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SCOTTISH SCHOOLS SCIENCE EQUIPMENT RESEARCH CENTRE

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Philip Harris Ltd., Lynn Lane, Shenstone, Staffs. WS14 0EE Tel.(0543) 480077.

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Hinterland Ltd., Mill Green Works, Mill Green, Hatfield, Herts. AL9 5NZ Tel.(07072) 71725.

Hogg Laboratory Supplies, Sloane Street, Birmingham B1 3BW Tel.021-233 1972.

Industry Year, Scottish Secretariat, Industry Year 1986, Glasgow Chamber of Commerce, 30 George Square, Glasgow G2 1EQ Tel. 041-204 2121.

Irwin-Desman Ltd., 294 Purley Way, Croydon CR9 4QL Tel.01-686 6441.

Mamod Ltd., 196 Bedford Avenue, The Trading Estate, Slough, Bucks.

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Cont. inside back cover.

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INTRODUCTION

Obituary - Mr.Hugh Medine

It is with great sadness that we report the death, suddenly on December 9th, 1985, of Hugh Medine. Hugh was Assistant Director (Chemistry) at SSSERC from 1968 until 1976 spending some of that period as Acting Director during Joe Stewart's absence abroad. He was also the staff member who carried out much of the initial collation of the material which eventually became, through the work of Allen Cochrane, the SSSERC manual on hazardous chemicals.

Hugh was a very active and practical man. He came to SSSERC with a background both in industry and education in Ayshire. Even when he retired from the Centre he took up a fourth career assisting his sons in running a sports goods and cycle business. In typical style it was he who re-wired the shop premises and straightened the buckled bike wheels.

With his breadth of interests, his refusal to recognise formal subject barriers, his infectious enthusiasm for practical science and technology, he represented the very best of the old committment to quality for all in education. In some ways he was also a man before his time. His attitudes, ways of thinking and working provide lessons for the future in carrying forward reforms in science and technology education, in what we all hope shortly will be better times.

ASE Annual Meetings

Once again the preparation of the first issue of the New Year sees us recovering from one ASE Annual Meeting - that of the UK parent body - and beginning to prepare for another - that of the Scottish Region.

UK ASE Meeting

This was held at York, early in the New Year (we cannot seem to break them of this most uncivilised habit). This bulletin issue carries a report on that meeting.

ASE Scottish Region Meeting

This will be held in Craigie College, Ayr, on Wednesday, Thursday and Friday, 2nd-4th April 1986. A varied programme will cover a range of interests from primary science through to the blurred boundaries of secondary and tertiary levels (I refuse to say "interface"!).

We intend exhibiting and, because the meeting coincides almost exactly with the formal 21st anniversary of the opening of SSSERC, we will try to stage something just a wee bit special.

Cost Index

Normally this issue would carry the figures for our Cost Index to November, 1985. Due to circumstances outwith our control we have been unable to gather all of the raw data needed to compute the index. We are therefore unable to supply a figure for the six-monthly period May - November, 1985. We apologise for this omission. We certainly hope to update the index for May 1985 to May 1986. That annual figure should be published sometime in June.

Did you know

-that 1986 is both "Industry Year" and "Energy Efficiency Year"?

For the former there is a Scottish Secretariat/ Directorate (see Address List, front inside cover) who can supply a contact point for your area. There are five area groups based on Aberdeen, Dundee, Edinburgh, Glasgow and Inverness (Highland).

As to the latter no doubt you have already noticed the television advertising campaign. Watch out later though for announcements on specific energy education events likely to be held in Edinburgh and Glasgow. Keep an eye out too for specially produced, sponsored, educational materials on energy matters.

Have you read

"The Public Understanding of Science", 1985, The Royal Society, ISBN 0 85403 2576, or -

"Schoolbook Spending Series 2 - Scotland. A Report from the Educational Publishers Council", 1985, The Publishers Association?

When the science education debate shifts away from pay and conditions to the next items on the agenda - objectives and resources - these papers may be essential reading.

* * * * *

OPINION

"Ad-hoccery makes a mockery"

or "Enough is Enough"

Sitting down to draft this article I can already see, aimed my way, the slings and arrows of unfortunate outrage. No doubt, SSSERC will be accused by some of being elitist or arrogant or cranky. In some quarters we will be labelled as all three! Such considerations have never stopped us in the past. On board the Titanic of current Scottish education, one more lecture on seamanship and navigation can do little harm.

The trigger for this piece was a television advertisement, broadcast in support of British Telecom and its activities. This advertisement is one of a series featuring animals. The theme of the campaign is that folk are dying to hear from you and that you should "Make that Call". What particularly caught my imagination was the ad with the penguins (well done again Edinburgh Zoo?). The scene is a factory or works with a collection of real, live King Penguins rushing about like mad things. Dubbed over are human voices saying repeatedly what sounds to me like:

> "Chop-chop, busy-busy, whack-whack, bang-bang"

The whole impression is one of frenetic activity, with little groups noisily rushing in and out of offices and workrooms. It is not at all clear what they are doing or producing. After a wee while they begin to run out of steam and slow down both verbally and physically. Then, the 'phone rings! A call, appreciative and approving! Off they all go again chop-chopping, busy-busying, whack-whacking and bang-banging with all their original frenzy.

Most amusing, I thought at first, to see current attempts at educational reform so parodied. It didn't stay funny for long.

The trouble is that the parallels are a little too close for humorous comfort. The point at which the analogy breaks down is most sharply saddening. The majority of teachers have been waiting too long for that appreciative, conciliating call.

As a result they now only chop-chop and whack-whack (strictly metaphorically) very slowly and "to rule". Leaving that, all too dangerous, matter on one side we can legitimately examine the other useful aspects of our British Telecom paradigm. The key areas impinged upon are those of curriculum development and its evaluation, equipment specifications and in-service training.

The cryptic curriculum

> "When you are hungry, it is no use just painting a picture of a cake".
>
> Old Chinese proverb.

In a number of areas at the more technological end of the educational spectrum, some individuals and a few educational supply companies are chop-chopping etc. away with great fervour. In TVEI's, ITEC's and other acronymic locations throughout the land they have all been busy-busying away as hard as ever. What I would like to know is: Who makes those occasional, appreciative 'phone calls ? What do the callers say that keeps all those technology penguins so hard at it? On what educational criteria are the approving signals based?

I am not saying that such activities are not underwritten by hard educational criteria. I am saying that many within the more established parts of the educational system would like to be informed as to the nature of those criteria. I suspect that, in SSSERC at least, we may have sympathy for many of the aims of such initiatives and projects. However, to date, we have seen more generalities than specifics. The defence will no doubt be made that much of what is going on is experimental. However that in itself is no excuse for a lack of initial, overt curricular specification.

It is this apparent curricular superficiality that is worrying. There is the feeling that so long as one can see students working with equipment that is obviously based on "new technology" that, of itself, is educationally a good thing. Computer gear and the odd CNC lathe too easily become the educational equivalents of animals in primary schools. Their mere presence imparts the right aura.

The focus can then be on acts of usage of hardware and software as ends rather than means. This reverses the classical order of curricular questioning:

> What should be learned, when, how and by whom?

Only when those questions have been fully addressed can we sensibly answer the last in the series - with what equipment? Recent neglect of these fundamentals has caused no end of trouble in course development as well as for equipment manufacturers and suppliers.

Equipment specification

> "It really does not matter whether the cat is black or white. What matters is whether or not it catches mice"
>
> Deng Xiao Ping

In March, 1982 I wrote a paper, one of a series published by the Scottish Central Committee on Science [1]. Along with a number of issues relating to curricular and equipment choices, it was pointed out that the hardware had the curriculum by the nose. I felt then, as now, that the means had to be found to change the order or at least bring more order into the change.

Still, after nearly four years, the evidence is that an insufficient number of educationalists have grasped the point. Too few yet can make the fundamental distinction between educational technology and technological education. The technology and its hardware continue to make the running. Hardware developments are currently in a relative lull. All the same, courses still tend to be written around available equipment. At worst, much of this gear appears on the educational market on a speculative, rather than a specified, basis. At best, its educational base is a very narrow and selective consensus. Time and again the square wheel is re-invented. The market is full of holes in some sectors and severely over-endowed with models and versions in others. Every new electronics teaching kit, and there are by now far too many, is the best thing since the frozen tattie scone.

Such an ad-hoc pattern of development and marketing is pitfall-ridden. The pitfalls, as several manufacturers have found to their cost, are very real and commercial as well as educational. As with the introduction of the new syllabuses in the 'sixties, there is an over-riding need for an educationally based discipline in the market. The difficulty here is that we have to deal now with orders of change and technological dynamism unparalleled then.

No one would seriously suggest that we could re-convene the ASE/Nuffield Apparatus Committees and their Scottish equivalents and start laying down a vast series of highly detailed equipment specifications. The pace of change is still too rapid for that. Nevertheless we do have to find means whereby we more effectively manage that change. We must also face the need to abandon ad-hoccery and backside-foremost modes of working.

We need to begin again to work outwards from sound educational principles, to indicate much more firmly to manufacturers and suppliers the types of equipment needed for the courses we want to teach. In short, it is time that the customers again called the tune.

That takes us full circle, back to all those well-funded initiatives. Calling the tune, as every student of the cliche knows, means having the wherewithal to pay. All sorts of questions remain unanswered as to sufficient funding to replace worn-out science equipment if and when course changes impinge on the generality of schools. The other requirement for a disciplined and sensible market place is the well informed customer. At present the informed customer base is far too small.

This brings us to our final, penguins parallel.

In-service training

A major cause of current confusion, both in equipment and in training matters, is a scarcity and thus a dilution of real expertise. There are far too few folk technically able to provide adequate training. At the same time there are too many in responsible positions content to learn the technological equivalent of water-skiing. They only ever want a quick trip round the bay, skimming the surface. What we need is more swimmers in at the technical deep end. (I warned that there would be cries of "Elitist!").

It is educational principle, rather than mere vested interest, which has led us to this conclusion.

Earlier I drew attention to the need to distinguish carefully between educational technology and technological education. In the former sphere, the user of a piece of hardware may not require an in-depth understanding of how it works. The major consideration here is usually - what can it do? Even in science a lot of instrumentation can be employed with that sort of 'systems approach'. The average teacher is not particularly interested in how a power supply or a scaler-timer works. All he needs to know is that it provides the necessary outputs or measures in the required ranges at acceptable levels of precision. The science comes first and the equipment is a means to an end.

Unfortunately that attitude carries over unaltered to the application of modern instrumentation in technological education. It is, to a significant extent, inappropriate in such a context. There are two major reasons why this is so.

Firstly, several aspects of new courses will require that principles of instrumentation and control be taught. The science must still come first but the equipment becomes itself a vehicle of, rather than merely an aid to, study. That being so, some teachers need to know how it works. With project work and problem solving becoming more important, teachers certainly need to know more than their pupils. The signs are that, already, too many teachers have fallen behind in that race.

Secondly, recent developments differ qualitatively from previous upheavals. They are double-edged. Not only can old content be taught in new ways but some activities, wholly new to schools, are for the first time technically feasible. Only an adequate knowledge of the technical features of equipment will allow proper identification of its educational possibilities and limitations. To compound the problem, new items of equipment appear continually. Device-specific knowledge without adequate training in technical principles is of little avail after an upheaval in the market place. If all you ever learned is to operate (just) "Bloggs Amazing Data Capture Suite and Interface", or to teach a systems-approach electronics course based on the "Joseph's Multi-coloured, Heavily subsidised, Wonder Kit", then watch out when the wind shifts. It will blow right up your pedagogical kilt.

The tragedy is that there are lasting principles, firmly based in science and its application. They are not as dauntingly difficult as many seem so determined to believe.

"To instruct some of your officials
to carry through reforms is like
climbing a tree to catch a fish."

Memorandum to the Emperor from Kang You Wei

As with equipment, so with training. Ad-hoccery is rife. Overlap and mis-direction are common. Decisions are too often based on pragmatic measures or the height of the political profile rather than on sound principle. Sometimes those ultimately deciding on training programmes lack appropriate technical expertise, educational experience or both.

Whatever training programmes are to be offered eventually under more normal conditions, I have grave doubts that they will constitute the type of cohesive and corporate approach to training which is undoubtedly needed. Far more likely are both competition and overlap between Colleges of Education, FE Colleges, CI's and other providers. Without much doubt, all will be looking to find money, fill staff time, compensate for falling student rolls etc. Whether they will provide the type of technological training classroom teachers really need is more in doubt. Whether or not those responsible have an overall strategy for the specification and provision of properly tailored training is equally questionable.

Endpiece

SSSERC staff have worked in so-called "third-world" countries. Very recently we were working with a group of administrators and educational policy planners from developing countries. In my view, for all the seriousness of their problems and the very necessary pragmatism of their responses to them, some of those folk had a better grasp of the real issues raised by technological change than many of their U.K. counterparts.

Recently, H.M. The Prince of Wales spoke of the danger of Britain becoming a fourth-rate nation. If we continue to handle such important issues in the manner outlined above, we undoubtedly will. Until we change the way in which we seek to implement much needed reforms, in the educational field we are, now, a fourth-rate nation.

Reference

1. "How can Microprocessors and Computers help in the teaching of Physics?", March 1982. A series of papers from the Ad Hoc (is this a 'sic' joke?) Group, on Logic Systems and Microelectronics, of the Scottish Central Committee on Science.

* * * * *

SAFETY NOTES

AIDS and School Science

Increasingly teachers and others have been approaching us directly for advice and information on the HTLV-III virus. We have answered those enquiries to the extent of our current knowledge.

For some time we have been considering the possible impact, on practical work in science, of the HTLV-III virus and what has become known as the Acquired Immune Deficiency Syndrome (AIDS). There are a number of reasons why to date nothing has appeared in the "Bulletin". Most important of these is that we have been kept in touch as to the eventual publication of considered, national medical guidance on this complex subject. Given that complexity, we had no wish to pre-empt specialist medical advice preferring to wait until we could give a properly balanced and considered account.

We should be in a position to prepare a full and factual account before Easter. In the meantime it is important that education authorities, and indeed individual teachers, form their own view on information from reliable sources. Already a number of less than accurate accounts have appeared in the popular press. We give below two more reliable sources which may be useful in arriving at an interim view based on fact rather than myth and rumour.

References

/over

References

1. "AIDS: facts and myths", Dr.Anthony Pinching, Times Educational Supplement, 27th September, 1985.

2. "Blood Sampling", ASE, Education in Science, No. 116, January 1986.

* *

Model Steam Engines

Following three serious accidents in England we have been requested to provide a safety summary on model steam engines of the type used in schools to demonstrate energy conversions.

Although the details differ, all three incidents involved the refilling of liquid fuel burners. Two accidents led the ASE Laboratory Safeguards Committeee to issue a statement in June, 1984 [1]. In both of these cases the teacher, thinking that the burner had gone out because the liquid fuel was exhausted, was refilling the trough type burner with methylated spirits. The fuel ignited and caused a flash fire, burning a pupil sitting about 1m away from the demonstration bench. In both incidents the burns were sufficiently severe so as to require skin graft treatment. In one case the burns were made far worse by the ignition of flammable clothing (a lightweight anorak of artificial fibre).

Since that time the DES have issued a circular drawing attention to the ASE 1984 report as well as to a third serious incident of a similar nature. ASE will be issuing further guidance in the January issue of "Education in Science".

We agree with ASE that these latest reports relate to the most serious school laboratory accidents we have heard about for some time. We don't share the impression however that the use of these engines in schools or at home has always been without safety problems.

As a result of a number of domestic incidents in the 'seventies (one reportedly fatal), SSSERC did publish some relevant safety advice in Bulletin 89 [3]. The School Science Service's "Physics Safety Notes" [4] also contain a number of entries relevant to both spirit burners and steam engines.

Until 1984, we had not heard of any further accidents with these engines. The problems involved in their safe use are not restricted to those related to the latest incidents. For completeness, we will both repeat the ASE Laboratory Safeguards Committee's advice [2] and augment it with our own [3] and that from the CLEAPSE School Science Service [4].

In relation to burners:

With three serious accidents in less than eighteen months the consensus of advice would be that the use of liquid fuel with these engines presents an unacceptable hazard. ASE Laboratory Safeguards Committee has therefore modified its original advice. What follows draws on that amended advice:

-use a burner specially designed for use with solid fuel. Modern engines are supplied with such burners. Mamod Ltd. can supply solid fuel burners for their older models.

-use only solid fuel in such burners: "hexamine" (a polymer of methanal and ammonia) is a better fuel than "metafuel" (ethanal tetramer). Whichever solid fuel is used, take sensible precautions in handling fuel blocks. For example avoid regular skin contact (use tongs) and avoid breaking up the blocks and raising excessive dust.

-never attempt to use a liquid fuel in a burner intended for solid fuel.

-destroy and discard any liquid fuel burners so that teachers cannot use them inadvertently. If the supply of solid fuel has run out, postpone the demonstration rather than attempt the use of liquid fuel.

In relation to engine boilers:

There have been scattered reports of scalds etc. arising from boiler explosions in some models. Our earlier research failed to substantiate any of these. With the exception of one heavily disputed case, burns from fuel again were the problem.

Mamod, the major UK manufacturer of such engines, stated at that time that actual boiler explosions in their models were "a physical impossibility" [3]. This claim was based on the fact that their boilers are riveted as well as soldered. They had exploded unriveted boilers under controlled conditions. The results of those tests led them to state that:

> "...instant condensation occurred and it would be necessary to be within inches of the boiler to sustain scalds of any description. Generally speaking within quite a short range one feels cold water on the skin. Such an explosion would require both the failure of the safety valve and a blockage in the steam pipe simultaneously, and in our experience this just does not happen accidentally."

A number of simple precautions will minimise the risks of any boiler failures:

-use only model engines of strong construction purchased from reputable manufacturers.

-the model which was marketed by MLI (ceased trading) should no longer be used. That model was designed to operate with town gas and the burner cannot be used safely with natural gas. In addition, its safety valve is difficult to check (see next entry) and has an unreliable performance record.

-inspect safety valves before use. Ensure that the movable part is free to operate. Defective parts such as ball bearings, washers or springs should be replaced. Replacement parts should be of the same type as those removed in order to avoid corrosion problems arising from the use of dissimilar metal combinations or straightforward rusting.

-keep the valve clear of any deposits such as calcium carbonate or other compounds which otherwise might build up through evaporation of water from the surfaces.

-use only the heat sources indicated above and avoid any use of a natural gas flame unless the boiler was designed to withstand such heating. Even then take care not to overheat.

-top up the boiler water as required, which will be quite frequently if the boiler is not to boil dry. Ideally this should be done with distilled or deionised water or at least, water which has been boiled to drive off the air.

-make sure that the boiler pressure has been allowed to fall to atmospheric before opening.

In general:

These accidents and a number of others involving demonstration experiments, point to the need not to have any pupils sitting too close to any demonstration bench. Pupils involved in the incidents reported on above were only a metre or so away. It must be remembered that seated pupils may not be able to get out of the way sufficiently quickly in an emergency. For many demonstrations 3m or so would seem more appropriate.

Much depends on the scale and degree of risk. It is difficult to lay down an exact yet practicable distance. It may be more helpful to envisage the practice of experienced teachers in traditional laboratory layouts. A useful rule of thumb was that for any hazardous demonstration, no pupil should ever come any closer than behind the first row of benches.

If pupils are to use model steam engines either in stand-alone activities or as a station in an energy circus, a solid fuel <u>must</u> be used.

A number of other incidents, which otherwise may have been quite minor, have led on to pupils suffering serious burns. This was simply because they were wearing flammable clothing or hair preparations incompatible with work in a laboratory. It is recognised that there are serious difficulties in this area. Nevertheless the requirements of laboratory discipline must always be explained to such pupils and the wearing of readily flammable clothing strongly discouraged.

References

1. "Education in Science", No.108, June 1984, ASE.

2. "Education in Science", No.116, January 1986, ASE. **N.B.** Ref.2 amends and updates Ref.1.

3. "Bulletin No.89", June 1976, SSSERC.

4. "Physics Safety Notes", 7.2 & 8.1, 1982, CLEAPSE School Science Service.

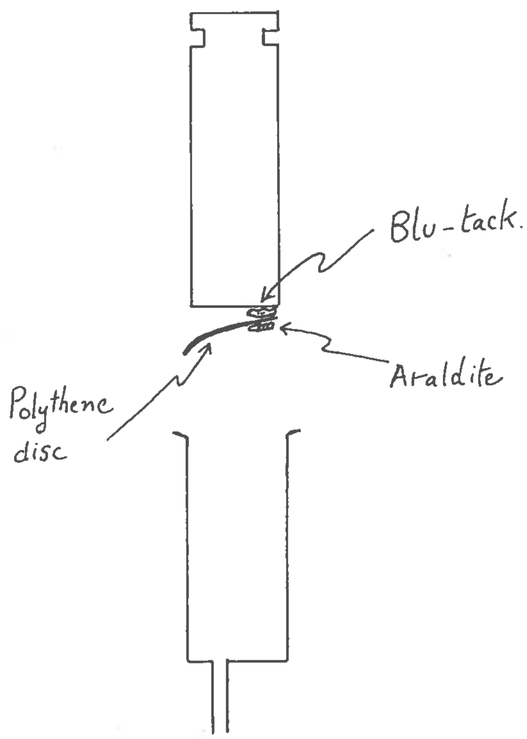
* *

Syringe modification
Anti-water pistol

The cheap and readily available disposable plastic syringe finds many applications in science laboratories. One of the commonest is that of dispensing measured volumes of liquids, particularly in S1 and S2. Misuse of syringes is too tempting for many of these pupils.

We have received a note from Mr.J.Calder of Forrester High, Edinburgh, showing a simple way of fitting a valve. This acts as flow restrictor which operates when expelling or dispensing the liquid reagent, but not during the filling operation.

A disc of polythene sheet (not too thin) and slightly smaller than the bore of the syringe, is cut. The disc is then temporarily attached to the base of the piston with a blob of Blu-tac. (Fig.1) A very small amount of Araldite is the put on one side of the disc, and the piston inserted into the cylinder with the adhesive diametrically opposite the nozzle. When the Araldite has set the piston is withdrawn and the Blu-tac removed. We now have a flap valve which allows easy filling of the syringe but which totally prevents outward flow. The final step is to insert a fine needle up the spout of the syringe and make a small hole in the polythene valve. This hole allows only a trickle to emerge even if the piston is pushed hard.



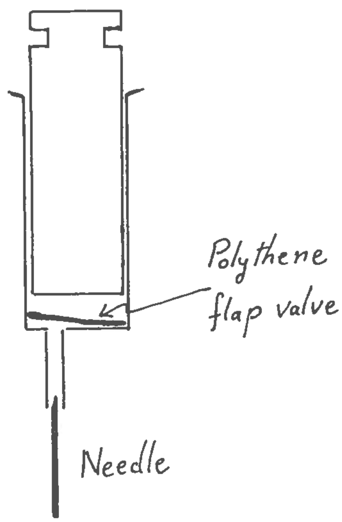


Fig.1

This device we have found to work very well with flat bottomed pistons eg. Gillette disposable. However many syringes have tapered or conical shaped pistons. On these, the pierced valve was less effective. A better method for syringes with conical pistons is to make the polythene disc slightly larger than the internal diameter of the syringe barrel and not to pierce it as described above. Enough fluid then escapes round the edge of the oversize disc.

Many syringes are manufactured with a trace of lubricant on the piston. In order to obtain a good adhesive bond, the surface should be slightly abraded with a small disc of sandpaper stuck to the end of a short length of dowelling.

* * * * *

CHEMISTRY NOTES

Protection of ammeters

Description

Mr Haggart, a teacher in Galashiels Academy, has sent us an ingenious solution to the problem of how to protect ammeters from the effects of an overload current. This is achieved by connecting a voltage regulator in series with the meter (Fig.1), the ingenuity being the unusual application of these devices. They are more normally used to provide voltage or current regulation, but in this situation they are there to provide current limiting.

The description below refers initially to the protection of a 100 mA range meter. The regulator is a positive adjustable device known as LM317L, the suffix 'L' denoting its 100 mA maximum current rating. What happens when you attempt to drive a current in excess of 100 mA through it is that a thermal shutdown effect takes place preventing the current rising further. The regulator therefore gets rather hot; typically this might be 150°C in the worst case so there is a problem of protection against burnt fingers. You can limit the temperature to which the device might rise by fitting a heatsink. However this has the effect of increasing the current limit. For example the current with no heatsink is 100 mA; with an infinite heatsink the limit is 300 mA. In order to protect a 100 mA meter it would be better to do without a heatsink. It may not be considered necessary to guard against burnt fingers on the grounds that an overload is likely only to occur for a short period.

As devised the device provides reasonable, but not fail-safe, protection against both reverse polarity and overload misuse. A typical voltage regulator has a 50% failure expectancy after one hour of severe overloading. When such failures occur, the regulator may well go open circuit thereby rendering the meter safe. Should the failed regulator go short circuit, the meter could be damaged. There is a small risk of this happening.

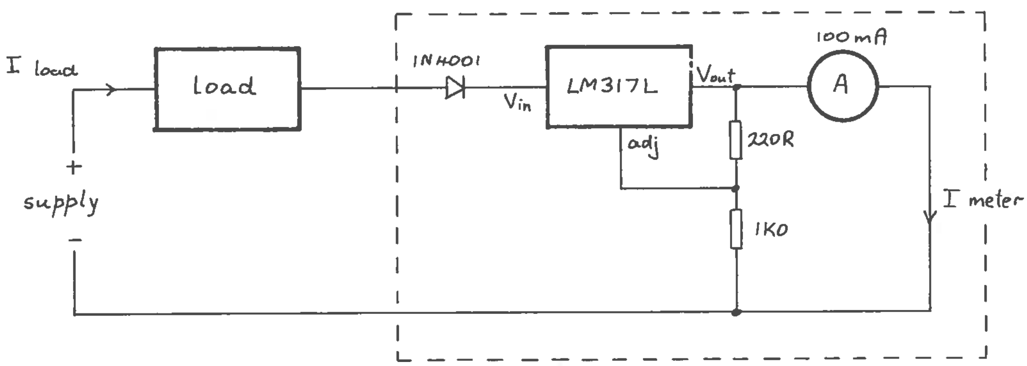


Fig.1 - Circuit to protect 100 mA ammeter.

The effect on meter accuracy has been assessed and there is a systematic error of 3 mA between the meter current and load current (Table 1). This error may lie within the overall meter accuracy and may be unimportant.

I load (mA)	I meter (mA)
2.7	0.0
22.9	20.0
42.9	40.0
63.0	60.0
82.7	80.0
103.0	100.0

Table 1

We have extended the principle and built a protection device for a 1 A meter using an LM317M regulator.

Construction

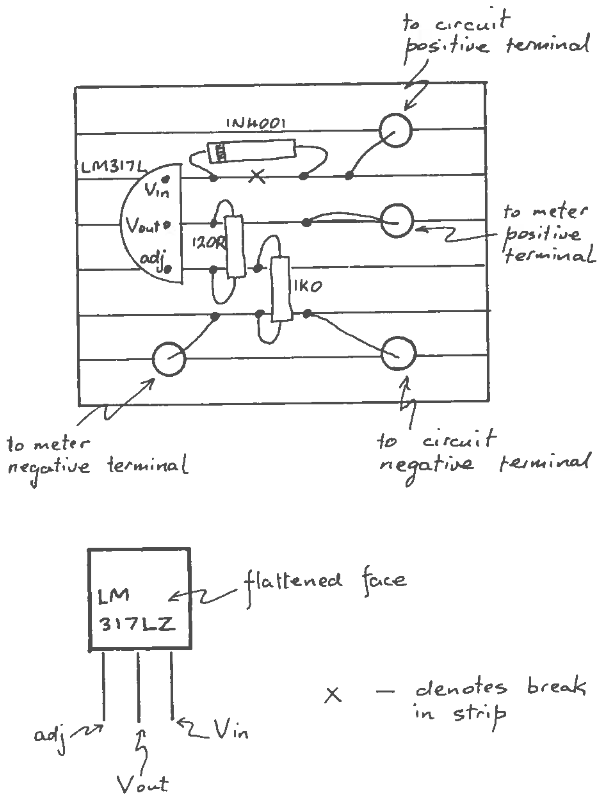


Fig.2 - Stripboard layout.

A stripboard layout for a 100 mA meter protection circuit is shown (Fig.2). The size is 0.6" by 0.8" (6 strips by 8 holes). Strain relief for the four flying leads is provided by taking them through enlarged holes.

The circuit should then be securely fastened to the meter and wired as illustrated (Fig.3).

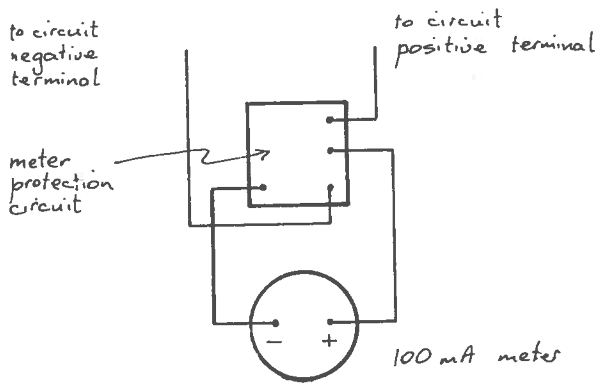


Fig.3 - Wiring circuit to meter.

The components cost under £1; they are obtained as follows:

item	supplier	stock no.	price	
regulator, LM317L	Farnell	LM317LZ	64 p	
	RS	303-179	67	
diode, 1N4001	Farnell	1N4001	4	
	RS	261-148	44	(10)
resistor, 120R ¼ W	SSSERC	420-120R	6	(10)
resistor, 1KO ¼ W	SSSERC	420-1KO	6	(10)

Applicability

This type of ammeter protection is not generally applicable because the ideal meter should not have a voltage dropped across it; the LM317L regulator and diode produce a total drop in p.d. of 3.7 V at 20 mA, 3.2 V at 100 mA. Ammeters thus protected should be used selectively in specialized applications such as conductivity experiments in Chemistry where one is comparing relative changes in current. For general metery in Physics or S1 electricity such protection would, regrettably, have an adverse effect on measurements.

* * * * *

A.C. current measurement Addendum - Bulletin 147

There are two riders to add to the article in Bulletin 147. The first can be dealt with briefly; it concerns the impression given that one might experience difficulty, of the sort outlined, in making a.c. current measurements with digital multimeters. This is an erroneous impression caused unfortunately by some misleading checks at the proof reading stage of that article. Since publication, further tests have indicated that the a.c. current ranges of all the digital multimeters tested are reliable and accurate.

It follows that we recommend the usage of such meters for quantitative measurements on a.c. current.

The second issue concerns a request for a circuit which converts a.c. current into d.c. voltage. The specified current range was 0-1 mA at frequencies between 50 and 500 Hz, the input being sinusoidal; the voltage output was 0-5 V d.c. The reason for the enquiry was that a school wanted to make accurate measurements of a.c. current and, not having a suitable a.c. ammeter, wondered whether they might use d.c. voltmeters. The solution is given below.

A.C. current to d.c. voltage conversion

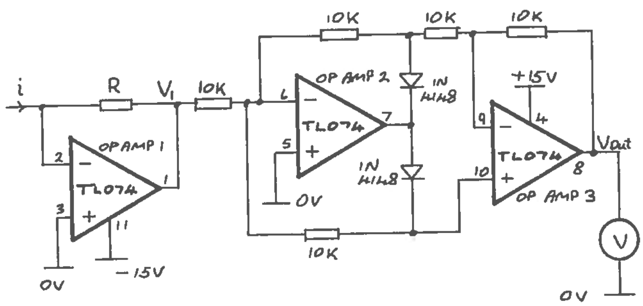


Fig.1 - Circuit diagram - a.c. current to d.c. voltage converter.

There are two parts to the conversion. Op amp 1 (Fig.1) is wired as a current to voltage converter, its output, V_1, being

$$V_1 = iR$$

Op amps 2 and 3 are wired as a precision full wave rectifier, a circuit which overcomes the voltage clipping of 0.6 to 1.0 V per diode associated with ordinary rectification. Teachers should be well acquainted with this effect, its characteristic symptom being the imperfect waveform of a rectified sine wave. By theory

$$V_{out} = V_1$$

when as in this case all the related resistors are equal. One should take care to match these; resistors from the same pack can be expected to be very close in value to one another.

One therefore gets the following theoretical relationship between the d.c. output voltage and a.c. input current

$$V_{out} = iR$$

where both V_{out} and i can be either peak values or r.m.s. values. To meet the specified request R was selected as 4K7 such that the output voltage, when the input current had its top value of 1 mA, could be handled by a 5 V voltmeter.

In practice the theoretical relationship is imperfect; there is indeed direct proportionality between V_{out} and i, but the relating equation turns out to be

$$V_{out} = 0.91x(iR),$$

the missing factor of 9% being due to the operation of the precision full wave rectifier. This linear relationship holds up to a frequency of 500 Hz, performance remaining acceptable up to 2 kHz (Fig.2). Take care that the signal levels never get large enough to cause saturation in the op amps; the peak voltage should be kept several volts below the power rail level.

A BIFET op amp, which has very low bias and offset currents, is the best choice. The TL074 is a suitable quad BIFET op amp package. Its RS stock number is 302-621 at £1.35.

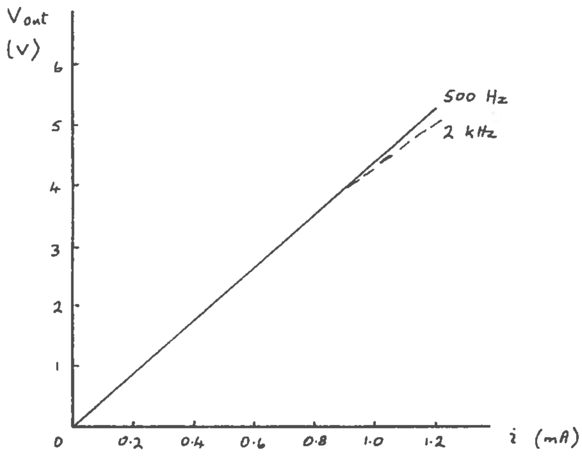


Fig.2 - Frequency performance.

The 1N4148 signal diodes have a corresponding stock number of 271-606. The resistors should be ¼ watt and carefully matched. As a general rule analogue circuits should be soldered rather than wire wrapped.

The circuit requires a dual rail power supply of either ±12 V or ±15 V. It could be powered from two 9 V batteries, but at the expense of a small reduction in sensitivity because, with the component values specified and a maximum input current of 1 mA r.m.s., the op amps would be verging on saturation. One might overcome this snag by reducing the value of R to 3K3.

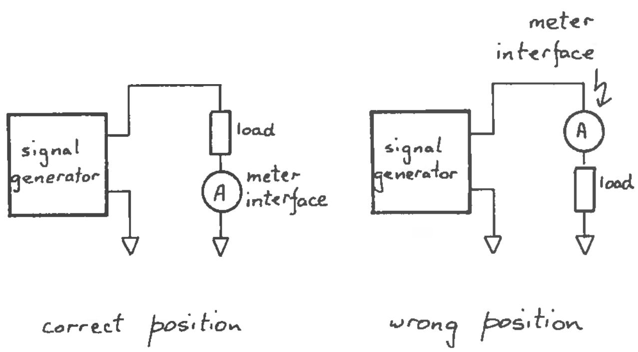


Fig.3 - Meter interface position.

The circuit position of the meter interface is important; it is essential that one terminal is connected to the 0 V line (Fig.3) (represented by a downward pointing arrow).

The wiring of the a.c. supply, load, meter interface, voltmeter and dual rail supply is shown in Figure 4, particular care being required over the connections to the 0 V line.

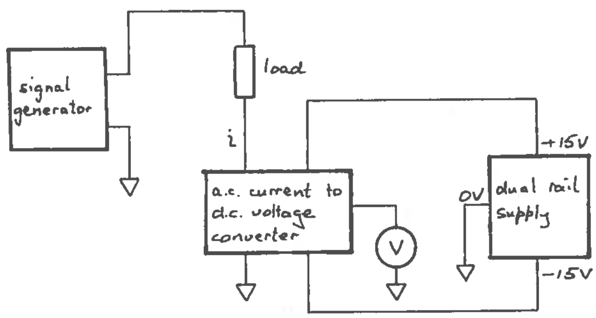


Fig.4 - Wiring diagram.

*   *

Velocity of sound in air

Abstract

This is an account of a way of determining the velocity of sound in air by measuring the time taken for sound to travel a set distance. The apparatus has home built elements comprising two sound activated switches and the processing circuitry required to operate a digital timer.

Preamble

With developments in electronics it might be possible to construct an instrument which gives a direct reading of the velocity of sound. An interesting construction project? But what a bore! Sound is a fickle subject to experiment with quantitatively. Readings can be digitized, but their sense depends on applying the principles of experimental method. In this article it is shown that one cannot lose sight of basics.

General description

The general method should be fairly clear from the apparatus layout (Fig.1). Sound reaching the near microphone starts the digital timer; the same sound wave carrying to the far microphone stops the timer.

There are three distinct parts to the sound activated switches. The microphone and signal conditioning elements (two required) convert the sound pick-up into a TTL compatible pulse. The signal processing part sets a latch at the onset of each microphone signal. A disparity in the outputs of these two latches is used to generate the pulse, operating the timer.

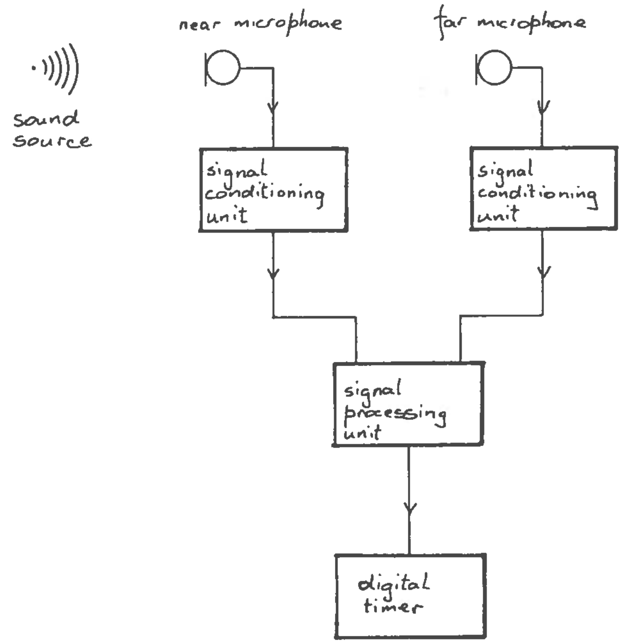


Fig.1 - Apparatus layout

Sensor and signal conditioning unit

Crystal microphone inserts are used on account of their cheapness. They would not seem to have any other recommendable features and we would welcome comments from teachers who have worked with better alternatives.

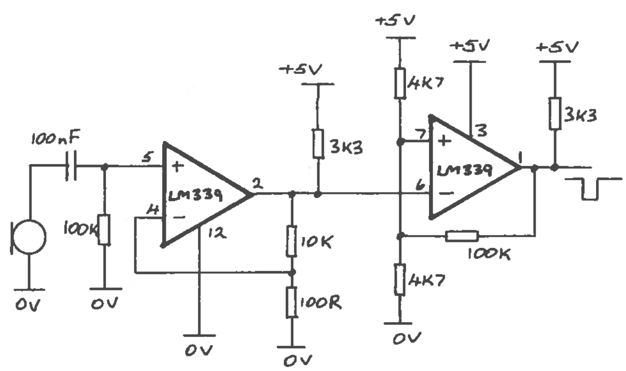


Fig.2 - Signal conditioning circuit.

The microphone is a.c. coupled to an op amp amplifier through a 100 nF capacitor (Fig.2). This is a situation where the op amp input must be connected to ground. A 100K resistor is connected from the (non-inverting) input to ground to provide a current path for the signal.

One of the four comparators in an LM339 package is used as an amplifier. Though not specifically designed for this job it operates satisfactorily in this case in which high fidelity is of no consequence. The op amp is used in its non-inverting mode; it has a gain of 100. As with most comparators a pull-up resistor of around 3K3 is required at its output.

The second stage is a comparator with Schmitt trigger input which has a threshold of around 2.5 V and smallish hysteresis. Thus a signal in excess of 25 mV applied to the input of the amplifier ought to operate the Schmitt trigger. The output is +5 V when the input is below the threshold, 0 V when above, and will drive directly coupled TTL inputs.

All four comparators on board the LM339 package are put to use, two each for both of the microphones. A further benefit in this choice of device is that, unlike most other op amp packages, it is powered from a single rail supply, at +5 V the same supply as for the digital components in the later stage. There is one precaution to bear with; the input voltage should not fall below -300 mV. With our type of microphone output this is considered not to be a problem.

Reviewing this design it might be thought that its many parameters, input coupling, amplifier gain, threshold and hysteresis, are somewhat arbitrary. They have all been researched and are considered to be the optimum values for this type of microphone. The point is touched on again in the discussion on experimental method.

Signal processing unit

The signals which the processing unit has to handle consist of trains of negative-going pulses (Fig.3) entering from the two sound switches just described. It can be seen that the unit has to trigger on the first negative-going edge at each input.

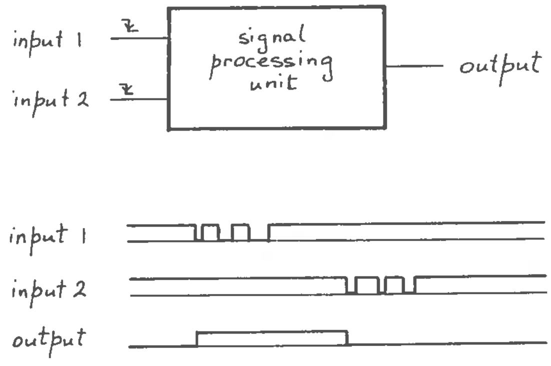


Fig.3 - Signal processing unit

Two edge-triggered, D-type flip flops detect these input signals, latching on the first edge. The flip flop used (74LS74) is positive-edge-sensitive. As the first edges on the input signals are negative-going, both input signals require inversion before they reach the flip flops. This is carried out by exclusive-OR gates which happen otherwise to be lying spare.

The function table of the D-type flip flop (Fig.4) is shown in Table 1. The shaded portions represent the functions which are in use.

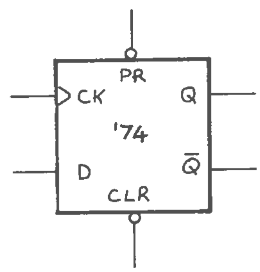


Fig.4 - Terminals of D-type flip flop

INPUTS				OUTPUTS		
PR	CLR	CK	D	Q	$\overline{Q}$	
L	H	X	X	H	L	
H	L	X	X	L	H	
L	L	X	X	H	H	- non stable
H	H	↑	H	H	L	
H	H	↑	L	L	H	
H	H	L	X	Q_0	$\overline{Q}_0$	

Table 1 - Function table of '74 flip flop

The PRESET (PR) input is used to initialize the flip flop. This input is marked (Fig.4) with an "o" symbol to signify that it is active when pulled low. It is therefore held high normally by tying it to the positive rail; it is activated by pressing the pushbutton. On initialization the Q output goes high.

The CLEAR (CLR) input is disabled by connecting it to the positive rail via a pull-up resistor.

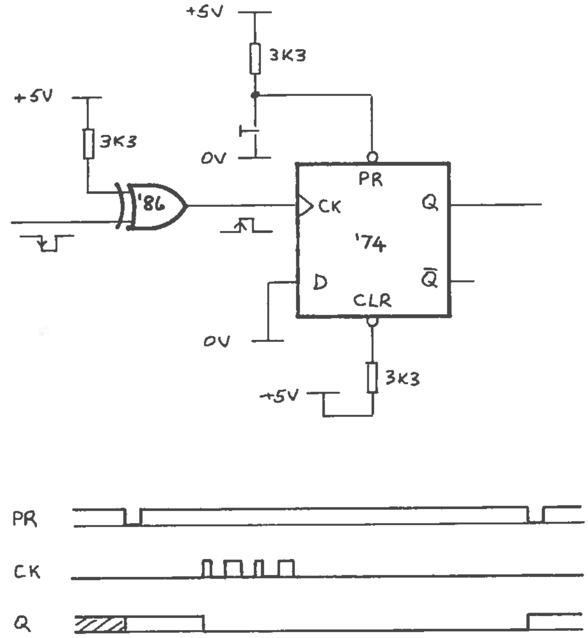


Fig.5 - D-type flip flop, signals and circuit

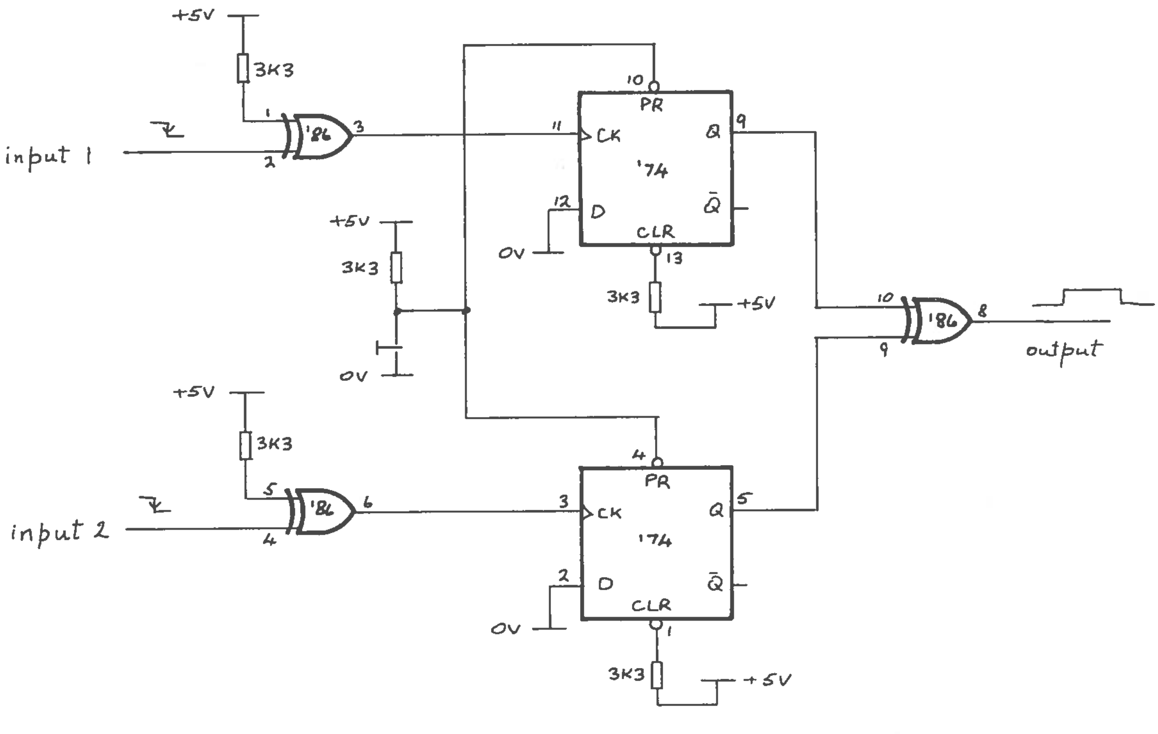


Fig.6 - signal processing circuit diagram

The edge-sensitive input is called CLOCK (CK). The onset of the leading edge from the sound switch triggers the flip flop which causes the Q output to equal the D input. As the D input is tied low Q becomes low also (Fig.5).

The outputs of the two flip flops are connected to the inputs of an exclusive-OR gate whose output is low when its inputs are the same and high when they are different. It therefore produces a positive pulse starting when the first flip flop triggers and ending when the second is activated.

The complete signal processing circuit is shown in Figure 6. You should connect a 100 nF capacitor across the power rail and ground to remove noise on the former, this capacitor being mounted physically close to the integrated circuit packages.

Digital timer

The sound switch is sensitive to a signal from a sharp report carrying up to 10 metres, a travelling time of 30 milliseconds. Either a millisecond or microsecond timer is required, the preferred resolution being 10 μs. One can construct such a timer out of a 100 kHz TTL oscillator and frequency meter, the pulse train being gated by the output from the signal processing unit (Fig.7).

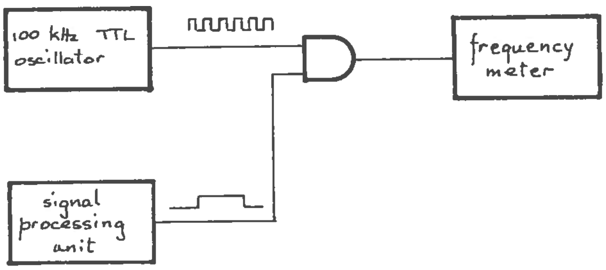


Fig.7 - Microsecond timer

As many departments will not have a digital frequency meter they will have to make do with their conventional laboratory timer(s); the modern ones have a resolution of 100 μs and are highly satisfactory for this experiment; those with a resolution of 1 ms, less so, but see below.

Certain laboratory timers are enabled to count only when their input signal is taken low; in this case the signal processor output should be inverted such that its output signal is low when the sound wave travels between the microphones. There is a fourth, unused gate in the exclusive-OR package which is available for this purpose.

Experimental details

Some variety of approach in the generation of a sound signal is possible; whatever the method its effects will be unwelcomed. We operated with two batons of wood; the short, sharp report having a 90% success rate at activating the timer when the set distance between the pick-ups was 1 metre, but somewhat below 50% at 10 metres. If elements of this discussion are reminiscent of a party conference the effect is not endearing; friends and colleagues retire to remote sanctuaries.

A set of readings of distance versus time is obtained and the velocity of sound is found from the gradient of the resulting graph.

It was initially hoped that the apparatus could be contained on a single workbench, using the high resolution timer and covering a range of 100 cm, by 10 cm increments. This hope was not realised.

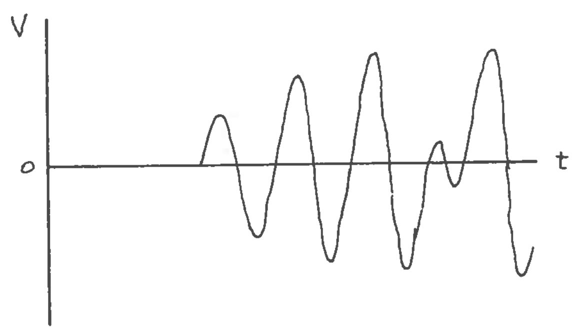


Fig.8 - the short, sharp report.

What happens is as follows. When the two batons are clapped together they generate a report which contains a train of waves at a frequency of about 2 kHz, the leading amplitude being somewhat lower than the succeeding one (Fig.8). This can be confirmed by capturing the signal from a microphone pick-up connected to a fast transient recorder such as a Unilab interface and BBC microcomputer. When the microphones are within 20 cm of one another the leading peak triggers both; when more than 60 cm apart the leading peak triggers the near one, the second peak triggers the far one; between 20 and 60 cm neither effect dominates.

This analysis is supported by the wide scatter in measurements at 40 cm compared to the much smaller range at 100 cm.

distance (cm)	**average time** (μs)	**standard deviation** (μs)
40	1487	413
100	3399	23

An attempt was made to make the far microphone more sensitive than the near one by adjustment of the various parameters referred to earlier; for various reasons it was decided that both sensors worked best at the same specified sensitivity.

Taking account of this triggering feature you should avoid separations which are less than 80 cm; either a set between 80 and 200 cm in 20 cm steps or between 1 and 10 m in 1 m steps being recommended. With either one of these you can expect a straight line, distance-time graph which does not pass through the origin because, as explained earlier, the two flip flops trigger on successive peaks of the sound. With a 2 kHz signal this results in the graph cutting the time axis at 500 μs. By one such means we obtained a value of 337 ms^{-1} for the velocity of sound. It should be pointed out that 10 m was the limit of reliable operation of the equipment. The standard deviations to be expected in the range between 2 and 9 metres lay between 170 and 410 μs.

An interesting point on experimental technique can be demonstrated using a millisecond timer. If one takes an ordered set of readings up to a distance of 10 m, by graphical treatment one can obtain a value for the velocity of sound to a precision far greater than the lowish precision of each individual reading of time.

Construction of circuit

This can be undertaken by a variety of means of which either soldering on 0.1" stripboard or connecting by wire wrapping are both relatively simple. The method by wire wrapping is particularly suitable in this context as it provides the quickest means of assembly. This technique is described in SSSERC Memo 1. By way of further encouragement the equipment you would require to purchase in order to wire wrap is listed below, as are the circuit components.

The wire wrapping tool that is simplest to use, the 'development' tool, is currently available at £21.47. A cheaper tool, the '3-in-1', is not difficult to work with either, though its usage is somewhat slower, and is priced at £7.71. Both tools require different wire dispensers, they being itemized immediately after their respective partner.

Wire wrapping is easier than soldering on stripboard because the layout does not require meticulous planning. As can be seen from the photographs of the sound switch (Fig.9) the components are mounted in geometrical order and the connections made in point to point fashion. Two types of wire wrap connections can be seen. Those with bared wire have been made with a 3-in-1 tool; those with covered wire with a development tool, the sharp corner of the wire wrap pin biting through the insulation to make electrical contact.

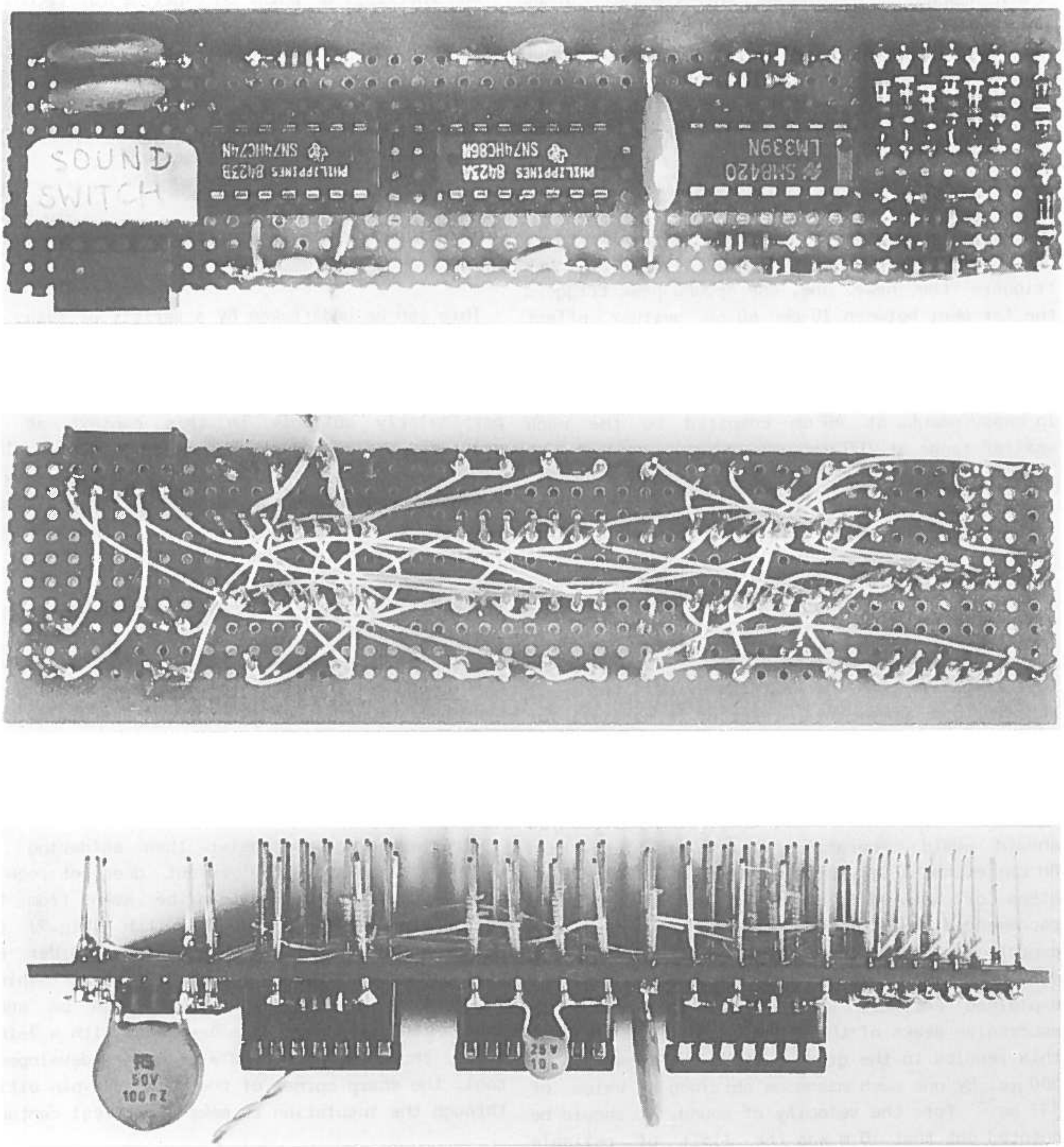


Fig.9 - construction by wire wrapping

item	**supplier**	**cat.no.**	**price**
wire wrapping			
development tool	RS	546-714	21.47
spare bobbin	RS	546-720	3.98
3-in-1 tool	RS	544-005	7.71
wire wrapping dispenser	RS	358-107	3.98
miniwrap terminal pins (500)	Verospeed	18-0226F	9.89
plain board, 454x95 mm area, 2.54 mm pitch	Verospeed	02-0134D	2.97
dual in line sockets (wire wrap) 14-way (10)	Verospeed	19-1650F	4.66
components			
insert microphones	SSSERC	333	0.40
	Tait	G142	0.33
74LS74 flip flop	Farnell	N74LS74AN	0.49
	RS	307-597	0.52
74LS86 exclusive-OR	Farnell	N74LS86N	0.43
(5)	RS	307-604	2.25
LM339 quad comparator	Farnell	LM339N	0.50
	RS	302-429	0.48

Pin-out diagrams for the integrated circuit packages are shown below (Fig.10)

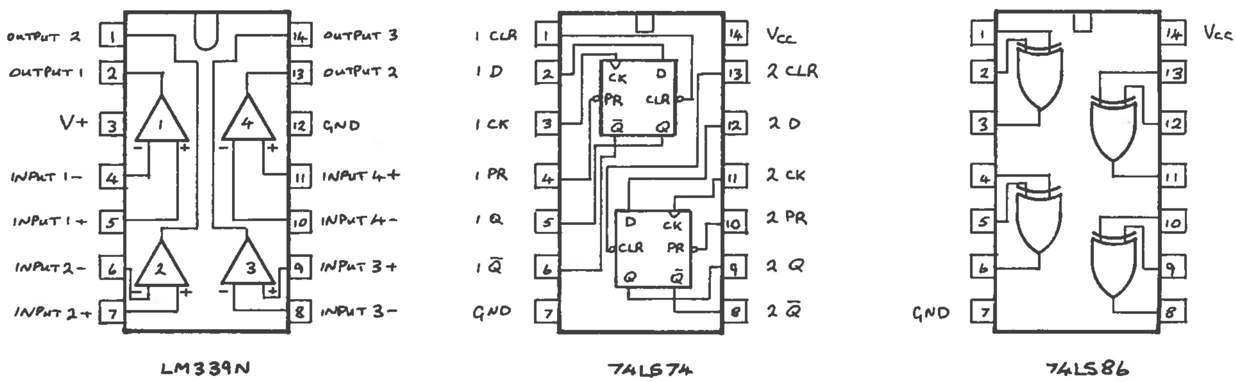


Fig.10 - Integrated circuit packages

ASE ANNUAL MEETING REPORT - YORK 1986

Introduction

The parent body meeting must rank as one of the most important dates in the UK science education calendar. The accompanying trade fair, with its equipment manufacturers' and publishers' exhibitions, is undoubtedly the largest available to U.K. school science circles. Our main reason for attending the meeting is to bring back relevant information on new apparatus. We also attempt to divine something of the major current and future issues in science education. We hope to convey herein some of our impressions as to trends as well as pointing to new or interesting equipment.

General Impressions

The meeting attracts many visitors from overseas who are faced with similar problems to our own, problems of syllabus innovation and resource needs without the wherewithal to meet them. Thus informal discussion, both in symposia and meal queues can be both stimulating and rewarding. It was also very good to see such a large 'tartan army' at this years event, especially when the meeting is held so close to Hogmanay when Scottish transport arrangements are difficult.

The Scots were certainly noticeable. A family friend, who teaches in the English midlands was almost complaining about seeing them everywhere. He had noted too, that many of the representatives of exhibiting firms were Scottish. Nonetheless no thefts of cattle or turf, or damaged goal posts, were reported. On the contrary one of the civilised, social highlights was a Scottish Reception. Here the inevitable haggis, oatcakes and malt were consumed by guests who then proceeded to burn off excess kilojoules in the dreaded eightsome reel.

I wonder, has anyone plotted a graph of Scots attendance against the distance of the venue south from Gretna or Carter Bar? The difficult part of the travelling must be the getting of a train seat on the 2nd of January. Once that is obtained, it doesn't cost much more to sit in it for another hundred miles or so. Given the success of this year we would hope to see a goodly Scots contingent at Cardiff in 1987.

New Equipment

In recent years it has been possible, and fashionable, to identify a set of themes or trends which clearly dominated the scene. This year there was no easily identified major movement or mood either in the formal sessions nor in the equipment exhibition. There were many threads, many new items of equipment. It is impossible to include all of them and what follows is an attempt at a reasonably equitable selection.

According to the lecturers on new chemistry equipment, 1986 is the year of the balance. New models of **electronic balance**, with wider ranges and greater sensitivities, abound. Prices continue to fall and discounts to rise.

Equally ubiquitous was **data logging software.** This continues to take on ever more friendly garb. Everyone was at it. Balance manufacturers were doing it, but only when interfaced. An SSCR (Secondary Science Curriculum Review) team were doing it, to victims on exercise bicycles. This was in order to measure pulse and heart rate, blood pressure, sweating rate, temperature and breathing rate.

Others were offering the means to do it. For example, the Philip Harris **"Datadisc"** (Cat.No. A29015/4 -disc, connecting lead and box at £49-95). This package allows the logging of four variables. All four can be plotted against time or any two plotted one against the other.

Software for use with balances from other firms included facilities such as:

-weight/time plots plus the means for storing and replotting that graph with subsequent superimposition on another plot.

-easy ways of determining slope (only some packages) - very useful for rates of reaction experiments.

-percentage weight losses.

-calculation and display of the average and standard deviation of a number of weighings.

Interfaces were standard on Oertling and Ohaus balances and available as optional extras on others.

In general software was more friendly. Notably the menus have been much improved. Often a choice can be made by moving an on-screen arrow or a frame over the required display type or function, rather than by selecting a number or letter by keystroke. Like BR, some of the suppliers are "getting there" in this respect. They still have some way to go in achieving consistency in these aspects of software design. Not only were different methods of item selection still apparent, these weren't always consistent within the one package.

"Ecosoft" from Harris looked a useful utility pack. On two discs and selling at £25, it claims to cover all the ecological data processing likely to be required for educational needs. Utilities include statistics routines, tests of significance, bar chart production etc.

Value for money continues to be a preoccupation. Funds for the purchase of equipment have reached their lowest real levels for many years. It would be unfair to describe only the new goodies on show. Manufacturers and suppliers are aware of and sympathetic to such problems. Several examples were noted of attempts to cut costs through sourcing cheaper items or redesigning existing equipment so as to use less expensive components or construction methods.

One example of the first approach may have come from Russia with love (or simply as a token of gratitude for all that cheap EEC butter)? Very inexpensive **pupil meters** were seen on the stands of Philip Harris, Hogg Laboratory Supplies and Irwin Desman. Russian made ammeters (0-1A and 0-2A) and voltmeters (0-6V and 0-15V) were available at £6 - Harris, £6-50 - Hogg and £5-20 - Irwin.

Biotechnology continues as a growth area. The range of kits goes on expanding with sets for making casein glues and junket and for studying microbial activity available from Griffin Biological and Harris Biological. A problem with kits largely based on consumables, is the availability of replacements. Harris Biological seem to have paid particular attention to this aspect and are offering refill sets for virtually all of their kits.

Griffin and George had on display a **fermenter** which was interfaced for data logging. An algal culture was being monitored for temperature, pH and oxygen levels using an 'Interbeeb' interface and 'Expandpack' connected to a BBC model B. Our own general impression is that fermentation technology still has a long way to go before it is either affordable or feasible for use in the average school laboratory. There are signs that we are not alone in taking that view and that further development work is already underway in several locations. Judging by the attendance at the seminar on "Biotechnology in School Science" the issues raised by developments in this area continue to grow in importance.

A most attractive and well designed **incubator** was on show at the Griffin stand (Cat.No. YXA-710-010D, £219-65). Of low-form style with a detachable top and circular access aperture it was very impressive, allowing access to cultures etc. for one arm but without the need to remove or open the whole lid.

The incubator and other Griffin products are listed in the "Griffin Catalist 1986" (groan!). In addition to chemical puns Griffin also continue to sell the real thing. One potentially useful new chemical entry is a **substitute for xylene** (dimethylbenzene). Because of its serious toxicity, doubts have been expressed about the continued use of xylene in microscopy. The launch of this new product is therefore timeous. Its chemical nature was not revealed to us but it smells of oranges. That in itself is one advantage over xylene.

Still on the theme of safety, we would draw your attention to a video entitled **"Collapse - Basic Life-saving Techniques"**. This is sold by Harris Biological in a VHS format at £18.95.

There is a general shortage, in educational establishments, of fully trained first-aiders. Even those who are so trained may not be immediately on hand in an emergency. This video may fill an important gap in training. It shows how several kinds of accident are best dealt with and includes all of the major techniques of resuscitation. At the price it may represent a very cost-effective investment in safety provision.

That much abused word **technology** was again cascading out of many mouths. In some sessions waterfalls of words were quickly emptying small reservoirs of thought. Too many still seem to think that they can gather the word technology unto themselves and equate it solely with their own concerns. Presumably they hope thus to confer a higher status to their pet subject in the hope of attracting funds. At the other extreme, definitions are adopted which are so wide as to embrace the reading aloud of a Shakespeare play as a technological activity on the grounds that it has a useful outcome! Our umbrella is not that large. It does however cover a wide range of activities, some examples of which we deal with below.

A firm fairly new to us is Technology Teaching Systems. Their stand was the only one with a **pneumatics kit** in action. A nice feature of the kit is the use of Schrader valves. These are potentially more durable than valve types used in other kits. Components were of manageable size with air cylinders, air reservoirs and control valves of various kinds, each available at around £10 or so. Of course, if large systems are to be built the overall costs mount up. The type of tubing and connector used open up the possibility of building air driven circuits as easily as those for electronics. This same firm is also a source of **Meccano** and **Lego** as well as several types of **motors** for control work.

Griffin's "Technology Catalogette" (who is this linguistic liberty taker at Griffin and George?) includes a teaching system for **structures and mechanisms**. This is basically a heavy duty plastic equivalent of pegboard on which to mount various, provided, structural and/or mechanical components such as gearwheels. On the same constructional theme are: **Stoky's Construction Kit** a Swiss variant of Meccano with which it is compatible and the **Plawco Construction Kit.** Both of these are available from Harris. The latter though has been directly available from Plawco for some time. The Plawco kit is based on PVC coated steel rods which can be cut, bent, shaped and connected in order to make model bridges as well as actual artefacts such as cassette or magazine racks.

Growth continues unabated in the number of firms entering the market, as well as of product ranges and pupil age coverage, for **electronics kits.** Notable newer items seem to be: Unilab's **"Electronics 11-13"**; Griffin's **"Electronics 16-18"** (to add to 11-13 and 13-16); Harris **13-16 modules** and the Omega Electronics **"Introduction to Electronics".**

Omega also now sell what must be one of the cheapest buggies around. With two motors on a sturdy aluminium framework it costs a mere £8-50. With driving circuitry and relay it becomes amenable to computer control for a further £33-80. Other accessories, including 'whiskers' and optical sensors, together with a course booklet are available.

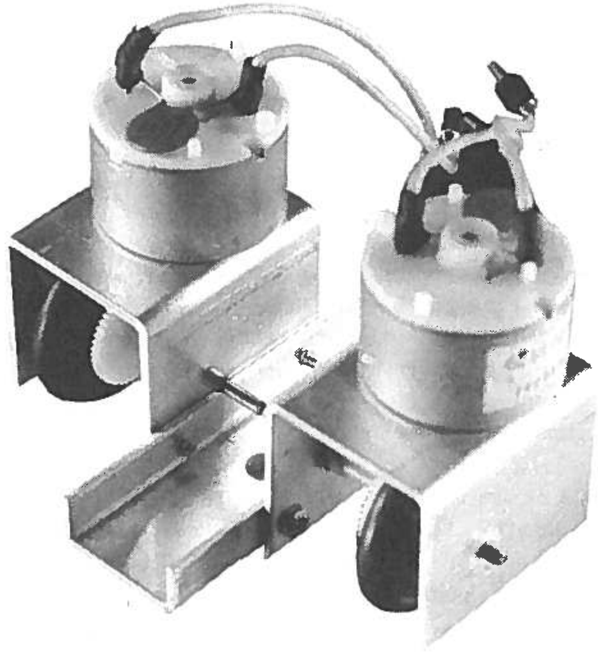


Fig.1. 'Nestic-Omega' Buggy

Such sensors and control systems were seen aplenty. Unfortunately they were still mostly being used to play with toy cranes, wee carts dubbed "pooper scoopers" or model railways. Things, by now, should have moved on. There was little evidence of any realisation by suppliers of the need to develop material mirroring industrial process control. Conditions in industrial chemical reactors or in the many miles of piping in petroleum refineries have been under automated control for many years. This is supposed to be "Industry Year". Where are the educational models of process control systems?

Apart from the fermenter set up already mentioned, the only other model process control system was on the stand of the National Centre for School Biotechnology.

The selection of equipment and materials on the MEP stand was most impressive. Even if you don't purchase any of the hardware many of the manuals, in what by now is a very wide range, are extremely useful. A catalogue of materials from the MEP Electronics and Control Technology Domain is available from Mrs Beth Davis at the address shown on the inside front cover of this bulletin. Three new MEP publications which looked particularly interesting were:

-**"The Book"**. Primarily aimed at teachers of CDT, this deals with control systems designed so as to need only the simplest of programming skills. Price £9-50.

-**"Control Pathways"**, a resource base consisting of Teacher's Guide and Pupil's Book, the latter written in such a way as to allow the use of whatever microprocessor controller is held by the school. This distance learning "Control Pathways File" represents good value at £2.

-**"The Book of Revelations"** At last, the hitch-hiker's guide to VELA! A route map to the data-logger at the end of the universe, based on trialled INSET materials. £9-80.

Finally, should you feel like getting away from it all, Hinterland Ltd. supply a kit for converting a plastic fizzy drink bottle into a **rocket**. The kit costs £4-99 plus 51p P.& P. It consists of a plastic collar which screws onto the standard bottle top and which holds three fins plus a plastic plug which is ejected once the contents of the bottle have been pumped up to the required pressure.

The basic idea behind the kit is a tried and tested one. What is new and clever is its adaptation to the plastics drink bottle designed to withstand high pressures. An extra, though very expensive, accessory is a special launching ramp with three trip bars on it which allow measurement of the rocket's acceleration rate.

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RS Components, PO Box 99, Corby, Northants. NN17 9RS Tel.(0536) 201201.

The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG

SSCR (Secondary Science Curriculum Review), ASE working group (Biology Health and Fitness), Convenor - Christopher J. Smith, Senior Biologist, Tabor High School, Braintree, Essex.

Tait Components Ltd., 973 Sauchiehall Street, Glasgow G3 7TQ Tel.041-339 9959.

Technology Teaching Systems Ltd., Penmore House, Hasland Road, Hasland, Chesterfield S41 0SJ Tel.(0246) 78993.

Verospeed, Stansted Road, Boyatt Wood, Eastleigh, Hants. SO5 4ZY Tel.(0703) 644555.

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S.S.S.E.R.C.

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