

new scientist

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Renaissance in high energy physics

The electronic slide-rule comes of age

It is now possible to buy pocket-sized scientific calculators capable of performing a range of trig, log and power functions for a third the price charged two years ago. Prices will fall further, but not so dramatically

Nicholas Valéry

Even those closest to the pocket calculator business have been overwhelmed by the pace of developments and the nose dive in prices. Indeed, so bloody has been the price war at the cheap end in particular that many a proud name has fallen by the wayside. Last week the second largest calculator manufacturer in the United States, Bowmar Instrument Corp, became the latest casualty. The company may yet survive—as an acquired or merged operation—but it will have to be slimmed down considerably.

Bowmar's problems are typical of the times. Envious of the handsome profits being made by the assembly houses who put calculators together from other suppliers' components and sell them at substantial profit, the giant US semiconductor manufacturers started to integrate their own companies vertically and moved heavily into the calculator assembly business. Texas Instruments was followed by Rockwell and, more recently, National Semiconductor. They brought with them a price advantage on the vital integrated circuits, plus greater technological ability and superior financial resources—and, above all, control over the supply of microcircuits to competitive manufacturers.

Texas Instruments quickly moved into the number one position in the United States—which is by far the largest calculator market in the world, accounting for 40 per cent of all machines sold. It became clear that the only survivors in the big league would be those that were vertically integrated. And so Bowmar as an assembly house took the necessary plunge—investing \$7 million in a large semiconductor plant in Chandler, Arizona. Their timing, however, couldn't have been worse: by then, many manufacturers had developed overcapacity, the shops and warehouses were stocked to overflowing, and everybody was strapped for cash. By mid-February, Bowmar reckoned its after-tax loss had soared to \$20 million on a year's sales of \$80 million. The company filed for protection under the federal bankruptcy law.

Ironically, some of the smaller manufacturers of calculators have been in a slightly stronger position. The shrewder ones saw the battle over the basic £8 calculator coming more than a year ago—and took steps to up-market as fast as possible. This had been made possible through the proliferation of models which, by 1973, had fragmented the market into quite well-defined sectors. These are now generally classified into four main groupings: four/five function calculators, dedicated calculators, desktop calculators, and programmable calculators. Their prices range from £8-15 for the simplest type of calculator to £2500 or more for a desktop programmable. Understandably, it is the so-called dedicated sector which has attracted most manufacturers looking to maintain profits

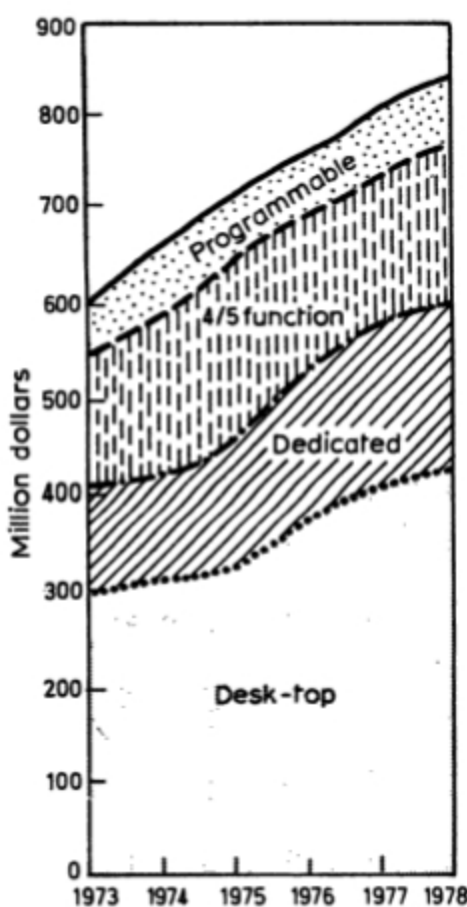
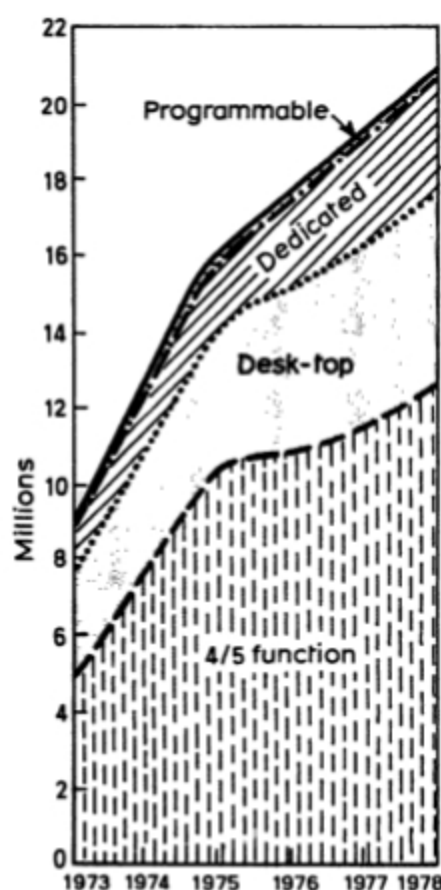
without the worst of the cut-throat competition found at the bottom end of the business.

The dedicated sector starts with the electronic slide-rules. These possess such keys as reciprocal, square, square root, and often a fully addressable memory as well as the usual four basic functions of add, subtract, multiply and divide. Its bigger brother is the scientific calculator which, in addition to the above, includes sine, cosine and tangent (and their arcs) as well as a natural log key and its antilog (e^x) and possibly a log to base 10 key and its antilog (10^x), and also a power key (x^y). Other features often found on scientific calculators include the facility for accepting trigonometric data in degrees or radians, an $x-y$ exchange key for swapping data in the display with that in the working register, and an exponent key for entering data in scientific notation (in the form of a signed mantissa and a signed exponent in the range 10^{-99} to 10^{+99}). Other dedicated machines include statistical and financial calculators and metric converters, but these still represent only a small fraction of the dedicated market.

Hewlett-Packard was the pioneer—and the model that nearly all other manufacturers would like to emulate. In 1972, the HP-35 was the only specialist machine on the market. A year later some 187 000 units had been sold in western Europe alone, accounting for 5 per cent of sales in volume and 8.5 per cent in value. Last year, sales of specialist calculators in Europe exceeded 600 000 units. These machines carried the highest profit of any calculators in the industry. In 1973, the average selling price for a scientific machine was around £120. By 1974, the average price had fallen 40 per cent to £72. Already the 1975 price pattern for scientific calculators is emerging—suggesting a similar percentage drop to around £45.

Notwithstanding the keen price competition even here, dedicated calculators are expected to account for the sharpest growth of all sectors in the calculator industry. A market research report from Creative Strategies Inc (CSI) of San Jose, California, predicts that:

- New handheld programmables will appear in 1975-76 not unlike the HP-65 at as little as £85 for the scientific-technical student market. Easy programming will be a key feature.
- Additional sources of scientific and slide-rule calculators will maintain downward price pressure and open up further the school and university student market.
- Many new market entrants will introduce new scientific programmable calculators, particularly by Japanese and West European manufacturers. The necessary MOS chips will be easier to obtain from this year on.
- New profession-oriented calculators will appear, including the medical calculator and special models for airline pilots, rally drivers



The expected growth of the US calculator market—in millions of units (top) and millions of dollars (above). Courtesy of Creative Strategies Inc, San Jose

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Example:

The charge on a 2 microfarad condenser oscillates through a 40 millihenry inductance and 20 Ohm resistance. Find the charge after 1 millisecond of discharge.

$$L \frac{d^2Q}{dt^2} + R \frac{dQ}{dt} + \frac{Q}{C} = 0$$

THUS $\frac{Q}{Q_0} = e^{-\frac{Rt}{2L}} \left(\cos \pi t + \frac{R}{2L} \sin \pi t \right)$ { 32 KEYSTROKES IN 14 SECONDS

WHERE $P = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} = 352668$ { 58 KEYSTROKES IN 24 SECONDS

HENCE $\frac{Q}{Q_0} = -0.7425$



All these special SR 36 features

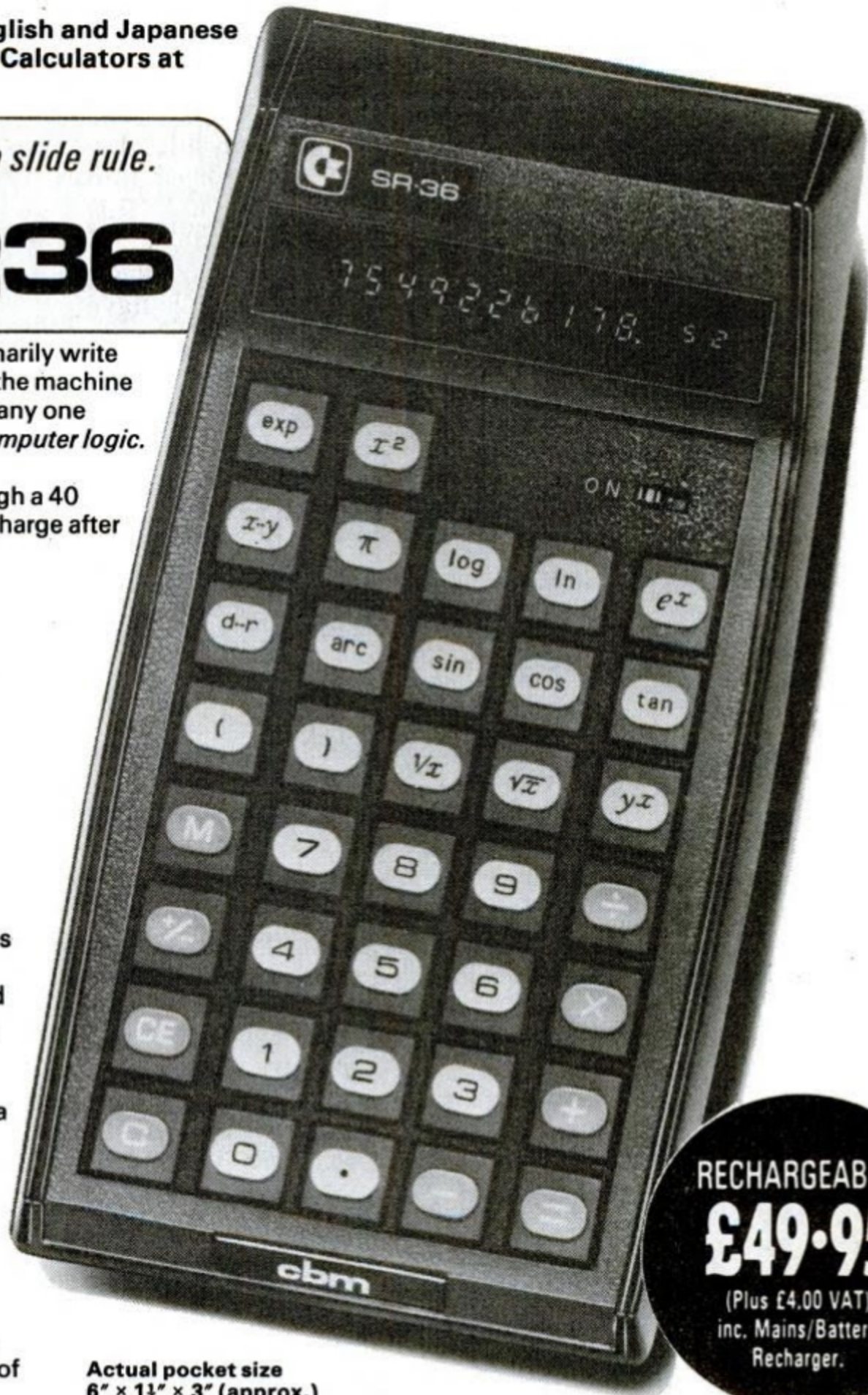
- 12 Character Display – shows a 10 Digit mantissa plus a two Digit Exponent. You can express quantities ranging from 10⁹⁹ to 10⁻⁹⁹.
- Special PARENTHESES KEYS – Accomplishes mixed chain calculations using two levels of Parentheses to group expressions. Other comparable machines surrender memory to achieve this, the SR 36 remains free to store other data in the additional memory register.
- Trigonometric functions and their inverse (arc) in degrees or radians.
- Log functions.
- Common and Natural Log Keys.
- Anti Logs – use Y^X and E^X keys for Common and Natural Anti Logs.
- Y^X Key – Raises one number to the power of another.
- E^X Key – Commands the Calculator to raise the Value of E to the displayed power.
- X², 1/X, Factor Exchange, π, and change sign keys.
- Automatic Floating Decimal.
- CLEAR ALL and clear Error Keys.

Find it in most good stores: CURRYS, LASKYS, LINDAIR, SUSSEX STNRS., SELFRIDGES and LONDON shops, e.g. MARBLE ARCH, CAVENDISH, McDONALD and METYCLEAN shops.

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and so on (Texas Instruments' SR-22 is designed for computer programmers).

- Special business calculators with two memories and per cent and compound interest keys will replace the one memory/per cent function machines currently sold to the business community.

Fight for the scientific market

Two years ago, between them the scientific and slide-rule calculators accounted for 97 per cent of the dedicated market. Their share dropped to around 78 per cent last year, and is expected to be under 70 per cent this year. "While the major market for the scientific/slide-rule calculators was professional (for instance, engineer and senior technician), sharp price reductions and market familiarity have tapped a far larger market reservoir in the educational field," declares the market research report published by CSI in December. The research company believes that, as in the United States, students in Europe pressed for simple electronic slide-rules, while university students purchased scientific machines like the Hewlett-Packard HP-35 and the Texas Instruments SR-50. "The higher prices commanded by these calculators stemmed from both their relative scarcity (until May 1974) and the price stability in the marketplace," says CSI.

However, there appears to be little hard evidence, at least in Britain, of heavy student demand for such relatively high priced calculators. It is difficult to believe that over the

past 12 months students in Europe have been in a position to pay anything like £130 for an HP-35 or £91.50 for an SR-50. More likely, I suspect, the "cheaper imitations" of the Hewlett-Packard calculator have been considered as alternatives by the same professional groups who otherwise might have been customers for Hewlett-Packard machines.

Indeed, it seems to be this policy of offering half the performance of a Hewlett-Packard calculator for around half its price that has created the real growth for the other 15 or so manufacturers who have muscled in on the scientific calculator business. Few have offered anything like the performance of an HP-45, let alone the recently introduced HP-55 or that ultimate in handheld calculators, the HP-65. But, then, the majority of even professional users like scientists, engineers and technicians often do not strictly need all that computational power. Hewlett-Packard, aware that it has a good run for its money (it sold 300 000 of its original HP-35 calculators and grossed \$105 million), has now produced a "stripped down" version called the HP-21 to plug the gap at the bottom end of the scientific market—in an effort to try to arrest the market penetration being made by its many imitators.

One feature common to all Hewlett-Packard pocket calculators (and those of two other manufacturers) is the use of a logic form known as Reverse Polish Notation (RPN). Competitors ridicule its complexity, while Hewlett-Packard understandably proclaims its virtues. It is probably fair to say that when the HP-35 was first designed, large-scale integrated MOS circuits could not pack the extra register needed for the alternative ("algebraic") form of logic. Suffice it to say that RPN is an unambiguous language which allows the user to enter data in the same way (from left to right) as he would read an equation. When used in conjunction with a multi-register memory stack, RPN dispenses with the need for either a parenthesis key or the operational hierarchy adopted by other calculators using conventional algebraic logic. The main objection that many would-be users have about RPN is that it requires considerable mental reorientation on the part of the user: it is simply not the natural form of algebra taught in school mathematics.

Personally, I believe that if a user is going to spend more than an hour a day or so on a calculator (as many engineers do) learning to think in RPN is worth the effort. In any event, it takes only a few hours to master the language. All it requires is that the data keyed into the display (x register) should be entered into the next level (y register) of the operational memory stack before the next piece of data is keyed in; with both numbers in the machine, the operation can then be performed. For simple arithmetic, RPN has clearly no advantages over algebraic logic. Thus three times four in RPN is 3 Enter 4 \times , giving a total of four keystrokes; the same sum in algebraic logic is $3 \times 4 =$ which is also four keystrokes. In this case, in fact, the algebraic machine would offer a distinct advantage: it can solve the problem in precisely

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- Log (base 10) and antilog — (x^y , 10 , $x \leftrightarrow y$, $=$)
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Table 1

Function	Value (£)
\pm - \times \div	8
$1/x$	2
x^2	2
\sqrt{x}	2
M	5
[()]	3
Sin Cos Tan/Arc	8
Hyperbolic	5
$\ln x / e^x$	4
$\log x / 10^x$	3
x^y	5
x1	2
$x - y$	1
Deg - rad	1
π	1

the way it is written down—and that is the main reason why most pocket calculators use algebraic logic. But, then, Hewlett-Packard would argue that scientific calculators are not really designed for performing simple arithmetic.

Fashionable algebraic

Fashions, however, are rarely governed by such exemplary logic. And it is undeniable that the practice among the £30 to £70 scientific calculators has been to adopt algebraic logic universally—possibly because many potential customers for these machines have graduated from basic four-function calculators and are familiar with their mode of operation. It is undeniable, too, that, though algebraic logic is more long-winded, it generally allows the inexperienced user to “stumble his way through” a problem.

On balance, an algebraic scientific machine is probably a better bet for the user who needs to perform calculations only once in a while. And in fairness to the many excellent scientific machines now on the market that use algebraic logic, they lose out to the HP-21 and HP-45 not so much because of the economy of the RPN language, but rather because of the way it is used in conjunction with a powerful operational stack type of memory—which comprises four separate storage registers in the case of the HP-21, supplemented with a further nine for the HP-45 and an additional 20 for the new HP-55!

Most pocket calculator prices have tumbled largely because of fierce competition in the marketplace. But technological improvements have also allowed manufacturers to trim production costs and pass on the savings. For instance, \$5 saved on the price of the chip can cut \$15 off the product's price in the shop. There has also been some dumping of cheap four/five function machines as manufacturers tried to cut their losses and get out of the business.

As yet, however, there has been no sign of heavy off-loading of scientific calculators. One or two makers may yet have to release batches of machines at marked down prices if they are forced to the wall, but the volumes involved would be nowhere near as high as in the cheap calculator business. Moreover, the presence of the big semiconductor firms now in the calculator business is tending to stabilise prices. Some, in fact, are being a bit too greedy. The SR-50, for instance, has about £15 worth of extra benefits (two extra keys and better quality control) compared with, say, the Commodore SR-36—suggesting that, at £79.95 (inc. VAT), the SR-50 really ought to be priced about £10 lower. Perhaps the arrival earlier this month of the new Hewlett-Packard HP-21 in the marketplace at £69.12 (inc. VAT) will stimulate lower prices.

The recommended retail prices quoted by manufacturers and importers of the cheaper scientific machines are rather meaningless. Take, for instance, the Commodore SR-36 which is quoted at £53.95 (inc. VAT) but

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TABLE 2 MAKE	MODEL	DISPLAY	LOGIC	$\frac{1}{x}$	\sqrt{x}	x^2	$\ln x$	e^x	$\log x$	10^x	y^x	$x\sqrt{y}$	$x-y$	sin cos tan (arc)	Hy- per- bo- lic	Ex- po- nent en- try	M	(/)	π	Ni- cad bat- tery	COMMENTS	REC. PRICE (inc. VAT)
ADLER	88T	Floating pt (8 digit)	Algebraic	✓	✓	✓	✓	✓			✓	✓	✓	✓			✓	✓	✓	✓	Rechargeable battery extra	£96.12
BOWMAR	MX 100	Floating pt (8 digit)	Algebraic	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£89.00
	MX 140	Sc. not. (10 + 2 digit)	Algebraic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		£79.95
CASIO	FX-10	Floating pt (8 digit)	Algebraic	✓	✓		✓	✓	✓	✓	✓			✓					✓		No arc key for inverse trig	£53.46
CITIZEN	820SR	Floating pt (8 digit)	Algebraic	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£86.35
COLEX	ESR	Floating pt (8 digit)	Algebraic	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		£74.52
COMMODORE (CBM)	SR36	Floating pt or sc. not. (10 + 2 digit)	Algebraic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		£53.95
HEWLETT- PACKARD	HP-21	Floating pt or sc. not. (8 + 2 digit)	Reverse Polish	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	Four register operational stack	£89.12
	HP-35	Fixed or sc. not. (10 + 2 digit)	Reverse Polish	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	Four register operational stack	£107.46
	HP-45	Fixed or sc. not. (10 + 2 digit)	Reverse Polish	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	As above plus nine data stores, etc.	£136.08
	HP-55	Fixed or sc. not. (10+2 digit)	Reverse Polish	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	As above plus 20 addressable registers, nine conversion keys, 100 hour digital timer, 49 step programming facility	£226.80
	HP-65	Fixed or sc. not. (10 + 2 digit)	Reverse Polish	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	Mostly as above but with 100 step programming facility, mag tape, five user definable keys	£442.80
KOVAK	809ESR	Fixed or floating pt (8 digit)	Algebraic	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£73.44
MINTRON	ESR 817	Floating pt. (8 digit)	Algebraic	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£52.93
NATIONAL SEMI- CONDUCTOR	Novus 4510	Floating pt. (8 digit)	Reverse Polish	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	Three register operational stack, M + x ²	£49.95
	Novus 4515	Floating pt. (8 digit)	Reverse Polish	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	As above but with 100 step programming facility	£99.95
	Novus 4520	Sc. not. (8 + 2 digit)	Reverse Polish	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	Four register operational stack	£72.45
	Novus 4525	Sc. not. (8 + 2 digit)	Reverse Polish	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	As above, but with 100 step programming facility	£119.95
QUALITRON	QI-515	Floating pt. (8 digit)	Algebraic	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		Around £50
	QI-1445	Floating pt. (8 digit)	Algebraic	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	Rechargeable battery extra	N/A
	QI-1448	Floating pt. or sc. not. (5 + 2 digit)	Algebraic	✓	✓		✓	✓			✓	✓	✓	✓			✓	✓	✓	✓	Rechargeable battery extra	N/A
	QI-1419	Floating pt. or sc. not. (10 + 2 digit)	Algebraic	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	Rechargeable battery extra	N/A
ROCKWELL	61R	Floating pt. (8 digit)	Algebraic	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	M + x ² key	£49.95
	63R	Floating pt. or sc. not. (10 + 2 digit)	Algebraic	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		£59.95
SHARP	PC-1801	Floating pt. (8 digit)	Algebraic	✓	✓		✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£96.12
SINCLAIR	Scientific	Sc. not. (5 + 2 digit)	Reverse Polish				✓	✓			✓	✓	✓	✓			✓	✓	✓	✓		£21.55 (£14.95) (kit)
	Oxford 300	Floating pt. or sc. not. (5 + 2 digit)	Algebraic	✓	✓		✓	✓			✓	✓	✓	✓			✓	✓	✓	✓		£32.35
SPECTRUM	SP70	Floating pt. or sc. not. (10 + 2 digit)	Algebraic	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£59.40
TEXAS INSTRUMENTS	SR-50	Sc. not. (10 + 2 digit)	Algebraic	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		£79.95
	SR-51	Fixed or floating pt. or sc. not. (10 + 2 digit)	Algebraic	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	Three addressable memories, 13 metric conversions	£129.95

Table 3
Breakdown of a scientific calculator price (mid-1975)
for 100 000 unit volume

	dollars
MOS integrated circuit	8.50
Semiconductor drivers, etc	1.20
LED display (10+2 digits)	3.20
Keyboard	2.40
Case	0.50
Printed circuit board, misc. components	0.50
Rechargeable battery	3.20
Charger/a.c. adapter	2.50
Total parts cost	22.00
Labour	2.00
Total manufacturing cost	24.00
Overhead contribution (50 per cent of manufacturing cost)	12.00
Marketing cost (15 per cent of factory selling price)	9.00
Manufacturer's profit (25 per cent of factory selling price)	15.00
Factory selling price	60.00
Recommended retail price (40 per cent mark-up)	84.00 (£35)

available from Mountaineer mail-order for £44.82 (inc. VAT) or from Laskys for £45.85 (inc. VAT). The Qualitron QI-515, currently recommended at "around £50 plus VAT," is expected to be in at least one chainstore next month for £43.15 (inc. VAT). It clearly pays to shop around for the 10 per cent or so discount that is generally available.

A quick look at the component costs expected later this year gives some idea of what prices manufacturers could be recommending in six months' time. Until recently, more than two-thirds of all US and European assembly houses used the Rockwell one-chip approach

in their scientific calculators. However, the high price of this chip precluded any substantial price cut below the £60 level. Now there is a variety of MOS chips available and their prices are expected to tumble dramatically this year—probably to around the £3 to £4 level. There is thus no reason why a machine with performance comparable to, say, an SR-36 could not have a recommended retail price of around £38 (inc. VAT) by later this summer. Table 3 gives a rough breakdown of the expected component costs.

When trying to compare the cost/performance of different slide-rule and scientific calculators, I rely on a crude set of function values acquired by experience. Adding up the values in Table 1 for a given machine's features gives a rough guide to the price one ought to pay. On a scientific machine I take for granted scientific notation as well as exponent entry and sign keys. This admittedly rough and ready rule gives £20 for a Sinclair Scientific (discounted now to around £17), £29 for the Sinclair Oxford 300 which is to be launched next month (said to be "around £30") and £43.50 for a Commodore SR-36 (available for £44.82). The same rule, however, shows some glaring inconsistencies in the prices of a number of scientific calculators currently offered around £65 to £90 which really, in terms of performance and facilities, are not worth more than £50. Of course, the purchaser should also weigh in mind such factors as quality, warranty and after-sales service when he makes a purchase. But, all told, the extra confidence that comes when buying a big name product can hardly be worth more than an additional £10.

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