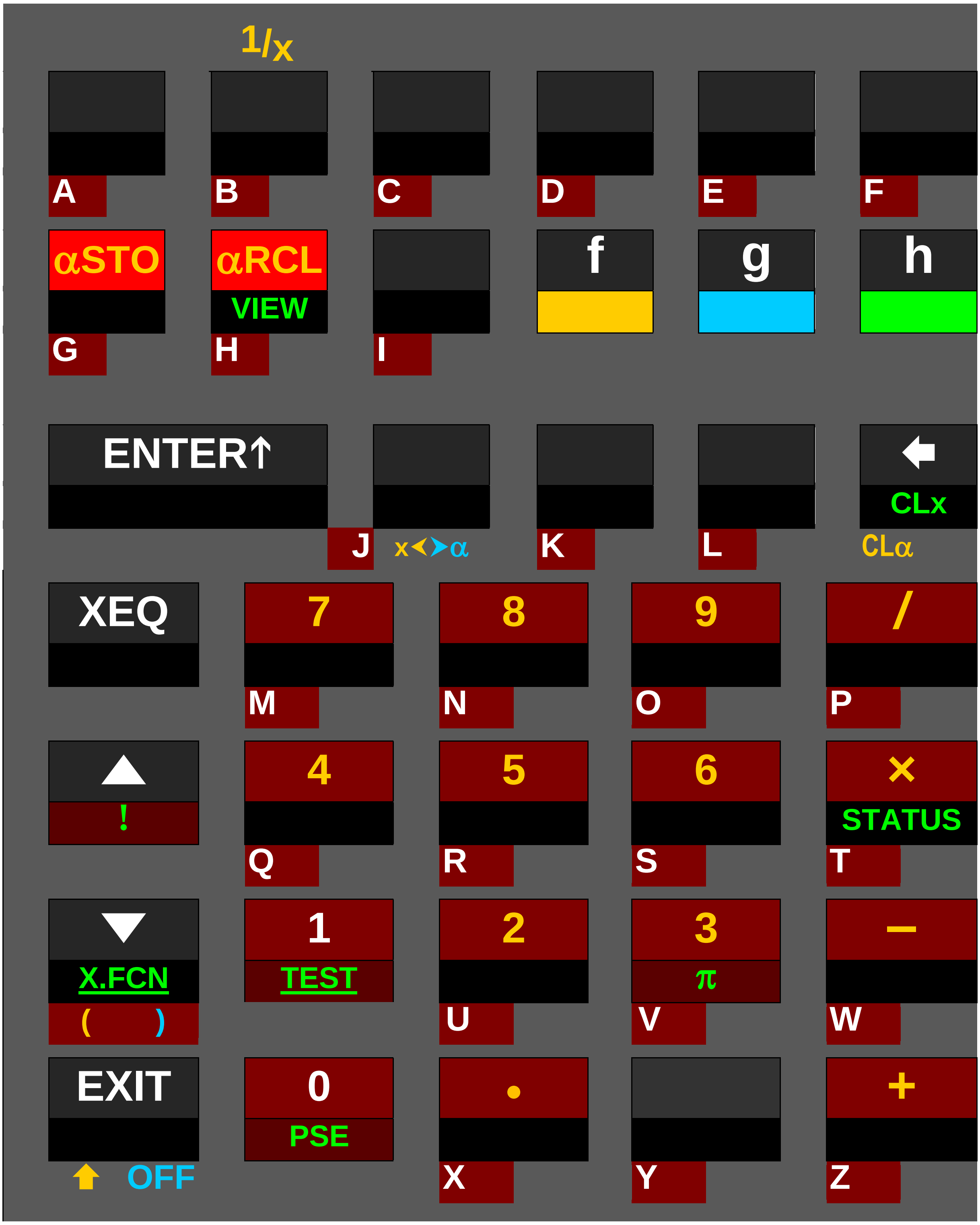

The dark red background is used to highlight changed key functionality.

In bases 11 … 15, those keys not needed for numeric input will work as shown in the first picture above.

In any integer base, attempts to enter an illegal digit – like e.g. 4 in binary – will be blocked.

**Alpha mode** is designed for text entry, e.g. for prompts. In this mode, the alpha register is displayed in the upper part of the LCD, and the numeric line (kept from your last calculation) is accessible by commands only. The display may look like this:

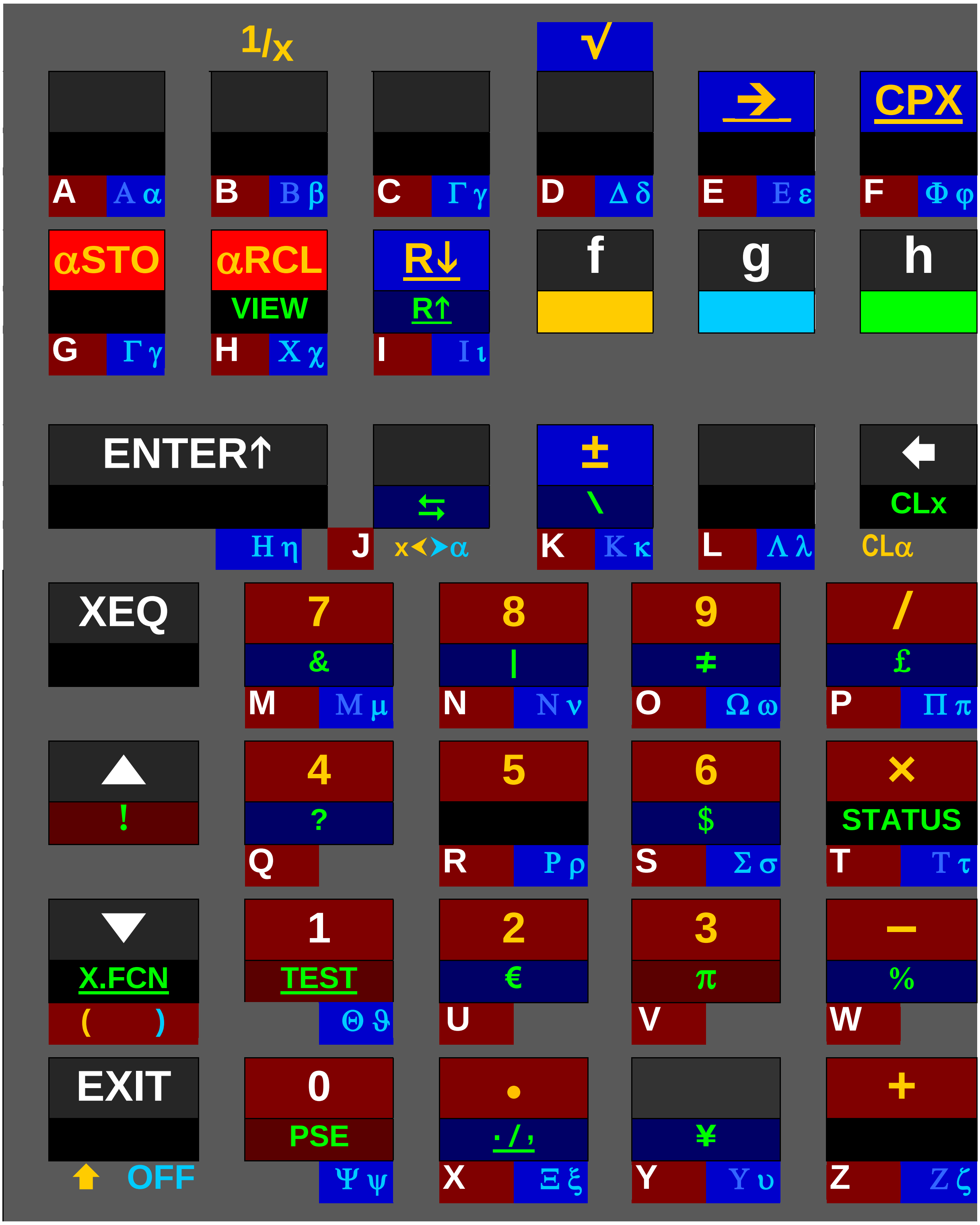

In alpha mode, almost all the mathematical operations are not needed nor applicable. So the keyboard is redefined automatically when you enter alpha mode, as you see overleaf.




All labels printed on dark red background in this picture append characters to ***alpha*** immediately or via alpha catalogs. Alpha mode starts with capitals, and 🡅 toggles upper and lower case. PSE appends a space. Primary function of most keys is appending the letter printed bottom left of this key – grey on the key plate. Prefix f will access the default primary functions there [2].

Looking at the standard labels on the keyboard, we can safely offer more:

[2] The digits 0 and 1 may also be called using f 0 or f 1, respectively.



All labels printed on dark blue background here append characters to ***alpha*** as well, but deviate from the labels printed on your WP 34S keyboard at these locations.

Prefix g leads to homonymic Greek letters where applicable [3]. And h gives access to logic symbols via the Boolean operations, to '!', to '?' at the letter Q, as well

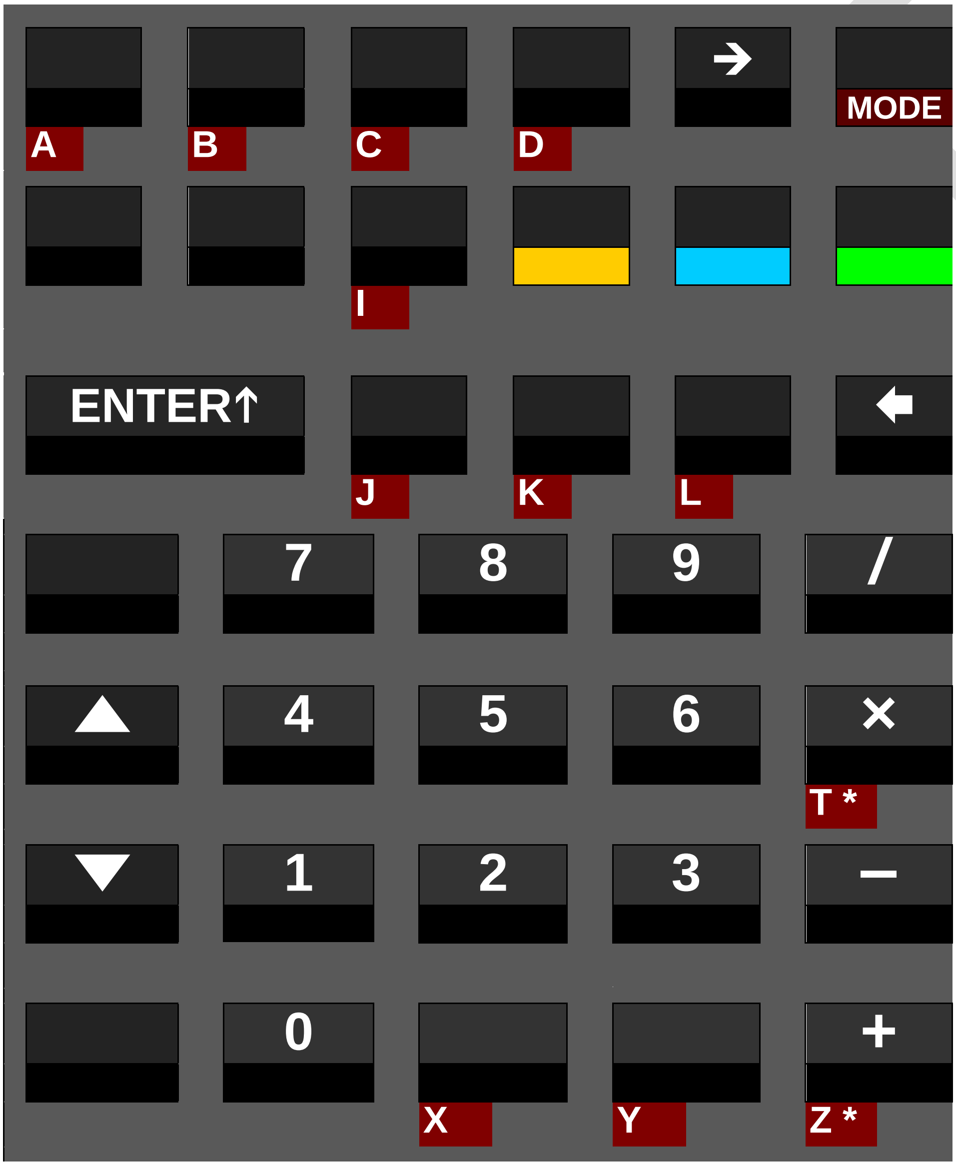
[3] "Homonymic" according to ancient Greek pronunciation. And we assigned **Gamma** also to **C** due to the alphabet, and **Chi** to **H** since this letter comes next in pronunciation. Three Greek letters require special handling: **Psi** is accessed via g 0 (below PSE), **Theta** via g 1 (below TEST and

as four currency symbols located next to the %-command as follows: **$** at the letter S, **€** at U for Euro, **£** at P, **¥** at Y for Yen or Yuan – and % at [−].

The catalogs [f] [→], [f] [CPX], [f] [R↓], [R↑], [TEST], and [./.] feature even more characters (see *below*). See the *index of operations* for αSTO, αRCL, and more alpha commands.

When ***alpha*** exceeds 31 characters, the leftmost character(s) are discarded.

A **temporary alpha mode** is entered during input processing in comparisons and in memory addressing, e.g. during storing. See the respective virtual keyboard here:




This mode is left automatically when sufficient characters are put in for the respective command. Examples are shown *below*.

Special rules apply for T and Z – see *below*.

following **T**), and **Eta** via [g] [ENTER↑] . **Omicron** is not featured since looking exactly like the Latin letter **O** in either case. – Where we printed Greek capitals with lower contrast, they look like the respective Latin letters in our fonts. Greek professors, we count on your understanding.

## REAL AND INTEGER OPERATIONS

Most of the commands your WP 34S features are mathematical operations or functions in real domain. “Real domain” means these functions use real numbers like 1 or 2.34 or $\pi$ or 5.6E-7, and work with them. Please note integer numbers like 8, 9, 10, or -1 are just a subset of real numbers.

Most real number functions provided operate on one number only – the number currently displayed. For example, key in

| | | |
|---|---|---|
| [.] [4] [9] | 0.49 | |

and press

| | | |
|---|---|---|
| [$\sqrt{x}$] | 0.7 | since $0.7^2 = 0.49$ |

Generally, such functions replace $x$ (i.e. the number currently displayed) by the result **f($x$)** , that’s all they do.

Some of the most popular mathematical functions, however, operate on two numbers. Think of + and – , for example. On your WP 34S, such a two-number real function replaces $x$ by the result **f($x, y$)** . Now the stack enters the game. Think of it like a pile of numbers. For subtracting two numbers, you need to know them first, then you can execute the subtraction. That’s the essence of RPN.

So having an account of 1,234 US$ and taking 56.7 US$ from it is solved as follows:

| | | |
|---|---|---|
| [1] [2] [3] [4] | 1234 | enter first number |
| [ENTER↑] | 1234. | separates the two numbers in input as in the very first example above |
| [5] [6] [.] [7] | 56.7 | enter second number |
| [–] | 1177.3 | subtract it from the first |

By [ENTER↑], the first number is “pushed on the stack” so a second separate number can be entered in sequence. The operation [–] takes its input from the lowest two stack levels **X** and **Y** but needs only **X** to put its result in. Knowing your WP 34S features more than only two stack levels, level **Y** is then filled with the content of the next higher level, i.e. $z$ . This goes on for higher levels, as shown *below*. Please note the top stack level content is repeated then (since there is nothing else available for filling). You may use this top level repetition for some nice tricks.

There are also a few three-number real functions included – e.g. Iβ and %MRR – replacing $x$ by the result **f($x, y, z$)** . Then **Y** is filled with $t$ and so on, and the content of the top level is repeated twice.

Some real functions (e.g. DECOMP) operate on one number but return two. Other operations (like RCL or SUM) do not consume any stack input at all but just return one or two numbers. Then these extra number(s) will be pushed on the stack, taking one level per real number.

## COMPLEX OPERATIONS

Mathematicians know more complicated items than real numbers. The next step are complex numbers. If you do not know them nor want to learn about them, leave them aside – you can use your WP 34S perfectly without them.

Else please note your WP 34S supports many operations in complex domain as well. The key **CPX** is employed as a prefix for calling complex functions. E.g. **CPX** **f** **COS** calls the complex cosine, and it is displayed and listed as $^{C}$COS (the elevated C is the signature for complex functions on your WP 34S). All such functions operating on complex numbers do so in Cartesian coordinates exclusively. Each complex number occupies two adjacent registers: the lower one for its real part and the higher one for its imaginary part.

Generally, if an arbitrary real function **f** operates on …

- … one real number $x$ only, then its complex sibling $^{C}$**f** will operate on the complex number $x_c = x + i\,y$ .
- … one register, e.g. **R12**, then $^{C}$**f** will operate on **R12** and **R13**.
- … $x$ and $y$, then $^{C}$**f** will operate on $x, y, z$ and $t$ .

Where one-number real functions replace $x$ by the result **f($x$)** , one-argument complex functions replace $x$ by the real part and $y$ by the imaginary part of the complex result $^{C}$**f($x_c$)** . Higher stack levels remain unchanged. Such functions are $^{C}$1/x, $^{C}$ABS, $^{C}$ANGLE, $^{C}$CUBE, $^{C}$CUBERT, $^{C}$FIB, $^{C}$FP, $^{C}$IP, $^{C}$RND, $^{C}$SIGN, $^{C}$W, $^{C}$W$^{-1}$, $^{C}$x!, $^{C}$x$^{2}$, $^{C}$**√‾**, $^{C}$**+/–**, $^{C}$Γ(x), the logarithmic and exponential functions with bases 10, 2 and **e**, as well as hyperbolic, trigonometric, and their inverses.

Two-number real functions replace $x$ by the result **f($x, y$)** . Analogously, two-argument complex functions replace $x$ by the real part and $y$ by the imaginary part of the complex result $^{C}$**f($x_c, y_c$)** . The next stack levels are filled with the complex contents of higher levels, and the complex number contained in the top two stack levels is repeated as shown *below*. Such complex functions are $^{C}$LOG$_{X}$, $^{C}$y$^{x}$, $^{C}$β(x,y), $^{C}$// , and the basic arithmetic operations in complex domain.

Where complex operations (like $^{C}$RCL) do not consume any stack input at all but just return a complex number, this will be pushed on the stack taking two levels.

## STATISTICAL DISTRIBUTIONS, PROBABILITIES ETC.

You will find a lot of statistics in your WP 34S, going far beyond the Gaussian distribution. Many preprogrammed functions are implemented here for the first time in an RPN calculator – we packed all in what we always had missed. All of these functions, however, have a few features in common:

- Discrete statistical distributions (e.g. Poisson, Binomial) are confined to integers. Whenever we sum up a probability mass function (pmf[4]) $p(n)$ to get a cumulated distribution function (cdf) $F(m)$ we start at $n = 0$. Thus,

$$F\ (m) = \sum_{n=0}^{m} p(n)\ .$$

- Whenever we integrate a function, we start at the left end of the integration interval. Thus, integrating a continuous probability density function (pdf) $f(x)$ to get a cdf $F(x)$ works as

$$F(x) = \int_{-\infty}^{x} f(\xi) d\xi = P(x)\ .$$

- Typically, $F$ starts with a very shallow slope, becomes steeper then, and runs out with a decreasing slope while slowly approaching 100%. Obviously you get the most precise results on the left side of the cdf using $P(x)$. On its right side, however, the "error probability" $Q(x) = 1 - P(x)$ is more precise: since $P(x)$ comes very close to 100% there, you may see 1.0000 displayed while e.g. $P(x) = 0.99996$ in reality.

- On your WP 34S, with an arbitrary cdf named ***XYZ*** you find ***XYZ$_P$*** for the pdf or pmf, and ***XYZ$^{-1}$*** for the inverse cdf, unless stated otherwise explicitly.

- For calculating confidence limits for the "true value" based on a sample evaluation, employing a particular confidence level (e.g. 95%), you must know your objective:
    - Do you want to know the upper limit, under which the "true value" will lie with a probability of 95%? Then take 0.95 as the argument of the inverse cdf to get said limit, and remember there is an inevitable chance of 100% – 95% = 5% for the "true value" being greater than it.



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[4] In a nutshell, discrete statistical distributions deal with "events" governed by a known mathematical model. The pmf then tells the probability to observe a certain number of such events, e.g. 7. And the cdf tells the probability to observe <u>up to</u> 7 such events, but not more.
For doing statistics with continuous statistical variables – e.g. the heights of three-year-old toddlers – similar rules apply: Assume we know the applicable mathematical model. Then the respective cdf tells the probability for their heights being less than an arbitrary limit value, for example less than 1m. And the corresponding pdf tells how these heights are distributed in a sample of let's say 1000 children of this age.

**WARNING:** This is a very coarse sketch of this topic only – please turn to textbooks about statistics to learn dealing with it properly.

The term pmf translates to German „Dichtefunktion", pdf to „Wahrscheinlichkeitsdichte", cdf to „Verteilungsfunktion" or „Wahrscheinlichkeitsverteilung".

- Do you want an upper <u>and</u> a lower limit confining the “true value”? Then there is an inevitable chance of 5%/2 = 2.5% for said value being less than the lower limit and an equal chance for it being greater than the upper limit. So you shall use 0.025 and 0.975 as arguments in two subsequent calculations using the inverse cdf to get both limits.

If you cannot live with these chances, inevitable as they are, employ an higher confidence level.

Turn to a good statistics textbook for more information, also about the terminology used and the particular distributions provided.

## MEMORY

| Stack registers |
|---|
| D * |
| C * |
| B * |
| A * |
| T |
| Z |
| Y |
| X |

| | |
|---|---|
| Mode | |
| Alpha (31 bytes) | |
| Display | |
| L | I ** |

| General purpose registers | User flags | Program steps |
|---|---|---|
| R00 | 00 | 000 |
| R01 | 01 | 001 |
| R02 | 02 | 002 |
| … | … | … |
| … | … | … |
| R85 | 97 | 504 |
| R86 Σ ($x^2$ $y$) | 98 | 505 |
| R87 Σ $x$ | 99 | 506 |
| R88 Σ $x^2$ | A | |
| R89 Σ $y$ | B *Big, overflow* | |
| R90 Σ $y^2$ | C *Carry* | |
| R91 Σ ($x$ $y$) | D *Danger* | |
| R92 *n* | | |
| R93 Σ (ln $x$) | | |
| R94 Σ (ln² $x$) | | |
| R95 Σ (ln $y$) | | |
| R96 Σ (ln² $y$) | | |
| R97 Σ(ln$x$ ln$y$) | | |
| R98 Σ ($x$ ln $y$) | | |
| R99 Σ ($y$ ln $x$) | | |
| J *** | | |
| K *** | | |

| | |
|---|---|
| X = | R100 |
| Y = | R101 |
| Z = | R102 |
| T = | R103 |
| A = | R104 |
| B = | R105 |
| C = | R106 |
| D = | R107 |
| L = | R108 |
| I = | R109 |
| J = | R110 |
| K = | R111 |

For the first time ever in a calculator, your WP 34S offers a choice of 4 or 8 stack levels. So either **T** or **D** will be the top level. Registers **A - D** will be allocated as stack registers if required.

Please see <u>*below*</u> for top level repetition and stack contents in complex calculations. While register **L** takes the real part of the last argument, **I** takes the imaginary part when a complex function was executed (see ᶜLASTx).

Using $\boxed{\Sigma+}$, registers **R86 - R99** will contain statistical sums as indicated. **J** and **K** may be taken for parameters of statistical distributions.

Unless required for the purposes just mentioned, **A - D, I, J,** and **K** are available as additional general purpose registers. For <u>*indirect addressing*</u>, the stack levels and named registers carry the numbers 100 … 111 as shown at right.

For information about the flags, please turn overleaf.

**Flags** 00 … 99 are free to use for whatever purpose you like. Flags A, B, C and D may be used the same way, but the system checks them, too. Flag A lights the big '=' symbol in display. In integer modes, flags B and C will be set by the system in analogy to the overflow and carry bits of the *HP-16C*. Some integer operations (like shift and rotate) also read flag C. Flag D may be set by the user to allow special results (infinities and non-numeric results) without getting an error. The system only reads D.

For *indirect addressing*, flags A … D carry the numbers 100 … 103.

In addition to the RAM provided, your WP 34S allows you to access **flash memory** for voltage-fail safe storage of user programs and data. Flash memory features up to ten segments (regions, banks) of 1 kB each. Segment 0 is the backup region, holding the image of the entire program memory, registers and calculator state as soon as you completed a SAVE. The other segments hold programs only. Alphanumeric labels (see below) in flash can be called via XEQ like in RAM. This allows creating program libraries in flash. Use CAT to see the labels defined already.

Flash memory is ideal for backups or other long-living data, but shall not be used for repeated transient storage like in programmed loops (since it will not survive more than some 10,000 flashes). Registers and standard user program memory, residing in RAM on the opposite, are designed for frequent data changes – but will not hold data with the batteries removed. So both kinds of memory have specific advantages and disadvantages you shall take into account for optimum benefit and long lasting joy with your WP 34S.

Find more about flash memory in *Appendix A* below.

Furthermore, there is a memory section called XROM (for "extended ROM"), where some additional routines live. Though written in user code, these are read only and thus can be called, executed, but not edited. For you, it shall make no difference whether a preprogrammed routine executes in ROM or XROM.

Structuring program memory and jumping around in it is eased by **labels** you may tag to any program steps – as known from previous programmable pocket calculators. Your WP 34S features a full set of alphanumeric labels as described *below*.

When a command like e.g. GTO ***xy*** is encountered, with ***xy*** representing one, two or three characters (like A, BC, 12, Tst, Pg3, x1µ, etc.), your WP 34S will search this label ***xy*** using the following method:

1. If ***xy*** is purely numeric, it will be searched forward from the current position of the program pointer. When the end of the program space is reached without finding ***xy***, the quest will continue at the start of the current segment. No other segments will be searched. This is as known from vintage HP calculators.
2. Else, i.e. if ***xy*** is an alpha label of up to three characters of arbitrary case, searching will start at program step 000 and cover the entire memory in the order RAM, flash segments 8, 7, …, 1, 0, and XROM, independent of the position of the program pointer.

## STACK MECHANICS

The following assumes you are familiar with RPN – else please turn to the *HP-42S Owner's Manual* first.

The fate of particular stack register contents depends on the operation executed, its domain (real or complex) and the stack size chosen. Real functions in a 4-level stack work as known for decades. In a larger stack, everything works alike on your WP 34S – just with more levels for intermediate results. Please note only the contents of **X** are displayed in any case. See below for details of the stack mechanics:

| | Level | Assumed stack contents at the beginning: | Stack contents after executing … | | | | | | | … real functions of | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | … the real stack register operations | | | | | | | … one number like $x^2$ | … two numbers like / |
| | | | ENTER | FILL | DROP | x⇆y | R↓ | R↑ | LASTx | | |
| With **4** stack levels | **T** | *t* | *z* | *x* | *t* | *t* | *x* | *z* | *z* | *t* | *t* |
| | **Z** | *z* | *y* | *x* | *t* | *z* | *t* | *y* | *y* | *z* | *t* |
| | **Y** | *y* | *x* | *x* | *z* | *x* | *z* | *x* | *x* | *y* | *z* |
| | **X** | *x* | *x* | *x* | *y* | *y* | *y* | *t* | *last x* | $x^2$ | $y / x$ |
| With **8** stack levels | **D** | *d* | *c* | *x* | *d* | *d* | *x* | *c* | *c* | *d* | *d* |
| | **C** | *c* | *b* | *x* | *d* | *c* | *d* | *b* | *b* | *c* | *d* |
| | **B** | *b* | *a* | *x* | *c* | *b* | *c* | *a* | *a* | *b* | *c* |
| | **A** | *a* | *t* | *x* | *b* | *a* | *b* | *t* | *t* | *a* | *b* |
| | **T** | *t* | *z* | *x* | *a* | *t* | *a* | *z* | *z* | *t* | *a* |
| | **Z** | *z* | *y* | *x* | *t* | *z* | *t* | *y* | *y* | *z* | *t* |
| | **Y** | *y* | *x* | *x* | *z* | *x* | *z* | *x* | *x* | *y* | *z* |
| | **X** | *x* | *x* | *x* | *y* | *y* | *y* | *d* | *last x* | $x^2$ | $y / x$ |

Calculating formulas from inside out stays a wise strategy in either stack. With more levels, however, stack overflow will hardly ever happen, even with the most advanced formulas you compute in your life as a scientist or engineer.

Calculating with complex numbers uses two registers or stack levels for each such number as explained above and shown here:

| | Level | Assumed stack contents at the beginning: | Stack contents after executing … | | | | | | | … complex functions of | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | … the complex stack register operations | | | | | | | … one number like $^{C}x^2$ | … two numbers like $^{C}/$ |
| | | | $^{C}$ENTER | $^{C}$FILL | $^{C}$DROP | $^{C}$x⇆y | $^{C}$R↓ | $^{C}$R↑ | $^{C}$LASTx | | |
| With **4** stack levels | **T** | **Im($y_c$) = Im($t_c$)** | **Im( $x_c$ )** | | $y_c = t_c$ | **Im( $x_c$ )** | $x_c$ | | $x_c$ | $y_c = t_c$ | $y_c = t_c$ |
| | **Z** | **Re($y_c$) = Re($t_c$)** | **Re( $x_c$ )** | | | **Re( $x_c$ )** | | | | | |
| | **Y** | **Im( $x_c$ )** | **Im( $x_c$ )** | | $y_c$ | **Im( $y_c$ )** | $y_c$ | | *last* $x_c$ | **Im( $(x_c)^2$ )** | **Im( $y_c / x_c$ )** |
| | **X** | **Re( $x_c$ )** | **Re( $x_c$ )** | | | **Re( $y_c$ )** | | | | **Re( $(x_c)^2$ )** | **Re( $y_c / x_c$ )** |

| | Level | Assumed stack contents at the beginning: | $^{C}$ENTER | $^{C}$FILL | $^{C}$DROP | $^{C}$x⇆y | $^{C}$R↓ | $^{C}$R↑ | $^{C}$LASTx | like $^{C}x^2$ | like $^{C}/$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| With **8** stack levels | **D** | **Im( $t_c$ )** | $z_c$ | $x_c$ | $t_c$ | $t_c$ | $x_c$ | $z_c$ | $z_c$ | $t_c$ | $t_c$ |
| | **C** | **Re( $t_c$ )** | | | | | | | | | |
| | **B** | **Im( $z_c$ )** | $y_c$ | $x_c$ | $t_c$ | $z_c$ | $t_c$ | $y_c$ | $y_c$ | $z_c$ | $t_c$ |
| | **A** | **Re( $z_c$ )** | | | | | | | | | |
| | **T** | **Im( $y_c$ )** | $x_c$ | $x_c$ | $z_c$ | $x_c$ | $z_c$ | $x_c$ | $x_c$ | $y_c$ | $z_c$ |
| | **Z** | **Re( $y_c$ )** | | | | | | | | | |
| | **Y** | **Im( $x_c$ )** | $x_c$ | $x_c$ | $y_c$ | $y_c$ | $y_c$ | $t_c$ | *last* $x_c$ | $(x_c)^2$ | $y_c$ / $x_c$ |
| | **X** | **Re( $x_c$ )** | | | | | | | | | |

So, an 8-level stack gives you the same flexibility in complex domain you are used to with a 4-level stack in real domain.

## COMPARING AND ADDRESSING REAL NUMBERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 User input | x= ?, x≠ ?, x< ?, x≤ ?, x≈ ?, x≥ ?, or x> ? | | | | RCL, STO, RCLM, STOM, RCLS, STOS, αRCL, αSTO, VIEW, VWα+, x⇄, DSE, ISG, DSZ, ISZ, FIX, SCI, ENG, DISP, BASE, KEY?, bit or flag commands, etc. | | |
| Dot matrix display | **OP _** (with temporary alpha mode set), e.g. x> _ | | | | **OP _** (with temporary alpha mode set), e.g. RCL _ [5] | | |
| 2 User input | 0 or 1 | *Stack level or named reg.*<br>X, Y, ... | ENTER↑ [6]<br>leaves temp. alpha mode. | →<br>opens indirect addressing. | *Stack level or named register*<br>X, Y, Z, .. , K [7] | ***Number** of register or flag or bit(s) or decimals* [8] | →<br>opens indirect addressing. |
| Dot matrix display | **OP *n***<br>e.g. x≤ 0 ? | **OP *x***<br>e.g. x≥ y ? | **OP r_** | **OP →_** | **OP *x***<br>e.g. SCI Z | **OP *nn***<br>e.g. SF 15 | **OP →_** |
| 3 User input | Compares ***x*** with the number **0**. | Compares ***x*** with the number on stack level **Y**. | *Register no.*<br>0 0 … 9 9 | Look right for more about indirect addressing. | Sets scientific display with the number of decimals specified in stack level **Z**. | *Stack level etc.*<br>X, Y, Z, ... , K | *Register number*<br>0 0 … 9 9 |
| Dot matrix display | | | **OP r *nn***<br>e.g. x≠ r23? | | | **OP → *x***<br>e.g. VIEW →L | **OP → *nn***<br>e.g. STO →45 |
| | | | Compares ***x*** with the number stored in **R23**. | | | Shows the content of the register where **L** is pointing to. | Stores ***x*** into the location where **R45** is pointing to. |



[5] For RCL and STO, any of +, −, ×, /, ▲, or ▼ may precede step 2, except in RCLM and STOM. VIEW ENTER↑ calls αVIEW, And ENG ENTER↑ calls ENGOVR, SCI ENTER↑ calls SCIOVR. See the index of operations.

[6] You may skip this for register numbers >19.

[7] Exceptions: RCL T, RCL× T, RCL Z, RCL+ Z require an ENTER↑ preceding T or Z, e.g. RCL + ENTER↑ Z for the latter. This holds for STO as well.

[8] Legal register numbers are 00 … 111 (00 … 99 may be specified directly). Valid flag numbers are 00 … 103, with the four top flags directly addressed via A, B, C, and D . Legal numbers of decimals are 0 … 11, accepted integer bases 2 … 16, bit numbers 0 to 63, and integer word size up to 64 bits. For numbers <10, you may key in e.g. 5 ENTER↑ instead of 0 5 . – Please take into account some registers may be allocated to special applications.

## COMPARING AND ADDRESSING COMPLEX NUMBERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 User input | CPX x= ? or x≠ ? | | | | CPX RCL, STO, or x⇄ | | |
| Dot matrix display | OP _ (with temporary alpha mode set) e.g. ▪x= _ | | | | OP _ (with temporary alpha mode set) e.g. ▪RCL _ [9] | | |
| 2 User input | 0 or 1 | *Stack level or named register* X, Z, A, C, L, or J | ENTER↑ [10] leaves temp. alpha mode | → opens indirect addressing. | *Stack level or named register* Z [11], A, C, L, or J | *Register number* 0 0 .. 9 8 [12] | → opens indirect addressing. |
| Dot matrix display | OP *n* e.g. ▪x= 0 ? | OP *x* e.g. ▪x≠ z ? | OP r_ | OP →_ | OP *x* e.g. ▪RCL L | OP *nn* e.g. ▪STO 18 | OP →_ |
| 3 User input | Compares ***x*** + *i* ***y*** with the real number **0**. | Compares ***x*** + *i* ***y*** with ***z*** + *i* ***t*** . | *Register number* 0 0 … 9 8 | Look right for more about indirect addressing. | This is CLASTx. | *Stack level or named register* X, Y, … , K | *Register number* 0 0 … 9 9 |
| Dot matrix display | | | OP r *nn* e.g. ▪x≠ r26? | | | OP → *x* e.g. ▪x<> →Z | OP → *nn* e.g. ▪STO →45 |
| | | | Compares ***x*** + *i* ***y*** with ***r26*** + *i* ***r27*** . | | | Swaps ***x*** with the contents of the register where **Z** is pointing to, and ***y*** with the contents of the next one. | Stores ***x*** + *i* ***y*** into 2 consecutive registers, starting with the one where **R45** is pointing to. |



[9] For RCL and STO, any of +, −, ×, or / may precede step 2. See the index of operations.

[10] You may skip this keystroke for register numbers >19.

[11] Exceptions: CRCL Z, CRCL + Z, CSTO Z, and CSTO + Z require an ENTER↑ preceding Z, e.g. CPX STO + ENTER↑ Z for the latter.

[12] You may key in e.g. 8 ENTER↑ instead of 0 8 . Take care of pairs, since a complex operation will always affect two registers: the one specified and the one following this. We strongly recommend storing complex numbers with their real parts at even register numbers. – Please take into account some registers may be allocated to special applications.

## ADDRESSING LABELS

| # | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | User input | A, B, C, or D | XEQ, GTO, LBL, LBL?, SLV, ∫, π, Σ, αGTO or αXEQ | | | | |
| | Dot matrix display | **XEQ *label*** e.g. XEQ C | **OP _** e.g. GTO _ | | | | |
| 2 | User input | Calls the function labeled **C**. | A, B, C, or D | ENTER↑ sets alpha mode. | → [13] opens indirect addressing and sets temporary alpha mode. | | *2-digit numeric label* 0 0 … 9 9 |
| | Dot matrix display | | **OP *label*** e.g. Σ B | **OP '_** | **OP →_** | | **OP *nn*** e.g. LBL 07 |
| 3 | User input | | Sums up the function labeled **B**. | ***Alphanumeric label*** (1 … 3 characters [14]) | *Stack level or named register* X, Y, Z, … , K | *Register number* 0 0 … 9 9 [15] | |
| | Dot matrix display | | | **OP '*label*'** e.g. SLV'F1µ' | **OP → *x*** e.g. ∫ →T | **OP → *nn*** e.g. XEQ →44 | |
| | | | | Solves the function **F1µ** (with **F1µ** keyed in as explained in footer). | Integrates the function whose label is on stack level **T**. | Executes the routine whose label is in **R44**. | |

Additionally, see *above* for the way your WP 34S searches labels, and look up GTO in the *index of operations* for two special cases applying to this command exclusively.



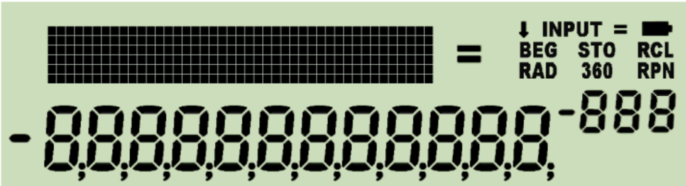
[13] Works with all these operations except LBL.

[14] The 3rd character terminates entry and closes alpha mode again – shorter labels need a closing ENTER↑. For the example given here you just press f 2 ENTER↑ CPX 1 f EXIT g 7 and you are done. Statements including labels being 2 or 3 characters long decrement the number of free program steps by 2. – **WARNING:** LBL A and LBL'A' are different animals! The latter is entered in alpha mode, the first via the hotkey directly.

[15] Some registers may be allocated to special applications. Please check the memory table above.

## DISPLAY AND MODES

The display features three sections: numeric, dot matrix and fixed symbols. The numeric section features a minus sign and 12 digits for the mantissa, as well as a minus sign and 3 digits for the exponent. The dot matrix is 6 dots high and 43 dots wide, allowing for some 7 to 12 characters, depending on their widths. The fixed symbols (except the big "=") are called *annunciators*, and are for indicating modes.




The dot matrix section above is used for

1. indicating some more modes than the annunciators allow,
2. passing additional information to the user.

The numeric section in the lower part of the LCD is used for displaying numbers in different formats, for status, or messages.

If two or more requests concur for display space, the items will be shown according to their priorities as follows:

1. error messages as described in a [paragraph further below](),
2. special information as explained below,
3. information about the modes the calculator is running in.

The *annunciators* or specific characters in the LCD signal the modes:

| **Integer base or mode name** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | DECM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Signaled by … in the exponent** | **b** | **3** | **4** | **5** | **6** | **7** | **o** | **9** | **d** | **-1** | **-2** | **-3** | **-4** | **-5** | **h** | |
| **Set by …** | 2 | BASE3, … , BASE7, 8, BASE9, 10, … , BASE15 | | | | | | | | | | | | | 16 | .d |
| **Cleared by …** | any other BASE setting, FRACT, a b/c, d/c . ALL, FIX, SCI, ENG, and TIME will set DECM | | | | | | | | | | | | | | | |

| **Mode name** | PRG | α | | | | FRC |
|---|---|---|---|---|---|---|
| **Signaled by …** | *STO* | *INPUT* | *360* | *RAD* | G | |
| **Set by …** | P/R | α<br>αON | DEG | RAD | GRAD | d/c, a b/c<br>2nd . in input<br>BASE1, FRACT |
| **Cleared by …** | P/R<br>EXIT | ENTER<br>αOFF<br>EXIT | GRAD<br>RAD | DEG<br>GRAD | DEG<br>RAD | BASE ≠ 1<br>H.MS, TIME, → H.MS<br>ALL, FIX, SCI, ENG |

***BEG*** indicates the program pointer standing at step 000 of program memory. A running program is signaled by a flashing ***RCL*** annunciator. ***RPN*** may be lit permanently. Time modes (12h / 24h) are seen in the time string directly. The numeric format of fraction mode is unambiguous as well. Further settings are signaled in the dot matrix section, like the different date modes being indicated there by **Y.MD** or **M.DY**. Defaults D.MY and DECM are not indicated. Please check the examples below.

Some mode and display settings may be stored and recalled collectively by STOM and RCLM. These are stack depth and contrast set, complete decimal display settings, trig mode, choices for date and time display, the parameters of integer and fraction mode, curve fitting model and rounding mode selected. STOM stores this information in the register you specify. RCLM recalls the contents of such a register and sets the calculator modes accordingly. Please note the user is responsible for recalling valid mode data – else your WP 34S may be driven into a lockup state! See the *index of operations* for more information about changing modes and the individual commands employed.

Some regional combinations may be set at once using a single command:

- SETCHN sets 24h, Y.MD, decimal point, and E3OFF;
- SETEUR sets 24h, D.MY, decimal comma, E3ON, and JG1582 (these settings apply also to South America);
- SETIND sets 24h, D.MY, decimal point, E3OFF, and JG1752;
- SETUK sets 12h, D.MY, decimal point, E3ON, and JG1752.
- SETUSA sets 12h, M.DY, decimal point, E3ON, and JG1752;

Please note the people living in the area of the former Soviet Union, in South Africa, Indonesia, and Vietnam use the decimal comma as well, but have different settings for dates and times.

Especially the angular modes deserve a closer look: there are three of them, DEG, RAD, and GRAD. And degrees (DEG) may be displayed in decimal numbers as well as in hours, minutes, seconds and hundredth of seconds (H.MS). Conversions are provided for going from one to the other:

| From<br>to | degrees H.MS | decimal degrees | radians | gon (grad) | current angular mode |
|---|---|---|---|---|---|
| degrees H.MS | — | →H.MS | — | — | — |
| decimal degrees | →H .d | — | rad→° | G→° | →DEG |
| radians | — | °→rad | — | G→rad | →RAD |
| gon/grad | — | °→G | rad→G | — | →GRAD |
| current angular mode | — | DEG→ | RAD→ | GRAD→ | — |

Please see the *index of operations* for the commands printed on white background, and the *catalog of unit conversions* for those printed on yellow.

Some commands and modes use the display in a special way. They are listed below in order of falling priority:

1. **VERS** generates a display similar to the one shown on the title page of this manual. Pressing any key will delete this message and return to previous state.

2. **SHOW** displays the full mantissa of $x$, i.e. all sixteen digits present internally. E.g. [π] [SHOW] returns


.

Pressing any key will return to previous display.

3. **STATUS** shows the status of 30 user flags very concisely in one display, allowing an immediate status overview after some training. If e.g. flags 2, 3, 5, 7, 11, 13, 14, 17, 19, and 23 are set, and labels B, C, and D are defined in program memory, STATUS will display this:


Within the numeric section, each row of horizontal bars in the mantissa shows the status of 10 flags. When a flag is set, the respective bar turns black. So here the top row of bars indicates flags 0 and 1 are clear, 2 and 3 set, and flag 4 clear. Then, the divider II separates the first group of five flags from the next. Top row bars on its right side indicate flags 5 and 7 are set. Next row of bars shows flags 11, 13, 14, 17, 19 are set, and in the lowest row only flag 23 is set. All other flags in the range from 10 to 29 are clear.

Scrolling down by [▼] will display flags 10 - 39, then 20 - 49 etc. until 70 - 99, 80 - D, and 90 - D. Scrolling up by [▲] reverts this. Alternatively, pressing a digit, e.g. 5, will show up to 30 flags starting with 10 times this digit, e.g. flags 50 - 79. The numeric exponent always indicates the status of the hotkeys top left on the keyboard – if all four labels are used in program memory then **ALL** will be displayed there.

The status will be displayed until any key is pressed but [▼], [▲], or a digit.

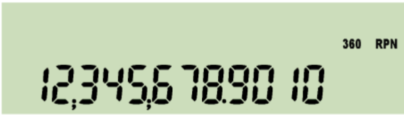
4. During **command input**, the dot matrix displays the command chosen until input is completed, i.e. until all required trailing parameters are entered. The prefixes [f], [g], and [h] are shown until they are resolved. If you pressed any of [f], [g], or [h] erroneously, recovery is as easy as follows:

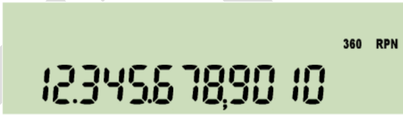
   - [f] [f] = NOP = [g] [g] = [h] [h] = [CPX] [CPX] = [→] [→]
   - [g] [f] = [h] [f] = [f]
     [f] [g] = [h] [g] = [g]
     [f] [h] = [g] [h] = [h]

In addressing, progress is recorded as explained in the *tables above* in detail. You may cancel such pending operations by **EXIT** as described *below*.

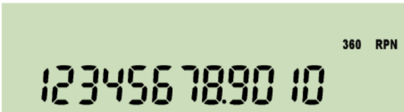
5. In **programming mode**, the numeric display indicates the program step (000 – 505) in the mantissa and the number of free steps in the exponent, while the dot matrix shows the command contained in the respective step, e.g.:

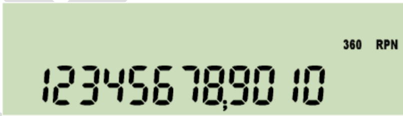

6. For **floating point decimal numbers**, the mantissa will be displayed adjusted to the right, the exponent to the left. Within the mantissa, either points or commas may be selected as radix marks [16], and additional marks may be chosen to separate thousands. Assume the display set to FIX 4, then 12.345678901 millions may look like:



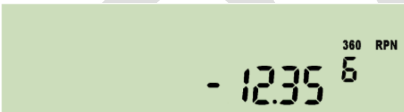
or


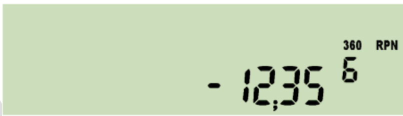

with thousands separators on, and without them like:



or



These separators may also be beneficial in integer or fraction modes described below. – With ENG 3 and after changing the sign, the same number will look like this:



or



If the last operation executed was a complex one, a capital **C** is displayed top left in the dot matrix pointing to the fact that you find the result of this function in **X** and **Y**.

Floating point decimal numbers within $10^{-383} < x < 10^{+385}$ may be entered easily. Using a decimal mantissa, even numbers down to $10^{-394}$ can be keyed in. The calculator works with numbers down to $10^{-398}$ correctly. Smaller values are set to zero. For results $x \geq 10^{+385}$, error 4 or 5 will appear (see *below*).

7. In **integer modes**, numbers are displayed adjusted to the right as well. Word size and complement setting are indicated in the dot matrix using a format ***xx.ww***, with ***xx*** being **1c** or **2c** for 1's or 2's complement, respectively, **un** for unsigned, or **sm** for sign-and-mantissa mode. Sign and first digit of the exponent show the base, a "c" in the second digit signals a carry bit set, an "o" in the third an overflow. Integer bases are indicated as follows:



[16] Starting here, decimal input is written using a point as radix mark throughout this manual, although significantly less visible, unless specified otherwise explicitly. By experience, the „comma people" are more capable to read radix points and interpret them correctly than vice versa.

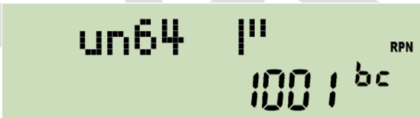
| Base | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sign and 1st digit of exponent displayed | **b** | **3** | **4** | **5** | **6** | **7** | **o** | **9** | **d** | **-1** | **-2** | **-3** | **-4** | **-5** | **h** |

The example shows the WP 34S displaying an arbitrary number in unsigned hexadecimal mode with word size 64 and carry set:


After changing to binary mode, this number will need 28 digits, being 1001001110100001010010110110. The 12 least significant digits will be displayed initially together with an indication that there are three display windows in total with the rightmost shown:


Now press ◀ and you will get the next 12 digits in the middle window:


Press ◀ again to show the most significant digits:

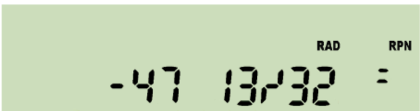


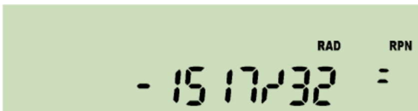

If leading zeros were turned on, there will be six display windows in this case, with the three "most significant" containing only zeros.

Please note numeric input is limited to 12 digits in any integer base.

8. **Fraction mode** works similar to HP-35S. In particular, DENMAX sets the maximum allowable denominator (see the *index of operations*). Display will look like in the examples below. If the fraction is exactly equal, slightly less, or greater than the floating point number converted, "=", "Lt", or "Gt" is indicated in the exponent, respectively. This mode can handle numbers with absolute values < 100,000 and > 0.0001. Maximum denominator is 9999. Underflows as well as overflows will be displayed in the format set before fraction mode was entered.

   Now assume your WP 34S being reset. Key in -47.40625 a b/c and you will see:

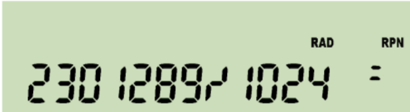
   

 or after d/c : 

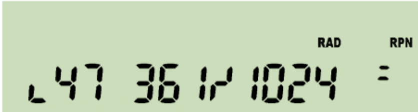
 .

   Please note integers like 123 will be displayed as "123 0/1" or "123/1" in fraction mode, respectively, to indicate this mode.

   Squaring the improper fraction shown above results in




Now, enter a b/c for converting this result into a proper fraction. You will get



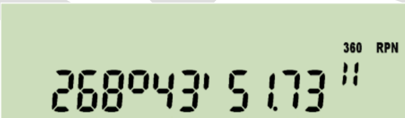

with a little hook left of the first digit shown. This indicates the leading number is displayed incompletely – there are at least two digits preceding 47 but no more display space. Press SHOW to unveil the integer part of this proper fraction is 2247.

Input in fraction mode is straightforward and logically coherent.

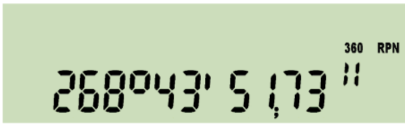
| Key in: | and get in proper fraction mode: |
|---|---|
| 1 2 . 3 . 4 ENTER↑ | 12 $^{3}/_{4}$ |
| 1 . 2 ENTER↑ | 1 $^{1}/_{5}$ |
| . 1 . 2 ENTER↑ | $^{1}/_{2}$ |
| . 1 2 ENTER↑ | $^{3}/_{25}$ ( = 0.12 ) |
| 1 . . 2 ENTER↑ | 1 $^{0}/_{1}$ ( = 1 $^{0}/_{2}$ ! ) |

For comparison, please note the HP-32SII reads the last input here as ½ – which is, however, not consistent with its other input interpretations in fraction mode.

9. In **H.MS display mode**, format is `hhhh°mm'ss.dd"` with the number of hours or degrees limited to 9000. Output may look like this:




or

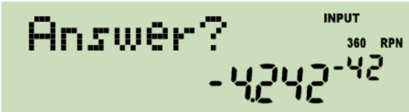



depending on the radix setting. For decimal times less than 5ms or 0.005 angular seconds but greater than zero, an "u" for underflow will be lit in the exponent section. For times or angles exceeding the upper limit, an "o" will be shown there signaling an overflow, and the value is displayed modulo 9000.

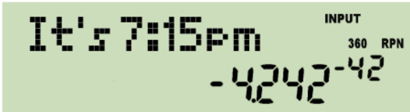
10. Output of the function **WDAY** will look as follows for an input of 1.13201 in M.DY mode (equivalent to inputs of 13.01201 in D.MY or 2010.0113 in Y.MD):

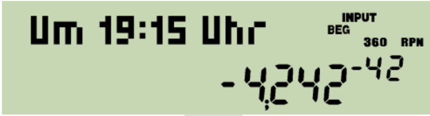

Expect similar displays after DAYS+. – Dates before the year 8 may be indicated differently to what they really were due to the inconsistent application of the leap year rule before this.

11. In **alpha mode**, the alpha register is displayed in the dot matrix, showing the last characters it is containing, while the numeric section keeps the result of the last numeric operation, e.g.:



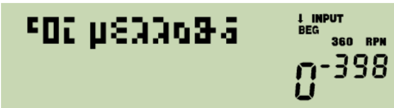

Different information may be appended to ***alpha***. See the commands starting with “α” in the index of operations below. E.g. αTIME allows creating texts like

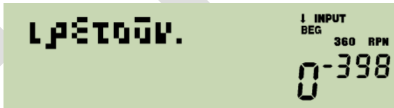


or



depending on time mode setting (12h / 24h). And αDATE will append – depending on date format setting – either 2011-04-16 or 16.04.2011 or 04/16/2011 to ***alpha***.

Please note ***alpha*** may contain up to 31 characters. And your WP 34S features a rich set of special letters. So you may easily store a message like






Use ▲ and ▼ for browsing it in steps of 6 characters. Browsing to the left will stop with the very first characters shown, browsing to the right stops showing the right end completely, i.e.


in this very special case.

**All keyboard input will be interpreted according to the mode set at input time.**

## FONTS

Your WP 34S features a large and a small font. Both are based on Luiz Viera’s fonts as distributed in 2004. Some letters were added and some modified for better legibility, since the dot matrix is only 6 pixels high here. The following tables show the characters directly accessible through the keyboard:

| |
|---|
| A B C D E F G H I J K L M N O P Q R S T U V W X Y Z |
| ABCDEFGHIJKLM NOPQRSTUVWXYZ |
| ABCDEFGHIJKLM NOPQRSTUVWXYZ |

| |
|---|
| a b c d e f g h i j k l m n o p q r s t u v w x y z |
| abcdefghijklm nopqrstuvwxyz |
| abcdefghijklm nopqrstuvwxyz |

| |
|---|
| Α Β Γ Δ Ε Ζ Η Θ Ι Κ Λ Μ Ν Ξ Ο Π Ρ Σ Τ Υ Φ Χ Ψ Ω |
| ΑΒΓΔΕΖΗΘΙΚΛΜ ΝΞΟΠΡΣΤΥΦΧΨΩ |
| ΑΒΓΔΕΖΗΘΙΚΛΜ ΝΞΟΠΡΣΤΥΦΧΨΩ |

| |
|---|
| α β γ δ ε ζ η ϑ ι κ λ μ ν ξ ο π ρ σ τ υ φ χ ψ ω |
| αβγδεζηϑικλμ νξοπρστυφχψω |
| αβγδεζηϑικλμ νξοπρστυφχψω |

| | | |
|---|---|---|
| 0 1 2 3 4 5 6 7 8 9 | ( ) + - × / ± . ! ? | ↔ % √ \ & \| ≠ $ € £ ¥ |
| 0123456789 | ()+-×/±.!? | ↔%√\&\|≠$€£¥ |
| 0123456789 | ()+-×/±.!? | ↔%√\&\|≠$€£¥ |

More characters live in the alpha catalogs you find *below*.

## INDEX OF OPERATIONS

All commands available are found below with their *names* and *keystrokes* necessary. Names printed in **bold** face in this list belong to functions directly accessible on the keyboard, the other commands may be picked from catalogs. The command names will show up in program listings as well. Sorting in index and catalogs is case insensitive and works in the following order:

␣, 0…9, A…Z, α…ω, ( ) + – × / ± , . ! ? : ; ' " # * @ _ ~
→ ← ↑ ↓ ↔ < ≤ = ≠ ≥ > % $ € £ ¥ √ ∫ ∞ & \ ^ | G [ ] { }

Super- and subscripts are handled like normal characters in sorting. The fifth last item in the sorting order list above is the indicator for the angular mode GRAD.

Generally, functions and keystroke programming will work as on *HP-42S*, bit and integer functions as on *HP-16C*, unless stated otherwise under remarks. Especially, all **tests** will return "true" or "false" in the dot matrix if called from the keyboard; if called in a program, they will skip the next program line if the test is false. Please refer to the manuals of the vintage calculators mentioned for additional information about traditional commands.

Functions available on the WP 34S for the first time on an RPN calculator are highlighted yellow under remarks, while operations carrying a familiar name but deviating in their functionality here are marked light red.

***Parameters*** will be taken from the lowest stack level(s) unless mentioned explicitly in the 2nd column – then they must follow the command. If ***underlined***, they may also be specified using indirect addressing, as shown in the *tables* above. Some parameters of statistical distributions must be given in registers **J** and **K** if specified.

In the following, each function is listed stating the mode(s) it will work in, abbreviated by their *indicators*. In this column an "&" stands for a Boolean AND, a comma for an OR, and a backslash for "not". So e.g. $2^x$ works in all modes but alpha. All operations may also be entered in mode PRG unless stated otherwise explicitly.

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| **c…** | CPX … | DECM | Indicates an operation allowing complex input(s) and/or complex results (see *above*). The prefix CPX may be heading all functions whose *names are printed in italics in this list*. |
| ***$10^x$*** | f $10^x$ | DECM | |
| 12h | h MODE 12h | \α | Sets 12h time display mode meaning 1:23 becomes 1:23 AM and 13:45 becomes 1:45 PM. This makes a difference in αTIME only. |
| 1COMPL | h MODE 1COMPL | \α | Sets 1's complement mode like in *HP-16C*. |
| ***1/x*** | f 1/x | DECM | |
| | B | DECM | Shortcut as long as label B is not defined yet. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| 24h | h MODE 24h | \α | Sets 24h time display mode meaning 1:23 AM becomes 1:23, and 1:45 PM becomes 13:45. |
| 2COMPL | h MODE 2COMPL | \α | Sets 2's complement mode like in *HP-16C*. |
| ***$2^x$*** | f $2^x$ | \α | |
| ***ABS*** | f $\lvert x\rvert$ | \α | Returns the absolute value. |
| | CPX f $\lvert x\rvert$ | DECM | Returns $r=\sqrt{x^2+y^2}$ in **X** and clears **Y**. |
| ***ACOS*** | g $COS^{-1}$ | DECM | Returns $\arccos(x)$ . |
| ***ACOSH*** | g $HYP^{-1}$ COS | DECM | Inverse hyperbolic cosine, known as *arcosh*. Note there is no need for pressing f here. |
| *AGM* | h X.FCN AGM | DECM | Returns the arithmetic-geometric mean of $x$ and $y$ . |
| **ALL** | h ALL ***n*** | \α | ALL 00 works like ALL in *HP-42S*. For $x > 10^{13}$, however, display will switch to SCI or ENG with the maximum number of digits necessary (see SCIOVR / ENGOVR). The same will happen if $x < 10^{-n}$ and more than 12 digits are required to show $x$ completely. |
| **AND** | h AND | Integer | Works bitwise as in *HP-16C*. |
| | | DECM | Works like AND in *HP-28S*, i.e. $x$ and $y$ are interpreted before executing this operation. 0 is "false", any other real number is "true". |
| ANGLE | h X.FCN ANGLE | DECM | Returns the angle between positive x-axis and the straight line from the origin to the point $(x, y)$ , i.e. $arctan(y/x)$ . This is a two-number function, it consumes $y$. |
| ***ASIN*** | g $SIN^{-1}$ | DECM | Returns $\arcsin(x)$ . |
| ***ASINH*** | g $HYP^{-1}$ SIN | DECM | Inverse hyperbolic sine, known as *arsinh*. |
| ASR | h X.FCN ASR ***n*** | Integer | Works like ***n*** (up to 63) consecutive ASR commands in *HP-16C*, corresponding to a division by $2^n$ . ASR 0 executes as NOP, but loads **L**. |
| ***ATAN*** | g $TAN^{-1}$ | DECM | Returns $\arctan(x)$ . |
| ***ATANH*** | g $HYP^{-1}$ TAN | DECM | Inverse hyperbolic tangent, known as *artanh*. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| BACK | h P.FCN BACK ***n*** | PRG | Jumps ***n*** program steps backwards ($1 \le n \le 99$). So e.g. BACK 01 goes to the previous step. Reaching step 000 stops program execution. |
| BASE | h MODE BASE ***n*** | \α | Sets the base for integer calculations, with $2 \le n \le 16$. Popular bases are directly accessible on the keyboard. Current integer base setting is indicated in the exponent as explained *above*.<br>Furthermore, BASE0 equals DECM, and BASE1 calls FRACT. See below.<br>**ATTENTION:** Going from DECM to any integer mode, the current stack contents will be truncated. Going from integer to DECM, the current stack contents will be converted. Other register contents will not! |
| **BASE10** | f 10 | | |
| **BASE16** | g 16 | | |
| **BASE2** | f 2 | | |
| **BASE8** | g 8 | | |
| BATT | h X.FCN BATT | DECM | Measures the battery voltage in the range between 1.9V and 3.4V and returns this value. |
| | | Integer | As above but returns the voltage in 0.1V units. |
| BC? | h TEST BC? ***n*** | Integer | Tests the specified bit in $x$ . |
| BestF | h STAT BestF | DECM | Selects the best curve fit model, maximizing the correlation like BEST does in *HP-42S*. |
| Binom | h PROB Binom etc. | DECM | Binomial distribution with the number of successes ***g*** in **X**, the probability of a success $p_0$ in **J** and the sample size ***n*** in **K**:<br>pmf [17]: $p_B(g;n;p_0) = \binom{n}{g} \cdot p_0^g \cdot (1-p_0)^{n-g}$ .<br>cdf: $F_B(m;n;p_0) = \sum_{g=0}^{m} p_B(g;n;p_0)$ , with the maximum number of successes ***m*** in **X**.<br>Binom $^{-1}$ returns ***m*** for given probabilities $F_B$ in **X** and ***p*** in **J** with sample size ***n*** in **K**. |
| $Binom_P$ | | | |
| Binom $^{-1}$ | | | |
| $B_n$ | h X.FCN $B_n$ | DECM | Returns the Bernoulli number for an integer $n > 0$ given in **X**:<br>$B_n = (-1)^{n+1} n \cdot \zeta(1-n)$ . See below for ζ. |
| $B_n$* | h X.FCN $B_n$* | DECM | Returns the Bernoulli number according to its old definition for integer $n > 0$ given in **X**:<br>$B_n^* = \frac{2 \cdot (2n)!}{(2\pi)^{2n}} \cdot \zeta(2n)$ . See below for ζ. |

[17] The pmf equals BINOMDIST(***g; n; p₀*; 0**) and the cdf BINOMDIST(***m; n; p₀*; 1**) in MS Excel.

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| BS? | h TEST BS? ***n*** | Integer | Tests the specified bit in $x$ . |
| Cauch<br>Cauch$_P$<br>Cauch $^{-1}$ | h PROB Cauch etc. | DECM | Cauchy-Lorentz distribution with the location $x_0$ specified in **J** and the shape $\gamma$ in **K** , also known as Lorentz or Breit-Wigner distribution:<br>pdf: $f_{Ca}(x)=\frac{1}{\pi\gamma}\cdot\frac{1}{1+\left(\frac{x-x_0}{\gamma}\right)^2}$<br>cdf: $F_{Ca}(x)=\frac{1}{2}+\frac{1}{\pi}\arctan\left(\frac{x-x_0}{\gamma}\right)$ .<br>Cauch$^{-1}$ returns $x$ for a given probability $F_{Ca}$ in **X**, with location $x_0$ in **J** and shape $\gamma$ in **K**. |
| CB | h X.FCN CB ***n*** | Integer | Clears the specified bit in $x$ . |
| CEIL | h X.FCN CEIL | DECM | Returns the smallest integer ≥ $x$ . |
| CF | h P.FCN CF ***n*** | \α | Clears the flag specified. |
| CLALL | h X.FCN CLALL | \PRG | Clears all registers and programs if confirmed. |
| CLFLAG | h P.FCN CLFLAG | \α | Clears all user flags. |
| **CLP** | h CLP | \PRG | Positions the program pointer to step 000 and clears the subroutine return stack. |
| | | PRG | Clears the program memory if confirmed. Not programmable. |
| CLREG | h X.FCN CLREG | All | Clears all general purpose registers. The stack and its contents are kept. |
| **CLSTK** | 0 g FILL<br>h P.FCN CLSTK | \α | Clears all stack registers. The general purpose registers and their contents are kept. |
| **CLx** | h CLx | All | Clears **X** only, disabling stack lift as usual. |
| **CLα** | f CLα | All | Clears the alpha register like CLA in *HP-42S*. |
| **CLΣ** | g CLΣ | DECM | Clears all statistical sums in the respective general purpose registers. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| ***COMB*** | f Cy,x | DECM | Returns the number of possible <u>sets</u> of $y$ items taken $x$ at a time. No item occurs more than once in a set, and different orders of the same $x$ items are <u>not</u> counted separately.<br>Formula: $C_{y,x} = \binom{y}{x} = \frac{y!}{x! \cdot (y-x)!}$ |
| *CONJ* | CPX X.FCN CONJ | DECM | Changes the sign of $y$, thus returning the complex conjugate of $x_c$. |
| **CORR** | g r | DECM | Returns the correlation coefficient for the current statistical data and curve fitting model. |
| ***COS*** | f COS | DECM | Returns the cosine of the angle in X. |
| ***COSH*** | f HYP COS | DECM | Returns the hyperbolic cosine of $x$. |
| COV | h STAT COV | DECM | Returns the population covariance for two data sets. It depends on the fit model selected. For LinF, it calculates<br>$COV_{xy} = \frac{1}{n^2}\left(n\sum x_i y_i - \sum x_i \sum y_i\right)$<br>See $s_{xy}$ for the sample covariance. |
| *CUBE* | h X.FCN CUBE | \α | Returns $x^3$. |
| *CUBERT* | h X.FCN CUBERT | \α | Returns $\sqrt[3]{x}$. |
| DATE | h P.FCN DATE | DECM | Recalls the date from the real time clock and displays it in the numeric section in the format selected. See D.MY, M.DY, and Y.MD.<br>The function DATE of *HP-12C* corresponds to DAYS+ in your WP 34S (see below). |
| DAY | h X.FCN DAY | DECM | Assumes $x$ containing a date in the format selected and extracts the day. |
| DAYS+ | h X.FCN DAYS+ | DECM | Works like DATE in *HP-12C*, adding $x$ days on a date in Y in the format selected and displaying the resulting date including the day of week in the same format as WDAY does. |
| DBLR | h X.FCN DBLR | Integer | Double precision commands for remainder, multiplication and division like in *HP-16C*. |
| DBL × | h X.FCN DBL× | | |
| DBL / | h X.FCN DBL/ | | |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| DEC | h P.FCN DEC ***r*** | \α | Decrements ***r*** by one, equivalent to 1 STO– ***r*** , but without modifying the stack. |
| **DECM** | f H.d | \α | Sets default decimal mode for calculations. |
| DECOMP | h X.FCN DECOMP | FRC | Decomposes ***x*** (after converting it into an improper fraction, if applicable), resulting in a stack [***numerator(x), denominator(x), y, z***] or [***num(x), den(x), y, z, t, a, b, c***] , respectively. Reversible by division. |
| **DEG** | g DEG | DECM | Sets angular mode to degrees. |
| DEG→ | h X.FCN DEG→ | DECM | Takes ***x*** as degrees and converts them to the angular mode currently set. |
| DENANY | h MODE DENANY | \α | Sets default fraction format like in *HP-35S*, allowing maximum precision. Any denominator up to the value set by DENMAX may appear. |
| DENFAC | h MODE DENFAC | \α | Sets "factors of the maximum denominator". With e.g. DENMAX = 60, possible denominators are 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60. |
| DENFIX | h MODE DENFIX | \α | Sets fixed denominator format, i.e. the denominator equaling DENMAX always. |
| DENMAX | h MODE DENMAX | \α | Works like /c in *HP-35S*, but maximum denominator settable is 9999. It will be set to this value if ***x*** < 1 or ***x*** > 9999 at execution time. For ***x*** = 1 the current setting is recalled. |
| DISP | h MODE DISP ***n*** | DECM | Changes the number of decimals shown while keeping the basic display format (FIX, SCI, ENG) as is. With ALL set, DISP will change the switchover point (see ALL). |
| *DROP* | h X.FCN DROP | \α | Drops ***x*** . See *above* for details and ᶜDROP. |
| **DSE** | f DSE ***r*** | PRG | Given `cccccc.fffii` in ***r*** , DSE decrements ***r*** by `ii`, skipping next program line if then `ccccccc` ≤ `fff` . If ***r*** features no fractional part then `fff` is 0 and `ii` is set to 1.<br>Note that neither `fff` nor `ii` can be negative, and DSE makes only sense with `cccccc` > 0. |
| DSL | h P.FCN DSL ***r*** | PRG | Works like DSE but skips if `ccccccc` < `fff` . |
| DSZ | h P.FCN DSZ ***r*** | PRG | Decrements ***r*** by one, and skips if $\lvert r \rvert < 1$ thereafter. Known from the *HP-16C*. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| D.MY | h MODE D.MY | \α | Sets the format for date display. |
| D→J | h X.FCN D→J | DECM | Takes $x$ as a date in the format selected and converts it to a Julian day number according to JG… |
| D→R | | DECM | Please see the *catalog of conversions below* for conversions from degrees to radians. |
| E3OFF | h MODE E3OFF | \α | Toggle the thousands separator (either a point or a comma depending on the radix setting). |
| E3ON | h MODE E3ON | | |
| **ENG** | h ENG ***n*** | \α | Sets engineering display format. |
| **ENGOVR** | h ENG ENTER↑ | \α | Numbers exceeding the range displayable in ALL or FIX will be shown in engineering format. See SCIOVR. |
| ***ENTER↑*** | ENTER↑ | \α | See *above* for details. |
| ENTRY? | h TEST ENTRY? | All | Checks the entry flag. This internal flag is set if:<br>• any character is entered in alpha mode, or<br>• any command is accepted for entry (be it via ENTER↑, a function key, or R/S with a partial command line). |
| erf | h X.FCN erf | DECM | Returns the error function or its complementary: $erf(x)=\frac{2}{\sqrt{\pi}}\int_0^x e^{-\tau^2}d\tau$ and $erfc(x)=1-erf(x)$ |
| erfc | h X.FCN erfc | | |
| ERR | h P.FCN ERR ***n*** | PRG | Raises the error specified. See *below* for the respective error codes. |
| EVEN? | h TEST EVEN? | \α | Checks if $x$ is integer and even. |
| $e^x$ | f $e^x$ | DECM | |
| ExpF | h STAT ExpF | DECM | Selects the exponential curve fit model $y=a_0e^{a_1x}$ . |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| Expon<br>Expon$_P$<br>Expon $^{-1}$ | h PROB Expon etc. | DECM | Exponential distribution with the rate $\lambda$ in **J** :<br>pdf [18]: $f_{Ex}(x) = \lambda \cdot e^{-\lambda x}$ ,<br>cdf: $F_{Ex}(x) = 1 - e^{-\lambda x}$ .<br>Expon $^{-1}$ returns the survival time $t_s$ for a given probability $F_{Ex}$ in **X** and rate $\lambda$ in **J**. |
| EXPT | h X.FCN EXPT | DECM | Returns the exponent $h$ of the number displayed $x = m \cdot 10^h$ . |
| *$e^x$ -1* | h X.FCN $e^x$-1 | DECM | Returns more accurate results for the fractional part of $e^x$ with $x \approx 0$ . |
| FAST | h MODE FAST | All | Sets the processor speed to “fast”. This is start-up default and is kept for fresh batteries. |
| FB | h X.FCN FB ***n*** | Integer | Inverts (“flips”) the specified bit in $x$ . |
| FC?<br>FC?C<br>FC?F<br>FC?S | h TEST FC? ***n*** etc. | \α | Tests if the flag specified is clear. Clears, flips, or sets this flag after testing, if applicable. |
| FF | h P.FCN FF ***n*** | \α | Flips the flag specified. |
| *FIB* | h X.FCN FIB | \α | Returns the Fibonacci number $F_x$ . |
| ***FILL*** | g FILL | \α | Copies $x$ to all stack levels. See details *above*. |
| **FIX** | h FIX ***n*** | \α | Sets fixed point display format. |
| FLOOR | h X.FCN FLOOR | DECM | Returns the largest integer $\leq x$ . |
| ***FP*** | g FP | DECM | Returns the fractional part of $x$ . |
| FP? | h TEST FP? | \α | Tests $x$ for having a nonzero fractional part. |
| FRACT | h MODE FRACT | \α | Sets fraction mode like in HP-35S, but keeps display format as set by PROFRC or IMPFRC. |
| FS?<br>FS?C<br>FS?F<br>FS?S | h TEST FS? ***n*** etc. | \α | Tests if the flag specified is set. Clears, flips, or sets this flag after testing, if applicable. |

[18] The pdf corresponds to EXPONDIST($x$; $\lambda$; **0**) and the cdf to EXPONDIST($x$; $\lambda$; **1**) in MS Excel.

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| $F_P(x)$<br>$F(x)$<br>$F^{-1}(p)$ | h PROB $F_P$ (x) etc. | DECM | F-distribution. The cdf F(x) equals 1 - Q(F) in *HP-21S*. The degrees of freedom are specified in **J** and **K**. |
| f'(x) | h P.FCN f'(x) ***label*** | DECM | Return the first or second derivative of ***f(x)***, respectively, with the function ***f(x)*** being specified in a routine starting with LBL ***label***. The return stack will have ***y***, ***z***, and ***t*** cleared and the position ***x*** in **L**. |
| f"(x) | h P.FCN f"(x) ***label*** | | Either command will attempt to call a user routine labeled 'δx' to provide a fixed step size ***dx***. If that routine is not defined, a step size of 0.1 is employed instead. |
| GCD | h X.FCN GCD | \α | Returns the Greatest Common Divisor of ***x*** and ***y*** . |
| Geom<br>$Geom_P$<br>$Geom^{-1}$ | h PROB Geom etc. | DECM | Geometric distribution:<br>pdf: $f_{Ge}(m) = p_0(1-p_0)^m$,<br>cdf: $F_{Ge}(m) = 1-(1-p_0)^{m+1}$ is the probability for a first success after ***m*** = ***x*** Bernoulli experiments. The probability $p_0$ for a success in each such experiment must be specified in **J**.<br>$Geom^{-1}$ returns the number of failures ***f*** before the first success for given probabilities $F_{Ge}$ in **X** and $p_0$ in **J**. |
| **GRAD** | g GRAD | DECM | Sets angular mode to gon or grads. |
| GRAD→ | h X.FCN GRAD→ | DECM | Takes ***x*** as given in gon or grads and converts them to the angular mode currently set. |
| **GTO** | h GTO ***label*** | PRG | Inserts an unconditional branch to ***label***. |
| | | \PRG, \α | Positions the program pointer to ***label***. |
| | h GTO . A , B , C , or D | \α | Positions the program pointer … (not programmable). … to one of these labels, if defined. |
| | h GTO . ***nnn*** | | … to step ***nnn*** . |
| | h GTO . . | | … to step 000 . |
| GTOα | h P.FCN GTOα | \α | Takes the first three characters of ***alpha*** (or less if there are less available) as a label and positions the program pointer to it. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| $H_n$ | h X.FCN $H_n$ | DECM | Hermite's polynomials for probability: $H_n(x) = (-1)^n \cdot e^{x^2/2} \cdot \frac{d^n}{dx^n}\left(e^{-x^2/2}\right)$ with ***n*** in **Y**, solving the differential equation $f''(x) - 2x \cdot f'(x) + 2n \cdot f(x) = 0$ . |
| $H_{np}$ | h X.FCN $H_{np}$ | DECM | Hermite's polynomials for physics: $H_{np}(x) = (-1)^n \cdot e^{x^2} \cdot \frac{d^n}{dx^n}\left(e^{-x^2}\right)$ with ***n*** in **Y**. |
| **H.MS** | f H.MS | DECM | Assumes **X** containing *decimal* hours or degrees, and displays them converted in the format `hhhh°mm′ss.dd″` as shown in the paragraph above. Will return to the previous decimal display with the next keystroke thereafter. |
| **H.MS+** | h P.FCN H.MS+ | DECM | Assumes **X** and **Y** containing times or degrees in the format `hhhh.mmssdd`, and adds or subtracts them, respectively. |
| **H.MS–** | h P.FCN H.MS– | | |
| IBASE? | h TEST IBASE? | \α | Returns the integer base set (see BASE). |
| **IMPFRC** | g d/c | \α | Sets fraction mode allowing improper fractions in display (i.e. $^5/_3$ instead of 1 $^2/_3$). Converts ***x*** according to the settings by DEN… Absolute decimal equivalents of ***x*** must not exceed 100,000. Compare PROFRC. |
| | | FRC | Allows displaying improper fractions. Thus converts a proper fraction in **X** into the equivalent improper fraction, if applicable. |
| INC | h P.FCN INC ***r*** | \α | Increments ***r*** by one, equivalent to 1 STO+ ***r*** , but without modifying the stack. |
| INTM? | h TEST INTM? | \α | Tests if your WP 34S is in an integer mode. |
| INT? | h TEST INT? | \α | Tests ***x*** for being an integer, i.e. having a fractional part equal to zero. Compare FP?. |
| ***IP*** | f IP | DECM | Returns the integer part of ***x*** . |
| ISE | h P.FCN ISE ***r*** | PRG | Works like ISG but skips if `ccccccc` ≥ `fff` . |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| **ISG** | g ISG *r* | PRG | Given `cccccc.fffii` in *r*, this function increments *r* by `ii`, skipping next program line if then `ccccccc` > `fff`. If *r* features no fractional part then `ii` is set to 1.<br>Note that neither `fff` nor `ii` can be negative, but `cccccc` can. |
| ISZ | h P.FCN ISZ *r* | PRG | Increments *r* by one, skipping next program line if then $\lvert r \rvert < 1$. Known from the *HP-16C*. |
| I β | h X.FCN Iβ | DECM | Returns the regularized incomplete beta function $\frac{\beta_x(x,y,z)}{\beta(y,z)} = \frac{1}{\beta(y,z)} \cdot \int_0^x t^{y-1}(1-t)^{z-1} dt$ with $\beta_x$ being the incomplete beta function and $\beta$ being Euler's beta (see below). |
| I Γ | h X.FCN IΓ | DECM | Returns the regularized incomplete gamma function $\frac{\gamma(x,y)}{\Gamma(x)}$ with $\gamma(x,y) = \int_0^y t^{x-1} e^{-t} dt$ being the lower incomplete gamma function. For $\Gamma$ see below. |
| JG1582 | h X.FCN JG1582 | DECM | These two commands reflect different dates the Gregorian calendar was introduced in different large areas of the world. D→J and J→D will be calculated accordingly. |
| JG1752 | h X.FCN JG1752 | | |
| J→D | h X.FCN J→D | DECM | Takes *x* as a Julian day number and converts it to a date according to JG... in the format selected |
| KEY? | h TEST KEY? *a* | All | Tests if a key was pressed while a program was running or paused. If no key was pressed, the next program step after KEY? will be executed, else it will be skipped and the code of said key will be found in address *a*. Key codes start top left and correspond to the rows and columns on the keyboard – so e.g. A corresponds to 11, CPX to 16, STO to 21, and + to 75. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| KTY? | h TEST KTY? ***a*** | All | Assumes a key code in address ***a*** . Checks this code returning<br>• 0 … 9 if it corresponds to a digit 0 … 9 ,<br>• 10 if it corresponds to ., EEX, or +/− ,<br>• 11 if it corresponds to f, g, or h ,<br>• 12 if it corresponds to any other key.<br>May help in user interaction with programs. |
| ***LASTx*** | RCL L | \α | See above for details. |
| **LBL** | f LBL ***label*** | PRG | Identifies programs and routines for execution and branching. See opportunities for specifying ***label*** in the table above. |
| LBL? | h TEST LBL? ***label*** | All | Tests for the existence of the label specified, anywhere in program memory. See opportunities for specifying ***label*** in the table above. |
| LCM | h X.FCN LCM | \α | Returns the Least Common Multiple of $x$ and $y$. |
| LEAP? | h TEST LEAP? | DECM | Takes $x$ as a date in the format selected, extracts the year, and tests for a leap year. |
| LgNrm<br>LgNrm$_P$<br>LgNrm$^{-1}$ | h PROB LgNrm etc. | DECM | Lognormal distribution with $\mu = \ln \bar{x}_g$ specified in **J** and $\sigma = \ln \varepsilon$ in **K**. See x̄g and ε below.<br>pdf: $f_{Ln}(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$ ,<br>cdf: $F_{Ln}(x) = \Phi\left(\frac{\ln x - \mu}{\sigma}\right)$ with $\Phi(z)$ denoting the standard normal cdf.<br>LgNrm$^{-1}$ returns $x$ for a given probability $F_{Ln}$ in **X**, $\mu$ in **J**, and $\sigma$ in **K**. |
| LinF | h STAT LinF | DECM | Selects the linear curve fit model $y = a_0 + a_1 x$ . |
| LJ | h X.FCN LJ | Integer | Left adjust as in *HP-16C*. |
| ***LN*** | g LN | DECM | Returns the natural logarithm of $x$ , i.e. the logarithm of $x$ for base *e*. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| $L_n$ | h X.FCN $L_n$ | DECM | Laguerre's polynomials (compare $L_n\alpha$ below): $L_n(x)=\frac{e^x}{n!}\cdot\frac{d^n}{dx^n}\left(x^n e^{-x}\right)=L_n^{(0)}(x)$ with ***n*** in **Y**, solving the differential equation $x\cdot y''+(1-x)y'+ny=0$ . |
| *LN1+x* | h X.FCN LN1+x | DECM | Natural logarithm of values close to zero. Returns $\ln(1+x)$ , providing a much higher accuracy in the fractional part of the result. |
| $L_n\alpha$ | h X.FCN $L_n\alpha$ | DECM | Laguerre's generalized polynomials with ***n*** in **Y** and **α** in **Z**: $L_n^{(\alpha)}(x)=\frac{x^{-\alpha}e^x}{n!}\cdot\frac{d^n}{dx^n}\left(x^{n+\alpha}e^{-x}\right)$ . |
| *LN β* | h STAT LNβ<br>h X.FCN LNβ | DECM | Returns the natural logarithm of Euler's $\beta$ function. See there. |
| *LN Γ* | h STAT LNΓ<br>h X.FCN LNΓ | DECM | Returns the natural logarithm of $\Gamma(x)$ . See there. |
| LOAD | h P.FCN LOAD | \α | Restore the entire backup. See SAVE. |
| ***$LOG_{10}$*** | g LG | DECM | Returns the logarithm of $x$ for base 10. |
| ***$LOG_2$*** | g LB | \α | Returns the logarithm of $x$ for base 2. |
| LogF | h STAT LogF | DECM | Selects the logarithmic curve fit model $y=a_0+a_1\ln x$ . |
| Logis<br>$Logis_P$<br>Logis $^{-1}$ | h PROB Logis etc. | DECM | Logistic distribution with ***μ*** given in **J** and ***s*** in **K**<br>pdf: $f_{Lg}(x)=e^{-\frac{x-\mu}{s}}\Big/ s\cdot\left(1+e^{-\frac{x-\mu}{s}}\right)^2$ ,<br>cdf: $F_{Lg}(x)=\left(1+e^{-\frac{x-\mu}{s}}\right)^{-1}$<br>Logis $^{-1}$ returns $F_{Lg}^{-1}(p)=\mu+s\cdot\ln\left(\frac{p}{1-p}\right)$ for a probability ***p*** given in **X**, ***μ*** in **J**, and ***s*** in **K**. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| ***LOGx*** | g LOGx | DECM | Returns the logarithm of $y$ for base $x$ . |
| | CPX g LOGx | DECM | Returns the complex logarithm of $z + i\,t$ for the complex base $x + i\,y$ . |
| LZOFF<br>LZON | h MODE LZOFF etc. | \α | Toggles leading zeros like flag 3 does in *HP-16C*. Relevant in integer modes only. |
| **L.R.** | h L.R. | DECM | Returns the parameters $a_1$ and $a_0$ of the fit curve through the data points accumulated, according to the model selected, and pushes them on the stack. For a straight regression line, $a_0$ is the y-intercept and $a_1$ the slope. |
| MANT | h X.FCN MANT | DECM | Returns the mantissa $m$ of the number displayed $x = m \cdot 10^h$ . Also see EXPT. |
| MASKL<br>MASKR | h X.FCN MASKL $\underline{n}$ etc. | Integer | Work like MASKL and MASKR on *HP-16C*, but with the mask length following the command instead of taken from **X**. |
| MAX<br>MIN | h X.FCN MAX etc. | \α | Returns the maximum (minimum) of $x$ and $y$ . |
| MIRROR | h X.FCN MIRROR | Integer | Reflects the bit pattern in $x$<br>(e.g. 000101 becomes 101000 for word size 6). |
| MONTH | h X.FCN MONTH | DECM | Assumes $x$ containing a date in the format selected and extracts the month. |
| M.DY | h MODE M.DY | \α | Sets the format for date display. |
| NAND | h X.FCN NAND | \α | Works in analogy to AND. |
| NaN? | h TEST NaN? | \α | Tests $x$ for being “Not a Number”. |
| nBITS | h X.FCN nBITS | Integer | Counts bits set in $x$ like #B does on *HP-16C*. |
| NEXTP | h X.FCN NEXTP | \α | Returns the next prime number > $x$. |
| NOP | h P.FCN NOP | PRG | “Empty” step FWIW. |
| NOR | h X.FCN NOR | \α | Works in analogy to AND. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| Norml<br>Norml$_P$ | h PROB Norml etc. | DECM | Normal distribution with an arbitrary mean $\boldsymbol{\mu}$ specified in **J** and standard deviation $\boldsymbol{\sigma}$ in **K** :<br>pdf [19]: $f_N(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$,<br>cdf: $F_N(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$. See below for $\Phi$. |
| Norml$^{-1}$ | h PROB Norml etc. | DECM | Returns ***x*** for a given probability $\boldsymbol{F_N}$ in **X**, mean $\boldsymbol{\mu}$ in **J**, and standard deviation $\boldsymbol{\sigma}$ in **K** [20]. |
| **NOT** | h NOT | Integer | Works in analogy to AND. |
| n$\Sigma$ | h STAT n$\Sigma$ | DECM | Recalls the number of accumulated data points. Necessary for basic statistics. |
| ODD? | h TEST ODD? | \α | Checks if ***x*** is integer and odd. |
| **OFF** | g OFF | PRG | Inserts a step to turn your WP 34S off under program control. |
| **OR** | h OR | \α | Works in analogy to AND. |
| ***PERM*** | g Py.x | DECM | Returns the number of possible arrangements of ***y*** items taken ***x*** at a time. No item occurs more than once in an arrangement, and different orders of the same ***x*** items are counted separately.<br>Formula: $P_{y,x} = x! \cdot C_{y,x}$ , compare COMB. |
| P$_n$ | h X.FCN P$_n$ | DECM | Legendre's polynomials:<br>$P_n(x) = \frac{1}{2^n n!} \cdot \frac{d^n}{dx^n}\left[\left(x^2-1\right)^n\right]$ with ***n*** in **Y**, solving the differential equation<br>$\frac{d}{dx}\left[\left(1-x^2\right)\cdot\frac{d}{dx}f(x)\right] + n(n+1)f(x) = 0$. |

[19] The pdf corresponds to NORMDIST(***x; μ; σ; 0***) and the cdf to NORMDIST(***x; μ; σ; 1***) in MS Excel.

[20] This corresponds to NORMINV($\boldsymbol{F_N}$***; μ; σ***) in MS Excel.

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| Poiss<br>Poiss$_P$<br>Poiss $^{-1}$ | h PROB Poiss etc. | DECM | Poisson distribution with the number of successes ***g*** in $\mathbf{X}$, the gross error probability $\boldsymbol{p_0}$ in $\mathbf{J}$, and the sample size ***n*** in $\mathbf{K}$. Alternatively, Poisson's $\lambda = n \cdot p_0$ may be in $\mathbf{J}$ if ***k*** = 1:<br>pmf [21]: $P_P(g;\lambda) = \frac{\lambda^g}{g!} e^{-\lambda}$,<br>cdf: $F_P(m;\lambda) = \sum_{g=0}^{m} P_P(g;\lambda)$, with the maximum number of successes ***m*** in $\mathbf{X}$.<br>Poiss $^{-1}$ returns ***m*** for given probabilities $\boldsymbol{F_P}$ in $\mathbf{X}$ and ***p*** in $\mathbf{J}$ with sample size ***n*** in $\mathbf{K}$. |
| PowerF | h STAT PowerF | DECM | Selects the power curve fit model $y = a_0 x^{a_1}$. |
| PRCL | h P.FCN PRCL ***n*** | \α | Recall the user program space from flash segment ***n*** to RAM where it may be edited then (see *above*). |
| PRIME? | h TEST PRIME? | \α | Checks if the absolute value of the integer part of ***x*** is a prime. The method is believed to work for integers up to 9E18. |
| **PROFRC** | f a b/c | DECM | Sets fraction mode like in *HP-35S*, allowing only proper fractions or mixed numbers in display. Converts ***x*** according to the settings by DEN… Absolute decimal equivalents of ***x*** must not exceed 100,000. Compare IMPFRC. |
| | | FRC | Allows displaying only proper fractions. Thus converts an improper fraction in $\mathbf{X}$, if applicable, e.g. $^5/_3$ into 1 2/3. |
| PROMPT | h P.FCN PROMPT | PRG | Displays ***alpha*** and stops program execution (equaling αVIEW followed by STOP actually). See *below* for more. |
| **PSE** | h PSE ***nn*** | PRG | Refreshes the display and pauses program execution for ***nn*** ticks, with $0 \le nn \le 99$. The pause will be terminated early as soon as a key is pressed. |
| PSTO | h P.FCN PSTO ***n*** | \α | Stores the user program space in flash segment ***n*** (see *above*). |

[21] The pmf corresponds to POISSON(***g***; ***λ***; **0**) and the cdf to POISSON(***g***; ***λ***; **1**) in MS Excel.

| Name | Keys to press | in modes | Remarks |
| --- | --- | --- | --- |
| PUTK | h P.FCN PUTK ***a*** | All | Assumes a key code in address ***a*** . Stops program execution, takes said code and puts it in the keyboard buffer resulting in immediate execution of the corresponding call. R/S is required to resume program execution.<br>May help in user interaction with programs. |
| P⇆ | h P.FCN P⇆ ***n*** | \α | Exchanges the user program space with the contents of flash segment ***n*** (see above). |
| **RAD** | g RAD | DECM | Sets angular mode to radians. |
| RAD→ | h X.FCN RAD→ | DECM | Takes $x$ as radians and converts them to the angular mode currently set. |
| **RAN#** | f RAN# | DECM | Returns a random number between 0 and 1 like RAN in *HP-42S*. |
| | | Integer | Returns a random bit pattern for the word size set. |
| *RCF* | h P.FCN RCF s<br>h X.FCN RCF s | \α | Works like RCL but recalls from a register in flash memory. Also the six recall arithmetic operations may be performed like with RCL. |
| RCF.RG | h P.FCN RCF.RG | \α | Recovers all general purpose registers from the backup region (see SAVE and above). |
| RCF.ST | h P.FCN RCF.ST | \α | Recovers the system state from the backup region (see SAVE and above). |
| ***RCL*** | RCL | \α | See the addressing table above for CRCL. |
| **RCLM** | RCL MODE s<br>h P.FCN RCLM s | \α | Recalls mode settings stored via STOM as described above. |
| RCLS | h P.FCN RCLS s | \α | Recalls 4 or 8 values from a set of registers starting at address ***s***, and pushes them on the stack. This is the converse command of STOS. |
| ***RCL+*** | RCL + s | \α | Recalls the content of address ***s***, executes the specified operation on it and pushes the result on the stack.<br>E.g. RCL–12 subtracts $r12$ from $x$ and displays the result (acting like RCL 12 −, but without losing a stack level). In analogy, CRCL–12 subtracts $r12$ from $x$ and $r13$ from $y$.<br>See the addressing table above for CRCL. |
| ***RCL–*** | RCL − s | \α | |
| ***RCL×*** | RCL × s | \α | |
| ***RCL/*** | RCL / s | \α | |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| **RCL↑** | RCL ▲ *s* | \α | RCL↑ (↓) recalls the maximum (minimum) of the values in ***s*** and **X**. |
| **RCL↓** | RCL ▼ *s* | | |
| **RDX,** | h MODE RDX**,** | \α | Sets the decimal mark to a comma. |
| | h P.FCN RDX**,** | | |
| | h ./, | | Toggles the radix mark. |
| **RDX.** | h MODE RDX**.** | \α | Sets the decimal mark to a point. |
| | h P.FCN RDX**.** | | |
| REALM? | h TEST REALM? | \α | Tests if your WP 34S is in real mode. |
| RECV | h P.FCN RECV | \α | Prepares your WP 34S for receiving data via serial I/O. See *Appendix A* for more. |
| RESET | h X.FCN RESET | All | Executes CLALL and resets all modes to start-up default, i.e. 24h, 2COMPL, ALL 00, DEG, DENANY, DENMAX 9999, DECM, LinF, PROFRC, RDX**.**, SCIOVR, SSIZE4, WSIZE 64, Y.MD. See these commands for more information. RESET is not programmable. |
| RJ | h X.FCN RJ | Integer | Right adjusts, in analogy to LJ on *HP-16C*. |
| RL | h X.FCN RL *n* | Integer | Works like ***n*** consecutive RLs / RLCs on *HP-16C*. For RL, 1 ≤ ***n*** ≤ 63. For RLC, 1 ≤ ***n*** ≤ 64. RL 0 and RLC 0 execute as NOP. |
| RLC | h X.FCN RLC *n* | | |
| RM | h MODE RM | \α | Sets the floating point rounding mode. This is for numerical mathematics geeks only, since it is only used when converting from the high precision internal format to packed real numbers. It will not alter the display nor change the behavior of ROUND. The following modes are supported:<br>0: round half even: ½ = 0.5 rounds to next even number (default).<br>1: round half up: 0.5 rounds up.<br>2: round half down: 0.5 rounds down.<br>3: round up: away from 0.<br>4: round down: towards 0 (truncates).<br>5: ceiling: rounds towards +∞.<br>6: floor: rounds towards –∞. |
| RM? | h TEST RM? | \α | Returns the floating point rounding mode set. See RM for more. |
| **RMDR** | h RMDR | \α | Equals RMD on *HP-16C*. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| ***ROUND*** | g RND | DECM | Rounds *x* using the current display format, like RND in *HP-42S*. |
| | | FRC | Rounds *x* using the current denominator, like RND in *HP-35S* fraction mode. |
| ROUNDI | h X.FCN ROUNDI | DECM | Rounds ***x*** to next integer. ½ rounds to 1. |
| RR | h X.FCN RR ***n*** | Integer | Works like ***n*** consecutive RRs / RRCs on *HP-16C*. See RL / RLC for more. |
| RRC | h X.FCN RRC ***n*** | | |
| **RTN** | g RTN | \PRG | Moves the program pointer to step 000. |
| | | PRG | Last command in a routine. Returns control to the calling routine in program execution, i.e. moves the program pointer one step behind the most recent XEQ instruction encountered. If there is none, program execution halts and the program pointer is set to step 000. |
| RTN+1 | h P.FCN RTN+1 | PRG | Returns control to the calling routine like RTN, but moves the program pointer to the second line following the most recent XEQ instruction encountered. If there is none, program execution halts. |
| R-CLR | h P.FCN R-CLR | DECM | Interprets ***x*** in the form `ss.nn` . Clears ***nn*** registers starting with number ***ss*** . E.g. for ***x*** = 34.56, R-CLR will clear **R34** through **R89**. |
| R-COPY | h P.FCN R-COPY | DECM | Interprets ***x*** in the form `ss.nndd` . Takes ***nn*** registers starting with number ***ss*** and copies their contents to ***dd*** etc. E.g. for ***x*** = 7.0345678, ***r07, r08, r09*** will be copied into **R45, R46, R47**, respectively. For ***x*** < 0 , R-COPY will take ***nn*** registers from flash memory instead, starting with register number \|***ss***\| there. |
| R-SORT | h P.FCN R-SORT | DECM | Interprets ***x*** in the form `ss.nn` . Sorts the contents of ***nn*** registers starting with number ***ss*** . Assume ***x*** = 49.036 , ***r49*** = 1.2 , ***r50*** = –3.4 , and ***r51*** = 0 ; then R-SORT will return ***r49*** = -3.4 , ***r50*** = 0 , and ***r51*** = 1.2. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| R-SWAP | h P.FCN R-SWAP | DECM | Works like R-COPY but swaps the contents of source and destination registers. |
| R→D | | DECM | Please see the *catalog of conversions below* for conversions of radians to degrees. |
| ***R↑*** | h R↑ | \α | Rotates the stack contents one level up or down, respectively. See *above* for details. |
| ***R↓*** | R↓ | | |
| **s** | g s | DECM | Takes the statistical sums accumulated, calculates the sample standard deviations $s_y$ and $s_x$ and pushes them on the stack. |
| SAVE | h P.FCN SAVE | \α | Saves user program space, registers and system state to flash memory. Program space is stored in segment 0. Registers and system state are in their own special region. |
| SB | h X.FCN SB ***n*** | Integer | Sets the specified bit in $x$ . |
| **SCI** | h SCI ***n*** | \α | Sets scientific display format. |
| **SCIOVR** | h SCI ENTER↑ | \α | Numbers exceeding the range displayable in ALL or FIX will be shown in scientific format (default as in vintage HP calculators). Compare ENGOVR. |
| SDL | h X.FCN SDL ***n*** | DECM | Shifts digits left by ***n*** decimals, equivalent to multiplying $x$ by $10^n$ . |
| SDR | h X.FCN SDR ***n*** | DECM | Shifts digits right by ***n*** decimals, equivalent to dividing $x$ through $10^n$ . |
| SEED | h STAT SEED | DECM | Stores a seed for random number generation. |
| SENDA | h P.FCN SENDA | \α | Sends all RAM data … <br>… via serial I/O to the device connected. See *Appendix A* below for more. |
| SENDL | h P.FCN SENDL ***n*** | \α | Sends the library file of region ***n*** into RAM … |
| SENDP | h P.FCN SENDP | \α | Sends the user program memory … |
| SENDR | h P.FCN SENDR | \α | Sends the general purpose registers 00 to 99 … |
| SERR | h STAT SERR | DECM | Works like s but pushes the standard errors $s/\sqrt{n}$ on the stack (i.e. the standard deviations of $\bar{x}$ and $\bar{y}$ ). |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| SERRw | h STAT SERRw | DECM | Works like sw but returns the standard error $s/\sqrt{\sum y_i}$ (i.e. the standard deviation of $\bar{x}$w). |
| SETCHN | h MODE SETCHN | \α | Sets some regional preferences (see *above*). |
| SETDAT | h X.FCN SETDAT | DECM | Sets the date for the real time clock (doesn't work with the emulator, since the emulator takes this information from the PC clock). |
| SETEUR<br>SETIND | h MODE SETEUR etc. | \α | Set some regional preferences (see *above*). |
| SETTIM | h X.FCN SETTIM | DECM | Sets the time for the real time clock (doesn't work with the emulator, since the emulator takes this information from the PC clock). |
| SETUK<br>SETUSA | h MODE SETUK etc. | \α | Set some regional preferences (see *above*). |
| SF | h P.FCN SF ***n*** | \α | Sets the flag specified. |
| **SHOW** | h SHOW | DECM & \PRG | Shows the full mantissa until the next key is pressed. See *above*. |
| | | PRG | Displays a CRC checksum of program memory contents, allowing validation of program integrity. Not programmable. |
| *SIGN* | h X.FCN SIGN | \α | Returns 1 for $x > 0$, $-1$ for $x < 0$, and 0 for $x = 0$ or non-numbers. |
| | CPX X.FCN SIGN | DECM | Returns the unit vector of $x + i\,y$ in $\mathbf{X}$ and $\mathbf{Y}$. |
| SIGNMT | h MODE SIGNMT | \α | Sets sign-and-mantissa mode for integers. |
| ***SIN*** | f SIN | DECM | Returns the sine of the angle in $\mathbf{X}$. |
| *SINC* | h X.FCN SINC | DECM | Returns $\frac{\sin(x)}{x}$. |
| ***SINH*** | f HYP SIN | DECM | Returns the hyperbolic sine of $x$. |
| SKIP | h P.FCN SKIP ***n*** | PRG | Skips ***n*** program steps forwards ($1 \le n \le 99$). So e.g. SKIP 02 skips over the next two steps, going e.g. from step 123 to step 126. If the skip would land beyond the end of occupied program memory, the same will happen as if a RTN had been encountered. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| SL | h X.FCN SL ***n*** | Integer | Works like ***n*** (up to 63) consecutive SLs on *HP-16C*. SL 0 executes as NOP. |
| SLOW | h MODE SLOW | All | Sets the processor speed to “slow”. This is also entered for low battery voltage. |
| **SLV** | f SLV ***label*** | DECM | Solves the equation f($x$) = 0, with f($x$) calculated by the routine specified. Two initial estimates of the root must be supplied in **X** and **Y** when calling SLV. For the rest, the user interface is as in *HP-15C*. This also means SLV acts as a test, so the next program step will be skipped if SLV failed to find a root. |
| SLVQ | h X.FCN SLVQ | DECM | Solves the quadratic equation $ax^2+bx+c=0$, with the real parameters put on the stack [ ***c, b, a***, …] , and tests the result.<br>• If $r := b^2 - 4ac \geq 0$, SLVQ returns $-\frac{b \pm \sqrt{r}}{2a}$ in **Y** and **X**. In a program, the step after SLVQ will be executed.<br>• Else, SLVQ returns the real part of the first complex root in **X** and its imaginary part in **Y** (the 2nd root is the conjugate of the first – see CONJ). If run directly from the keyboard, the complex indicator is lit then – in a program, the step after SLVQ is skipped.<br>In either case, ***r*** is returned in **Z**. Higher stack levels are kept unchanged. **L** contains ***c***. |
| SMODE? | h TEST SMODE? | \α | Returns the integer sign mode set, i.e.<br>2 (meaning “true”) for 2’s complement,<br>1 (“true” again) for 1’s complement,<br>0 (i.e. “false”) for unsigned, or<br>-1 (i.e. “true”) for sign and mantissa mode. |
| SPEC? | h TEST SPEC? | \α | True if ***x*** is special, i.e. infinity or NaN. |
| SR | h X.FCN SR ***n*** | Integer | Works like ***n*** consecutive SRs on *HP-16C*. SR 0 executes as NOP. |
| SSIZE4 | h MODE SSIZE4 | \α | Sets the stack size to 4 or 8 levels, respectively. See *above*. The same will happen if stack size is changed via RCLM. |
| SSIZE8 | h MODE SSIZE8 | | |
| SSIZE? | h TEST SSIZE? | \α | Returns the number of stack levels accessible. |
| **STATUS** | h STATUS | \PRG | Shows the status of all user flags, similar to STATUS on *HP-16C*. See *above*. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| ***STO*** | STO ***d*** | \α | See the *addressing table above* for ᶜSTO. |
| **STOM** | STO MODE ***s***<br>h P.FCN STOM ***s*** | \α | Stores mode settings for later use as described *above*. Take RCLM to recall them. |
| **STOP** | R/S | PRG | Stops program execution. May be used to wait for an input, for example. |
| STOS | h P.FCN STOS ***d*** | \α | Stores all stack levels in a set of 4 or 8 registers, starting at destination ***d***. |
| ***STO+*** | STO + ***d*** | \α | Executes the specified operation on the content of address ***d*** and stores the result into said address.<br>E.g. STO–12 subtracts $x$ from $r12$ like the sequence RCL 12 x≷y − STO 12 does, but without touching the stack at all.<br>See the *addressing table above* for ᶜSTO. |
| ***STO–*** | STO − ***d*** | | |
| ***STO×*** | STO × ***d*** | | |
| ***STO/*** | STO / ***d*** | | |
| **STO↑** | STO ▲ ***d*** | \α | STO↑ (↓) takes the maximum (minimum) of the values in ***d*** and $\mathbf{X}$ and stores it. |
| **STO↓** | STO ▼ ***d*** | | |
| SUM | h STAT SUM | DECM | Recalls the linear sums $\Sigma y$ and $\Sigma x$. Useful for elementary vector algebra in 2D. |
| sw | h STAT sw | DECM | Returns the standard deviation for weighted data $$s_w = +\sqrt{\frac{\sum y_i \cdot \sum\left(y_i \cdot x_i^2\right) - \left[\sum\left(y_i \cdot x_i\right)\right]^2}{\left(\sum y_i\right)^2 - \sum y_i^2}}$$ with the weights entered in y via Σ+. |
| sxy | h STAT sxy | DECM | Returns the sample covariance for two data sets. It depends on the fit model selected. For LinF, it returns $$s_{xy} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{n \cdot (n-1)} .$$ See COV for the population covariance. |
| ***TAN*** | f TAN | DECM | Returns the tangent of the angle in $\mathbf{X}$. |
| ***TANH*** | f HYP TAN | DECM | Returns the hyperbolic tangent of $x$. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| TICKS | h P.FCN TICKS | \α | Returns the number of ticks from the real time clock at execution time. With the quartz built in, 1 tick = 0.1 s. Without, it may be 10% more or less. So the quartz is inevitable prerequisite for the clock being useful in medium to long range. |
| TIME | h P.FCN TIME | DECM, α | Recalls the time from the real time clock at execution, displaying it in the format `hh.mmssdd` in 24h-mode. Chose FIX 6 for best results. |
| $T_n$ | h X.FCN $T_n$ | DECM | Chebychev's (a. k. a. Čebyšev, Tschebyschow, Tschebyscheff) polynomials of first kind $T_n(x)$ with ***n*** in **Y**, solving the differential equation $(1-x^2)y''-x\cdot y'+n^2 y=0$. |
| TOP? | h TEST TOP? | PRG | Executes the next step only if it is called from a program that isn't a subroutine, i.e. if the program running flag is set and the return stack pointer points to an empty stack. |
| $t_P(x)$<br>t(x)<br>$t^{-1}(p)$ | h PROB t(x) etc. | DECM | Student's t distribution. t(x) equals 1 – Q(t) in *HP-21S*. The degree of freedom is stored in **J**. |
| $U_n$ | h X.FCN $U_n$ | DECM | Chebychev's polynomials of second kind $U_n(x)$ with ***n*** in **Y**, solving the differential equation $(1-x^2)y''-3x\cdot y'+n(n+2)y=0$. |
| UNSIGN | h MODE UNSIGN | \α | Sets unsigned mode for integers. |
| VERS | h X.FCN VERS | \PRG | Shows the firmware version and build number. |
| **VIEW** | h VIEW <u>s</u> | \α | Displays the content of address ***s*** until the next key is pressed. See <u>*below*</u> for more. |
| **VWα+** | h VIEW <u>s</u> | α | Displays the alpha register in the top line plus the contents of address ***s*** in the bottom line until the next key is pressed. See <u>*below*</u> for more. |
| *W* | h X.FCN W | DECM | Returns Lambert's W for given ***x*** ≥ –1/e . |
| WDAY | h X.FCN WDAY | DECM | Takes ***x*** as a date in the format selected and returns the name of the day in the dot matrix and a corresponding integer in the numeric display (Monday = 1, Sunday = 7). |
| $W^{-1}$ | h X.FCN $W^{-1}$ | DECM | Returns ***x*** for given W ( ≥ -1). See W above. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| Weibl | h PROB Weibl etc. | DECM | Weibull distribution with the shape parameter ***b*** in **J** and the characteristic lifetime ***T*** in **K**: pdf [22]: $f_W(t)=\frac{b}{T}\left(\frac{t}{T}\right)^{b-1}e^{-\left(\frac{t}{T}\right)^b}$, cdf: $F_W(t)=1-e^{-\left(\frac{t}{T}\right)^b}$. Weibl $^{-1}$ returns the survival time $t_s$ for given probability $F_W$, ***b*** in **J** and ***T*** in **K**. |
| Weibl$_P$ | | | |
| Weibl $^{-1}$ | | | |
| WSIZE | h MODE WSIZE ***n*** | \α | Works like on *HP-16C*, but with the parameter following the command instead of taken from **X**. Reducing the word size truncates the values in the stack registers employed, including **L**. WSIZE 0 sets the word size to maximum, i.e. 64 bits. |
| WSIZE? | h TEST WSIZE? | \α | Recalls the word size set. |
| ***x*** $^2$ | g $x^2$ | \α | |
| **XEQ** | XEQ ***label*** | PRG | Calls the respective subroutine. |
| | | \PRG, \α | Executes the respective program. |
| | A, B, C, or D (you may need f for reaching these hotkeys in integer bases >10.) | PRG | Calls the respective subroutine, so e.g. XEQ C will be inserted when C is pressed. |
| | | \PRG, \α | Executes the respective program if defined. |
| XEQα | h P.FCN XEQα | \α | Takes the first three characters of ***alpha*** (or less if there are less) as a label and calls or executes the respective routine. |
| XNOR | h X.FCN XNOR | \α | Works in analogy to AND. |
| **XOR** | h XOR | \α | Works in analogy to AND. |
| **x̄** | f x̄ | DECM | Returns the arithmetic means, pushing $\bar{y}=\frac{1}{n}\sum y$ and $\bar{x}=\frac{1}{n}\sum x$ on the stack. See also s, SERR, and σ. |

[22] The pdf equals WEIBULL(***x; b; T;* 0**) and the cdf WEIBULL(***x; b; T;* 1**) in MS Excel.

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| $\bar{x}_g$ | h STAT $\bar{x}_g$ | DECM | Returns the geometric means, pushing $\bar{y}_g = \sqrt[n]{\prod y} = e^{\frac{1}{n}\sum \ln y}$ and $\bar{x}_g = \sqrt[n]{\prod x}$ on the stack. See also ε , $ε_m$ , and $ε_P$ . |
| $\bar{x}_w$ | h STAT $\bar{x}_w$ | DECM | Returns the weighted arithmetic mean $\sum xy \Big/ \sum y$ . See also sw and SERRw. |
| $\sqrt[x]{y}$ | h X.FCN $\sqrt[x]{y}$ | \α | |
| $\hat{x}$ | h STAT $\hat{x}$ | DECM | Returns a forecast ***x*** for a given ***y*** (in **X**) following the fit model chosen. See L.R. for more. |
| ***x !*** | h ! | DECM | Return the factorial, equaling *Γ(x + 1)* . |
| x → α | g x◀▶α | All | Interprets ***x*** as character code. Appends the respective character to ***alpha***, similar to XTOA in *HP-42S*. |
| ***x⇆*** | h x⇆ ***r*** | \α | Swaps the contents of **X** and ***r*** , in analogy to ***x⇆y***. |
| ***x⇆y*** | x⇆y | \α | Swaps ***x*** and ***y*** , performing Re⇆Im if a complex operation was executed immediately before. See above for details. |
| x < … ? | h TEST x < ? ***a*** | \α | Compare ***x*** with ***a***. E.g. h TEST x < ? K will compare ***x*** with the contents of register **K** , and will be listed as x<K? in a program. See the examples given in the addressing table above for more.<br>x ≈ ? will be true if the rounded values of ***x*** and ***a*** are equal (see ROUND).<br>CPX f x = ? ***a*** and CPX g x ≠ ? ***a*** compare the complex number $x + i\,y$ as explained in the addressing table above.<br>The signed tests x = +0 ? and x = –0 ? are meant for integer modes 1COMPL and SIGNMT, and for DECM if flag **D** is set. Then, e.g. 0 divided by -7 will display -0. |
| x ≤ … ? | h TEST x ≤ ? ***a*** | | |
| ***x = … ?*** | f x = ? ***a*** | | |
| x = +0 ? | h TEST x=+0? | | |
| x = –0 ? | h TEST x=–0? | | |
| x ≈ … ? | h TEST x ≈ ? ***a*** | | |
| ***x ≠ … ?*** | g x ≠ ? ***a*** | | |
| x ≥ … ? | h TEST x ≥ ? ***a*** | | |
| x > … ? | h TEST x > ? ***a*** | | |
| YEAR | h X.FCN YEAR | DECM | Assumes ***x*** containing a date in the format selected and extracts the year. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| $y^x$ | f $y^x$ | \α | In integer modes $x$ must be $\geq 0$. |
| | C | \α & \(13, 14, 15, h) | Shortcut working as long as label C is not defined yet. |
| ŷ | f ŷ | DECM | Returns a forecast $y$ (in **X**) for a given $x$ following the fit model chosen. See L.R. for more. |
| Y.MD | h MODE Y.MD | \α | Sets the format for date display. |
| αDATE | h X.FCN αDATE | \integer | Takes $x$ as a date and appends it to ***alpha*** in the format set. See DATE. – To append a date stamp to ***alpha***, call DATE αDATE. |
| αDAY | h X.FCN αDAY | \integer | Takes $x$ as a date, recalls the name of the respective day and appends its first 3 letters to ***alpha***. |
| αGTO | h P.FCN αGTO ***nn*** | \α | Takes the contents of **R*nn*** as character code. Takes the first three characters of the converted code (or less if there is only less) as an alpha label and positions the program pointer to it. |
| αIP | h X.FCN αIP | All | Appends the integer part of $x$ to ***alpha***, similar to AIP in *HP-42S*. |
| αLENG | h X.FCN αLENG | All | Returns the number of characters found in ***alpha***, like ALENG in *HP-42S*. |
| αMONTH | h X.FCN αMONTH | \integer | Takes $x$ as a date, recalls the name of the respective month and appends its first 3 letters to ***alpha***. |
| αOFF | h P.FCN αOFF | PRG & α | Work like AOFF and AON in *HP-42S*, turning alpha mode off and on. |
| αON | h P.FCN αON | PRG & \α | |
| **αRCL** | f RCL ***s*** | α | Interprets the content of the source ***s*** as characters and appends them to ***alpha***. |
| | h X.FCN αRCL ***s*** | \α | |
| αRC# | h X.FCN αRC# ***s*** | All | Takes the content of ***s*** as a number, converts it to a string in the format set, and appends this to ***alpha***. If e.g. ***s*** = 1234 and ENG 2 and RDX**.** are set, then ␣1.23E3 will be appended. |
| αRL | h X.FCN αRL ***n*** | All | Rotates ***alpha*** by ***n*** characters like AROT in *HP-42S*, but with $n \geq 0$ and the parameter trailing the command instead of taken from **X**. αRL 0 executes as NOP. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| αRR | h X.FCN αRR ***n*** | All | Works like αRL but rotates to the right. |
| αSL | h X.FCN αSL ***n*** | All | Shifts the ***n*** leftmost characters out of ***alpha***, like ASHF in *HP-42S*. αSL 0 equals NOP. |
| αSR | h X.FCN αSR ***n*** | All | Works like αSL but takes the ***n*** rightmost characters instead. |
| **αSTO** | f STO ***d*** | α | Stores the first (i.e. leftmost) 6 characters in the alpha register into destination ***d*** . |
| | h X.FCN αSTO ***d*** | \α | |
| αTIME | h X.FCN αTIME | \integer | Takes ***x*** as a decimal time and appends it to ***alpha*** in the format `hh:mm:ss` according to the time mode selected. See TIME. – To append a time stamp to ***alpha***, call TIME αTIME. |
| αVIEW | h VIEW α | All | Displays ***alpha*** in the top line and - - - in the bottom line until the next key is pressed. See *below* for more. |
| | h P.FCN αVIEW | | |
| | h X.FCN αVIEW | | |
| αXEQ | h P.FCN αXEQ ***nn*** | \α | Takes the contents of **R*nn*** as character code. Interprets the first three characters (or less if there are only less) of the converted code as an alpha label and calls or executes the respective routine. |
| α → x | f x◀▶α | All | Returns the character code of the leftmost character in ***alpha*** and deletes this character, like ATOX in *HP-42S*. |
| *β* | h STAT β | DECM | Returns Euler's Beta $B(x,y)=\frac{\Gamma(x)\cdot\Gamma(y)}{\Gamma(x+y)}$ with $\mathrm{Re}(x)>0$ , $\mathrm{Re}(y)>0$. Called $\beta$ here for avoiding ambiguities. |
| | h X.FCN β | | |
| *Γ* | h STAT Γ | DECM | Returns $\Gamma(x)$ . Additionally, h ! calls $\Gamma(x+1)$. |
| | h X.FCN Γ | | |
| ΔDAYS | h X.FCN ΔDAYS | DECM | Assumes **X** and **Y** containing dates in the format chosen and calculates the number of days between them. Works like in *HP-12C*. |
| **Δ%** | g Δ% | DECM | Returns $100\cdot\frac{x-y}{y}$ like %CH in *HP-42S*. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| ε | h STAT ε | DECM | Calculates the scattering factors (or geometric standard deviations) for lognormally distributed data $\ln(\varepsilon_y)=\sqrt{\frac{\sum \ln^2(y)-2n\cdot\ln(\bar{y}_G)}{n-1}}$ and $\ln(\varepsilon_x)$ and pushes them on the stack. This ε works for the geometric mean x̄g in analogy to s for the arithmetic mean x̄ but multiplicative. |
| εm | h STAT εm | DECM | Works like ε but pushes the scattering factors of the geometric means $\varepsilon_m=\varepsilon^{1/\sqrt{n}}$ on the stack. |
| ε p | h STAT ε p | DECM | Works like ε but with a denominator ***n*** instead of ***n – 1***, returning the scattering factors of the populations. – Streichkandidaten. Zusatzabschnitt über lognv Daten vorne einfügen. |
| ζ | h X.FCN ζ | DECM | Returns Riemann's Zeta function for real arguments, with $\zeta(x)=\sum_{n=1}^{\infty}\frac{1}{n^x}$ for ***x*** > *1* and its analytical continuation for ***x*** < *1* : $\zeta(x)=2^x\pi^{x-1}\sin\left(\frac{\pi}{2}x\right)\cdot\Gamma(1-x)\cdot\zeta(1-x)$ . |
| ***π*** | h π | DECM | Complex version copies **π** in **X** and clears **Y**. |
| Π | f π ***label*** | DECM | Computes a product with the routine specified by ***label***. Initially, **X** contains the loop control number in the format `cccccc.fffii` and the product is set to 1. Each run through the routine specified computes a factor. At its end, this factor is multiplied with said product; the operation then decrements `ccccccc` by `ii` and runs said routine again if then `ccccccc` ≥ `fff`, else returns the resulting product in **X**. |
| Σ | g Σ ***label*** | DECM | Computes a sum with the routine specified by ***label***. Initially, **X** contains the loop control number in the format `cccccc.fffii` and the sum is set to 0. Each run through the routine specified computes a summand. At its end, this summand is added to said sum; the operation then decrements `ccccccc` by `ii` and runs said routine again if then `ccccccc` ≥ `fff`, else returns the resulting sum in **X**. |
| σ | h STAT σ | DECM | Works like s but returns the standard deviations of the populations instead. |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| $\Sigma \ln^2 x$ | h STAT $\Sigma \ln^2 x$ etc. | DECM | Recall the respective statistical sums. These sums are necessary for curve fitting models beyond pure linear. Calling them by name enhances readability of programs significantly. |
| $\Sigma \ln^2 y$ | | | |
| $\Sigma \ln x$ | | | |
| $\Sigma \ln xy$ | | | |
| $\Sigma \ln y$ | | | |
| $\Sigma x \ln y$ | | | |
| $\Sigma y \ln x$ | | | |
| σw | h STAT σw | DECM | Works like sw but returns the standard deviation of the population instead. $\sigma_w = +\sqrt{\frac{\sum y_i (x_i - \bar{x}_w)^2}{\sum y_i}}$ |
| $\Sigma x$ | h STAT $\Sigma x$ etc. | DECM | Recall the respective statistical sums. These sums are necessary for basic statistics and linear curve fitting. Calling them by name enhances readability of programs significantly. |
| $\Sigma x^2$ | | | |
| $\Sigma x^2 y$ | | | |
| $\Sigma xy$ | | | |
| $\Sigma y$ | | | |
| $\Sigma y^2$ | | | |
| **Σ+** | h Σ+ | DECM | Adds a data point to the statistical sums. |
| | A | DECM | Shortcut as long as label A is not defined yet. |
| **Σ–** | h Σ– | DECM | Subtracts a data point from the statistical sums. |
| φ(x) | h PROB φ(x) | DECM | Standard normal pdf: $\varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$ . |
| **Φ(x)** | f Φ | DECM | Standard normal cdf $\Phi(z) = \int_{-\infty}^{z} \varphi(x)dx$ , equals 1 – Q in *HP-32E* and 1 – Q(z) in *HP-21S* with ***z*** = ***x*** . |
| **Φ⁻¹(p)** | g Φ⁻¹ | | |
| $\chi^2$ | h PROB $\chi^2$ etc. | DECM | Chisquare distribution. The cdf $\chi^2$ (with the degrees of freedom given in **J**) equals 1 - Q($\chi^2$) in *HP-21S*. |
| $\chi^2$INV | | | |
| $\chi^2_P$ | | | |
| *(-1)* $^x$ | h X.FCN (-1) $^x$ | \α | For $x$ not being a natural number, this function will return $\cos(\pi \cdot x)$ . |

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| + | + | \α | Returns $y + x$ . |
| – | − | \α | Returns $y - x$ . |
| × | × | \α | Returns $y \cdot x$ . |
| / | / | \α | Returns $y / x$ . |
| +/– | +/– | \α | Unary minus like CHS in *HP-35*. |
| →DEG | → ( g ) DEG | DECM | Takes $x$ as an angle in the angular mode currently set and converts it to degrees. Prefix g may be omitted. |
| →GRAD | → ( g ) GRAD | DECM | Like →DEG, but converts to gon or grads. |
| →H | → f H.d | DECM | Takes $x$ as hours or degrees in the format `hhhh.mmssdd` and converts them into a decimal time or angle. |
| →H.MS | → f H.MS | DECM | Takes $x$ as decimal hours or degrees and converts them into `hhhh.mmssdd` as in vintage HPs. For calculations, use H.MS+ or H.MS– then or reconvert to decimal values before. |
| →POL | g →P | DECM | Assumes **X** and **Y** containing 2D Cartesian coordinates $(x, y)$ of a point and converts them to the respective polar coordinates $(r, \vartheta)$ with the radius $r = \sqrt{x^2 + y^2}$ |
| →RAD | → ( g ) RAD | DECM | Works like →DEG, but converts to radians. |
| →REC | f R← | DECM | Assumes **X** and **Y** containing 2D polar coordinates $(r, \vartheta)$ of a point and converts them to the respective Cartesian coordinates $(x, y)$ . |
| % | f % | DECM | Returns $\frac{x \cdot y}{100}$ , leaving **Y** unchanged. |
| %MG | h X.FCN h % MG | DECM | Returns the margin [23] $100 \cdot \frac{x - y}{x}$ in % for a price $x$ and cost $y$ , like %MU-Price in *HP-17B*. |

[23] Margin corresponds to „Handelsspanne“ in German.

| Name | Keys to press | in modes | Remarks |
|---|---|---|---|
| %MRR | h X.FCN<br>h % MRR | DECM | Returns the mean rate of return in percent per period, i.e. $100 \cdot \left[ \left( \frac{x}{y} \right)^{1/z} - 1 \right]$ with $x$ = FV = future value after $z$ periods, $y$ = PV = present value.<br>For $z = 1$ , Δ% returns the same result easier. |
| %T | h X.FCN<br>h % T | DECM | Returns $100 \cdot \frac{x}{y}$ , interpreted as % of total. |
| %Σ | h STAT h % Σ<br>h X.FCN<br>h % Σ | DECM | Returns $100 \cdot \frac{x}{\sum x}$ . |
| %+MG | h X.FCN<br>h % +MG | DECM | Calculates a sales price $y/(1-0.01 \cdot x)$ by adding a margin of $x$ % to the cost $y$ , as %MU-Price does in *HP-17B*. |
| √‾ | f √x | \α | |
| | D | \α, \14, \15, \h | Shortcut working as long as label D is not defined yet. |
| ∫ | g ∫ ***label*** | DECM | Integrates the function given in the routine specified. Lower and upper integration limits must be supplied in **Y** and **X**, respectively. Otherwise, the user interface is as in *HP-15C*. |
| ∞? | h TEST ∞? | \α | Tests $x$ for infinity. |
| \|\| | g \|\| | DECM | Returns $\left( \frac{1}{x} + \frac{1}{y} \right)^{-1}$ . |

**Alphanumeric input:**

| Character | Keys to press | in modes | Remarks |
|---|---|---|---|
| ␣ | h PSE | α | Appends a blank space to ***alpha***. |
| ° | . | DECM | Separates degrees or hours from minutes and seconds, so input format is `hhhh.mmssdd`. The user has to take care where an arbitrary real number represents such an angle or time. |
| **0 … 9** | 0 … 9 | \α | Standard numeric input. For integer bases <10, input of illegal digits is blocked. Please note you cannot enter more than 12 digits in the mantissa. |
| | | in addressing | Register input. See the *tables* above for more. |
| | 0, 1, f 2, … , f 9 | α | Appends the respective digit to ***alpha***. |
| **A … F** | A … F (grey print) | 11, 12, 13, 14, 15, h | Numeric input for digits >10. See page 6 for more information. |
| **A … Z** | A … Z (grey print) | in addressing | Register input. See the *addressing tables* above for the letters applicable. |
| | | α | Appends the respective Latin letter to ***alpha***. Use f ↑ to toggle cases. |
| **EEX** | EEX | DECM & \FRACT | Works like E in the Pioneers. |
| **A … Ω** | g A … g O (grey print) | α | Appends the respective Greek letter to ***alpha***. f ↑ will toggle cases. See page 7 for more. |
| **(** | f ◄( | α | Appends the respective symbol to ***alpha***. |
| **)** | g )► | | |
| **+** | f + | | |
| **–** | f − | | |
| **x** | f × | | |

| Character | Keys to press | in modes | Remarks |
|---|---|---|---|
| / | Second [.] | DECM | A persistent 2nd [.] in input switches to fraction mode. It will be interpreted as explained below. Please note you cannot enter [EEX] after you entered [.] twice – but you may delete the 2nd dot while editing the input line. |
| | | FRC | First [.] is interpreted as a space, 2nd as a fraction mark. E.g. input of [2][.][3][.][4] results in 2 ¾ in the display. Improper fractions may be entered starting with a [.], e.g. [.][3][.][2]. |
| | [f] [/] | α | Appends a slash to ***alpha***. |
| ± | [f] [+/-] | α | Appends the respective symbol to ***alpha***. |
| , | [h] [./,] [XEQ] | | |
| . | [f] [.] | | |
| '.' or ',' | [.] | DECM | Inserts a radix mark as selected. |
| ! | [h] [!] | α | Appends the respective symbol to ***alpha***. |
| ? | [h] [Q] (grey print) | | |
| ⇆ | [h] [x⪌] | | |
| ≠ | [h] [XOR] | | |
| % | [h] [−] | | |
| $ | [h] [S] (grey print) | | |
| € | [h] [U] (grey print) | | |
| £ | [h] [P] (grey print) | | |
| ¥ | [h] [Y] (grey print) | | |
| √ | [f] [D] | | |
| & | [h] [AND] | | |
| \ | [h] [NOT] | | |
| \| | [h] [OR] | | |

## Non-programmable Control, Clearing and Information Commands

| Keys to press | in modes | Remarks |
|---|---|---|
| ⬅ [24] | Input pending | Deletes the last digit or character put in. |
| | α | Deletes the rightmost character in ***alpha***. |
| | PRG | Deletes current step. |
| | Else | Acts like CLx. |
| ▲ / ▼ [25] | Status open | Goes to previous / next set of flags. |
| | Catalog open | Goes to previous / next item in this catalog. |
| | α | Scrolls the display window six characters to the left / right in ***alpha*** if possible. If less than six characters are beyond the limits of the display window on the left / right side, the window will be positioned to the beginning / end of string. Useful for longer strings. |
| | Else | Acts like BST / SST in *HP-42S*. |
| f ◀ / g ▶ | Integer | Shifts the display window to the left / right like in *HP-16C*. Helpful while working with small bases. |
| f ⇧ | α | Toggles upper and lower case (indicated by ⬇). |
| | \α | Enters a memory browser. |
| h P.FCN DEL$_P$ ***label*** | PRG | Deletes program steps from the current position downstream until, but excluding, the label specified. If said label is not found, “No such label” will be thrown. If the program pointer is on the step containing said label, nothing will be deleted. |
| ENTER↑ | Catalog open | Selects the current item like XEQ below. |
| | α | Turns alpha mode off. |
| | Else | Acts like the command ENTER described above. |

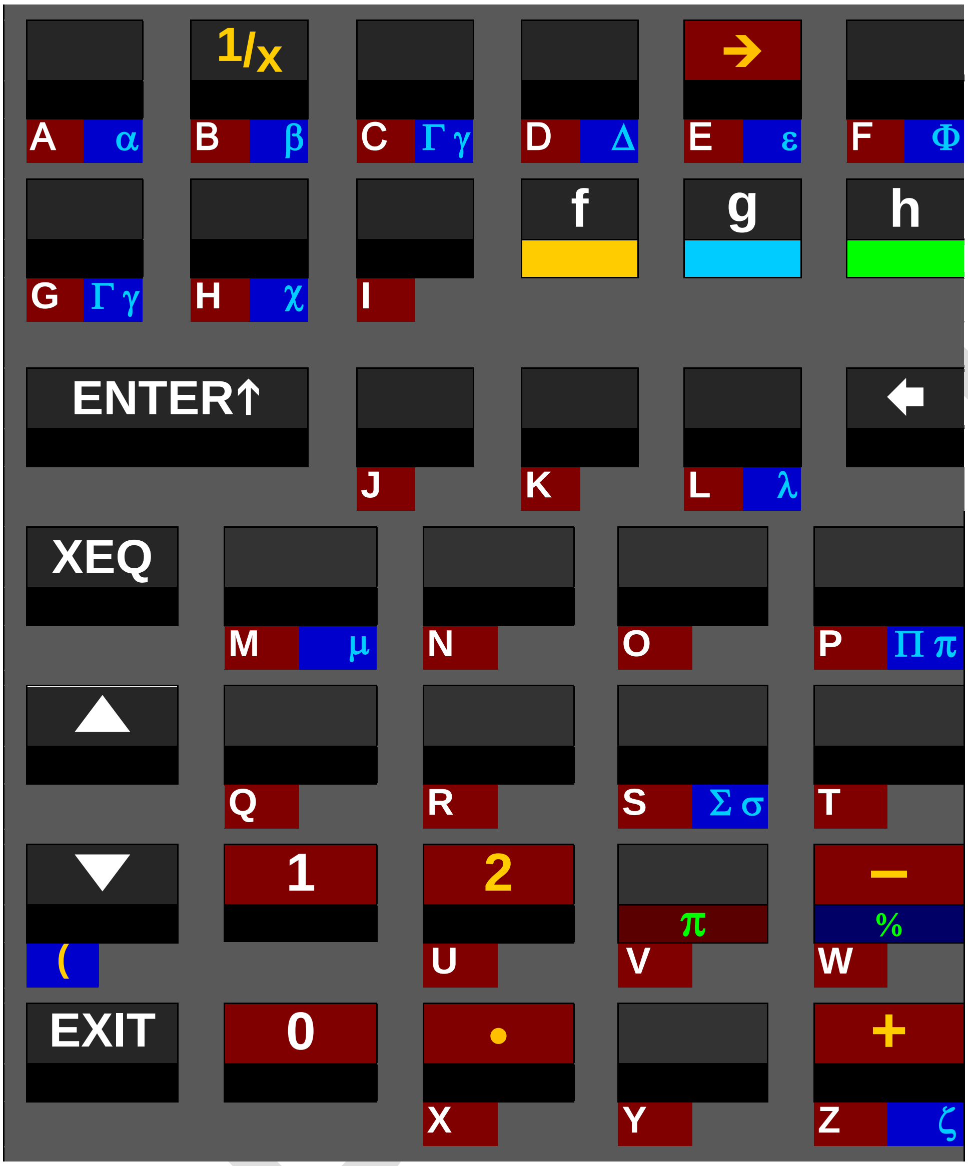
[24] The mode conditions specified will be checked top down for this command:
If there is a pending input, the last digit / character entered will be deleted;
else if alpha mode is set, the last character of ***alpha*** will be deleted;
else if the WP 34S is in programming mode, the current step will be deleted;
else CLx will be called. Period.
This method holds for all commands listed here using this symbolic.

[25] These two navigation keys will repeat with 5Hz when held down for longer than 0.5s.

| Keys to press | in modes | Remarks |
|---|---|---|
| EXIT | Catalog open | Leaves the catalog without executing anything. |
| | Input pending | Cancels the execution of pending operations, returning to the calculator status as it was before. |
| | Program running | Stops the running program like R/S . See below. |
| | PRG | Leaves programming mode like P/R . See below. |
| | α | Turns alpha mode off like ENTER↑ . See above. |
| | Else | Does nothing. |
| g OFF | \PRG | Turns calculator off. |
| ON | Calculator off | Turns calculator on. |
| | Else | There are several ON-key combinations available. See *below* for more. |
| h P/R | \α | Toggles programming mode for keyboard entry. |
| R/S | Program running | Stops the program execution immediately. “Stopped” will be shown in the upper row until the next keystroke. |
| | \PRG & \α | Runs the current program or resumes its execution starting with the current step. |
| | α | Appends an ‘Y’ to ***alpha***. |
| | PRG | Acts like the command STOP described above. |
| XEQ | Catalog open | Selects the item currently displayed and exits, executing the respective command. See *below*. |
| | Else | Acts like the command XEQ described above. |
| f α | \α | Turns on alpha mode for keyboard entry. When entering alpha constants in programs, please note there is no concatenation character – added characters are appended to ***alpha*** always. For starting a new string, use CLα first. Alpha constants will be listed like e.g. ‘Test 1’. |

## CATALOGS

A catalog on your WP 34S is a collection of items, e.g. operations or characters. Opening a catalog will set alpha mode to allow for typing the first character(s) of the item wanted. A subset of the full alpha keyboard shown *above* is sufficient for browsing:




Please note f → will just call the character → while browsing a catalog. f B (= 1/x ) eases operations in *CONV*.

▲ and ▼ browse the open catalog. ENTER↑ or XEQ select the item shown, recall or execute it, and exit the catalog, while EXIT will just leave it without executing anything, returning to the mode as set before.

See *below* for some examples.

Such catalogs may be called using the keystrokes listed below:

| Keys to press | in modes | Contents of said catalog |
|---|---|---|
| h CAT | \α | Predefined alpha labels. Some special rules apply here:<br>▲ and ▼ browse the catalog as usual, but in the numeric line the location of the respective label is indicated (RAM, Lib for XROM, or SEG ***n*** for flash memory segment ***n*** ).<br>0 – 8 trigger a search starting in the flash segment specified (and continued in further segments as long as necessary) for the first alpha label defined.<br>ENTER↑ goes to the alpha label as displayed, while XEQ or R/S execute it. These keystrokes will perform a label search as described *above*. Labels in XROM cannot be accessed by ENTER↑ .<br>. goes to the first alpha label in XROM.<br>◄ or EXIT leave CAT returning to the state as it was before. |
| h CONST | DECM | Constants like in HP35s. Picking a constant will recall it. See the constants listed in a *table below*. |
| CPX CONST | DECM | This catalog contains the same constants as in real domain. Picking one, however, does a complex recall here. So, if the stack did look like [$x$, $y$, …] before calling CONST, it will contain [***constant***, **0**, $x$, $y$, …] thereafter. |
| h CONV | DECM | Conversions as listed in a *table below*. |
| f CPX | α | "Complex" letters mandatory for many languages. Case is determined by setting (see f ↑ above). |
| h MODE | \α | Mode setting functions. |
| h PROB | DECM | Extra probability distributions. |
| h P.FCN | \α | Extra programming and I/O functions. |
| f R↓ | α | Subscripts. |
| h R↑ | α | Superscripts. |
| h STAT | DECM | Extra statistical functions. |
| h TEST | \α | All tests except the two on the keyboard. |
| | α | Comparison symbols and brackets, except f ( and g ). |

| Keys to press | in modes | Contents of said catalog | |
|---|---|---|---|
| h X.FCN | DECM | Extra real functions. | These three catalogs are merged in mode PRG to ease programming. |
| | Integer | Extra integer functions. | |
| | α | Extra alpha functions. | |
| CPX X.FCN | DECM | Extra complex functions. | |
| h ./, | α | Punctuation marks and text symbols. | |
| f → | α | Arrows and mathematical symbols. | |

Reopening the very last catalog called, the last command selected therein is displayed for easy repetitive use.

See the *table below about addressing cataloged items*, and the next pages for detailed item lists of the various catalogs. Within each catalog, items are sorted alphabetically (see *above* for the sorting order). You may access particular items fast and easily by typing the first characters of their names. See *below* for some examples and constraints.

A single function, e.g. CB, may be contained in more than one catalog.

The alpha catalogs are found three pages below. See also the special catalogs CONST and CONV in separate paragraphs further below.

## Catalog Contents in Detail:

| MODE |
|---|
| 12h |
| 1COMPL |
| 24h |
| 2COMPL |
| BASE |
| DENANY |
| DENFAC |
| DENFIX |
| DENMAX |
| DISP |
| D.MY |
| E3OFF |
| E3ON |
| FAST |
| FRACT |
| LZOFF |
| LZON |
| M.DY |
| RDX, |
| RDX. |
| RM |
| SETCHN |
| SETEUR |
| SETIND |
| SETUK |
| SETUSA |
| SIGNMT |
| SLOW |
| SSIZE4 |
| SSIZE8 |
| UNSIGN |
| WSIZE |
| Y.MD |

| PROB |
|---|
| Binom |
| Binom$_P$ |
| Binom$^{-1}$ |
| Cauch |
| Cauch$_P$ |
| Cauch$^{-1}$ |
| Expon |
| Expon$_P$ |
| Expon$^{-1}$ |
| $F_P(x)$ |
| F(x) |
| $F^{-1}(p)$ |
| Geom |
| Geom$_P$ |
| Geom$^{-1}$ |
| Lgnrm |
| Lgnrm$_P$ |
| Lgnrm$^{-1}$ |
| Logis |
| Logis$_P$ |
| Logis$^{-1}$ |
| Norml |
| Norml$_P$ |
| Norml$^{-1}$ |
| Poiss |
| Poiss$_P$ |
| Poiss$^{-1}$ |
| $t_P(x)$ |
| t(x) |
| $t^{-1}(p)$ |
| Weibl |
| Weibl$_P$ |
| Weibl$^{-1}$ |
| φ(x) |
| $\chi^2$ |
| $\chi^2$ INV |
| $\chi^2_P$ |

| STAT | |
|---|---|
| BestF | ε |
| COV | $\varepsilon_m$ |
| ExpF | $\varepsilon_p$ |
| LinF | σ |
| LNβ | $\Sigma\ln^2x$ |
| LNΓ | $\Sigma\ln^2y$ |
| LogF | Σlnx |
| nΣ | Σlnxy |
| PowerF | Σlny |
| SEED | σw |
| SERR | Σx |
| SERRw | $\Sigma x^2$ |
| SUM | $\Sigma x^2y$ |
| sw | Σxlny |
| sxy | Σxy |
| $\bar{x}$g | Σy |
| $\bar{x}$w | $\Sigma y^2$ |
| $\hat{x}$ | Σylnx |
| β | %Σ |
| Γ | |

| TEST |
|---|
| BC? |
| BS? |
| ENTRY? |
| EVEN? |
| FC? |
| FC?C |
| FC?F |
| FC?S |
| FP? |
| FS? |
| FS?C |
| FS?F |
| FS?S |
| IBASE? |
| INTM? |
| INT? |
| KEY? |
| KTY? |
| LBL? |
| LEAP? |
| NaN? |
| ODD? |
| PRIME? |
| REALM? |
| RM? |
| SMODE? |
| SPEC? |
| SSIZE? |
| TOP? |
| WSIZE? |
| x < ? |
| x ≤ ? |
| x ≈ ? |
| x ≥ ? |
| x > ? |
| ∞? |

| P.FCN | |
|---|---|
| BACK | RCLM |
| CF | RCLS |
| CLFLAG | RDX, |
| CLSTK | RDX. |
| DATE | RECV |
| DEC | RTN+1 |
| DEL$_P$ | R-CLR |
| DSL | R-COPY |
| DSZ | R-SORT |
| ERR | R-SWAP |
| FF | SAVE |
| f '(x) | SENDA |
| f "(x) | SENDL |
| GTOα | SENDP |
| H.MS+ | SENDR |
| H.MS- | SF |
| INC | SKIP |
| ISE | STOM |
| ISZ | STOS |
| LOAD | TICKS |
| NOP | TIME |
| PRCL | VWα+ |
| PROMPT | XEQα |
| PSTO | αGTO |
| PUTK | αOFF |
| P↔ | αON |
| RCF | αXEQ |
| RCF.RG | αVIEW |
| RCF.ST | |

X.FCN varies with the mode set, except in PRG. It contains in …

… alpha mode:

| |
|---|
| CLALL |
| CLREG |
| RESET |
| VERS |
| αDATE |
| αDAY |
| αIP |
| αLENG |
| αMONTH |
| αRC# |
| αRL |
| αRR |
| αSL |
| αSR |
| αTIME |

… decimal mode:

| | | |
|---|---|---|
| AGM | MANT | αDATE |
| ANGLE | MAX | αDAY |
| BATT | MIN | αIP |
| $B_n$ | MONTH | αLENG |
| $B_n$* | NAND | αMONTH |
| CEIL | NEXTP | αRCL |
| CLALL | NOR | αRC# |
| CLREG | $P_n$ | αRL |
| CUBE | RAD→ | αRR |
| CUBERT | RCF | αSL |
| DAY | RESET | αSR |
| DAYS+ | ROUNDI | αSTO |
| DECOMP | SDL | αTIME |
| DEG→ | SDR | β |
| DROP | SETDAT | Γ |
| D→J | SETTIM | ΔDAYS |
| erf | SIGN | ζ |
| erfc | SINC | $(-1)^x$ |
| EXPT | SLVQ | %MG |
| $e^x$ -1 | $T_n$ | %MRR |
| FIB | $U_n$ | %T |
| FLOOR | VERS | %Σ |
| GCD | W | %+MG |
| GRAD→ | WDAY | |
| $H_n$ | $W^{-1}$ | |
| $H_{np}$ | XNOR | |
| Iβ | $^x\sqrt{y}$ | |
| IΓ | YEAR | |
| JG1582 | | |
| JG1752 | | |
| J→D | | |
| LCM | | |
| $L_n$ | | |
| LN1+x | | |
| $L_n\alpha$ | | |
| LNβ | | |
| LNΓ | | |

… integer modes:

| | |
|---|---|
| ASR | RCF |
| BATT | RESET |
| CB | RJ |
| CLALL | RL |
| CLFLAG | RLC |
| CLREG | RR |
| CUBE | RRC |
| CUBERT | SB |
| DBLR | SEED |
| DBL* | SIGN |
| DBL/ | SL |
| DROP | SR |
| FB | VERS |
| FIB | XNOR |
| GCD | XROOT |
| LCM | αIP |
| LJ | αLENG |
| MASKL | αRCL |
| MASKR | αRC# |
| MAX | αRL |
| MIN | αRR |
| MIRROR | αSL |
| NAND | αSR |
| nBITS | αSTO |
| NEXTP | $(-1)^X$ |
| NOR | |

| CPX X.FCN |
|---|
| $^C$AGM |
| $^C$CONJ |
| $^C$CUBE |
| $^C$CUBERT |
| $^C$DROP |
| $^Ce^x$ -1 |
| $^C$FIB |
| $^C$LN1+x |
| $^C$LNβ |
| $^C$LNΓ |
| $^C$RCF |
| $^C$SIGN |
| $^C$SINC |
| $^C$W |
| $^CW^{-1}$ |
| $^C$β |
| $^C$Γ |
| $^C(-1)^x$ |

| CPX | | | | | |
|---|---|---|---|---|---|
| À | | | à | | |
| Á | | | á | | |
| Â Ã Ā Ă | | | â ã ā ă | | |
| Ä | | | ä (ă) | | |
| Å | | | å | | |
| Ć | | | ć | | |
| Č | | | č | | |
| Ç | | | ç | | |
| È | | | è | | |
| É | | | é | | |
| Ê Ē Ĕ Ě | | | ê ē ĕ ě | | |
| Ë | | | ë (ě) | | |
| | | | *ℏ* | | |
| Ì | | | ì | | |
| Í | | | í | | |
| Î Ĩ Ī Ĭ | | | î ĩ ī ĭ | | |
| Ï | | | ï ( ĭ ) | | |
| Ñ Ň | | | ñ ň | | |
| Ò | | | ò | | |
| Ó | | | ó | | |
| Ô Õ Ō Ŏ | | | ô õ ō ŏ | | |
| Ö | | | ö (ŏ) | | |
| Ø | | | ø | | |
| Ř | | | ř | | |
| Š | | | š | | |
| | | | ß | | |
| Ù | | | ù | | |
| Ú | | | ú | | |
| Û Ũ Ū Ŭ | | | û ũ ū ŭ | | |
| Ü | | | ü (ŭ) | | |
| Ů | | | ů | | |
| Ý | | | ý | | |
| Ÿ | | | ÿ | | |
| Ž | | | ž | | |

Here are the contents of the alpha catalogs making the WP 34S the most versatile global calculator known. Large font is printed in grey cells on this page. Accented letters show the same width as plain ones wherever possible.

| ./, |
|---|
| , : ; ‘ “ # * @ _ ~ ` ⊙ ⊕ |
| |
| |

| TEST |
|---|
| < ≤ = ≈ ≥ > [ ] { } |
| |
| |

| → |
|---|
| → ← ↑ ↓ ∫ ∞ ^ |
| |
| |

| R↓ (subscripts) |
|---|
| 0 1 2 A B c e k m n p u μ ∞ |
| |
| |

| R↑ (superscripts) |
|---|
| c ° 2 X x̄ x̂ ȳ ŷ -1 |
| |
| |



The letters provided in your WP 34S allow for correct writing the languages of more than $3 \cdot 10^9$ people (still only half of mankind yet), i.e.:

Afrikaans, Català, Cebuano, Česky, Cymraeg, Deutsch, Eesti, English, Español, Euskara, Français, Gaeilge, Galego, Greek, Bahasa Indonesia, Italiano, Basa Jawa, Kiswahili, Kreyòl ayisyen, Magyar, Bahasa Melayu, Nederlands, Português, Quechua, Shqip, Slovenčina, Slovenščina, Basa Sunda, Suomeksi, Svenska, Tagalog, Winaray, Zhōngwén (with a little trick explained below), and almost Dansk and Norsk (sorry, no æ) as well as Hrvatski and Srpski (no đ). If you know further living languages covered, please tell us.

Mandarin Chinese (Zhōngwén) features four tones, usually transcribed like e.g. mā, má, mă, and mà. So you need different letters for ā and ă here, and for e, i, o, and u as well. With six pixels total character height we found no way to display these in both fonts nicely, keeping letters and accents separated for easy reading. For an unambiguous solution, we suggest using a dieresis (else not employed in Hànyŭ pīnyīn) representing the third tone here. Pinyin writers, we ask for your understanding.

## Addressing Catalog Items

| | | | | |
|---|---|---|---|---|
| 1 | User input | CONST, CONV, MODE, PROB, P.FCN, STAT, TEST, or X.FCN | CPX, R↓, or R↑ in alpha mode | →, TEST, or ./, in alpha mode |
| | Dot matrix display | **Shows 1st item in selected catalog.** (e.g. BC? in P.FCN) Alpha mode is set. | (e.g. Á in CPX) | (e.g. , in ./,) |
| 2 | User input | XEQ, ▼, ▲, EXIT, or 1st character (e.g. F) | XEQ, ▼, ▲, EXIT, or character (e.g. O) | |
| | Dot matrix display | **Shows 1st item starting with this character *)** (e.g. FB) | **Shows 1st item starting with this letter *)** (e.g. Ó) | |
| 3 | User input | XEQ, ▼, ▲, EXIT, or 2nd character (e.g. S) | | |
| | Dot matrix display | **Shows 1st item starting with this sequence *)** (e.g. FS?) | | |
| 4 | User input | XEQ, ▼, ▲, or EXIT (e.g. ▼) | | |
| | Dot matrix display | **Shows next item in this catalog** (e.g. FS?C) | (e.g. Ò) | (e.g. ?) |
| … | | Continue browsing this way until reaching the item desired (e.g. FS?F). | (e.g. Ö). | (e.g. :). |
| n | User input | XEQ Calculator leaves the catalog returning to the mode set before | | |
| | Dot matrix display | … and executes or inserts the command chosen, or recalls the constant selected. **Result** | … and appends the selected character to ***alpha***. **Contents of alpha register** (e.g. Östl. Seite:) | |

*) If a character or sequence specified is not found in this catalog then the first item following alphabetically will be shown. If there is no such item, then the last item in this catalog is displayed. You may key in even more than two characters – after 3 seconds, however, or after ▼ or ▲, the search string will be reset and you may start with a first character again.

## Constants

Below you find the contents of the catalog CONST. Navigation works as in the catalogs mentioned before. Names of astronomical and mathematical constants are printed on colored background below. Values of physical constants (*incl. their relative standard deviations given in parentheses below*) are from CODATA 2010, copied in July 2011, unless stated otherwise explicitly. Green background denotes exact or almost exact values. The more the color turns to red, the less precise the respective constant is known [26].

For the units, remember Tesla with $1T = 1\frac{Wb}{m^2} = 1\frac{V \cdot s}{m^2}$, Joule with $1J = 1N \cdot m = 1\frac{kg \cdot m^2}{s^2}$ and on the other hand $1J = 1W \cdot s = 1V \cdot A \cdot s = \frac{1}{e} eV \approx 6.24 \cdot 10^6 TeV$. Thus $1\frac{J}{T} = 1A \cdot m^2$.

| Name | Numeric value | Unit | Remarks |
|---|---|---|---|
| **a** | 365.2425 *(per definition)* | $d$ | Gregorian year |
| **a$_0$** | 5.2917721092**E**-11 *(3.2**E**-10)* | $m$ | Bohr radius $= \frac{\alpha}{4\pi \cdot R_\infty}$ |
| **a$_m$** | 384.4**E**6 *(1**E**-3)* | $m$ | Semi-major axis of the Moon's orbit around the Earth |
| **a⊕** | 1.495979**E**11 *(1**E**-6)* | $m$ | Semi-major axis of the Earth's orbit around the sun. Within the uncertainty stated here, it equals 1 AU. |
| **c** | 2.99792458**E**8 *(per definition)* | $m/s$ | Vacuum speed of light |
| **c$_1$** | 3.74177153**E**-16 *(4.4**E**-8)* | $m^2 \cdot W$ | First radiation constant $= 2\pi \cdot h \cdot c^2$ |
| **c$_2$** | 0.014387770 *(9.1**E**-7)* | $m \cdot K$ | Second radiation constant $= hc/k$ |
| **e** | 1.602176565**E**-19 *(2.2**E**-8)* | $C$ | Electron charge $= \frac{2}{K_J R_K} = \Phi_0 G_0$ |
| **eE** | 2.718281828459045… | 1 | Euler's e. Please note the letter *e* represents the electron charge elsewhere in this table. |
| **F** | 96485.3365 *(2.2**E**-8)* | $\frac{C}{mol}$ | Faraday's constant = *e N$_A$* |
| **Fα** | 2.5029078750958928... | 1 | Feigenbaum's α |
| **Fδ** | 4.6692016091029906... | 1 | Feigenbaum's δ |
| **g** | 9.80665 *(per definition)* | $m/s^2$ | Standard earth acceleration |

[26] The bracketed values printed here for your kind attention allow you to compute the precision of results you may obtain using these constants. The procedure to be employed is called error propagation. It is often ignored, though essential for trustworthy results – not only in science. Please turn to respective texts before you believe in 4 decimals of a calculation result based on yardstick measurements.

| Name | Numeric value | Unit | Remarks |
|---|---|---|---|
| **G** | 6.67384**E**-11 *(1.2**E**-4)* | $\frac{m^3}{kg \cdot s^2}$ | Newton's gravitation constant. See **GM** below for a more precise value. |
| **$G_o$** | 7.7480917346**E**-5 *(3.2**E**-10)* | $1/\Omega$ | Conductance quantum $= 2e^2/h = 2/R_K$ |
| **$G_c$** | 0.915965594177… | 1 | Catalan's constant |
| **$g_e$** | 2.00231930436153 *(2.6**E**-13)* | 1 | (Landé's) electron g-factor |
| **GM** | 3.986004418**E**14 *(2.0**E**-9)* | $m^3/s^2$ | Newton's gravitation constant times the Earth's mass with its atmosphere included (according to WGS84, see **Sa** below). |
| **h** | 6.62606957**E**-34 *(4.4**E**-8)* | $J\ s$ | Planck constant |
| **$\hbar$** | 1.054571726**E**-34 *(4.4**E**-8)* | | $= h/2\pi$ |
| **k** | 1.3806488**E**-23 *(9.1**E**-7)* | $J/K$ | Boltzmann constant $= R/N_A$ |
| **Kj** | 4.83597870**E**14 *(2.2**E**-8)* | $Hz/V$ | Josephson constant $= 2e/h$ |
| **$l_p$** | 1.616199**E**-35 *(6.0**E**-5)* | $m$ | Planck length $= \sqrt{\hbar G/c^3} = t_p c$ |
| **$m_e$** | 9.10938291**E**-31 *(4.4**E**-8)* | | Electron mass |
| **$M_m$** | 7.349**E**22 *(5**E**-4)* | | Mass of the Moon |
| **$m_n$** | 1.674927351**E**-27 *(4.4**E**-8)* | | Neutron mass |
| **$m_p$** | 1.672621777**E**-27 *(4.4**E**-8)* | $kg$ | Proton mass |
| **$M_p$** | 2.17651**E**-8 *(6.0**E**-5)* | | Planck mass $= \sqrt{\hbar c/G} \approx 22\mu g$ |
| **$m_u$** | 1.660538921**E**-27 *(4.4**E**-8)* | | Atomic unit mass $= 10^{-3}\ kg / N_A$ |
| **$m_u c^2$** | 1.492 417 954**E**-10 *(4.4**E**-8)* | $J$ | Atomic unit mass energy equivalent |
| **$m_\mu$** | 1.883531475**E**-28 *(5.1**E**-8)* | | Muon mass |
| **M⊙** | 1.9891**E**30 *(5**E**-5)* | $kg$ | Mass of the sun |
| **M⊕** | 5.9736**E**24 *(5**E**-5)* | | Mass of the Earth |
| **$N_A$** | 6.02214129**E**23 *(4.4**E**-8)* | $1/mol$ | Avogadro's number |
| **NaN** | | | "not a number" |
| **$p_o$** | 101325 *(per definition)* | $Pa$ | Standard atmospheric pressure |
| **$q_p$** | 1,8755459**E**-18 *(6.0**E**-5)* | $As$ | Planck charge $= \sqrt{4\pi\varepsilon_0 \hbar c} \approx 11.7e$ . This was in CODATA 2006, but in 2010 no more. |

| Name | Numeric value | Unit | Remarks |
|---|---|---|---|
| **R** | 8.3144621 *(9.1**E**-7)* | $\frac{J}{mol \cdot K}$ | Molar gas constant |
| **r$_e$** | 2.8179403267**E**-15 *(9.7**E**-10)* | $m$ | Classical electron radius $= \alpha^2 \cdot a_0$ |
| **R$_K$** | 25812.8074434 *(3.2**E**-10)* | $\Omega$ | von Klitzing constant $= h/e^2$ |
| **R$_m$** | 1.737530**E**6 *(5**E**-7)* | $m$ | Mean radius of the Moon |
| **R$_\infty$** | 1.0973731568539**E**7 *(5.0**E**-12)* | $1/m$ | Rydberg constant $= \alpha^2 m_e c / 2h$ |
| **R⊙** | 6.96**E**8 *(5**E**-3)* | $m$ | Mean radius of the sun |
| **R⊕** | 6.371010**E**6 *(5**E**-7)* | $m$ | Mean radius of the Earth |
| **Sa** | 6.3781370**E**6 *(per definition)* | $m$ | Semi-major axis of the model WGS84 used to define the Earth's surface for GPS and other surveying purposes (→ http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html) |
| **Sb** | 6.3567523142**E**6 *(1.6**E**-11)* | $m$ | Semi-minor axis of WGS84 |
| **Se$^2$** | 6.69437999014**E**-3 *(1.5**E**-12)* | 1 | First eccentricity squared of WGS84 |
| **Se'$^2$** | 6.73949674228**E**-3 *(1.5**E**-12)* | 1 | Second eccentricity squared of WGS84 (it is really called e'$^2$ in this article, I apologize) |
| **Sf $^{-1}$** | 298.257223563 *(per definition)* | 1 | Flattening parameter of WGS84 |
| **T$_o$** | 273.15 *(per definition)* | $K$ | = 0°C, standard temperature |
| **t$_p$** | 5.39106**E**-44 *(6.0**E**-5)* | $s$ | Planck time $= \sqrt{\hbar G / c^5} = \frac{l_p}{c}$ |
| **T$_p$** | 1.416833**E**32 *(6.0**E**-5)* | $K$ | Planck temperature $= \frac{c^2}{k}\sqrt{\frac{\hbar c}{G}} = \frac{M_p c^2}{k} = \frac{E_p}{k}$ |
| **V$_m$** | 0.022413968 *(9.1**E**-7)* | $m^3/mol$ | Molar volume of an ideal gas at standard conditions $= RT_0 / p_0$ |
| **Z$_o$** | 376.730313461… | $\Omega$ | Charact. impedance of vacuum $= \sqrt{\frac{\mu_0}{\varepsilon_0}} = \mu_0 c$ |
| **α** | 7.2973525698**E**-3 *(3.2**E**-10)* | 1 | Fine-structure constant $= \frac{e^2}{4\pi\varepsilon_0 \hbar c} \approx \frac{1}{137}$ |
| **γEM** | 0.5772156649015328 6… | 1 | Euler-Mascheroni constant |
| **γ$_p$** | 2.675222005**E**8 *(2.4**E**-8)* | $\frac{1}{s \cdot T}$ | Proton gyromagnetic ratio $= 2\mu_P / \hbar$ |

| Name | Numeric value | Unit | Remarks |
|---|---|---|---|
| $\varepsilon_0$ | 8.854187817…**E**-12 | $\frac{A\cdot s}{V\cdot m}$ or $F/m$ | Electric constant, vacuum permittivity $=\frac{1}{\mu_0 c^2}$ |
| $\lambda_c$ | 2.4263102389**E**-12 *(6.5**E**-10)* | $m$ | Compton wavelength of the electron $= h/m_e c$ |
| $\lambda_{cn}$ | 1.3195909068**E**-15 *(8.2**E**-10)* | | Compton wavelength of the neutron $= h/m_n c$ |
| $\lambda_{cp}$ | 1.32140985623**E**-15 *(7.1**E**-10)* | | Compton wavelength of the proton $= h/m_p c$ |
| $\mu_0$ | 1.2566370614…**E**-6 | $\frac{V\cdot s}{A\cdot m}$ | Magnetic constant, also known as vacuum permeability $=4\pi\cdot 10^{-7}\frac{V\cdot s}{A\cdot m}$ (per definition) |
| $\mu_B$ | 9.27400968**E**-24 *(2.2**E**-8)* | $J/T$ or $A\cdot m^2$ | Bohr's magneton $=e\hbar/2m_e$ |
| $\mu_e$ | -9.28476430**E**-24 *(2.2**E**-8)* | | Electron magnetic moment |
| $\mu_n$ | -9.6623647**E**-27 *(2.4**E**-7)* | | Neutron magnetic moment |
| $\mu_p$ | 1.410606743**E**-26 *(2.4**E**-8)* | | Proton magnetic moment |
| $\mu_u$ | 5.05078353**E**-27 *(2.2**E**-8)* | | Nuclear magneton $=e\hbar/2m_p$ |
| $\mu_\mu$ | -4.49044807**E**-26 *(3.4**E**-8)* | | Muon magnetic moment |
| $\pi$ | 3.141592653589793… | 1 | |
| $\sigma_B$ | 5.670373**E**-8 *(3.6**E**-6)* | $\frac{W}{m^2 K^4}$ | Stefan Boltzmann constant $=\frac{2\pi^5 k^4}{15h^3c^2}$ |
| $\Phi$ | 1.618033988749894… | 1 | Golden ratio $=\frac{1+\sqrt{5}}{2}$ |
| $\Phi_0$ | 2.067833758**E**-15 *(2.2**E**-8)* | $V\,s$ | Magnetic flux quantum $= h/2e = 1/K_J$ |
| $\omega$ | 7.292115**E**-5 *(2**E**-8)* | $rad/s$ | Angular velocity of the Earth according to WGS84 (see **Sa** above) |
| $-\infty$ | | 1 | Negative and positive infinity (may the Lord of Mathematics forgive us calling these two 'constants') |
| $\infty$ | | | |

## Unit Conversions

Find below the contents of the catalog CONV [27]. Navigation works as in the other catalogs. There is one specialty, however: f B (i.e. 1/x ) will execute the inverse of the conversion displayed and leave CONV.

Example: Assume the display set to FIX 3. Then keying in

| | | |
|---|---|---|
| 4 h CONV A | will display | acres→ha and 1.619 below telling you 4 acres equal 1.619 hectares. |
| Now press f B | and you will get | 9.884 instead, being the amount of acres equaling 4 hectares. |
| Press h CONV again and you will see | | acres→ha and 4.000 below confirming what was just said. |
| Leave the catalog via EXIT | | and the display will return to 9.884. |

The constant $T_0$ may be useful for conversions of temperatures, too; it is found in the *catalog CONST* and is not repeated here since being only added or subtracted. The conversion factors or divisors listed below for your information are user transparent in executing a conversion – those printed on light green background in this table apply exactly.

| Conversion | | Remarks | Class |
|---|---|---|---|
| °C→°F | * 1.8 + 32 | | Temperature |
| °F→°C | - 32 ) / 1.8 | | Temperature |
| °→G | / 0.9 | Converts to ‘grads’ or ‘gon’ | Angle |
| °→rad | * π / 180 | Equals D→R | Angle |
| acres→ha | * 0.4046873 | 1 ha = $10^4$ m² | Area |
| ar.→dB | $20\lg\left(a_1/a_2\right)$ | Amplitude ratio | Ratio |
| atm→Pa | * 1.01325**E**5 | | Pressure |
| AU→km | * 1.495979**E**8 | Astronomic units | Length |
| bar→Pa | * 1**E**5 | | Pressure |
| Btu→J | * 1055.056 | British thermal units | Energy |
| cal→J | * 4.1868 | | Energy |
| cft→*l* | * 28.31685 | Cubic feet | Volume |

[27] For most readers, many of the units appearing in CONV may look obsolete at least. They die hard, however, in some corners of this world. All these corners have in common is English being spoken there. For symmetry reasons, we may also add some traditional Indian and Chinese units. Anyway, this catalog provides the means to convert local to common units.

| Conversion | | Remarks | Class |
|---|---|---|---|
| cm→inches | / 2.54 | | Length |
| dB→ar. | $10^{R_{dB}/20}$ | Amplitude ratio | Ratio |
| dB→pr. | $10^{R_{dB}/10}$ | Power ratio | Ratio |
| fathom→m | * 1.8288 | | Length |
| feet→m | * 0.3048 | | Length |
| flozUK→*ml* | * 28.41306 | 1 $l = {}^{1}/_{1000}$ $m^3$ | Volume |
| flozUS→*ml* | * 29.57353 | | |
| galUK→ *l* | * 4.54609 | | |
| galUS→ *l* | * 3.785418 | | |
| G→° | * 0.9 | Grads or gon | Angle |
| g→oz | / 28.34952 | | Mass |
| G→rad | * π / 200 | | Angle |
| g→tr.oz | / 31.10348 | | Mass |
| ha→acres | / 0.4046873 | 1 ha = 10000 $m^2$ | Area |
| $HP_e$→W | * 746 | Electric horse power | Power |
| hpUK→W | * 745.6999 | British horse power | Power |
| inches→cm | * 2.54 | | Length |
| inHg→Pa | * 3386.389 | | Pressure |
| J→Btu | / 1055.056 | | Energy |
| J→cal | / 4.1868 | | Energy |
| J→kWh | / 3.6**E**6 | | Energy |
| kg→lb | / 0.4535924 | | Mass |
| kg→stones | / 6.35029318 | | Mass |
| km→AU | / 1.495979**E**8 | Astronomic units | Length |
| km→*l.y.* | / 9.460730**E**12 | Light years | Length |
| km→miles | / 1.609344 | | Length |
| km→nmi | / 1.852 | Nautical miles | Length |
| km→pc | / 3.085678**E**16 | Parsec | Length |

| Conversion | | Remarks | Class |
|---|---|---|---|
| kWh→J | * 3.6E6 | | Energy |
| lbf→N | * 4.448222 | | Force |
| lb→kg | * 0.4535924 | | Mass |
| *l.y.*→km | * 9.460730**E**12 | Light years | Length |
| $l$ →cft | / 28.31685 | 1 $l$ = $^{1}/_{1000}$ m$^3$ | Volume |
| $l$ →galUK | / 4.54609 | | |
| $l$ →galUS | / 3.785418 | | |
| miles→km | * 1.609344 | | Length |
| m$l$→flozUK | / 28.41306 | 1 $ml$ = 1 cm$^3$ | Volume |
| m$l$→flozUS | / 29.57353 | | |
| mmHg→Pa | * 133.3224 | 1 torr = 1 mm Hg | Pressure |
| m→fathom | / 1.8288 | | Length |
| m→feet | / 0.3048 | | Length |
| m→yards | / 0.9144 | | Length |
| nmi→km | * 1.852 | Nautical miles | Length |
| N→lbf | / 4.448222 | | Force |
| oz→g | * 28.34952 | Ounces | Mass |
| Pa→atm | / 1.01325**E**5 | 1 Pa = 1 N/m$^2$ | Pressure |
| Pa→bar | / 1**E**5 | | Pressure |
| Pa→inHg | / 3386.389 | | Pressure |
| Pa→mmHg | / 133.3224 | | Pressure |
| Pa→psi | / 6894.757 | | Pressure |
| Pa→torr | / 133.3224 | | Pressure |
| pc→km | * 3.085678**E**16 | Parsec | Length |
| pr.→dB | $10\lg\left(\frac{P_1}{P_2}\right)$ | Power ratio | Ratio |
| psi→Pa | * 6894.757 | Pounds per square inch | Pressure |
| PS(hp)→W | * 735.4988 | Horse power | Power |
| rad→° | * 180 / π | Equals R→D | Angle |

| Conversion | | Remarks | Class |
|---|---|---|---|
| rad→G | * 200 / π | | Angle |
| stones→kg | * 6.35029318 | | Mass |
| s.tons→t | * 0.9071847 | Short tons | Mass |
| tons→t | * 1.016047 | Imperial tons | Mass |
| torr→Pa | * 133.3224 | 1 torr = 1 mm Hg | Pressure |
| tr.oz→g | * 31.10348 | Troy ounces | Mass |
| t→s.tons | / 0.9071847 | 1 t = 1000 kg | Mass |
| t→tons | / 1.016047 | | |
| W→HP$_e$ | / 746 | | Power |
| W→hpUK | / 745.6999 | | Power |
| W→PS(hp) | * 735.4988 | | Power |
| yards→m | * 0.9144 | | Length |

You may, of course, combine conversions as you like. For example, filling your tires with a maximum pressure of 30 psi the following will help you at a gas station in Europe and beyond:

3 0 h CONV P S XEQ
h CONV P ▼ XEQ resulting in 2.1 bar.

Now you can set the filler and will not blow your tires.

In cases of emergency of a particular kind, remember Becquerel equals Hertz, Gray is the unit for deposited or absorbed energy ( $1Gy = 1J/kg$ ), and Sievert ($Sv$) is Gray times a radiation dependant dose conversion factor for the damage caused in human bodies.

In this area also some outdated units may be found in older literature: Pour les amis de Mme. Curie, $1Ci = 3.7 \cdot 10^{10} Bq = 3.7 \cdot 10^{10} decays/s$. And for those admiring the very first Nobel laureate in physics, Mr. Röntgen, for finding the x-rays (ruining his hands in these experiments), the charge generated by radiation in matter was measured by the unit $1R = 2.58 \cdot 10^{-4} \, {}^{As}\!/_{kg}$ . A few decades ago, Rem (i.e. Röntgen equivalent men) was measuring what Sievert does today.

**Predefined Global Alpha Labels**

There are a few labels employed and provided for particular tasks already. You find them listed in CAT when the respective routines are loaded in XROM. Thus they will not take any steps from user program memory.

| | |
|---|---|
| WHO | Displays credits to those brave men who did the work. |
| δx | Provides the step size for differentiation. See f '(x) and f "(x) in the *Index of Operations* for more information. |

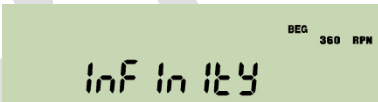
More routines are found at *http://wp34s.svn.sourceforge.net/viewvc/wp34s/library/* as text files with extension *.wp34s* by convention. This includes, for example, a suite of basic 3D vector operations, a TVM application, and more. You may open these files using e.g. Notepad, and download them following your needs. README_ASM explains the loading procedure.

## MESSAGES

There are some commands generating messages, also in the dot matrix section of the display. Four of them, DAY, DAYS+, STATUS, and VERS, were introduced above in the *paragraph about display* already. Others are PROMPT, αVIEW and many more alpha commands, and the test commands as mentioned *above*.

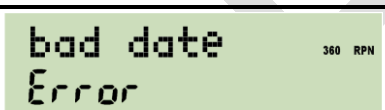
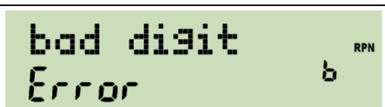
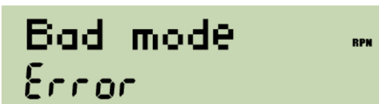
Also two constants will return a special display when called: **NaN** and ∞ will show


or




, respectively.

Furthermore, there are a number of error messages. Depending on error conditions, the following messages will be displayed in the mode(s) listed:

| Message | Error Code | Mode(s) | Explanation and Examples |
|---|---|---|---|
|   | 2 | DECM | Invalid date format or incorrect date in input, e.g. month >12, day >31 etc. |
|   | 9 | Integer | Invalid digit in integer input, e.g. 2 in binary, 9 in octal, or +/- in unsigned mode. |
|   | 13 | All | Caused by calling an operation in a mode where it is not defined, e.g. SIN in hexadecimal. |

| Message | Error Code | Mode(s) | Explanation and Examples |
|---|---|---|---|
| Domain<br>Error | 1 | \α | An argument exceeds the domain of the mathematical function called. May be caused by roots or logs of negative numbers (if not preceded by CPX ), by 0 / 0, LN(0), $\Gamma(0)$, TAN(90°) and equivalents, ATANH(x) for $\lvert\mathrm{Re}(x)\rvert \geq 1$, ACOSH(x) for $\mathrm{Re}(x) < 1$, etc. |
| Invalid<br>dAtA | 18 | All | Set when there is a checksum error either in flash or as part of a serial download. It is also set if a flash segment is otherwise unusable. |
| invalid<br>PArAMEtEr | 16 | \α | Similar to error 1 but a parameter specified in **J** or **K** is out of supported range for the function called. May appear e.g. if LgNrm is called with $j < 0$. |
| I/O<br>Error | 17 | \α | Please see Appendix A. |
| No such<br>LAbEL | 6 | All | Attempt to address an undefined label. |
| No write / In FLASH | 19 | All | Attempt to delete program lines while inside a flash segment.. |
| Out of range<br>Error | 8 | All | • A number exceeds the valid range. Caused e.g. by specifying decimals >11, word size >64, negative flag numbers, integers $\geq 2^{64}$, hours or degrees >9000, invalid times, denominators ≥9999 etc.<br>• A register address exceeds the valid range. May also happen in indirect addressing.<br>• An R-operation (e.g. R-COPY) attempts exceeding valid register numbers (0 .. 99). |
| Solve / FAILEd | 20 | DECM | The solver did not converge. |
| SLV ∫ Σ Π<br>nEStEd | 7 | PRG | Nested use of solve (SLV and SLVQ), integrate, sum or product is not allowed. |
| Stack<br>CLASH | 12 | All | STOS or RCLS attempt using registers that would overlap the stack. Will happen with e.g. SSIZE = 8 and STOS 94. |

| Message | Error Code | Mode(s) | Explanation and Examples |
|---|---|---|---|
| Too few dAtA PoIntS | 15 | DECM | A statistical calculation was started based on too few data points, e.g. regression or standard deviation for < 2 points. |
| Too long Error | 10 | All | Keyboard input is too long for the buffer (should never happen, but who knows). |
| undefined OP-COdE | 3 | All | An instruction with an undefined op-code occurred (should never happen, but who knows). |
| Word size too SMALL | 14 | Integer, \PRG | Stack or register content is too big for the word size set. |
| +∞ Error | 4 | \α, \PRG | • Division of a number > 0 (or < 0) by zero.<br>• Divergent sum or product or integral.<br>• Positive (or negative) overflow in DECM (see *above*). |
| −∞ Error | 5 | | |
| >8 levels nEStEd | 11 | PRG | Subroutine nesting exceeds 8 levels. |

Any key pressed will erase the error message displayed and execute with the stack contents present. Thus, the easiest return to the display shown before the error occurred is pressing a prefix twice.

## PROGRAMMED INPUT AND OUTPUT

A number of commands may be employed for controlling I/O of programs. In the index above, their behavior is described if they are entered from the keyboard. Executed by a program, however, this will differ in a characteristic way.

With a program running, the display will be updated at certain instances only instead of after each operation. So where a command in manual mode shows an information until the next key is pressed, it will show it until the next display update in automatic mode. Such an update will occur with PROMPT, PSE, STOP, VIEW, VWα+, and αVIEW only. This allows for the following operations (please note parameters are omitted here):

- Output of messages or other information for a defined time interval using the following code segment
  …
  VIEW
  PSE
  …
  (or simply PSE alone) for plain numeric calculated output or
  …
  αVIEW (or even VWα+)
  PSE
  …
  for complex alphanumeric information you composed in ***alpha***.

- Asking ("prompting") for numeric input employing
  …
  αVIEW (or VWα+)
  STOP
  …
  or simply PROMPT, the latter being identical to VWα+ X plus STOP.
  Whatever number you key in will be in **X** when you continue the program by pressing R/S . If you want it elsewhere, take care of it.

- Prompting for alphanumeric input by
  …
  αON
  PROMPT
  αOFF
  …
  Whatever you key in will be appended to ***alpha*** here. Again, the program will continue when you pressed R/S .

Please see the index for more information about these commands and their parameters.

## INTERACTIVE PROGRAMMING

This chapter deals with writing programs that interact with the user. Topics covered are the display of messages, getting input from the user, hot keys and truly interactive "real time" programs.

### Interrupting a Program for Display of Information

When a program is started, the display contents are replaced by the "Running Program" message. To display a number while a program is executing, use VIEW in programming and specify a register to display. Here, **X** is a valid parameter so you can present the standard top stack level contents to the user. The command formats the number to the present settings and updates the LCD to display it. This causes a small overhead so expect that your program slows down a bit with each update. This is especially true if the displays follow each other in a tight loop because the flicker avoidance logic needs to wait for a complete display refresh cycle before the next update is allowed.

Another way to show what would normally appear on the display without a program running is to use the PSE instruction specifying the time in 10ths of seconds to suspend execution. A time of zero will have the same effect as a VIEW **X** instruction. PSE following VIEW ***s*** works as expected: it will display the contents of address ***s***. The display will then stay unchanged until the next VIEW or PSE instruction is executed, not only for the time specified with PSE. The next PSE or STOP will switch back to the normal display of ***x*** . VIEW ***s*** followed by STOP will display the contents of address ***s*** until the user presses R/S .

To make things clearer: VIEW immediately displays the register when encountered in program execution. When followed by PSE or STOP, the display persists. Only the next PSE or STOP (or keyboard entry after the program has halted) will revert to the normal ***x*** display. To make sure that STOP or PSE always display a specific information it is best to directly precede it by the respective VIEW instruction. There is no way to get the "Running Program" message back once it has been replaced by a programmed display.

Generally speaking, a message is a string of characters that is shown in the upper region of the display. The program interface to this area is via the alpha register. You need to switch to alpha mode to access most of the commands that deal with this register. The annunciator INPUT lights if alpha mode is active. The X.FCN catalogue changes in alpha mode to contain alpha commands. Displaying a message will normally start with a CL[alpha] instruction because most commands append their output to what is already stored. To save space, characters in program mode may be entered in groups of three by typing α while already in alpha mode. This saves one program step per three characters but does not allow all special symbols to be entered because the catalogues are not available in this mode. Single characters and grouped characters can be freely mixed. The register is 31 characters wide. The display capacity is considerably smaller and depends on the width of each symbol. The display switches to a smaller font if necessary. The contents can be scrolled in interactive alpha mode with the up and down arrow keys (as described above).

If you just want to display a text message and no number with it, use αVIEW. To get to this command you must be out of alpha mode and open the P.FCN catalogue. g A brings you to the alpha commands. The αVIEW display starts at the first character of the string. The numeric portion of the LCD is replaced by three dashes. You can of course display a message together with a chosen register. Go to alpha mode and press

VIEW. This will produce the αVW+ nn command. It is meant to display alpha together with ('+') numeric data coming from any register. As with VIEW, X is allowed here. The above comments regarding PSE or STOP following any of these commands are valid here, too.

Another way to display the alpha register is to switch to alpha mode with αON. The main difference is that you are presented the tail of the string instead of its head. Also, a PSE is necessary to update the actual display which αON alone does not do. If followed by a STOP, alpha mode stays on causing user input to go to the upper display! αOFF returns everything to normal.

### Temporary Displays

Whenever the display does not show the actual contents of the X register in the current mode, this is considered a temporary display. To distinguish this from the normal display, the RPN annunciator is off during temporary displays and on otherwise. The following displays are considered temporary:

1. Any errors,
2. αVIEW,
3. αVW+ ***nn***,
4. VIEW ***nn*** where ***nn*** is not X,
5. VIEW X if encountered in a program because X may have changed before the stop,
6. H.MS display,
7. Temporary display in another base (not programmable).

Press EXIT or ← to get back to the normal display.

### Data Input

The easiest way of getting user input, apart from expecting everything on the stack, is just stopping the program with STOP, letting the user input a number and let him press R/S to continue execution. Without any clue what the program is asking for, this is only suitable for very simple programs. The least you want to do is present a message to the user what he is supposed to enter when the program stops. This can be done with any of the [alpha]VIEW commands followed by STOP. There is a shorthand especially made for this: PROMPT. It is a combination of [alpha]VW+ X and STOP. It displays the alpha register together with the current X register and halts program execution. This is good for entering a lengthy list of parameters in a given order without much programming.

### Hotkeys

A more versatile way of doing things is using the dedicated keys A to D in the top row. If the user presses one of these keys the program executes the next subroutine or program with a label of the same name. If you have more than one program using labels A to D in RAM or in a flash region, it's necessary to move the program counter (PC) to the top of the program and stop there. A typical program structure might be the following:

```
LBL 'MYP'
CL[alpha]
[alpha]'Hel'
[alpha]'lo!'
LBL 00
PROMPT
BACK 01
LBL A
ENTRY?
SKIP 01
XEQ 01
STO 01
GTO 00
LBL B
...
```

This sets up a message and stops. R/S does nothing, it simply returns to the prompt. If the user enters a number and hits A, the program starts with the ENTRY? test which is true if the user has entered fresh data. The input will be stored in register 01 and the program jumps back to the prompt. If the user has not entered any information after the last prompt, subroutine 01 will be called to compute a new value which is then stored and displayed. This is the way the TVM application is implemented.



### Keyboard Codes

Sometimes, the hot keys A to D aren't enough. But there are ways to extend the number of directly addressable subroutines by a simple trick: shorthand addressing of numeric labels. To make this possible, each key is identified by a row and a column, each starting with one.

| | | | | | |
|---|---|---|---|---|---|
| A | B | C | D | -> | CPX |
| 11 | 12 | 13 | 14 | *15* | *16* |
| STO | RCL | Rv | f | g | h |
| *21* | *22* | *23* | 24 | 25 | 26 |
| ENTER^ | | x<>y | +/- | EEX | <- |
| 31 | | *32* | *33* | *34* | 35 |
| XEQ | 7 | 8 | 9 | / | |
| *41* | 42 | 43 | 44 | *45* | |
| ^ | 4 | 5 | 6 | x | |
| *51* | 52 | 53 | 54 | *55* | |
| v | 1 | 2 | 3 | - | |
| *61* | 62 | 63 | 64 | *65* | |
| EXIT | 0 | . | R/S | + | |
| *71* | 72 | 73 | *74* | *75* | |

Whenever you are asked for the entry of a two-digit label, any of the keys marked in *italic* in the above picture can be used as direct input. The label will be replaced by the row/column code of the respective key. Some keys are not available this way because they have a predefined meaning in this context. They can still be used for a short address by preceding the key with the f prefix. Only the f prefix itself cannot be used for shorthand addressing. If you want to associate a program with the key STO, just put the label 21 in front of the routine and it can be conveniently called with XEQ STO by the user.

### Direct Keyboard Access

The same codes are returned by the KEY? command which allows true "real time" response to user input from the keyboard. KEY? takes a register argument (X is allowed but does not lift the stack) and stores the key most recently pressed during program execution in the specified register. R/S and EXIT cannot be queried, they stop program execution immediately. The keyboard is active during execution but it is of course desirable to show a message and suspend the program with the PSE command while waiting for user input. PSE is interrupted by a key press, so you can simply use a PSE 99 statement in a loop to wait for input. KEY? acts as a conditional at the same time so a typical user input loop will look like this:

```
LBL 'USR'
CLα
α 'KEY'
α ?
LBL 00
αVIEW
PSE 99
KEY? 00
GTO 00
LBL?->00
XEQ->00
GTO 00
```

This code fragment prompts for a key and stores it in register 00. The line directly after KEY? is executed when no key was pressed. The statement KEY? is only executed every 9.9 seconds if the user does not press a key. If he does, the PSE is immediately terminated, KEY? is executed, finds the key code and stores it in register 00. The LBL→00 instruction checks if a label corresponding to the key code has been defined and executes it if found. Instead of the dumb waiting loop, the program can do some computations and update the display before the next call to PSE and KEY? – think of a lunar lander game.

To be even more versatile, the instruction KTY? ***nn*** is designed to return the key type of a row / column code in register ***nn***: 0 to 9 for the respective digits, 10 for the other numeric keys (. , +/- and EEX), 11 for any of the three shift keys and 12 for the rest. An invalid code in the target register throws an "Invalid Range Error".

If you decide not to handle the key in the program you may feed it back to the main processing loop of the calculator with the PUTK ***nn*** command. What happens is that the program halts and the key is treated as if pressed after the stop. This is especially useful if you want to allow numeric input while waiting for some special keys like the arrows. This allows writing of a vector or matrix editor in user code. After execution of the PUTK command the user is responsible for letting the program continue its work by pressing R/S or a hot key.

# APPENDIX A: SUPPORT FOR FLASHING, SERIAL I/O ETC.

## How to Flash Your HP 20b or 30b

You may do the flashing yourself. Then you need your calculator, a special connecting cable, and specific software on your PC or Mac. A PC featuring an hardware serial port and running Windows XP is beneficial. **Please read this paragraph completely before actually starting the procedure.**

- You will get the necessary software – the SAM-BA In-system Programmer – here for free:

  *http://www.atmel.com/dyn/products/tools_card.asp?tool_id=3883*

  Install it as explained by Atmel.

- You may get the cable from Gene Wright.

- The specific file you will need to transmit to your calculator to make it your WP 34S is called `calc.bin` and is included in the zipped package you can download from here:

  *http://sourceforge.net/projects/wp34s/files/*

  Alternatively, you may download `calc.bin` alone from

  *http://wp34s.svn.sourceforge.net/viewvc/wp34s/trunk/realbuild/*

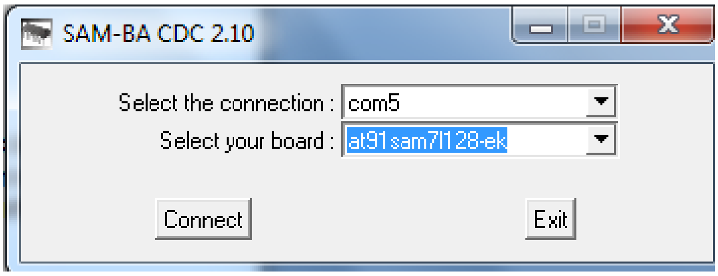
Now, having got these three (SAM-BA, the cable, and `calc.bin`), please turn to the file *http://dl.dropbox.com/u/10022608/Flashing%20a%2020b%20Calculator.pdf* (edited by Tim Wessmann and Gene Wright). Read it thoroughly for information about connecting and flashing.

> **ATTENTION:** If your PC does not feature an hardware serial interface, you will need an USB-to-serial converter to connect the special cable to your PC. Following our experience, converters containing FTDI chips will work – others may not.
>
> On other operating systems than XP flashing may work or not (definitively not on Windows 2000 or earlier). Please check.
>
> On Windows 7 load MS Windows Virtual PC and Windows XP Mode, then work therein.

Then proceed as described in *Flashing a 20b Unit* in said file, steps 1 to 3 only.

> **ATTENTION:** Flashing your *HP 20b* or *30b* will erase the HP firmware in step 3, meaning your business calculator will be gone then. The firmware will be replaced with the WP 34S file completely! After this flash is finished, you will have a *WP 34S RPN Scientific* – i.e. your calculator will react as documented in this very manual.
>
> This also means your device will not do anything useful for you between step 3 and 13. It may even look dead – it is not, be assured, at least it will just be eating your batteries (see below)! If you (have to) interrupt the flashing process at any time in this interval for any reason whatsoever, don't worry: simply start again. You may, however, not get any feedback displayed in step 3 anymore. That does not matter, just stick to the procedure.
>
> As long as the cable is connected to your calculator, it will draw a considerable current from the calculator batteries. If you happen to hang anywhere in the flashing process, also the processor is left running at full speed. So chances are high your coin cells will be drained while you are trying to find out what is going wrong. Thus it is wise to disconnect the cable from your calculator when you will not need the cable for the next couple of minutes. For repeated flashing, an external 3V DC supply may pay very fast. Take care to connect + to the outer and – to the inner contact. The following will work with a good 3V supply only.

Having completed step 3 of said file, call your SAM-BA for step 4. It may take a long time to start up (some sixty seconds), so be patient. When it launches (step 5), a window pops up:




Choose the correct connection (take the port you put your cable in – it may differ from what is printed here). Select the board built in your calculator (i.e. AT91SAM7L128-EK as shown). Press [Connect] then. This was step 6.

In step 7, put in the address of `calc.bin` on your PC. Then continue according to steps 8 to 13. Not reaching step 7 may be due to low supply voltage on your calculator (see above).

After flashing successfully, a keyboard overlay is very helpful for further work since most labels deviate from the ones used on said business calculators. You may get adhesive overlays from Eric Rechlin. Preliminary paper overlays are most easily made of a file provided here:

> *http://wp34s.svn.sourceforge.net/viewvc/wp34s/artwork/wp34s_overlay.png*
>
> Set the overall width of this picture to 68mm and print it. Cut it out, span it over your WP 34S using some transparent adhesive tape, and you are done.

### Commands for Handling Flash Memory on Your WP 34S

Flash memory is very useful for backups as explained *above*. Alternatively to the commands SAVE and LOAD contained in X.FCN (see the *index of operations*), you may use another approach. Hold down **ON** (i.e. **EXIT** ) and press one of the following keys:

| | |
|---|---|
| **STO** for backup: | Creates a copy of the RAM in flash memory like SAVE does. |
| **RCL** for restore: | Restores the most recent backup like LOAD does. |
| **S** (i.e. **6** ) for SAM-BA: | Clears the GPNVM1 bit and turns the calculator off. |
| | **ATTENTION:** You can only boot in SAM-BA mode! Without the SAM-BA software and the cable mentioned above, you will be lost! |

These ON key combinations have to be pressed twice in a row without releasing the ON key to be executed.

We recommend doing a SAVE or **ON** + **STO** before flashing a new release! After flashing, your backup will still be available – if you used **ON** + **S** to get into SAM-BA boot mode and didn't accidently press the ERASE button on the cable.

Further flash memory operations are PRCL, PSTO, P⇆, RCF, RCF.RG, and RCF.ST. See the *index*.

## Mapping of Memory Regions to Emulator State Files

| Region | Start address in flash | State file | Remarks |
|---|---|---|---|
| Unnamed | `0x11FC00` | `wp34s-R.dat` | Backup of 112 registers, flags and state. |
| 0 | `0x11F800` | `wp34s-0.dat` | Backup of program memory (506 steps). |
| 1 | `0x11F400` | `wp34s-1.dat` | Space for generic user programs. Each region contains 506 steps again. The files `wp34s-`***n***`.dat` are written whenever a respective flash command is executed. You will find some sample files at Sourceforge. |
| 2 | `0x11F000` | `wp34s-2.dat` | |
| 3 | `0x11EC00` | `wp34s-3.dat` | |
| 4 | `0x11E800` | `wp34s-4.dat` | |
| 5 | `0x11E400` | `wp34s-5.dat` | |
| 6 | `0x11E000` | `wp34s-6.dat` | |
| 7 | `0x11DC00` | `wp34s-7.dat` | |
| 8 | `0x11D800` | `wp34s-8.dat` | |
| 9 | `0x11D400` | `wp34s-9.dat` | |
| RAM | n/a | `wp34s.dat` | Backup of the <u>emulator</u> RAM area (registers, state, and programs) – this file is written only when exiting the emulator. |

All files are only read into memory at emulator startup.

## Data Transfer Between Your WP 34S and Your PC (SAM-BA)

This method is superseded by the one using serial I/O commands – see next paragraph. It is still interesting enough to leave it here as a reference.

The entire RAM is saved to address `0x11F800` (relative address `0x1F800`) by SAVE or its equivalent ON + STO . This content can be copied to your PC or loaded from it if the special interface cable mentioned above is connected. Then, the transfer is performed as follows:

1. From calculator to PC:
   a. Press ON + STO,
      then ON + D (see below),
      then ON + S .
   b. Press ON once again and start SAM-BA on the PC. Both devices should connect.
   c. Set the start address to `0x11F800` and the size to `0x800`.
   d. Enter a file name of your choice in the receive field. You can now receive the file with SAM-BA.
   e. Move it into your emulator directory (where `wp34sgui.exe` is stored) under the name `wp34s.dat` .
   f. The emulator should accept the file. Your registers and programs will then be in place.

g. To get your calculator back in business, start the "Boot from flash" script in SAM-BA – the same procedure you should know from flashing the firmware.

h. Reset and press **ON** to power up. Restore with **ON** + **RCL** . If RAM is lost (most probably due to an accidental press of the ERASE button on the cable), the most recent backup (i.e. the one of step a. here) will be automatically restored.

2. From PC to calculator:

   a. Execute steps 1.a + b.

   b. Set the start address to `0x11F800` .

   c. Point SAM-BA to your `wp34s.dat` file from the emulator.

   d. You can now send the short file with SAM-BA.

   e. Execute steps 1.g + h.

The program regions accessible with the commands PSTO, PRCL and P⇆ are stored at addresses mentioned in the table above and have a length of `0x400` (1 kB) each. The emulator creates files `wp34s-`***n***`.dat`, with ***n*** being the region number. You can handle these files the same way as the complete state file from the emulator. The regions have identical formatting and can be swapped by copying their data to the 'wrong' place. The register and state portion of the backup area at `0x11FC00` is formatted differently.

If you want to get your emulator data from your PC into your calculator all in once, do the following in Windows:

```
copy /b calc.bin+wp34s-9.dat+wp34s-8.dat+ … +wp34s-2.dat
        +wp34s-1.dat+wp34s.dat calc-full.bin
```

As an alternative, the following will copy the backup data instead of the RAM state file:

```
copy /b calc.bin+wp34s-9.dat+ …
        +wp34s-1.dat+wp34s-0.dat+wp34s-R.dat calc-full.bin
```

The resulting file can be transferred into flash and all data will be readily available.

## Data Transfer Between Your WP 34S and Your PC (Serial I/O)

You will need the special interface cable mentioned above once again, or a *modified 20b or 30b* as described elsewhere. Said special cable draws current from the batteries of your calculator; it shall thus be disconnected from your WP 34S as soon as not needed anymore.

Communication is between your WP 34S and another WP 34S. The Windows emulator counts as a valid partner so you can exchange data between your WP 34S and the PC. Since PCs tend to have more than one port you have to tell the emulator which one to use. Create a text file `wp34s.ini` in the directory where the state files `wp34s.dat` reside and put the name of the port as the only line in this file, e.g. `COM5:` – the very same port SAM-BA uses to access your WP 34S for flashing.

The following commands allow for sending programs, registers or all RAM. They are found in the P.FCN catalog.

On the receiving device, start the command RECV. It will display `Wait...` .

On the sender you have four choices:

1. SENDP will send the user program space. After successful termination, the receiver will display `Program` .

2. SENDR will send the registers 00 to 99. The receiver will display `Register` after successful termination.
3. SENDA will send the complete 2 KB of non-volatile memory. The receiver will display `All RAM` after successful termination.
4. SENDL ***n*** will send a library region directly. It will arrive in RAM and may be stored using PSTO.

The commands for sending and receiving feature a fixed timeout of some 10 seconds for setting up the connection. After an interval of inactivity of said length, `I/O Error` is displayed indicating no communication has occurred. If `I/O Error` appears in the middle of a transmission try again.

> On a device without the crystal installed, you may get said error because of the baud rate setting may be a bit too far off. To determine the speed, use the loop
>
> ```
> CLx
> INC X
> BACK 01
> ```
>
> and let it run for 30 seconds. The expected result at nominal speed is around 191000. The I/O commands accept a correction factor in percent in **X**. Try with 95 if your device is a bit too slow or 105 if it is a bit too fast. Values between 80 and 120 are accepted – all other are ignored. On the emulator or with the crystal installed, ***x*** is ignored.

The little "=" annunciator is lit while the serial port is in use. **EXIT** can be used to abort the communication.

### More Keyboard Commands Employing ON

**ON** + **+** or **−** : Adjust display contrast.

**ON** + **C** : Tells the system a quartz **c**rystal is installed for the real time clock. The quartz is inevitable prerequisite for the clock being useful in medium to long range (see TICKS). Its installation is a hardware modification described elsewhere.

> **ATTENTION:** If this command is entered though the hardware does not contain said modification, the system will hang and can only be brought back to live with a reset or a battery pull!

**ON** + **D** : Enters **d**ebugging mode (use at your own risk).

**ON** + **.** : Toggles the radix mark as **./,** does.

# APPENDIX B: MORE ROUTINES AND COMMANDS

## Library Routines

TVM and WHO live in the library file `wp34s-1.dat`, located in the library directory. Here is how to install these two routines in the emulator and on the calculator.

1. Copy `wp34s-1.dat` into the emulator directory.
2. Start the emulator and the calculator with the serial cable still connected. Make sure a file `wp34s.ini` exists in the emulator directory naming the COM port in use.
3. Make sure you have a backup of your programs on the calculator and on the emulator.
4. Use PRCL 1 on the emulator to copy the library into user program RAM.
5. Use RECV on the calculator and SENDP on the emulator. This will transfer the program memory of the emulator to the calculator.
6. On the calculator, use PSTO to save the library.
7. Restore your backups.

Alternatively use SAM-BA to transfer the image directly to a RAM region as described elsewhere.

## Internal Commands (Use at Your Own Risk)

Some commands are used in internal routines exclusively and are not accessible from the keyboard. Others are placed here until they are sufficiently tested for being officially released. They are listed below for sake of a complete documentation only:

| Name | Purpose and remarks | | |
|---|---|---|---|
| iC ***n*** | Recalls internal constants, selected by the number specified: | | |
| | 0 | 0 | |
| | 1 | 1 | |
| | 2 | 5.01402 | Kronrod only weight loop initializer (constants 5 - 14 below) |
| | 3 | 15.02903 | Gauss-Kronrod weight loop initializer (constants 15 - 29 below) |
| | 4 | 0.149445554002916905664936468389821 | Midpoint location is 0.5.<br>Kronrod weight for midpoint k10 |
| | 5 | 0.995657163025808080735527280689003 | Kronrod location of k0 and k20 |
| | 6 | 0.011694638867371874278064396062192 | Kronrod weight for k0 and k20 |
| | 7 | 0.930157491355708226001207180059508 | Kronrod location of k2 and k18 |
| | 8 | 0.054755896574351996031381300244580 | Kronrod weight for k2 and k18 |
| | 9 | 0.780817726586416897063717578345042 | Kronrod location of k4 and k16 |
| | 10 | 0.093125454583697605535065465083366 | Kronrod weight for k4 and k16 |
| | 11 | 0.562757134668604683339000099272694 | Kronrod location of k6 and k14 |
| | 12 | 0.123491976262065851077958109831074 | Kronrod weight for k6 and k14 |
| | 13 | 0.294392862701460198131126603103866 | Kronrod location of k8 and k12 |
| | 14 | 0.142775938577060080797094273138717 | Kronrod weight for k8 and k12 |
| | 15 | 0.973906528517171720077964012084452 | Location of g0, g9, k1 and k19 |
| | 16 | 0.066671344308688137593568809893332 | Gauss weight for g0 and g9 |
| | 17 | 0.032558162307964727478818972459390 | Kronrod weight for k1 and k19 |

| Name | Purpose and remarks |
| --- | --- |
| | 18 0.86506336668898451073209668842349 3 Location of g1, g8, k3 and k17<br>19 0.14945134915058059314577633965769 7 Gauss weight for g1 and g8<br>20 0.07503967481091995276704314091619 0 Kronrod weight for k3 and k17<br><br>21 0.67940956829902440623432736511487 4 Location of g2, g7, k5 and k15<br>22 0.21908636251598204399553493422816 3 Gauss weight for g2 and g7<br>23 0.10938715880229764189921059032580 5 Kronrod weight for k5 and k15<br><br>24 0.43339539412924719079926594316578 4 Location of g3, g6, k7 and k13<br>25 0.26926671930999635509122692156946 9 Gauss weight for g3 and g6<br>26 0.13470921731147332592805400177170 7 Kronrod weight for k7 and k13<br><br>27 0.14887433898163121088482600112972 0 Location of g4, g5, k9 and k11<br>28 0.29552422471475287017389299465133 8 Gauss weight for g4 and g5<br>29 0.14773910490133849137484151597206 8 Kronrod weight for k9 and k11<br><br>Constants 2 .. 29 are for the 10 / 21 point Gauss-Kronrod quadrature used by the internal integration command. Locations are in the range (0, 1) which is scaled to match the interval of integration. The quadrature sums the weight times the function value at each location to estimate the integral. In Gauss-Kronrod schemes the Gauss points are common to both quadratures although the weights are different. This means two estimates of the integral can be performed without increasing the number of function evaluations which in turn allows an estimate of the error to be made. The cost for this is a reduction in the degree of polynomial function that is always integrated exactly. |
| | The following commands starting with M. are building blocks designed to provide the low level support routines for creating more useful matrix functions as keystroke programs. I.e. they represent the basic linear algebra subprograms of the WP 34S matrix support. A matrix is represented within your WP 34S by its descriptor (MD), formatted `bb.rrcc` with<br>***rr*** being the number of rows and<br>***cc*** the number of columns. Thus the matrix has ***rr*** × ***cc*** elements.<br>They are stored in consecutive registers starting at base address \|***bb***\| .<br><br>**Example:** A descriptor 7.0203 represents a 2×3 matrix – let us call it (M). Then its elements $m_{11} = r07$ , $m_{12} = r08$ , $m_{13} = r09$ , $m_{21} = r10$ , $m_{22} = r11$ , and $m_{23} = r12$ .<br><br>If ***cc*** is omitted, it is set to ***rr*** so a square matrix is assumed. The maximum number of matrix elements is 100 – it is the number of general purpose registers available. A vector descriptor looks like `bb.01cc` or `bb.rr01` . |
| M.ALL | Takes a MD in **X** , saves it in **L**, and returns a value suitable for ISG or DSL looping in **X**. The loop processes <u>all</u> elements in the matrix. The loop index is DSL if the descriptor is negative and ISG for positive. |
| M.COL | Takes a MD in **X** and a column number in **Y**. Returns a loop counter in **X**, dropping the stack. The MD is saved in **L**. The loop processes all elements $m_{iy}$ only. The loop index is DSL if the descriptor is negative and ISG for positive. |
| M.COL? | Takes a MD in **X** , saves it in **L**, and returns the number of columns in this matrix. |

| Name | Purpose and remarks |
|---|---|
| M.DET | Takes a MD in **X** and returns the determinant of the matrix. The matrix must be square and is not modified. |
| M.DIAG | Takes a MD in **X** , saves it in **L**, and returns a loop counter in **X**. The loop processes all elements along the matrix diagonal, i.e. all elements $\boldsymbol{m_{ii}}$ . The loop index is DSL if the descriptor is negative and ISG for positive. |
| M.IJ | Takes a MD in **X** and a register number in **Y**. Returns the column that register represents in **Y** and the row in **X**. The MD is saved in **L**. M.IJ is similar to *PPC M4*. |
| M.INV | Takes a square MD in **X** and inverts the matrix in-situ. Doesn't alter the stack. |
| M.LIN | Takes a base register in **X**, a vector descriptor in **Y**, and a square MD in **Z**. Solves the system of linear equations $(Z) \cdot \vec{x} = \vec{y}$ and returns the filled out MD in **X**. |
| M.REG | Takes a MD in **X**, a row number in **Y**, and a column number in **Z**. The MD is saved in **L**. M.REG returns the register index in **X** (popping the stack twice). It is similar to *PPC M5*. |
| M.ROW | Takes a MD in **X** and a row number in **Y**. Returns a loop counter in **X**, dropping the stack and setting last **L** like all two-argument commands. The loop processes all elements $\boldsymbol{m_{yi}}$ only. The loop index is DSL if the MD is negative and ISG for positive. |
| M.ROW? | Takes a MD in **X**, saves it in **L**, and returns the number of rows in this matrix. |
| M.R× | Takes a MD in **X**, a row number in **Y**, and a real number in **Z**. It multiples each element $\boldsymbol{m_{yi}}$ by $\boldsymbol{z}$. The stack is unchanged. M.R× is similar to *PPC M2*. |
| M.R+× | Takes a MD in **X**, a destination row number in **Y**, a source row number in **Z**, and a real number in **T**. It multiples each element $\boldsymbol{m_{zi}}$ by $\boldsymbol{t}$ and adds it to $\boldsymbol{m_{yi}}$ . The stack is unchanged. M.R+× is similar to *PPC M3*. |
| M.R⇆ | Takes a MD in **X** and two row numbers in **Y** and **Z**. It swaps the contents of rows $\boldsymbol{y}$ and $\boldsymbol{z}$. The stack is unchanged. M.R⇆ is similar to *PPC M1*. |
| M.SQR? | Takes a MD in **X** and generates an error if it is not square. Else does nothing. |
| M.TRN | Takes a MD in **X** and returns the descriptor for the transpose of **X**. The transpose is done in-situ and does not require any additional registers or storage. |
| M.+× | Takes two MDs in **X** and **Y**, and a real number in **Z**. Returns $(X) + (Y) \cdot z = (X)$ . Thus a scalar multiple of one matrix is added to another matrix. The multiply adds are done internally in high precision and results should be exactly rounded. |

| Name | Purpose and remarks |
|---|---|
| M.× | Takes two MDs in **Y** and **Z** and the integer part of $x$ as the base address of the result. Returns $(Z)\cdot(Y) = (X)$. The fractional part of $x$ is updated to match the resulting matrix – no overlap checking is performed.<br><br>All calculations are done internally in high precision, although it would still be possible to trick the code up and produce bad results. It would be very difficult to get the same degree of accuracy in RPN since the best that can easily be achieved there is $a{\cdot}b{+}c{\cdot}d$ and a matrix multiply adds more terms than this. |
| | The following two solver commands SLVI and SLVS may use some hidden registers and flags. The start points of the respective register and flag blocks are passed as one argument ***n***.<br><br>Registers:<br>***n***+0 , ***n***+1: first two estimates ***a*** and ***b*** for the root<br>***n***+2: third estimate ***c***<br>***n***+3: function value at first estimate **f(*a*)**<br>***n***+4: function value at second estimate **f(*b*)**<br><br>Flags:<br>***n***+0 .. ***n***+7: an eight bit iteration counter<br>***n***+8: “bracket flag” – true if we've got an interval with ***f(a)*** * ***f(b)*** < *0*<br>***n***+9: true if all function evaluations have been constant so far |
| SLVI ***<u>n</u>*** | Initializes the solver. SLVI clears the iteration counter, takes ***a*** and ***b*** and calculates **f(*a*)** and **f(*b*)**, sets the last 2 flags accordingly, and produces a guess ***c***. There is no stack interaction. |
| SLVS ***<u>n</u>*** | Solver step. Updates the internal solver state based on the last function evaluation. In particular, SLVS takes ***a***, ***b***, ***c***, **f(*a*)**, and **f(*b*)** from the register block plus **f(*c*)** from **X** and updates the register values so that ***c*** and **f(*c*)** replace one of ***a*** and **f(*a*)** or ***b*** and **f(*b*)**. It also produces a new guess ***c*** and returns zero in **X** if the solving should continue and non-zero if not. Otherwise, the stack isn't altered. |
| | The built in solver loop looks like this in principle, assuming ***n*** = *0* :<br><br>    SLVI ; calculate **f(*a*)** and **f(*b*)** and initialize the registers and flags<br>  LBL 00<br>    RCL 02 ; recall ***c***<br>    XEQUSR ; call the user's subroutine calculating **f(*c*)**<br>    x≈ 0? ; test if the solution has converged<br>    GTO 01 ; converged, so exit the routine<br>    SLVS ; update estimates<br>    x= 0? ; should we continue?<br>    GTO 00 ; loop back again<br>  LBL 01<br>    RCL 02 ; best guess so far<br>    RTN<br><br>The actual solver is fairly complex. A combination of quadratic interpolation and a guarded secant method is used. |
| XEQUSR | Calls a user subroutine (used by SLV, ∫, Π and Σ ). The subroutine is defined by the argument to the initial command (either numeric of alpha label). |

# APPENDIX C: RELEASE NOTES

| | Date | Release notes |
|---|---|---|
| 1 | 9.12.08 | Start |
| 1.1 | 15.12.08 | Added the table of indicators; added NAND, NOR, XNOR, RCLWS, STOWS, //, N, SERR, SIGMA, < and >; deleted HR, INPUT, 2 flag commands, and 2 conversions; extended explanations for addressing and COMPLEX & …; put XOR on the keyboard; corrected errors. |
| 1.2 | 4.1.09 | Added ASRN, CBC?, CBS?, CCB, SCB, FLOAT, MIRROR, SLN, SRN, >BIN, >DEC, >HEX, >OCT, BETA, D>R, DATE, DDAYS, D.MY, M.DY, Y.MD, CEIL, FLOOR, DSZ, ISZ, D>R, R>D, EMGAM, GSB, LNBETA, LNGAMMA, MAX, MIN, NOP, REAL, RJ, W and WINV, ZETA, %+ and %-; renamed the top left keys B, C, and D, and bottom left EXIT. |
| 1.3 | 17.1.09 | Added AIP, ALENG, ARCL, AROT, ASHF, ASTO, ATOX, XTOA, AVIEW, CLA, PROMPT (all taken from 42S), CAPP, FC?C, FS?C, SGMNT, and the …# commands; renamed NBITS to BITS and STOWS to WSIZE; specified the bit commands closer; deleted the 4 carry bit operations. |
| 1.4 | 10.2.09 | Added CONST and a table of constants provided, D>J and J>D, LEAP?, %T, RCL and STO ▲ and ▼, and 2 forgotten statistics registers; deleted CHS, EMGAM, GSB, REAL and ZETA; purged and renamed the bit operations; renamed many commands. |
| 1.5 | 5.3.09 | Added RNDINT, CONV and its table, a memory table, the description of XEQ B, C, D to the operation index, and $a$ and $g_e$ to the table of constants; put CLSTK on a key, moved CLΣ and FILL, changed the % and log labels on the keyboard, put CLALL in X.FCN; checked and cleaned alpha mode keyboard and added a temporary alpha keyboard; rearranged the alphabet to put Greek after Latin, symbols after Greek consistently; separated the input and non-programmable commands; cleaned the addressing tables. |
| 1.6 | 12.8.09 | Added BASE, DAYS+, DROP, DROPY, E3OFF, E3ON, FC?F, FC?S, FIB, FS?F, FS?S, GCD, LCM, SETDAT, SETTIM, SET24, SINC, TIME, VERS, αDAY, αMONTH, αRC#; %Σ, as well as F-, t-, and $\chi^2$-distributions and their inverses; reassigned DATE, modified DENMAX, FLOAT, αROT, and αSHIFT; deleted BASE arithmetic, BIN, DEC, HEX, and OCT; updated the alpha keyboards; added flags in the memory table; included indirect addressing for comparisons; added a paragraph about the display; updated the table of indicators; corrected errors. |
| 1.7 | 9.9.09 | Added P.FCN and STAT catalogs, 4 more conversions, 3 more flags, Greek character access, CLFLAG, DECOMP, DENANY, DENFAC, DENFIX, Iβ, IΓ, αDATE, αRL, αRR, αSL, αSR, αTIME, 12h, 24h, fraction mode limits, normal distribution and its inverse for arbitrary μ and σ, and Boolean operations working within FLOAT; deleted αROT, αSHIFT, the timer, and forced radians after inverse hyperbolics; renamed WINV to $W^{-1}$, and beta and gamma commands to Greek; added tables of catalog contents; modified label addressing; relabeled PRGM to P/R and PAUSE to PSE; swapped SHOW and PSE as well as Δ% and % on the keyboard; relabeled Q; corrected CEIL and FLOOR; updated X.FCN and alpha commands; updated the virtual alpha keyboard. |
| 1.8 | 29.10.09 | Added R-CLR, R-COPY, R-SORT, R-SWAP, RCLM, STOM, alpha catalogs, 1 more constant and some more conversions, a table of error messages, as well as the binomial, Poisson, geometric, Weibull and exponential distributions and their inverses; renamed some commands; put $\sqrt{\ }$ instead of π on hotkey D. |
| 1.9 | 14.12.09 | Added two complex comparisons; swapped and changed labels in the top three rows of keys, dropped CLST; completed function descriptions in the index. |
| 1.10 | 19.1.10 | Added IMPFRC, PROFRC, $^{C}$ENTER, αBEG, αEND, and an addressing table for items in catalogs; updated temporary alpha mode, display and indicators, RCLM and STOM, alpha-commands and the message table; renamed the exponential distribution; wrote the introduction. |
| 1.11 | 21.9.10 | Changed keyboard layout to bring Π and Σ to the front, relabeled binary log, swapped the locations of π, CLPR, and STATUS, as well as SF and FS?; created a menu TEST for the comparisons removed and the other programmable tests from P.FCN; added %MG, %+MG, %MRR, RESET, SSIZE4, SSIZE8, SSIZE?, $^{C}$DROP, $^{C}$FILL, $^{C}$R↓, $^{C}$R↑, registers J and K, a table of contents and tables for stack mechanics and addressing in complex operations; updated memory and real number addressing tables, DECOMP, αOFF, αON, Π, and Σ; renamed ROUNDI, WSIZE?, β(x,y), Γ(x) and the constant $p_0$ ; deleted DROPY (use x↔y, DROP instead), αAPP, αBEG, αEND, and the "too long error" message; deleted Josephson and von Klitzing constants (they are just the inverses of other constants included in CONST already); brought more symbols on the alpha keyboard. |
| 1.12 | 22.12.10 | Modified keyboard layout; added catalogs MODE and PROB; changed mode word, catalog contents and handling (XEQ instead of ENTER), as well as some non-programmable info commands; expanded IMPFRC and PROFRC; added a paragraph about the fonts provided and explained alpha catalogs in detail; added PRIME? and some conversions; deleted FRACT, OFF and ON. |
| 1.13 | 3.2.11 | Modified keyboard layout; modified αTIME, radix setting, H.MS+ and H.MS-; added EVEN?, FP?, INT?, LZOFF, LZON, ODD?, RCLS, STOS, returned FRACT; added and renamed some conversions; updated the paragraph about display; added appendices A and B; baptized the device WP 34S. |

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| 1.14 | 18.3.11 | Started the Windows emulator.<br>Added DEC and INC, renamed FLOAT to DECM; redefined αTIME and H.MS mode; updated appendix A; documented the annunciators BEG and = as well as underflows and overflows in H.MS; corrected some errors showing up with the emulator. |
| 1.15 | 21.3.11 | Modified FIX, removed ALL from MODE, updated CONV. |
| 1.16 | 27.3.11 | Added LBL?, f'(x), and f"(x); modified PSE; upgraded catalog searching. |
| 1.17 | 9.5.11 | Modified keyboard layout for adding a fourth hotkey; added AGM, BATT, $B_n$, $B_n$*, Cauch, Lgnrm, Logis and their inverses, all the pdf, COV, CUBE, CUBERT, DEG→, ENGOVR, ENTRY?, erfc, GRAD→, GTO . *hotkey*, KEY?, RAD→, SCIOVR, SERRw, SLVQ, sw, sxy, TICKS, TVM, xg, ε, $\varepsilon_m$, $\varepsilon_p$, ζ, σw, $(-1)^x$, the polynomials, four angular conversions, four Planck constants, the regional settings, global alpha labels, and three messages; renamed most cdf; changed →DEG, →RAD, →GRAD to leaving angular mode as set; altered PSE for early termination by keystroke; made D.MY default instead of Y.MD; moved degrees to radians conversions to CONV; removed $^{C}$CLx, H.MS mode, %+ and %-; corrected errors. |
| 1.18 | 5.6.11 | Expanded program memory; modified label addressing (A ≠ 'A') and fraction mode limits, changed ANGLE to work in real and complex domains, renamed MOD to RMDR, changed the keyboard layout; put BACK, ERR, SKIP, and SPEC? to the main index; added CAT and the I/O commands for flash memory, expanded R-COPY; corrected x→α. |
| 2.0 | 21.7.11 | Entered beta test phase.<br>Added DAY, MONTH, YEAR, FAST, SLOW, S.L, S.R, VWα+, flag A, ON + and –, some constants, and a paragraph about I/O; renamed old DAY to WDAY, RRCL to RCFRG, SRCL to RCFST; added an inverse conversion shortcut, stones⇆kg, and changed Pa⇆mbar to Pa⇆bar; modified the VIEW commands, ALL, DISP, MODE, RCLM, STOM, and X.FCN; repaired hyperlinks; corrected some errors; included flash.txt; updated the first chapters, explained stack mechanics in more detail. |
| 2.1 | 3.10.11 | Added serial I/O commands, $DEL_P$, DSL, EXPT, IBASE?, INTM?, ISE, KTY?, MANT, NEXTP, PUTK, REALM?, RM, RM?, SMODE?, TOP?, $\sqrt[x]{y}$, signed tests for zero, some constants, and the paragraph about interactive programming; updated the values in CONST to CODATA 2010, also updated SLVQ, SHOW, Σ, Π, and the paragraphs about statistics, predefined alpha labels and memory; corrected some errors; deleted complex ANGLE, →BIN, →DEC, →HEX, and →OCT; redistributed the contents of X.FCN and P.FCN; renamed S.L and S.R to SDL and SDR; put '?' on the alpha keyboard and moved £ to P to make room for π; expanded Appendix A; reorganized the structure of the document; added first aid to the front page; rewrote the keyboard chapter. |
| 2.2 | 6.10.11 | Added matrix operations. |