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1981 Phys. Educ. 16 239

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The Unilab Blue Chip range for introducing microelectronics

W H Jarvis

For reasons which are obvious, Physics Education does not normally carry descriptions of commercially produced apparatus, other than in the form of a brief note. Two factors lead us to make an exception in this case. Firstly the explosion in schools microprocessors is such that the majority of school and college physics teachers are naive users, yet determined to become involved. Secondly a number of companies are developing modular teaching equipment in the field. It is not easy for those users to discriminate.

By inviting an article from a manufacturer we are not making any value judgment. We believe that whatever readers think of the Blue Chip range, this account will help readers better to know the questions to ask and the features to look for.

Eric Deeson, Honorary Editor

This article is intended to help those who will shortly be teaching modern electronics for the first time. The following topics will be discussed: the slang name 'micro', the attitudes of examining boards, the rapid obsolescence of specified electronic devices, costs, analogue and digital systems, 'How clear are the instructions?', power supplies and batteries, 'CMOS or TTL?' and 'Where do we go from here?'. The views expressed are those of the author, and not necessarily those of Unilab.

Teaching modern electronics

It is unfortunate that the abbreviation 'micro' has come to imply 'Things with keyboards and screens which can help make geography more interesting'. It is even more unfortunate that several local authorities have spent thousands of pounds on machines costing twice as much as suitable Commodore Pets, in the belief that in so doing they are fulfilling their duty to keep schoolchildren abreast of modern technology.

By contrast a number of examining boards have already introduced syllabuses which include some solid state electronics. This immediately provokes two extreme reactions: 'This is third-year degree stuff', and 'My ten-year-old son has done all this on the kitchen table whilst watching the *Muppet Show*'. Both, of course are true; and most examining boards have found a satisfactory compromise, along the lines of teaching the properties and uses of the more common semiconductors, whilst saying nothing of how they work. This compromise leaves teachers with another problem: that of the rate of obsolescence of any specific device. For example, whilst solid-state diodes will always be essential, the wonder device of today is obsolete next year.

The next consideration in equipping for a course leading to one of the modern electronic syllabuses (O, higher, A or CSE) is obviously cost. If we make the (conservative) assumption that 75% of the cost of a manufactured teaching aid is labour and overheads, it follows that whilst an operational amplifier in integrated circuit form might cost 50p, a board for teaching its properties and uses will cost from £7, according to how many ancillary components are included and—most important—how many terminals are provided, and of what type.

It is unfortunate, therefore, that the excellent range of apparatus designed during the original Nuffield project should have been made at a time when labour (but not components) was vastly cheaper, and schools had far greater resources, including the generous support of many large industries. In the same way that no one in 1965 would have spent unnecessarily on gold plated brass contacts and polished mahogany casework, so in 1981 no one can pay unnecessarily for casework and looks which go far beyond the requirements for strength, safety, reliability and clarity.

With this in mind, Unilab launched its Blue Chip range, in the first instance to meet the needs of electronics options in the physics syllabuses (O and A) of two particular boards. Thus were generated six 'boards', each carrying all the components—apart from meters, power supply and oscilloscope—for studying the properties and uses of the n-p-n transistor, the operational amplifier, multivibrators,

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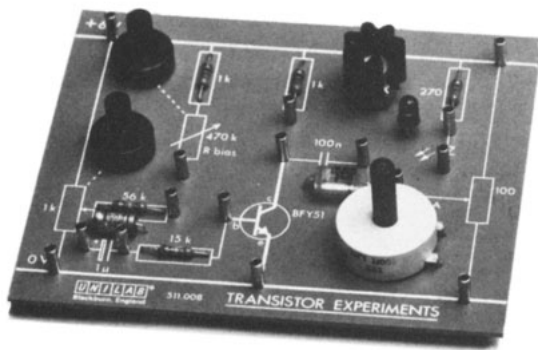


Figure 1 Blue Chip board for transistor experiments

the analogue computer, the QUAD NAND gate and binary counting/dividing. A seventh board carries six light-emitting diodes and six 'amplifiers' for showing the logic state (high or low) of any point on the other boards.

The first noticed, and much criticised, feature of these boards are the 2 mm sockets, obviously not directly compatible with the 4 mm standard adopted at least 15 years ago. Taking into account the fact that made-up stackable 2 mm leads cost 22p more than the 4 mm equivalents, one is tempted to say 'there goes the saving'—until one takes into account the cost of installing 2 mm, as distinct from 4 mm, sockets. (Later, as more complex boards joined the range, it soon became apparent that there would not have been room for 4 mm sockets anyway.)

Looking at the board likely to be used first in any course (figure 1) we see how the requirements listed above have been met. For strength, the plastic material of the board can withstand considerable bending, pressing flat on to the table top, etc, without cracking; and the 2 mm sockets are not soldered in, as might appear, but riveted. Solder is applied later to ensure a good connection.

For safety, supply voltages of 5–15 V are suggested; and there is little about the boards which could cause mechanical injury, although ICs, when inexpertly dragged from their sockets, occasionally bite.

For easy replacement, the ICs are not soldered directly to the boards, but are plugged into sockets—as are transistors, where appropriate. These are the devices most likely to be damaged by wrong connections ('The transistor is a device for protecting fuses'—anonymous examiner); and to replace a typical IC costs about 25p.

The fourth requirement is clarity, to which end Blue Chip boards have the circuit shown diagrammatically on top in white, and the copper printed circuit clearly visible below. When possible these coincide, and components are visible from above, usually labelled. Although standard American

symbols have been used, much of our production being exported, some teachers and examiners still express a preference for the symbols used in Britain alone, 20 years ago. Because of the disproportionate cost of producing more than one version of each board, we have aimed at the more popular option in each case.

Use of range in teaching

Having looked at one board to see how the design policy was determined, we now look at the range, to see how the separate boards take a logical place in a typical course (figure 2).

After seeing how the transistor can be used to amplify, switch or 'square' (in the sense of producing a nearly square wave having the same frequency as a sine-wave input), one states that all integrated circuits are ready-made circuits containing hundreds of transistors and other components, prearranged to carry out desired functions. Such ICs fall into two main groups: 'linear', where output is equal to input voltage multiplied by a positive or negative constant within certain limits; and 'digital', where only two voltages are considered, one near to zero or 'earth', and one near to the supply voltage. (It is true that ICs can also be grouped into TTL and CMOS; but these distinctions are not important at this stage and will be covered later.)

Following the 'analogue' branch in figure 2, the operational amplifier board carries a choice of feedback and input components. The user selects these (by plugging into the appropriate 2 mm sockets) to give one of the following functions:

$$V_{out} = - (0.01 \text{ or } 0.1 \text{ or } 1 \text{ or } 10 \text{ or } 100) V_{in}$$

$$\text{or } V_{out} = - \int k V_{in} dt$$

where k has one of the above values. (In all cases the value of V_{out} cannot exceed about 95% of the positive or negative supply rail voltage.)

Didactically, this can be quite an important moment, as the student realises he has a really cheap, versatile, accurate device which makes it positively easy to construct useful gadgets, ranging from an audio amplifier to a system which can solve differential equations. To aid the study of the latter, the analogue computing board carries three op. amps, two wired as integrators, and one as a ' $\times - 1$ ' stage; with this, the equation for simple harmonic motion can be set up, and it is a delight to see the slow wave appear on the oscilloscope screen when the last connection has been made. 'Damping' can now be added; and here a price comparison is justified, for this approach costs around one-third of the price of the Nuffield modules needed to achieve the same result. Op. amps also make more predictable and

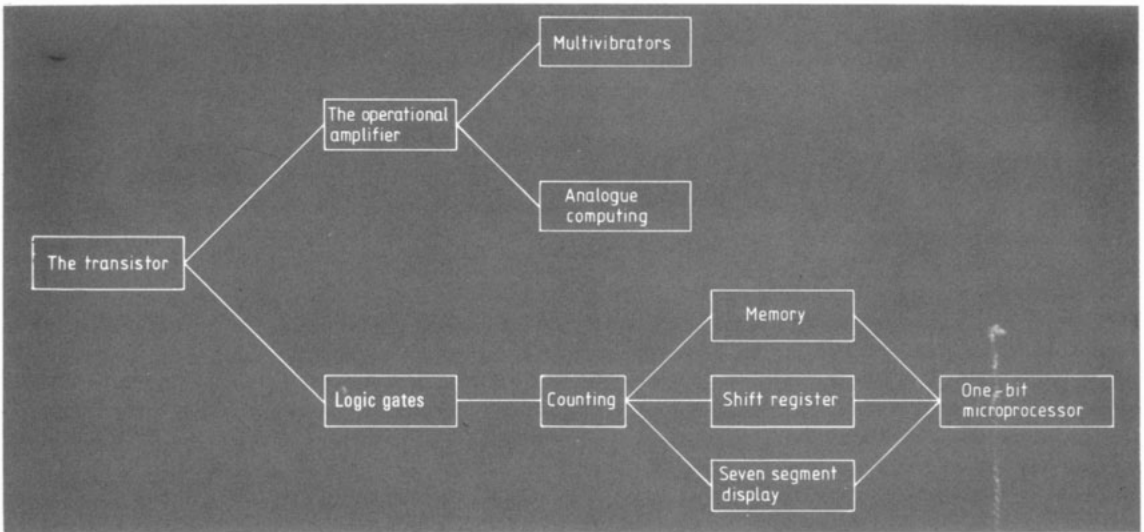


Figure 2 Outline of a typical modern electronics course

reliable multivibrators than circuits containing at least two transistors, so a separate board is provided for the study of multivibrators.

Returning to figure 2 and looking at the 'digital' branch, here we start to see what chips are to be found when you look inside a so called 'micro', assuming one means a small programmable computer with keyboard and display. The choice of QUAD NAND as the starting point for logic gates needs justifying, as it is so much easier to explain a single AND gate and a single OR gate. The fact is that the one chip, price about 25p, contains four NAND gates and these can be interconnected to carry out any of the functions AND, OR, EXCLUSIVE OR and NOR. Two such chips can also make the 'half adder' essential in binary arithmetic. The same could be done with other gates, but as so many would be required, and the chips cost essentially the same whether they carry one or four gates (and in any event cost a great deal more to mount and connect), the choice of the QUAD NAND is the most economic.

Since all digital computing is done in binary, another board provides bounce-free pulses and four stages of binary counting (0000 to 1111) (figure 3). With this board it is necessary to use the 'hex indicator', so called because it carries six light-emitting diodes, and the single IC needed to drive them without unduly 'loading' the circuits being studied. The 'hex indicator' board is of course also used when the logic states of any other device are to be displayed.

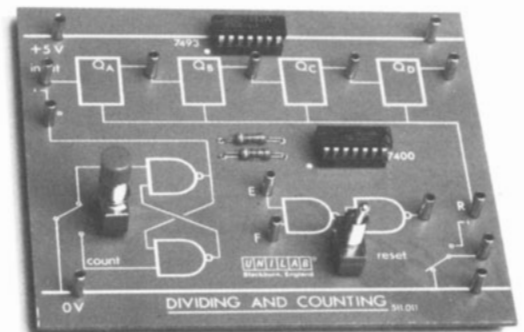
At this stage we have mentioned all the original Blue Chip boards; and before looking at the additions, teachers unfamiliar with modern electronics might like to be reassured that the instruction

booklet assumes that the boards are being used by someone—student or teacher—with no previous experience of chips, or of the jargon which has necessarily grown up around them. Detailed instructions are given, with pictorial diagrams, and examples of the results which should be obtained (figure 4).

Power supplies

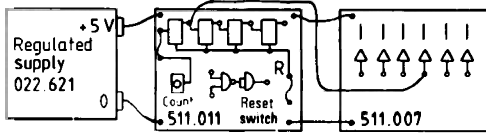
Because of the present need to minimise expense, it is necessary to decide whether one's existing power supplies will suffice. For operational amplifiers a 'twin' or 'centre-tapped' power supply is essential. This could be arranged using resistors as a potential divider across an existing supply; but the current through the resistor chain would have to be very large compared with the current taken by the op. amp. Consequently there would be hot, and therefore possibly dangerous, resistors around, although the energy waste would be minimal.

Figure 3 Blue Chip board for dividing and counting



Connect a 5 V regulated power supply to the Dividing and Counting Board, and to the Indicators board, in parallel. Connect the 'count' output to one of the indicator inputs, and confirm that pressing the button sends the count voltage from high to low until the button is released.

Now connect the RESET point R to 0 V through the switch; the count button output to Q_A inputs; and Q_A output to indicator 4 input.



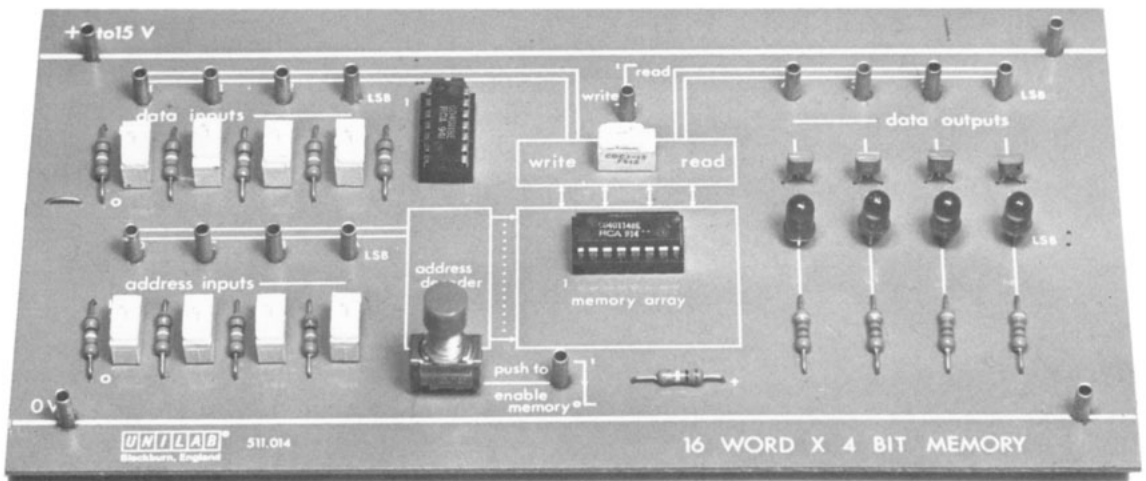
Put the reset switch in the 'on' position (towards the user), then confirm that when the 'count' button is operated repeatedly, indicator No. 4 shows '1' then '0' alternately.

Now connect Q_B output to indicator input 3, Q_C output to indicator 2, and Q_D output to indicator 1. Repeated pressing of the 'count' button will now display binary numbers in order, up to binary 15 (1111); and operation of the 'reset' switch at any stage will return the count to binary 0 (0000).

Figure 4 Extract from instruction booklet

The 'twin 15 V' supply made specially by Unilab for operational amplifier uses eliminates these risks. In addition it is regulated, so that you can be sure the supply rails are at + and - 15 V regardless of mains voltage or load current (within specified limits); also, if either side of the supply is accidentally shorted, no harm results, and resetting is automatic when the short circuit is removed. At about £20 it costs less than an ordinary unregulated supply, and can run several op. amps simultaneously.

Figure 5 Blue Chip RAM board



Batteries could be used and often are; but the cost saving is very short term. I would strongly recommend using rechargeable batteries ('nicads') rather than any kind of unchargeable battery, as they are not easily damaged if the simple instructions are followed, and normally last for at the very least 500 charge discharge cycles.

The provision of a 'twin 15 V supply' alone, unfortunately, does not close the question of power supplies, because several IC's in the Blue Chip range are of the transistor-transistor logic type (TTL) and should never be used on more than 5 V. Therefore a separate regulated supply, or separate batteries, are needed. Of course this is a nuisance, and the reason is historic. Whilst it is now easy to obtain chips of the CMOS (complementary metal oxide silicon) type, which will run happily from up to 18 V and are *not* in practice damaged by everyday handling and static fields, in the early days of MOS the devices collapsed at a glance, and acquired a very bad reputation. (There is no stronger disincentive to learning than experiments which never work.) The only problem with CMOS devices is that they cannot operate as fast as TTL; but for teaching purposes no one wants changes to take place at over a million a second, anyway.

A regulated 5 V supply is also available for about £20. These mains operated supplies have to conform, of course, to the stringent safety requirements of individual local authorities as well as to European standards.

What next?

The Blue Chips described so far meet examination requirements which existed in 1978. The next three (figure 5) are a random access memory, a shift register

and a seven-segment decoder/readout. They represent the areas most likely to be the building blocks which make up a useful microcomputer. The random access memory (figure 5) shows how a single chip can offer 16 'pigeon-holes' in each of which may be stored a random number between 0-15. The user can look at or change the contents of each pigeon-hole either by using the switches on the board or by making electrical connections from other boards.

The shift register is the most versatile and important 'number handler'. A four-digit binary number may be put into the register serially (one digit at a time) or in parallel (all digits at one instant). The same number may be passed on to another board, again in serial or parallel fashion. A single connection switches the register from serial to parallel mode. Another connection allows the complement of any number to be presented at the outputs (e.g. 0101 instead of 1010). Yet another connection resets the whole register to zero. In practical use the shift register crops up more than any other single chip in a working microcomputer.

The decoder/readout simply 'translates' a four-digit binary number to its decimal equivalent. For example, if the four input pins are connected to 0, 0, +, +, the display will read 3 (the decimal equivalent of 0011). If the binary input exceeds 9, the display shows blank (as distinct from 0).

'The one-bit micro'

I shall conclude by bowing to the inevitable, and using the regrettable and ambiguous name 'micro'. Here we use it to mean 'microcomputer', in that we provide a board containing many chips (figure 6). Amongst these chips is a *microprocessor*, consequently the board can be programmed to carry out all sorts of functions, and to change functions as time goes by. We have found that new users respond best to being shown how the whole board can act as a two-input AND gate. Any two of the pins can be nominated as AND gate input terminals, and any one of the eight output terminals as AND gate output. Users can then prove that the whole board acts as programmed. All programming is carried out in binary; for example, the code for ENABLE THE INPUT is 1010 and to load this instruction, a user presses input switches 8 and 2 followed by the STEP switch. The microcomputer is now waiting for the user to give it a number, so that it knows which input pin is the master input switch. There are only 16 possible commands and the progress of data through the board is made visible at every stage by light-emitting diodes. The program can be stepped manually as slowly as wished; or run at about 250000 steps per second from a self-contained free-running oscillator. This board requires a single regulated 5 V supply, and

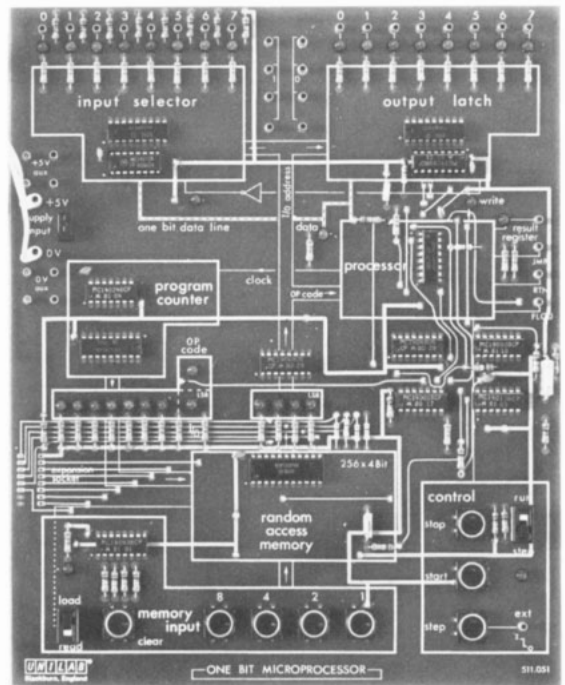


Figure 6 One-bit micro

is at present the 'top end' of the Unilab Blue Chip range.

Unilab has always regarded ideas from teachers as one of the most important 'raw materials'; and in the case of the Blue Chip range we would like to acknowledge the great deal of help and advice given by many teachers, lecturers and members of examining boards. Also, the 'one-bit micro' is largely the work of David Thompson of Welbeck College, Nottingham. Regrettably it would not be possible to name all the individuals who have helped in developing this range; but we are nevertheless extremely grateful.

Teaching electronics

An introductory course on 'The teaching of electronics' will be held in the Physics Department of Richard Taunton College, Southampton on 21-23 July. A sound knowledge of basic electricity will be assumed and by the end of the course teachers are expected to reach a standard between AO and A-level in electronics. The syllabuses of many courses from CSE to A-level will be compared and methods of tackling the subject material in school or college will be discussed. A 'systems' approach will be used in the teaching and the technology of microchips will be covered.

Further details can be obtained from Mrs D L Warwick, Department of Education, The University, Southampton SO9 5NH.