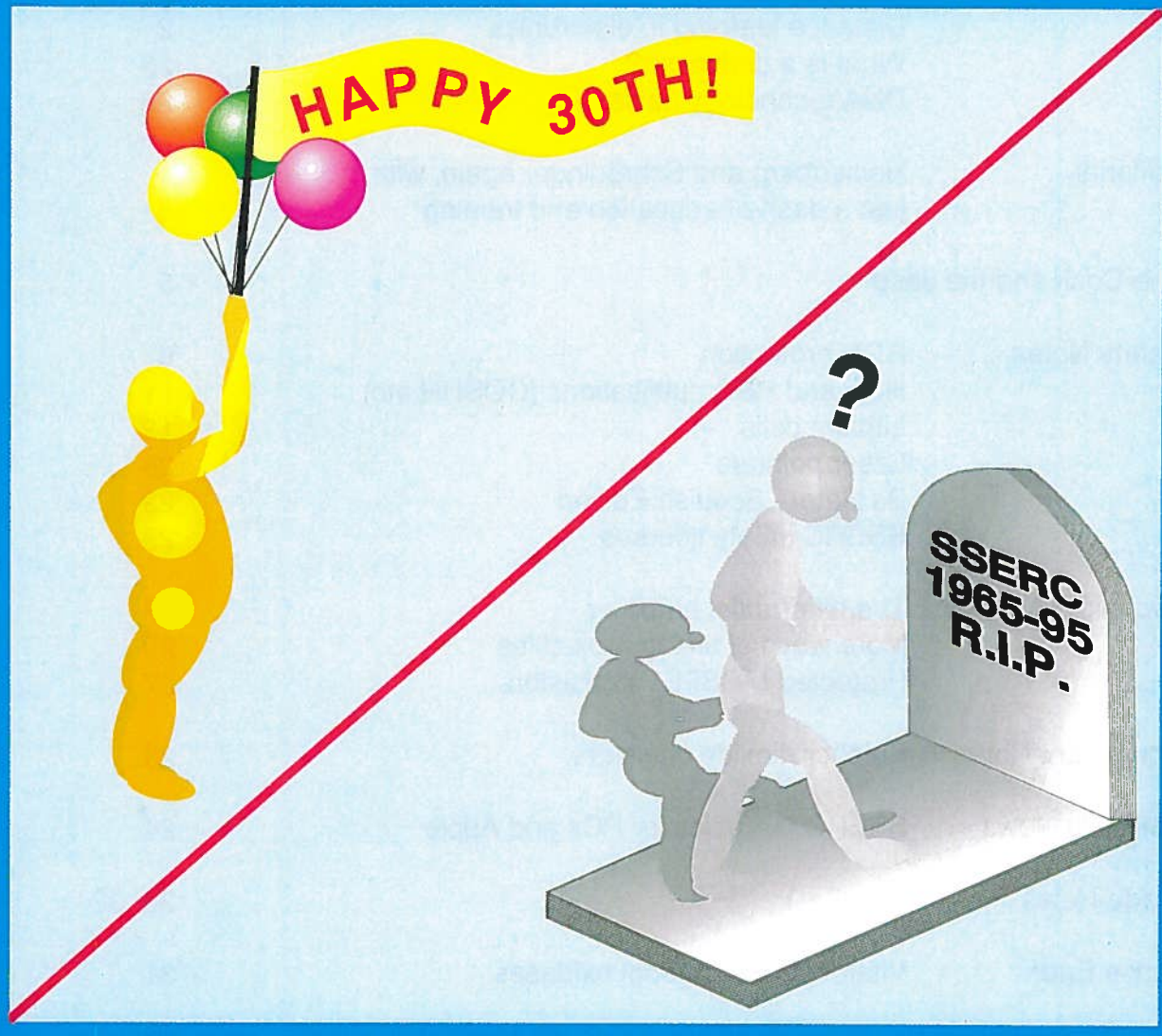
SCOTTISH SCHOOLS EQUIPMENT RESEARCH CENTRE



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NEWS REPORTS

Technology education framework

SCCC have recently published *A Framework for Technology Education in Scottish Schools*, which proposes a set of principles to underpin the future development of technology education in Scottish schools in the late 1990s and beyond. The paper is for consultation and discussion. It is the Council's hope that the paper will help to stimulate widespread and constructive debate about this area of the school curriculum.

Any comments or enquiries about the contents of the paper should be addressed to Dr Dennis Stewart, Director, at the Dundee office of SCCC.

Edinburgh Science Festival

The Festival opened with a discussion between the philosopher, Mary Midgley, the scientist, Aubrey Manning, and Stirling University Principal, Andrew Miller, on **putting science in its place**. Referral was made to the bad effects of science - pollution, weapons of mass destruction, and such like - and to quack science from the relatively harmless claims of advertisers to the inestimably harmful assertions of totalitarian regimes that their brand of government was progressive because it was allegedly based on the scientific method. That science can be a pejorative term is without question. Nevertheless the paradox is that for all the harm caused by science, or in the name of science, the World needs science to prevent the harm from getting worse. On that chastening note the Festival opened.

Sir Arthur Wolfendale, former Astronomer Royal, strayed wildly from his lecture subject, **cosmic rays**, to speculate on the nature of the universe (or universes?). Will our universe continue to expand forever, or will it stop expanding and contract to a Big Crunch, or is it in that intermediate state wherein it expands to infinity, then falls back in on itself? His own preference is for the third option, because this lets us work out the total energy of the universe. The calculation is quite simple. When the universe stops expanding, the total potential energy is zero, everything being infinitely spread out. The total kinetic energy is also zero, everything being at rest. The total energy is therefore zero. I don't agree with this reasoning. I am merely your reporter of this cosmological matter.

If the festival opened weary with the cares of our poor planet, it closed with brilliance. Paul Davies, author of the *New Physics* and much, much else, had jetted in from South Australia and many other terrestrial landing strips to dazzle us with **A Short History of Time Travel.**

Beginning with travel into the future, he explained how this is a reality by travelling near to the speed of light (Einstein's Special Theory of Relativity). There is confirming experimental evidence with clocks in aircraft and with muons in circular orbits.

Travel into the past is also feasible because of the warping of time and space by gravity (Einstein's General Theory of Relativity). Gravity slows time. If the Earth collapsed to the size of a pea, it would become a black hole. Nothing can escape from a black hole. It represents an infinite time warp within which time stands still.

The concept of wormholes was then explained. If the throat opens, it leads you into another universe. There is however the problem of how to keep the throat open so as to pass through it (there are also the problems of spaghettification and cosmic censorship wherein cause and effect break down). The key would seem to be antigravity effects. Three means have been postulated : centrifugal forces, electric charge, or negative pressure. Kit Thorne's negative pressure time machine was described. Unlike positive pressure, which is caused by compressive forces and gravitates, negative pressure is the effect of tensile forces and antigravitates. The big problem is that mass usually swamps antigravity. However the Casimir effect generates a tiny force of attraction giving a region of negative pressure without a compensating region of extra energy. This process looks like your best bet for travelling through a wormhole.

So where would we go to? Well it might be to another universe. Or it might be to another point in our own universe, in which case we would have travelled backwards in time. But this leads to practical difficulties. Suppose you travel backwards in time and do something wicked like kill your mother, or kill your younger self. How does history unfold? The causal nature of the universe is disturbed. It strikes at the heart of science, which attempts to give a rational description of Nature.

Paul Davies posed the same problem enunciated last year in Edinburgh by Stephen Hawking - does God throw dice in black holes? The Hawking's Chronology Protection Hypothesis maintains that the universe is kept safe for historians. However Davies thinks that time travel back into History is possible, but warns that the universe is weirder than we might be inclined to think. Because of the Heisenberg Uncertainty Principle, we cannot predict whether, say, an electron will be scattered to left or to right during a collision. When the electron strikes its target, the universe splits in half, one to left, the other to right. This is the Schrödinger cat effect. One universe has a live cat. The other one a dead one. It is not one universe, but a quantum multiverse - or lots of universes. In time travel, the traveller flips from one universe to another, which might bring consistency and order to our historical record.

Is this serious physics or recreational physics? Davies finished his talk by referring to his time travelling friend Frank Tipler, of whom he asked this very question. Tipler's answer, as he backed out of the room in a hurry, was, "Am I mad? We shall see!" and with that he was off!

Perhaps my family are right to maintain that your Time Travel reviewer lives on another planet!

ASE Scotland Annual Meeting

This year's meeting was held in the week before Easter in the welcoming hospitality of Bannockburn High School.

Scotland has the unenviable record of the highest incidence of death by **heart attack** in the World. Three major causes are high blood pressure, high cholesterol level and smoking. Professor Shepherd of Glasgow University explained how these factors combine multiplicitively rather than additively to affect the risk. The risk factors are related to the standard of living. For instance the risk of death in an affluent part of Glasgow like Bearsden is quite low, whereas in an impoverished part like Easterhouse it is many times greater. Because of our nation's appalling record of coronary disease, information on its causes should be given to pupils at school. The lifestyle of a person has a direct effect on the risk.

Children love **dinosaurs**! Because there are very few Jurassic outcrops in Scotland, dinosaurs have been, until very recently, absent from Scotland's fossil record. Nevertheless evidence of a dinosaur presence in Scotland has recently come to light. A few years ago part of the bone from, possibly, a therapod, a meat eating dinosaur, was discovered at Staffin in the Isle of Skye. This bone is now on display in the National Museum in Edinburgh.

However the definite evidence only came last year. Neil Clark of the Hunterian Museum in Glasgow University described how two massive bone fragments were found in a mid-Jurassic sediment in Staffin last year. Reckoning that the fragments were from the same bone, probably the femur of a sauropod dinosaur, a herbivorous type, he fabricated the missing central section of the femur out of resin. By this means he was able to assemble the whole bone - two parts real, one part artificial. It was about one metre in overall length and 20 cm in diameter.

Following a press conference to announce this discovery he received a further dinosaur bone from a Skye resident. He was astonished to find that it was the missing part of his legbone, exactly resembling his artificial piece. This fossil relic may eventually be put on display in a private museum in Skye.

Colin Cartwright and colleagues at Abertay University have worked up a hugely satisfying lecture on **rainbows**. By means of demonstrations with dry rainbows, a laser beam transmitted through a cylindrical flask of water, and computer simulations of ray optics, the mechanism of primary, secondary and multiple rainbows is explained. This is a stimulating entertainment, well worth a school outing should the opportunity present itself.

ASE technician membership

The technician service is a valued and invaluable part of science education. To mark this fact the ASE have introduced a special class of membership for technicians. The annual fee is only £10, which is excellent value for money. For this the technician member would receive copies of ASE journals and have the right to attend ASE meetings such as the Annual Meeting in January and the Annual Scottish Meeting at Easter.

This membership scheme gives technicians an opportunity to keep informed on matters relating to apparatus, to health and safety, and to other issues pertaining to the technician service in schools. Membership should lead to a more rewarding and fulfilling career. If you are interested in taking out membership, please write to the of the ASE at Headquarters (see address list, inside rear cover).

Satrosphere will come to you!

Satrosphere is the well known, greatly admired, interactive science and technology exhibition in Aberdeen. If however you cannot conveniently get to Aberdeen to see it, why not invite Satrosphere to set up an exhibition in your school. Under this new venture, trained helpers will convey the exhibition to your venue, set it up, maintain it, explain it, and give shows and demonstrations. The first exhibitions on light and sound will be available from July 1995. For further information contact Denise at Satrosphere.

Distance learning in electronics

Northern College of Education have several distance learning electronics courses for teachers. Their Certificate Course in Electronics entails about 160 hours of private study and some college based work comprising an induction day, three 2 day workshops, and a terminal day. The course elements include systems, components, computer measurement, circuit construction skills and pedagogy. The course is suitable for either Physics or Technology teachers.

Other more specialized courses that are entirely for private study are Analogue Electronics for Higher Grade Physics, Digital Electronics for CSYS Physics and Analogue and Digital Electronics (a two part course) for Higher Grade Technological Studies. Although these course materials have been written to train teachers, they may also be of direct use for pupils. If you are interested in any of these courses then please contact Dr Peter Craig at Northern College (Aberdeen Campus).

EDITORIAL

"Well, hello again - Heisenberg!"

This issue, our one hundred and eighty fifth, is being prepared in difficult circumstances. This should be a happy time, at least partly spent in planning minor celebrations of a thirtieth year of service to teachers, technicians and pupils. SSERC staff are instead again worrying over their and the Centre's future. At the root of that angst is the considerable uncertainty over the intentions of the new Unitary Authorities when they take over Scottish Local Government functions in April 1996.

In theory the economies of scale offered by organisations like SSERC will be even more advantageous to a greater number of smaller Authorities. That may well prove academic if we cannot weather the financial storms of this transitional year. In seeking to keep Councils' basic, core contributions under tight control we have had to resort to fee charging and direct sales for additional services such as training. With the twin complications of moves toward Devolved Management and the natural desire of Authorities' own staffs to provide as much as possible themselves locally, and thus protect their own jobs, we haven't been able to generate as much miscellaneous income as in other recent years. There seemed no point in asking the Local Authorities for increases in real terms to their basic contributions (which previously we had cash-frozen).

The somewhat inevitable result has been a significant trading deficit which has eaten deep into our already insignificant reserves. We may have to cease trading - at least as a Company Limited by Guarantee.

Some, although probably not SSERC staff, may enjoy the irony of it all. The even more sybillant Centre (the one with the extra S for "Science") came into being in 1965. It was set up by the old County and City Councils because SSSERC offered them significant economies. The Centre's founding was a thus a collective, yet self-interested, move. It survived the next re-organisation in 1974 and has since served Scottish science and technology education well for a further 21 years. Whether or not as a Centre we outlive the next upheaval is conjectural. Watch this space or not, as the case may be.

If you see Schrödinger : Wave!

An introductory part of all of our courses on the Management of Health and Safety tends to the irreverent. This is the bit about those aspects of contemporary life which are merely managerial and thus largely content-free. Recently, in contrasting a new third culture, Management, with the established arts, sciences and technologies, I showed a group of secondary headteachers a slide which included the Wave Equation. This, in a sub-conscious, polymathic - and thus uncharacteristic - Freudian slip I attributed orally to the composer Schönberg.

cont./next col.

Not a flicker was there, not even the slightest hint of the merest lift of a single corner of a lone mouth. Should I get made redundant (we've opened a book already but there's to be no off-course betting) I'm going to apply for ARC (Action Research in the Classroom) Funding. I already have the title of my M.Ed. thesis picked out, it will be :

"Promotion and Humour in Education : Another inverse square law?"

W(h)ither Higher?

"Higher Still" and the not unconnected, mooted merger of the assessment bodies at last seem to have concentrated a few minds on the key question, which is : Will the new whole be greater than the mere sum of the parts? Or, to use the dreaded managerial-speak : Is there to be a dash or more of synergism? If there is anything at all of worth in Higher Still - or the likely merger of SCOTVEC and SEB - it will lie, surely, in the new agency being able to draw on the strengths of both predecessors as well as using the opportunity to dump some of the less useful but highly specialised baggage which each of them has undoubtedly accumulated.

For example, we have no basic quarrel with the intentions behind competence based assessment. The principle is accepted as sound, especially at SSERC where most of our staff development effort goes into improving practical skills. We admit however to some disquiet as to the weak theoretical basis of some of the course design and assessment practices used for a number of SVQs and NVQs. This could usefully be more openly and honestly acknowledged by some of the interested parties. To some neutral observers, parts of these courses appear to have no better foundation than that which a group of practitioners, having sucked their pencils and held wet fingers up in the vocational wind, poured down onto paper (lots of paper).

And, when folk start inventing lots of specialised, exclusivist terminology (eg *mapping domains, functional analyses, range statements* etc.) we are all entitled to the faint suspicion that much is as yet incompletely understood. Jargon may well be the last refuge of the temporarily intellectually challenged.

There is a parallel phenomenon, well kent by science and technology teachers, which has been described by educational researchers and which we call the labelling syndrome. This is where children learn much of the vocabulary and how to put a name to things. The temptation then is to equate this process with understanding. SSERC staff have always seen this in the form of a chemical analogy. It's like taking bottles of worrying unknowns from shelves and labelling them *Substance X* or *Chemical Y*. We can then replace the bottle feeling much more comfortable about it. This is because giving something a name seems to bring it under our control. The fact that we still have no

more clue than we did before, as to what the bottle really contains, may suddenly cease to bother us. Some aspects of the identification, definition and assessment of elements of competence apparently have not progressed much beyond this naming and labelling stage.

In contrast, the techniques of external assessment of knowledge and, to a somewhat lesser extent, of understanding, have been well developed by SEB. Too well some might claim. There is little doubt however that a major strength of the Board lies in the business of the reliable and holistic assessment of combinations of those disparate elements, topics and interpretation skills which go to make up a course of study known as a subject. At SSERC we fully acknowledge that strength and we are hardly famous for an unquestioning loyalty to the concept of a subject-based curriculum.

Yet, in that very need for integration there lies a major potential weakness of modular courses. It is reasonable and desirable to assess student competence continually and internally skill by skill, module by module. But, there is then a serious danger we may thereby atomise that which in reality is complex, organic and seamless. A person's overall competence at any stage must be multi-skilled and never merely intra-modular. Sooner or later it becomes inescapable that there must be assessment which requires the student to pull together all of the disparate elements and apply them in an integrated way to new situations and unfamiliar problems.

Shedding all the obsfucating jargon : It is that overall collection of knowledge, experience and skills applied to purposeful action which constitutes true competence. This is the major challenge set by *Higher Still*. It is not one to be faced solely by the students; nor only by their future employers - if any.

"Per ardua" without the ". . astra'?

Germane to our discussion of Higher Still - and the related SCOTVEC, SEB, assessment debate - is the whole business of the inter-relationship of education and training. One of the best pieces of writing I have seen on this topic was published in what for many is an obscure source [1].

It deserves a wider readership, so :

". . . in the UK, education does not enjoy the prestige and support that once it did. Some who have little patience with education prefer training. To me this is a false antithesis; training is the short term teaching of an educated person for some practical and usually fairly immediate purpose. Or, to put it the other way round, education is the broad, long-term basis which permits practical training to be fully appreciated, applied and developed.

This is not to denigrate training, even at its most basic. However the limitation of that sort of training, when it does not have an educational foundation, is that it often does not include the wherewithal for critical evaluation and consequent improvement of the techniques taught. Unless these are being applied by an alert, educated mind, the chance of their further development, perhaps of their replacement, is very much reduced. We have too often concentrated on immediate advantage to the exclusion of investing in the future.

When I speak about education I by no means lose sight of the parallel importance of training. I wish I could be sure that all who speak so enthusiastically about training had a similar realisation of the values of education."

Reference

1. O'Donoghue, P.N., 1990, *The Ninth Hume Memorial Lecture*, South Mimms : UFAW, cited by the author in *Ethical Issues in Biomedical Sciences*, Institute of Biology, 1993, ISBN 0 900490 31 4.

[P.N. O'Donoghue is a former General Secretary of the Institute of Biology.]

The Cock and the Jasp

In a recent article on the rise of the Scottish ship-building industry we asserted that one of the causes had been the Eighteenth Century intellectual movement known as the Enlightenment. This movement had science at its core. It was inspired by the mechanics of Newton and the steam engine of Watt. It was driven by the belief that living conditions and social order could be improved by the intelligent applications of the discoveries of science. Great stuff! If only life were that simple!

This essay does not seek to explore what went wrong with such belief. Rather we will look back to the age out of which the Enlightenment sprang. The Renaissance in Scotland is remembered now as the period when our nation's ancient universities were founded: St Andrews, Glasgow and Aberdeen in the Fifteenth Century; Edinburgh in the Sixteenth. However the ideas current in Renaissance Scotland are not much known about today. It is a fragment of these ideas that this article will now review.

Bear with me: it will take some explaining. The source [1], a moral fable written in late medieval times in Scotland, is *The Cock and the Jasp*. The story is simple. A cock goes out one day to a dunghill to get his dinner. Scratching around for draf or corne, small wormis or snaillis, he uncovers a precious stone, the Jasp of the story's title, jasp meaning jasper. Reflecting on what to do with his find, he decides to leave it aside at the edge of the midden for someone else to discover:

It is a pietie I suld the find, for quhy
. . . . .
I lufe fer better thing of les availl,
as draf or corne, to fill my tume entraill.

After the tale comes the Moralitas. In Henryson's other fables, the moralitas is predictable. What you expect from reading the fable part of The Cock and the Jasp is for the author to commend the actions of the cock. The fowl would seem to have done the prudent thing by contenting himself with foraging for further food than dallying with a marvellous stone. There are present day overtones. Far better to earn one's living from honest endeavour than from a chance win on the National Lottery, or from a director's share option in a privatised national utility! It therefore comes as a shock when the Moralitas asserts:

Quha can governe ane realme, citie or hous
Without science? No man, I yow assure.

The jasp is a metaphor for science. The cock should have allowed his need for food to look after itself, and pursued that which makes life vital and unique:

This cock, desyrand mair the sempill corne
Than ony jasp, may till ane fule be peir
Quhilk at science makis bot ane moik and scorne
And na gude can; als lytill will he leir;

So surprised at what I was reading on coming across this story, I read and reread these passages looking for the irony that I supposed must be there. Surely the text doesn't mean what it appears to mean! But of irony there is none. The meaning is as plain as it is written:

Quha is enemy to science and cunning
Bot ignorants, that understandis nocht?
Quhilk is sa nobill, sa precious and sa ding
That it may not with eirlie thing be bocht?
Weill wer that man over all uther that mocht
All his lyfe dayis in perfite studie wair
To get science, for him neidis na mair.

Henryson's message is clear. Mankind should strive to seek out and understand science and to pursue life through the intelligent application of science:

Haif we richis na better lyfe we bid,
Of science thocht the saull be bair and blind.

The meaning of *science* was of course quite different in Fifteenth Century Scotland. To Henryson it meant Biblical wisdom, especially the kind of wisdom reflected in the Book of Proverbs. There may well have been a double meaning, for the word then also meant practical wisdom. Personally I have no trouble with multiple meanings and am astonished at how well the present meaning of science fits into the Moralitas. A fable after all is allegoric. It is up to the reader to interpret it as he or she will.

Quha can governe ane realme, citie or hous
Without science? No man, I yow assure.

What relevance, if any, does the Moralitas have to life or to education today? It is from the study and application of science that many problems besetting us today should be tackled. If we ignore this wisdom, if science, engineering and technology are relegated out of the core of education, or if they are avoided by popular choice in favour of less demanding pursuits, we are doing no more than scratching around on a dunghill looking for wormis or snaillis, corne or draf. This realisation surely lay behind the Age of Enlightenment!

Reference

1. Bawcutt P and Riddy F, *Selected poems of Henryson and Dunbar*, Scottish Academic Press, 1992.

SAFETY NOTES

RCD Protection

The article explains why some form of supplementary protection from the electricity supply is often recommended in practical work areas.

This report was triggered off by a school asking whether residual current device (RCD) protection should be installed in science laboratories. We replied to say that it should. We pointed out that in a low risk workplace where there may be accidental abuse or damage, or single fault failure, the risk of harm by electric shock is highly improbable. In such a situation, the normal means of protection - insulation together with a protective earth conductor and overload devices - should suffice. However we asserted that in a school laboratory there are significant environmental risks and other risks associated with misbehaviour and unpredictability. Children can behave irrationally, irresponsibly, or malevolently, and in general do unexpected things. Or to use the highly memorable phrase of an HMI schools' inspector, commenting on behaviour in science laboratories, children are naturally curious and venturesome.

Nevertheless our recommendation was refuted by the engineer responsible for the school's services. He continued to maintain that normal means of protection should suffice. We had therefore to do some research to find out whether our recommendation could be substantiated, or whether we had egged the pudding, so to speak. Our findings are described below.

Direct and indirect contact

Two forms of electric shock are recognised : direct contact and indirect contact. Persons are normally protected against direct contact (Fig. 1) by the insulation of live parts supplemented by barriers or enclosures. Electric shock by indirect contact (Fig. 2) occurs as a result of fault conditions. For instance if there is an insulation failure then a live conductor can make contact with an exposed-conductive-part causing that part to become live. Any person touching that live exposed-conductive-part might get an electric shock.

One purpose of the protective earth conductor and overload devices (fuses, etc.) is to provide automatic disconnection and thereby ensure that the consequences of electric shock by indirect contact are not serious. In the event of a single fault, the protective system acts to prevent serious harm. In a normal electrical system, electric shock by indirect contact is highly improbable because two fault conditions would have to occur together. It would require both a failure in the basic insulation and also a failure in either the protective earth conductor system, or in supplementary insulation.

Electric shock by direct contact is also highly improbable because there is no direct access to conductors at hazardous live voltages. However direct contact can occur as a result of abuse of the system. If a person overrides or defeats the protective measures of an electrical system, then that person can be at risk of electric shock by direct contact. This risk may exist in schools because of irresponsible actions of children.

It should be appreciated that the protective earth conductor and overload devices which are part of standard electrical installations protect persons only from indirect contact types of shock, but not from direct contact shocks. In high risk areas where there is a risk of direct contact shock, a higher standard of electrical protection can be achieved by supplementary means such as residual current devices, isolating transformers, or the creation of earth free areas. In science laboratories, the most common way is by the first of these.

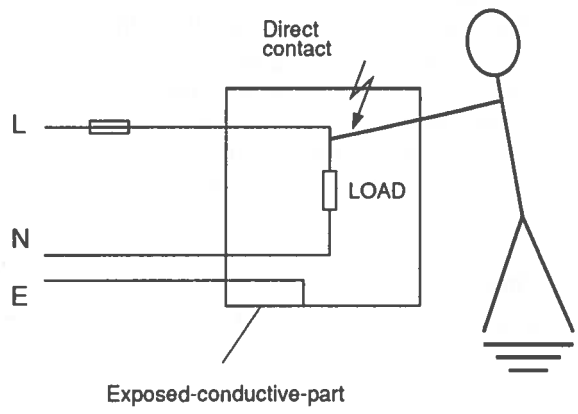


Figure 1. Electric shock by direct contact.

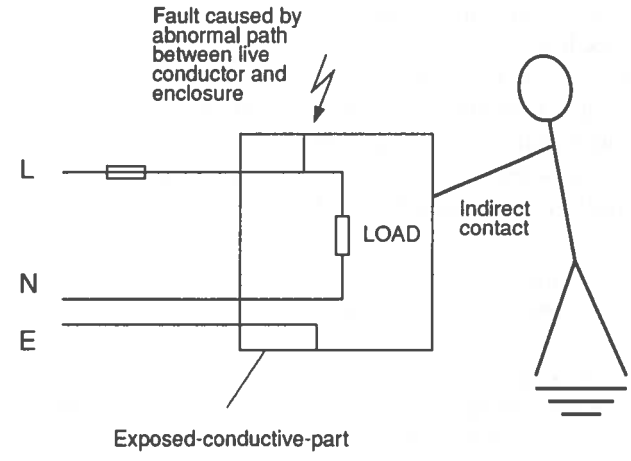


Figure 2. Electric shock by indirect contact.

RCD protection

RCDs are current sensitive devices. The principle of operation is as follows: after the current from the phase supply conductor flows through the load, it should all return to the supply neutral. The RCD senses for a current imbalance in the phase and neutral conductors. If there is a fault condition causing a portion of the phase current to flow back to the supply neutral point via an earth path then the RCD disconnects the load from the supply in a few milliseconds (Figs. 3 and 4).

The relationship[1] between phase, neutral and residual currents is

$$I_{phase} = I_{neutral} + I_{residual}$$

where $I_{neutral} = I_{phase}$ in conditions of no fault path between phase and earth. If there is a fault path, the difference is known as the residual current.

[1] Not strictly so. Residual current is the vector sum of the instantaneous values of current flowing through all live conductors of a circuit at a point in the electrical installation.

It should be appreciated that an RCD does not protect against shock. It is intended to reduce the severity of shock by disconnecting the supply within two a.c. cycles of the first occurrence of shock. Furthermore it does not offer protection against a direct phase to neutral pathway through the human body.

An RCD should not be used as the sole means of protection against direct contact. However an RCD is recognised as reducing the risk of harm arising from electric shock in certain conditions, some of which are listed below :

(a) where there is a risk of direct contact;

(b) to supply portable equipment for use outdoors so that the consequences of direct contact are unlikely to cause harm;

(c) to supply agricultural and horticultural installations so that the consequences of direct contact are unlikely to cause harm;

(d) to protect against indirect contact in systems where the earth fault loop impedance cannot practicably be reduced to the appropriate value.

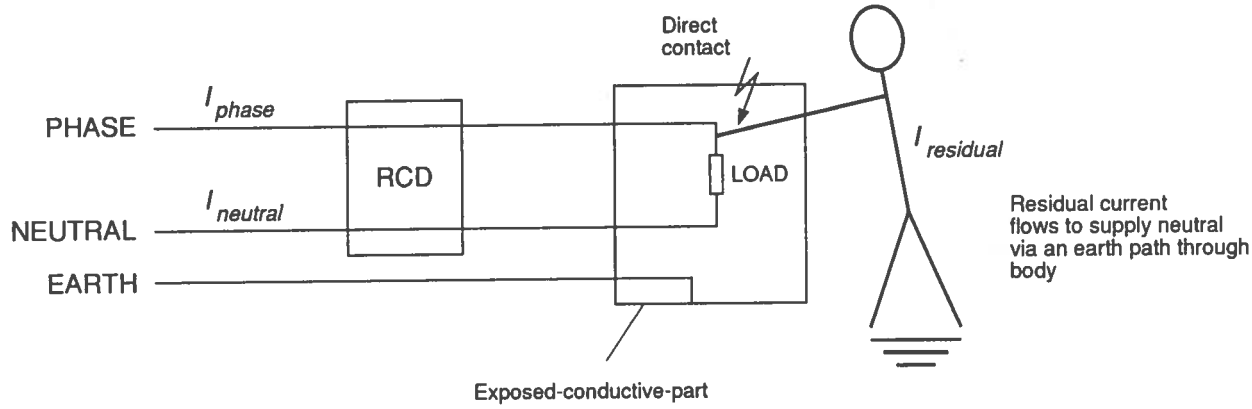


Figure 3. RCD protection. RCD cuts off supply if neutral current differs from phase current. Typical trip current is 10 mA or 30 mA. Nominal operation time is 30 ms.

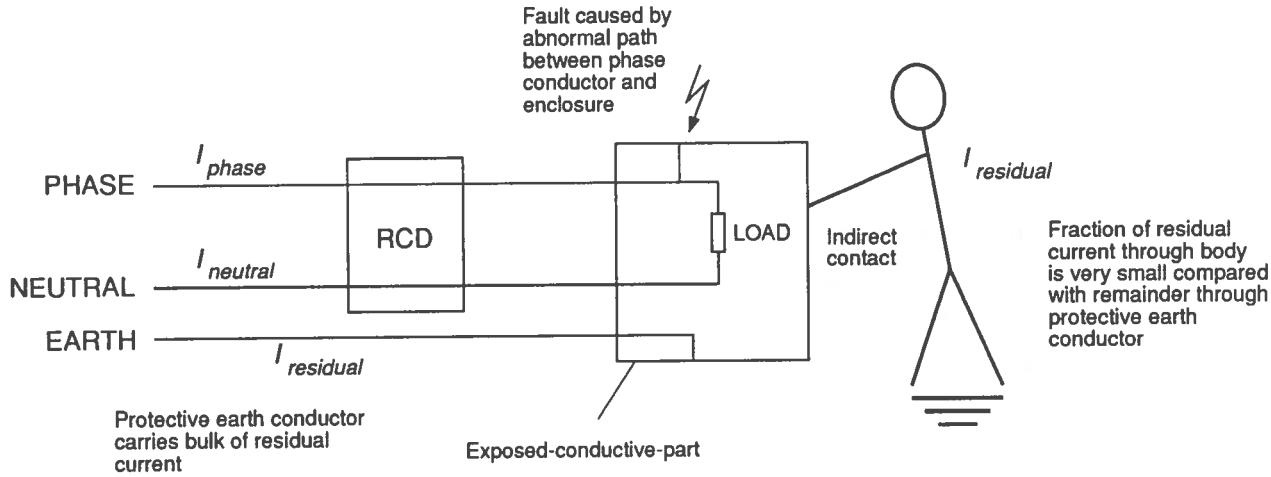


Figure 4. RCD protection. RCD cuts off supply if neutral current differs from phase current. Typical trip current is 10 mA or 30 mA. Nominal operation time is 30 ms. If the fault is caused by a direct short between phase and earth, or phase and neutral, the resulting overload current would be so massive that either a fuse or circuit breaker would cut off the supply before the RCD could react.

School laboratories would not be areas specifically defined under (b) or (c) above. Nor would they be expected to have an abnormal earth fault loop impedance (d). However they are places where there is a risk of direct contact (for reasons discussed above and described below). They also have other adverse environmental conditions.

Risk of direct contact

The Centre has been aware from accident reports and from anecdotal evidence that there have been some near misses in school laboratories. To investigate the frequency of these near misses, we prepared a questionnaire listing twelve types of incidents which could cause direct contact and sent this to the Principal Teachers of Physics in ten schools. We received eight replies. These are summarised in Tables 1 and 2.

Analysing these replies, we find that :

(a) Every school sending in data for the last two sessions (1992-93 and 1993-94) report instances of dangerous occurrences.

(b) The average rate of occurrence was 4 per 2 years.

(c) The long term pattern of dangerous occurrences (12 types, 7 returns) is summarized opposite.

58	No reported incidence of dangerous occurrence
16	Rare event (less than 1 occurrence in 5 years)
8	Moderately frequent event (between 1 occurrence in 5 years and 1 a year)
2	Frequent event (more than 1 occurrence a year)

To give one particularly nasty example of a dangerous occurrence, one teacher reported that an unbent paperclip had been inserted into the live socket of a 13 A socket outlet and left for children in the following class to find.

Commenting on the accuracy of the data, the returns may under-record the frequency, partly because of forgetfulness, partly to protect the reputation of the respondee and partly because every science teacher may not have been questioned. It is improbable that the returns over-estimate the frequency.

In drawing up conclusions from the survey, it is clear that dangerous occurrences take place, but are relatively infrequent. Those that have occurred in the survey schools have not, so far as we are aware, caused persons to be harmed by electric shock. However the risk of severe electric shock from direct contact is established by the data. The average frequency of incident is about 2 per year per science department, this figure being a conservative estimate from the data.

Dangerous occurrence	Frequency of occurrence							
	1	2	3	4	5	6	7	8
inserting a screwdriver, or wire, or other conductor into the live socket of a 13 A socket outlet;	1	6	1	0	0	-	1	1
inserting a screwdriver, or wire, or other conductor into the enclosure of a portable appliance;	0	0	1	0	0	-	0	0
opening or otherwise dismantling a 13 A socket outlet;	0	0	0	1	0	-	1	0
opening or otherwise dismantling the enclosure of a portable appliance;	0	0	0	0	0	-	0	0
cutting a flexible cord;	1	0	0	0	0	-	0	0
heating a flexible cord with a soldering iron;	0	2	0	0	0	-	2/3	0
heating a flexible cord with a Bunsen flame;	0	0	0	0	0	-	0	0
heating the enclosure of a portable appliance with a soldering iron;	0	0	0	0	0	-	0	0
heating the enclosure of a portable appliance with a Bunsen flame;	0	0	0	0	0	-	0	0
flooding a portable appliance or 13 A socket outlet with water;	0	0	0	0	1	-	0	*
getting a shock through touching the phase live pin of a 13 A plug that is being inserted into, or withdrawn from, a 13 A socket outlet;	0	0	0	0	0	-	0	0
during the pupil exercise to wire up a 13 A plug, inserting the plug into a live 13 A socket outlet;	0	0	4	1	0	-	0	1
Other incidents (please describe) :	1	-	-	-	-	-	-	-

Table 1. Data on dangerous occurrencies with socket outlets and portable appliances in science laboratories. Each column gives number of occurrencies in each of eight particular schools during two school sessions (1992-93 and 93-94).

Dangerous occurrence	Frequency of occurrence							
	1	2	3	4	5	6	7	8
inserting a screwdriver, or wire, or other conductor into the live socket of a 13 A socket outlet;	-	F	R	0	0	MF	MF	R
inserting a screwdriver, or wire, or other conductor into the enclosure of a portable appliance;	-	0	R	0	0	MF	0	0
opening or otherwise dismantling a 13 A socket outlet;	-	0	0	R	0	0	MF	0
opening or otherwise dismantling the enclosure of a portable appliance;	-	0	0	0	0	0	0	0
cutting a flexible cord;	-	0	R	0	R	0	0	0
heating a flexible cord with a soldering iron;	-	MF	R	0	R	R	F	0
heating a flexible cord with a Bunsen flame;	-	0	0	R	R	0	0	0
heating the enclosure of a portable appliance with a soldering iron;	-	0	0	0	0	0	0	0
heating the enclosure of a portable appliance with a Bunsen flame;	-	0	0	0	0	0	0	0
flooding a portable appliance or 13 A socket outlet with water;	-	0	0	0	MF	0	0	MF
getting a shock through touching the phase live pin of a 13 A plug that is being inserted into, or withdrawn from, a 13 A socket outlet;	-	0	0	0	R	0	0	0
during the pupil exercise to wire up a 13 A plug, inserting the plug into a live 13 A socket outlet;	-	R	MF	R	0	R	0	R
Other incidents (please describe) :	-	-	-	-	-	-	0	-

Table 2. Data on dangerous occurrencies with socket outlets and portable appliances in science laboratories. Each column relates to the place of work of the respondee. Period relates to the teaching career of respondee.

KEY TO TABLE :

0	not happened
R	rare (less than 1 occurrence in 5 years)
MF	moderately frequent (between 1 occurrence in 5 years and 1 a year)
F	frequent (more than 1 occurrence a year)
-	no data

Because not one of the schools responding to the survey gave a nil return, it would be reasonable to infer that all schools are at risk. Clearly the main cause is the abuse of the system by children. Since the population of school-children in any school is transitory, this further supports the contention that all schools are at risk.

Although the frequency of direct contact is low, the potential harm (i.e. fatal accident) is serious and this must inflence the risk assessment.

Contributory environmental hazard

Other contributions to the risk of electric shock in science laboratories are wetness, the presence of earthed metal, the positioning of socket outlets and the continual porterage of portable appliances.

There are several contributions to wetness including the water supply, burning gas without an external flue, boiling water, and in some laboratories, the provision of aquarium tanks. Further contributions come from exhaled air from a relatively large number of persons for the size of room and, in wet weather, from evaporation off wet clothes. With all these contributions, the air inside a laboratory can have a relative humidity of 100% on occasions. This value would be abnormal in other indoor situations.

Earthed metal in laboratories may include gas taps and pipes, enclosures of socket outlets, ducting and overhead booms for services, water taps and sinks. Most of these fitments are classed as extraneous-conductive-parts.

It is standard design practice that the workbenches at which the children sit have 13 A socket outlets. This proximity is a contributory environmental hazard.

Portable electrical apparatus in laboratories receives in general far more handling and transporting than equivalent apparatus in household, office or industrial use. Typically this apparatus is stored outwith laboratories and is carried to laboratories for use. This continual portering causes considerable mechanical stress to enclosures and electrical parts, resulting in many fault conditions.

In commenting on the latest edition of the Wiring Regulations [1] the IEE list five factors identified with increased risks : wetness, absence of, or minimal, clothing, restrictive conductive locations, presence of earthed metal and arduous conditions.

Applying these selection criteria to science laboratories, increased risks include wetness, presence of earthed metal and arduous conditions, the third factor because of the continual transporting and handling of apparatus and because of abuse by children. The science laboratory would therefore appear to meet the IEE's selection criteria to be classed as a special location, thereby requiring a supplement or modification to the general requirements of the other parts of the Wiring Regulations.

Other practice and guidance

Many schools have already been provided with a higher standard of electrical protection in science laboratories by supplementing the basic requirements of the Wiring Regulations. Clearly some engineers do not need to be convinced.

The relevant HSE Guidance Note [2] states :

> *A higher standard of electrical protection can be achieved through the use of residual current devices (RCDs), isolating transformers, or earth free areas*

and referring both to electric shock and to the fire-prevention role an RCD can play in detecting insulation breakdown :

> *RCDs may be used to provide additional backup protection against fire and shock.*

The relevant British Standard [3] recommends :

> *All bench outlets and certain fixed equipment should be protected by a residual current device with a nominal tripping current of not more than 30 mA.*

We also understand that a Department for Education (DfE) document on safety in science education [4], being prepared jointly by the Association for Science Education and CLEAPSS, is likely to carry the following recommendation:

> *3.9.2 Safety provision within the science department : Services, fittings, etc. : Mains electricity : The protection of each laboratory with a residual current device (earth-leakage circuit breaker) operating at no more than 30 mA and in less than 30 ms is recommended.*

Furthermore a draft document [5] from the DfE Architects and Buildings Branch states:

> *7.9 Protection by residual current devices is recommended.*

Conclusions

Whilst the IEE Wiring Regulations do not specifically include school science laboratories in their list of special locations, these places meet with the criteria set out in the Regulations for particular requirements. A survey into the incidence of dangerous occurrences with mains electricity in science laboratories shows an average frequency of not less than 2 per year per school. There is thus a significant risk of electric shock by direct contact. Contributory factors that compound the risk of shock in laboratories include wetness, the presence of earthed metal, the nearness in place of socket outlets to children and the continual handling and transport of portable appliances. The accident history suggests that the risk might be considered to be tolerable. However the cost of safety measures is not great compared to the risk of injury or loss of life. Furthermore most of the persons at risk are children. They require a higher standard of protection than does the general public.

In conclusion the Centre recommends that school laboratories are areas where a higher standard of electrical protection is required. The normal provisions of the Wiring Regulations should be supplemented by means such as residual current devices. This is also the advice given by other authorities and agencies.

We should add to this recommendation the point that no two laboratories are identical. The authorities responsible for the premises need to ensure that the risk of personal injury from the electrical installation is assessed. The assessment should consider the points made in the above article.

Technology work areas

Although the investigation was directed at science laboratories, the conclusions can be inferred to relate to technology work areas. In those areas where power tools are not used, many of the hazards are similar to those found in laboratories.

Less water is used. But the frequency of usage of soldering irons and small hand tools such as screwdrivers and wire cutters is higher. The range of portable electrical apparatus is less. But the provision of electrical trunking on workbenches, often with complex extra low voltage supplies, is an additional hazard because of the nearness of children, the possibility of abuse, and the effects of wear and tear.

The scope of the article does not include work areas where power tools are used.

References

1. *Protection Against Electric Shock*, Extract from Section 8 - *Special Installations or Locations*, Guidance Note Number 5 to the 16th Edition of the Wiring Regulations, IEE, 1992.
2. *Electrical safety in schools (Electricity at Work Regulations 1989)*, Guidance Note GS 23, Health and Safety Executive, 1990.
3. BS 3202 : Part 4 : 1991 *Laboratory furniture and fittings : Part 4. Recommendations for installation.*

cont./over

4. *Safety in science education for key stages 3, 4 and 5*, Association for Science Education for the DfE, June 1995 Draft.

5. *Secondary school accommodation - National Curriculum Series, Section 7 : Environmental Health & Safety*, Architects and Building Branch, DfE, 1995 Draft.

Further comments on RCDs

There are several points which should be made about RCD protection which do not logically fit into the previous article.

1. RCD devices can fail to danger. It is therefore essential to test periodically that any installed RCD is in proper working order. Any such test should be carried out with a speciallised RCD test instrument. This test requirement should be taken into account when drawing up a school's electrical maintenance policy.

2. Following our survey into dangerous occurrences with electrical installations, we understand from the Health and Safety Executive that problems related to 13 A socket outlets located near water taps are a relatively frequent occurrence. The most popular solution is to resite the socket in a more appropriate location rather than install RCDs. This is the correct approach because it will prevent injury, whereas the use of RCDs may not.

3. Other forms of secondary protection such as low voltage or isolated supplies may be better and more appropriate than RCDs. This will depend on the risk, which depends on the specific location.

We would welcome comment and contribution from readers on means of protecting children from dangerous occurrencies with electricity.

HSE and HSC Publications

COSHH Revision - ACOPs

Following the 1994 revision of the COSHH Regulations, the HSE (Health and Safety Executive) has now published a set of three Approved Codes of Practice (ACOP) in one volume [1]. The three Approved Codes are the : Control of Substances Hazardous to Health (General ACOP), Control of Carcinogenic Substances (Carcinogens ACOP) and the Control of Biological Agents (Biological Agents ACOP). The General ACOP follows the useful format of a number of HSE published codes and it contains both the Regulations themselves with some interpretation and additional guidance as necessary in good, plain English on applying occupational exposure standards (OESs) and on controlling other substances which have not been assigned an OES.

The Biological Agents ACOP was produced to meet the requirements of the European Directive on risks from work-based exposure to biological agents. It provides practical guidance on applying the COSHH Regulations in such a context. The Carcinogens ACOP gives a revised definition of carcinogens and general and up to date background information on occupational cancers. The volume of three ACOPs is available from HSE Books (ISBN 0 7176 08190) at £6-75.

Animals, allergy and other issues

We have previously drawn readers' attention to an apparently growing problem of sensitisation and allergy, and not just in atopic individuals (for example see Bulletin 183 [2]). Some time ago the Education Services Advisory Committee of the HSC (Health and Safety Commission) produced two reports which are germane to this general topic. With the advent of the COSHH revision and of the Biological Agents ACOP, we judged it would be timeous to remind a section of our readers of the availability of these useful, and mercifully succinct, advisory documents. Both titles should be of some interest to teachers and technicians generally. They are likely however to be more directly applicable by Health and Safety representatives or specialists, especially in those institutions where significant numbers of animals are routinely maintained and used in teaching courses in husbandry etc. This is especially so with the second title.

The publication of wider interest is : *What you should know about allergy to laboratory animals* [3] and the second : *Health and safety in animal facilities* [4]. The latter is aimed more at Higher and Further Education establishments. These would include agricultural teaching institutions but the term animal facility is widely defined as any place where animals may be kept or taken for the purposes of teaching. Similarly the scope of this second publication goes beyond that of biohazards and takes in a number of other, more general, health and safety issues.

cont./overleaf

New and expectant mothers

We are always at pains to point out, on our courses on COSHH and related topics, the somewhat higher risks to females of child bearing age of certain activities involving the handling of some chemicals and biological agents. The HSE has published some useful general guidance on this subject [5]. Safety Officers and Safety Reps may find this guidance useful in interpreting the requirements of those parts of the Management of Health and Safety Regulations 1992 (as amended in 1994 : SI No 2865) which implement the European Directive on Pregnant Workers.

The scope of the guidance extends beyond COSHH and takes in other requirements such as those of the Manual Handling Operations Regulations 1992.

References

1. *COSHH ACOPS*, HSE, 1994, ISBN 0 7176 08190.
2. *Felt-tip pens*, Safety Notes, Bulletin 183, SSERC, Winter 1994.
3. *What you should know about allergy to laboratory animals*, HMSO for HSC, ESAC, 1990, ISBN 0 11 885527 1
4. *Health and safety in animal facilities*, HMSO for HSC, ESAC, 1992, ISBN 0 11 886353 3.
5. *New and expectant mothers at work*, HS(G) 122, HSE Books, 1994, ISBN 0 7176 0826 3.

Lithium cells

We had an enquiry from a teacher about lithium 3.5 V AA cells. He went on to write : "They seem too good to be true. I have measured the 'capacity' (in mAh and joules to, say, 50% initial voltage) and it looks as though you get far more joules per penny than with any other kind of non-rechargeable cell."

This note is to warn you of the dangers of using lithium cells. In fact they should not be used in any way at all in schools except in properly designed apparatus supplied by reputable manufacturers. Lithium cells can explode without warning under many common conditions such as shorting or charging. There was an instance where an entire laboratory was wrecked as a result of a single cell exploding. Table 1 summarises the possible consequences of lithium battery abuse [1].

Children should never be allowed to use these cells for any kind of benchwork because of the risk of shorting, or forced discharging, or connection to another power source. However the list of dangerous occurrences with lithium cells published by the HSE [1] involves circuits designed by engineers that have developed faults.

The lesson from these incidents is that such circuitry must be designed to fail to safety. There may have to be, for example, redundancy in protection methods so that if one component fails, another takes its place. Because of the technical demands of designing suitable protection methods, lithium cells should not be incorporated into circuits which are school-built.

Most types of lithium cell are non-rechargeable. Do not ever attempt to recharge one of these. With certain types there is no safe recharging current. If a cell is being disposed of, the terminals should be taped over with insulation to prevent shorting. The cell may then be disposed of with ordinary refuse. A summary of safety measures is given below:

Do not:

1. allow children to use lithium cells;
2. use lithium cells with school-built circuits or equipment;
3. charge non-rechargeable lithium cells;
4. short-circuit lithium cells;
5. connect lithium cells to form a battery, or connect in series or in parallel combinations;
6. open, dismantle, crush or puncture lithium cells;
7. heat, incinerate or solder lithium cells,
8. enclose or encapsulate lithium cells;
9. substitute ordinary primary or rechargeable cells with similar lithium cells.

Do:

1. use lithium cells only for specified equipment, ensuring the correct polarity;
2. insulate the terminals before disposing of lithium cells.

Reference

1. Guidance Note GS43 *Lithium batteries*, Health and Safety, Executive, 1987.

Type of abuse	Possible consequences
Charging and connection to other power sources	Venting, explosion
Forced discharge	Venting
Short circuit	Overheating, venting
Incineration or overheating	Venting, explosion if heating is excessive (over 175°C)
Physical damage	Release of potentially hazardous materials, spontaneous ignition

Table 1. Consequences of lithium battery abuse (from GS43). The term 'forced discharge' refers to use in any series-connected arrangement when a prematurely discharged cell can have further discharge current forced through it by the other cells driving current through the load.

The differential amplifier

The purpose of the differential amplifier is widely misunderstood, it being far more than a mere difference amplifier. This article discusses its true function and describes ways of illustrating this.

Op-amps are differential amplifiers. Conventionally they have a differential input and single-ended output (Fig. 1).

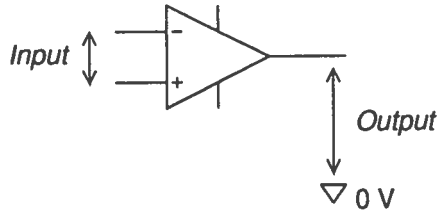


Figure 1. The conventional op-amp with differential input and single ended output.

What does the term differential mean? The term is usually associated with the Differential Amplifier (Fig. 2) - a circuit which is analysed in school syllabuses.

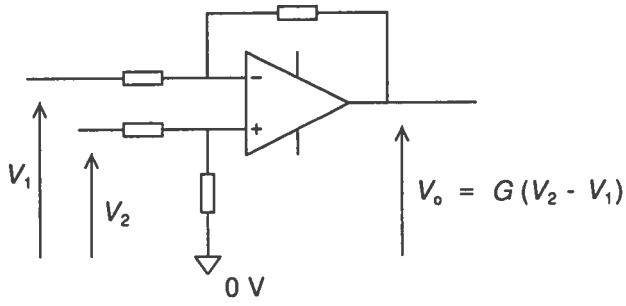


Figure 2. The classic differential amplifier.

Many descriptions of its function fall short of the full thing [1] [2] [3] [4] [5]. It is more than being a difference amplifier, though this is what it is sometimes called [6] [7] [8] [9] [10] (Fig. 3).

Publications relating to Higher Grade Technological Studies [1] [2] [6] [7] [8] consistently refer to the amplifier as a *difference amplifier*.

The Learning Outcomes in the Higher Grade Physics syllabus [3] are correct in so far as they go:

2.4.9 State that the differential amplifier amplifies the p.d. between its two inputs

2.4.10 State the differential mode gain equation

$$V_O = (V_2 - V_1)(R_f / R_1)$$

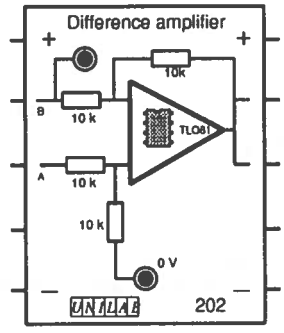
but are a penny short of the full shilling. They mislead, because they do not go far enough. The amplifier's true purpose is to:

> reject the common mode voltage on the two inputs V_1 and V_2 and selectively amplify the voltage difference $(V_2 - V_1)$,
>
> that is, differentiate between wanted and unwanted signals.

Perhaps the confusion arose because there is a subtraction operator in the gain equation, because the process of differentiation is achieved by subtraction, and because of the similarities of the words difference and differential. If you wish to subtract one signal from another, use for preference a summing amplifier. Because it sums algebraically, it can handle subtraction. An inverting amplifier may also be needed in the process.

Another confusion is the op-amp differentiator, which produces a time dependent derivative in the calculus sense of differentiation.

The remainder of the article consists of descriptions of three circuits to illustrate the differential amplifier concept. They are an ECG amplifier, a microphone amplifier and a strain gauge amplifier. Two of the applications are concerned with the removal of mains hum from signals that otherwise would be too weak to see. The third application relates to a circuit for amplifying the signal from an out-of-balance bridge with resistive sensors.



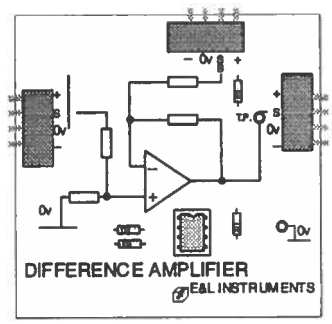


Figure 3. Examples of educational products where the differential amplifier is called a *difference amplifier*.

ECG amplifier

An ECG signal can be picked up across two sites in the body, typically right arm and left leg. Its magnitude is about 1 mV. But as anyone who has ever touched an input lead to a CRO knows, the body acts as a pick-up aerial for 50 Hz signals radiated by mains conductors. It may also pick up high frequency oscillations from fluorescent luminaires and from other sources. The amplitude of this noise may be many millivolts. Usually it exceeds the ECG signal manyfold. By connecting to a differential amplifier, electrical noise common to both inputs is subtracted out whereas the ECG signal is selectively amplified (Fig. 4).

Whilst in principle this is a simple demonstration, in practice, because of safety considerations, it is not so straightforward. Because of the risk that any mains recording apparatus such as a CRO or computer might malfunction, it is not permissible to directly connect such apparatus to human tissue. Some form of electrical

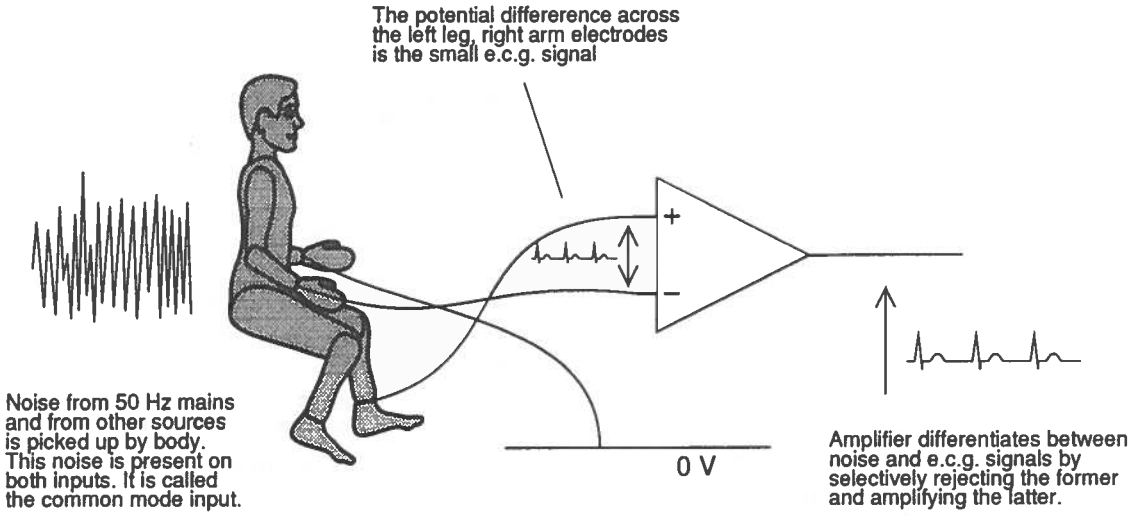


Figure 4. The ECG amplifier differentiates between the ECG signal and mains noise, selecting one and rejecting the other.

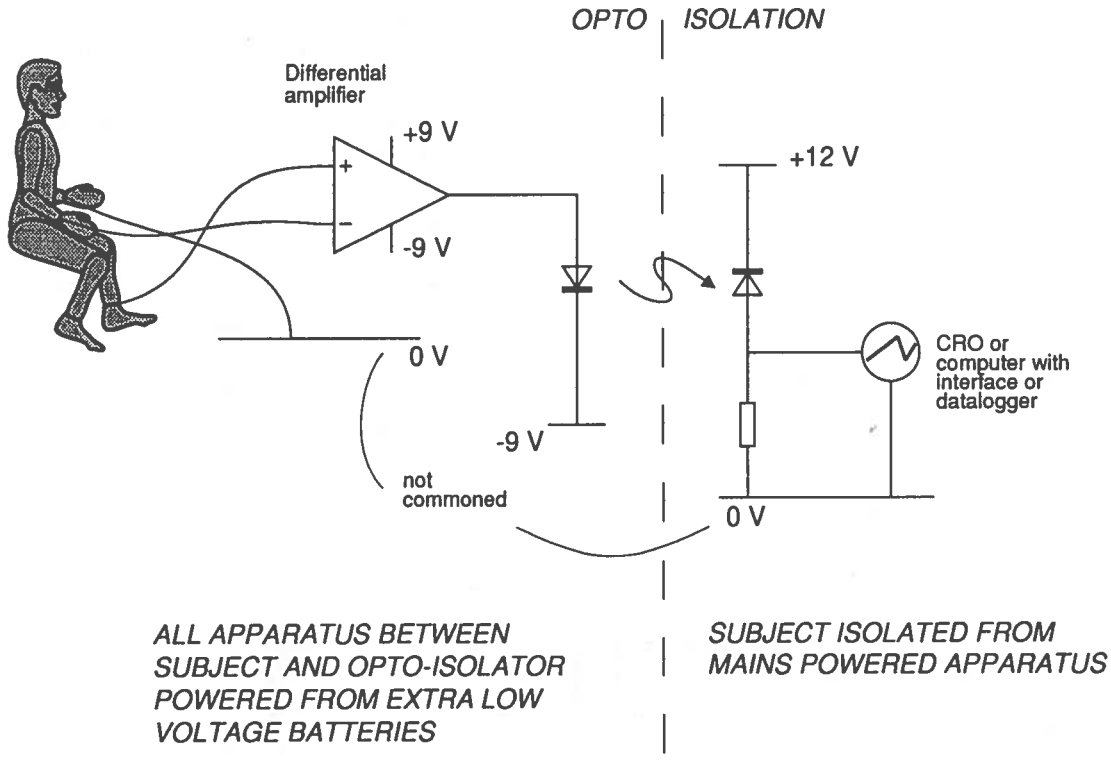


Figure 5. Because of electrical safety considerations, no person may be directly connected to mains apparatus. Any circuitry wired to a person must be at extra-low voltage and must be isolated from mains appliances.

isolation must be interposed between electrodes in contact with skin and mains apparatus (Fig. 5). This requires opto-isolation. This may take the form of a proprietary instrument, for instance the Unilab Biological Amplifier 743.001, or a DIY circuit. We have devised a circuit for this purpose (Fig. 6). Note that it requires three batteries. LT power supplies with mains inputs must not be substituted.

You may wonder why this precaution is needed when pupils daily handle leads connected to mains driven apparatus, as happens whenever labpacks or oscilloscopes are used. In casual handling, electrical contact with the skin is poor. Usually the skin is dry. Usually it is only the fingertips that make contact, the skin there being thicker than normal and thus a better insulator. Usually the surface contact area is small. Furthermore contact is maintained by grip, which can often readily be released. By contrast ECG electrodes have a large surface area and are strapped to the skin which may be moistened with a conducting fluid. Under this type of environmental condition, there is no safe voltage which may be applied across parts of the body [11].

A parts list for components in the ECG amplifier is shown in Table 1. Regarding the Linear Optocoupler IL300D, made by Siemens, this consists of an infrared LED irradiating a pair of PIN photodiodes. One of the photodiodes is in a negative feedback loop. It compensates for the LED's non-linear, time and temperature characteristics. Because of this feedback mechanism, the output photodiode generates a reverse leakage current that is linearly related to the signal applied to the LED driver amplifier.

Part	Supplier	Stock number	Qnty.
Dual op-amp TL072	Rapid	TL072	1
Optocoupler IL300D	RS	228-961	1
Resistor 820R, 5%	SSERC	420 820R	1
Resistor 2K2, 1%	RS	148-584	2
Resistor 3K9, 1%	RS	148-641	1
Resistor 22K, 1%	RS	148-815	1
Resistor 33K, 1%	RS	148-859	1
Resistor 47K, 1%	RS	148-893	2
Capacitor 22p	Rapid	08-0465	1
Switch, DPST	Rapid	75-0110	1
PP3 battery clip	SSERC	729	3
AA battery holder	SSERC	730	1
PP3 battery	-	-	2
AA cell	-	-	1
Diecast aluminium box	RS	225-192	1
4 mm socket outlets	-	-	3

Table 1. List of parts for ECG amplifier.

The circuit should be hard-wired on stripboard and screened by housing it in a die-cast aluminium box. A size suitable for including the three batteries should be chosen (see Table 1).

The subject may be wired to the amplifier in several different ways, one of which is illustrated (Figs. 4 and 5). Another suitable arrangement would be to connect the 0 V reference electrode to the left leg and the two amplifier inputs to each of the arms. Electrodes can be fashioned out of metal plate, perhaps about 30 mm square, but the dimensions aren't important. Either brass or aluminium may be used. To prevent injury, the corners should be rounded off. Any burrs on edges should be

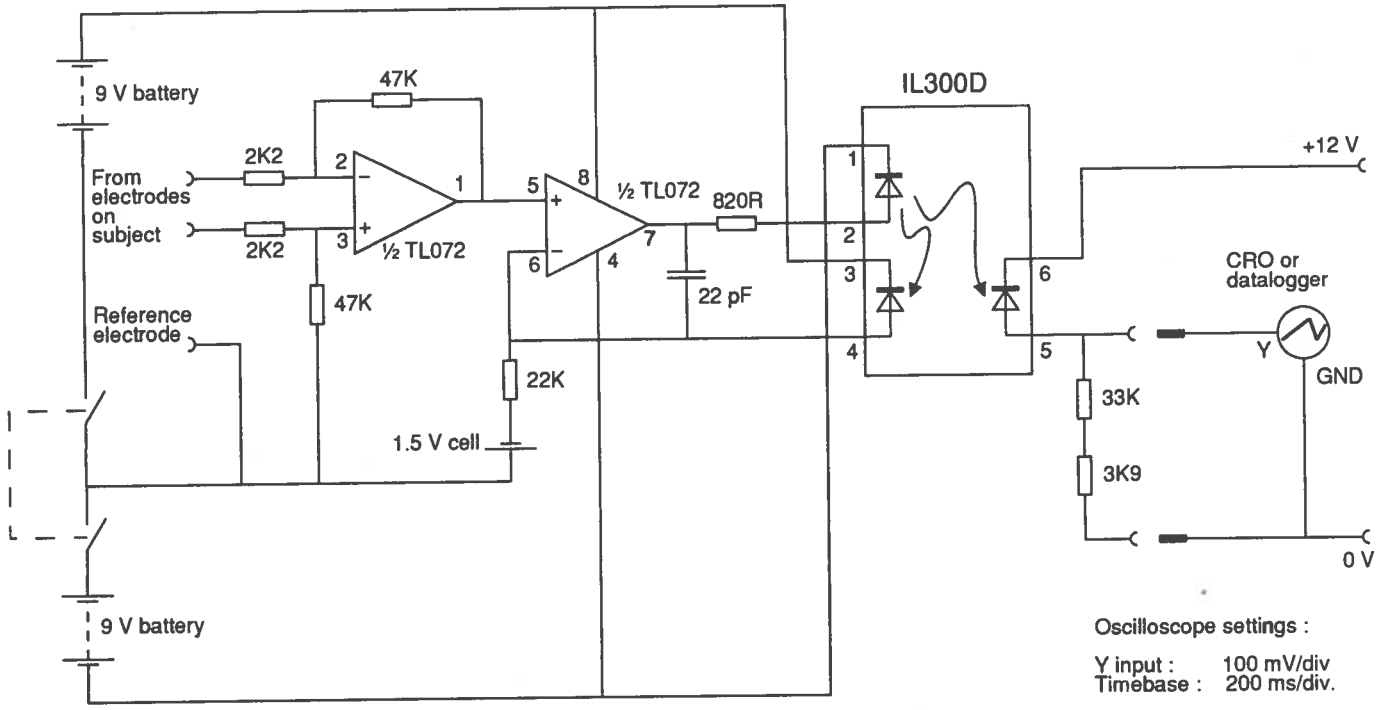


Figure 6. Circuit diagram of ECG amplifier. There must be no electrical conductor between parts connected to the subject and parts connected to mains apparatus.

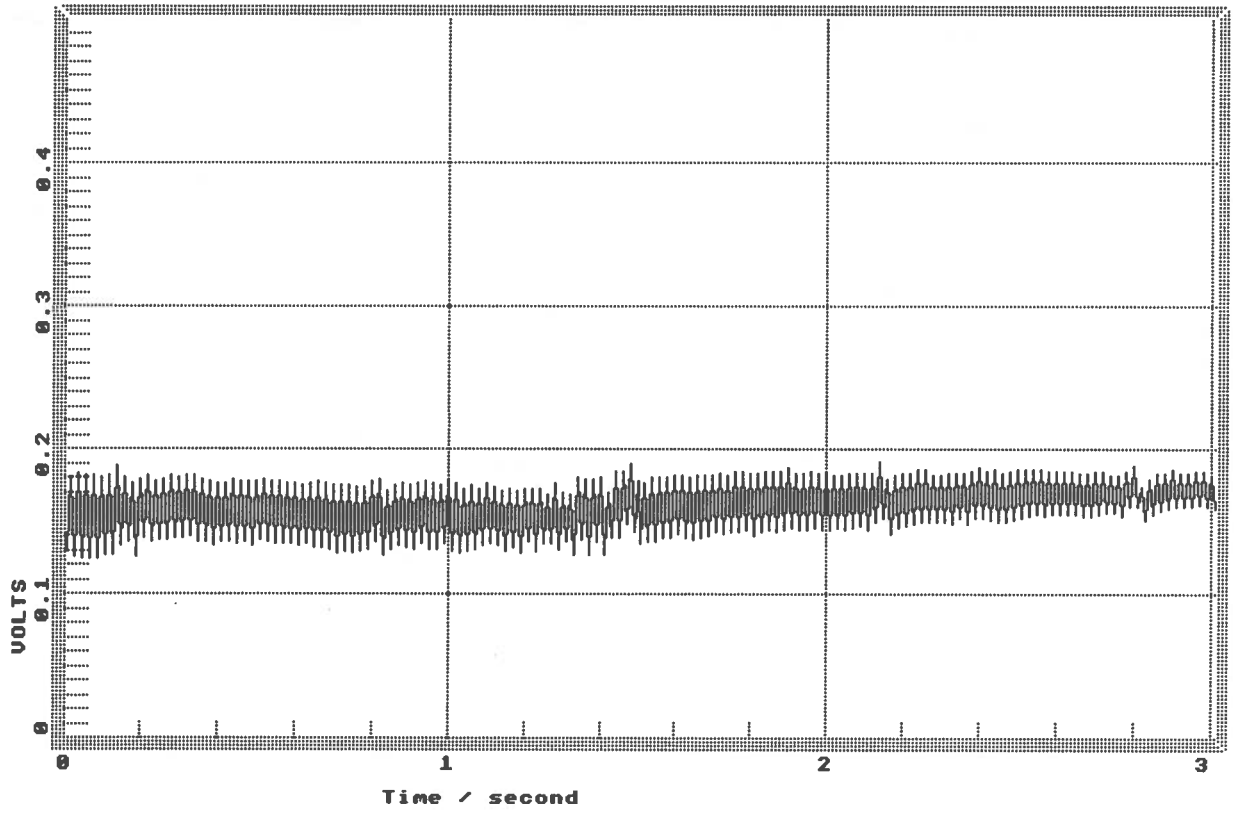


Figure 7. Signal obtained when only one electrode is connected to amplifier. Mains hum dominates signal. The ECG component is just discernible. Signal captured with Harris Datadisc PP running on an Acorn A3000 Computer.

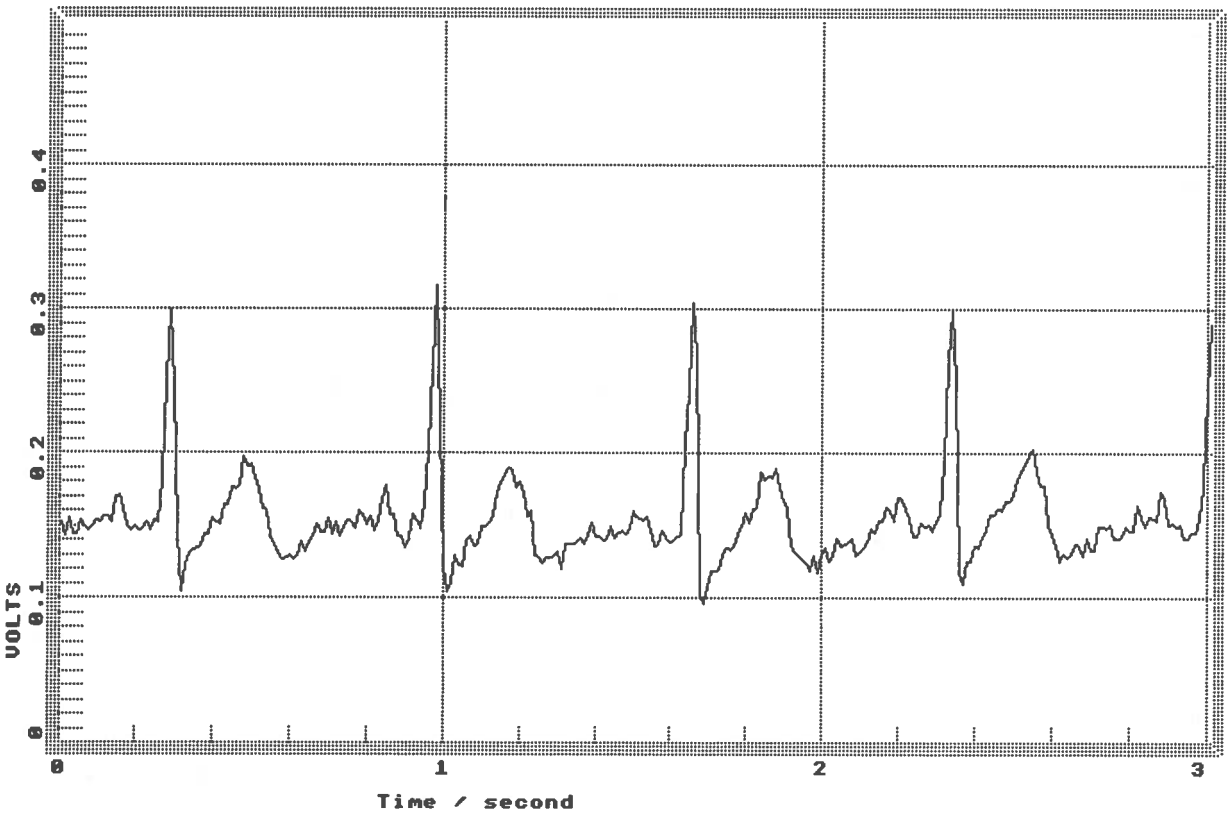


Figure 8. Signal obtained when two body electrodes are connected, one each, to the differential inputs. Signal captured with Harris Datadisc PP running on an Acorn A3000 Computer.

removed by filing. A 2 m flexible lead (either 16/0.2 mm or 24/0.2 mm) should be soldered to each electrode for connection to the amplifier. Electrodes may be secured to limbs with elastic bands, but not tightly so, though the electrodes to the arms may be gripped in the palms of each hand. Skin in contact with an electrode may be pre-moistened with a saline solution to improve conductivity. This is not needed with large electrodes. The subject should be instructed to sit immobile and relaxed.

The output may be viewed on either a CRO, preferably with storage facility, or a microcomputer with interface. If using an interface, a sample rate of 100 per second is needed. The CRO is preferred, because no further amplification is necessary. A computer based system may require an additional amplifier with voltage offset. Examples of signals are shown. When a single body electrode is connected to the amplifier, the ECG signal is only just discernible above the 50 Hz noise (Fig. 7). When two body electrodes are connected to the amplifier, this noise is rejected and the ECG signal is selectively amplified (Fig. 8).

One further dodge may be necessary to get this effect. The circuit has deliberately been designed to include the basic differential amplifier. After all, the purpose of the article is to illustrate this amplifier, not to design a medical instrument. No refinements have been added and it should work as shown (Fig. 6). But in practice ECG amplifiers use a variety of tricks with *RC* filters to select and reject. You may then find that fitting a 1 µF capacitor across the oscilloscope input improves performance by removing high frequency noise that sometimes may be generated within the circuit.

Microphone amplifier

In one of his textbooks, Brimicombe [9] suggests using two microphone amplifiers to demonstrate the effectiveness of the differential amplifier. We have taken up this idea and worked out practical circuit arrangements. In one circuit, the signal is amplified by a single-input inverting amplifier (Fig. 9). In the other, a double-input differential amplifier is used (Fig. 10).

An audio signal of say 400 Hz is broadcast from a speaker and picked up by a microphone. The leads connecting the microphone to the amplifier are deliberately long so as to be susceptible to pick up stray 50 Hz radiation. After being twisted together, an overall length of 1 m is suitably effective. A 25 cm portion of this microphone lead is then taped to a flexible cord conducting the mains supply to a bench instrument, say the signal generator. By this means, you can be assured of picking up 50 Hz noise. The twisted pair should be made

Part		Supplier	Stock number	Qnty.
Microphone		SSERC	745	1
Op-amp	TL071	Rapid	TL071	2
Resistor	1K0, 5%	SSERC	420 1K0	3
Resistor	100K, 5%	SSERC	420 100K	3
Wire	7/0.2 mm	Rapid	01-0445	-
SIL sockets		Rapid	22-0465	-

Table 2. List of parts for microphone amplifiers.

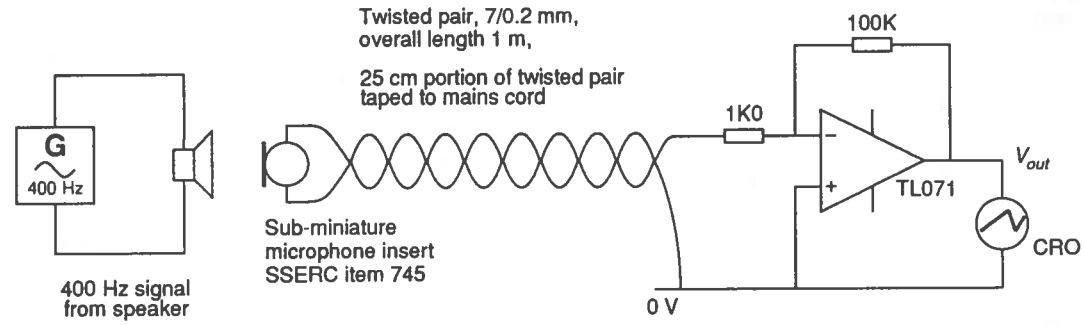


Figure 9. Microphone amplifier with single-input, inverting amplifier.

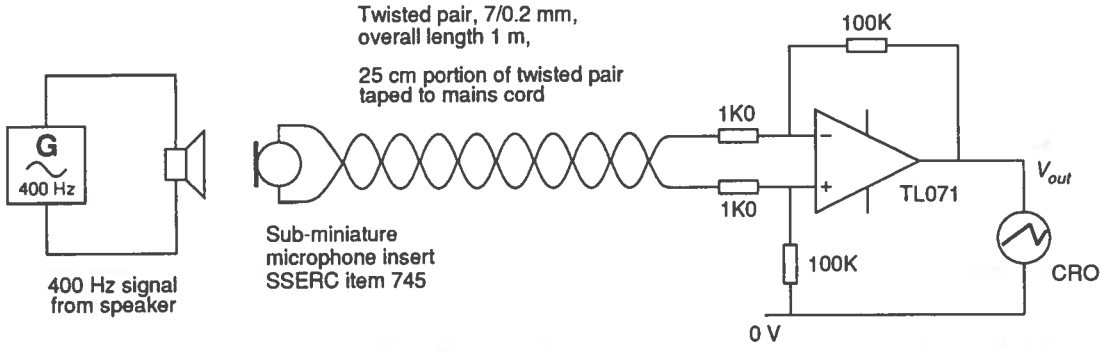


Figure 10. Microphone amplifier with double-input, differential amplifier.

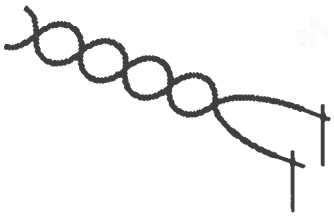


Figure 11. Microphone lead showing how to terminate multi-stranded, flexible wire for insertion into breadboard sockets.

from flexible, insulated wire, such as 7/0.2 mm. At the amplifier end, solder short lengths (20 mm) of solid wire (1/0.6 mm) for connection to the amplifiers (Fig. 11). If the amplifiers are built on breadboard, the solid copper will readily connect to any socket. If the amplifiers are hard-wired to stripboard, then solder a pair of low profile turned pin SIL sockets to the stripboard. The solid copper will connect to these. Never use solo SIL sockets - they become insecure in usage. Use doubled, or in longer strips.

The amplifiers each have a gain of x100, no precision parts being specified (Table 2). The output should be viewed on a CRO, a storage type is not necessary nor is a computer interface unless a paper copy of the signal is wanted. Sample traces (Fig. 12) show the effectiveness of the differential amplifier. 50 Hz mains noise clearly dominates the signal from the microphone on the single-input amplifier output. However because 50 Hz noise is present as a common mode signal on the microphone leads, it is nearly eliminated by the differential amplifier, whereas the 400 Hz signal is selectively amplified.

As to why there is still a 50 Hz component, albeit weak, on the differential amplifier's output, that could be a matter for investigation. The input leads may not pick up exactly similar signals, the differential amplifier may not do exactly as supposed, and the conductors within the amplifier and from the amplifier to the CRO are also liable to pick up mains noise.

Strain gauge amplifier

In our third and final illustration, we look at a resistive bridge network which has strain gauges in two arms of the bridge (Fig. 13). By mounting the gauges on opposite sides of a cantilever arm, one is in tension whilst the other is in compression. This doubles the out-of-balance voltage that could be expected from a single gauge bridge. It also compensates for temperature.

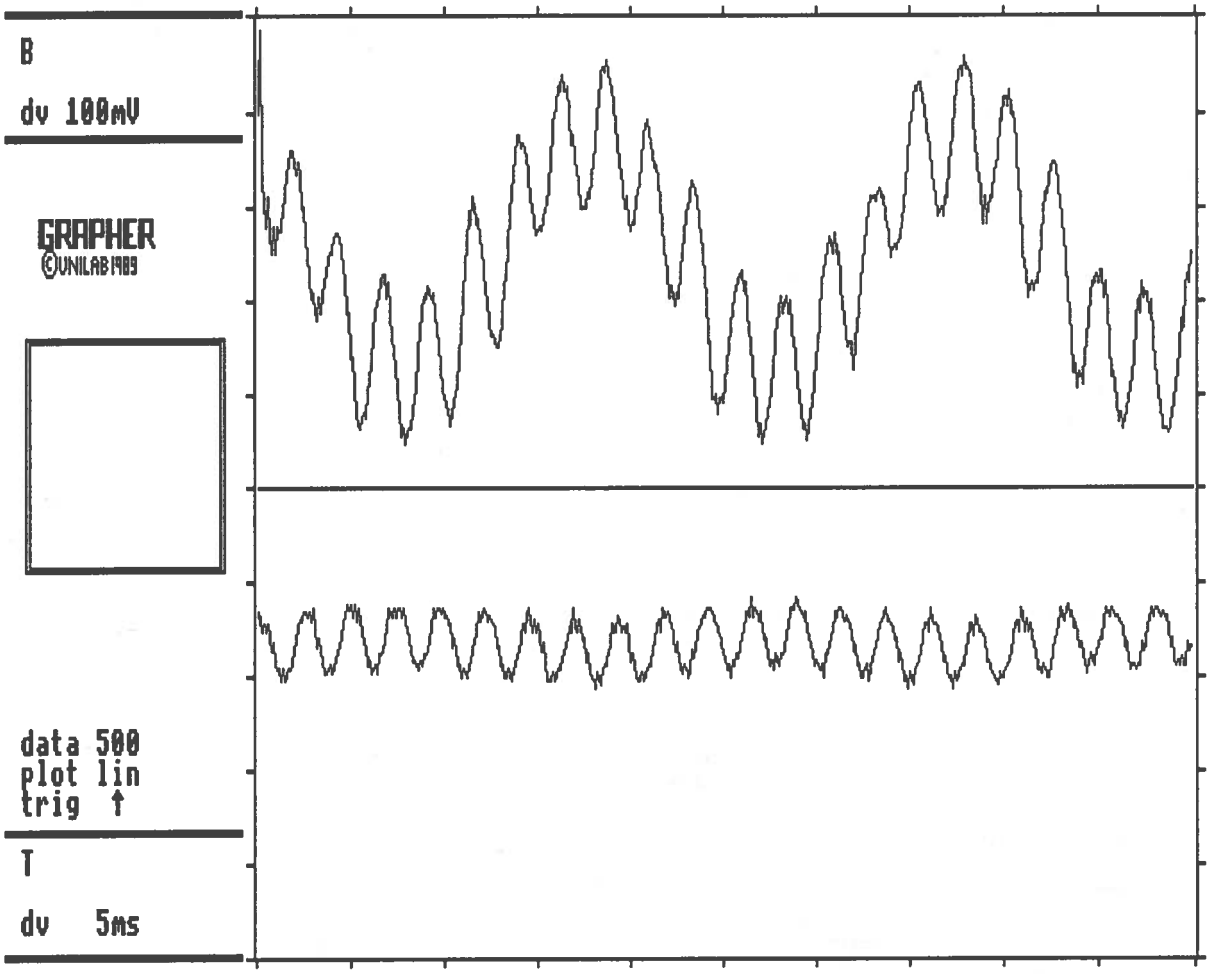


Figure 12. Microphone amplifier outputs. Top signal is from inverting amplifier (Fig. 9). Bottom signal is from differential amplifier (Fig. 10). Signals captured with Unilab Grapher running on an Acorn A3000 Computer.

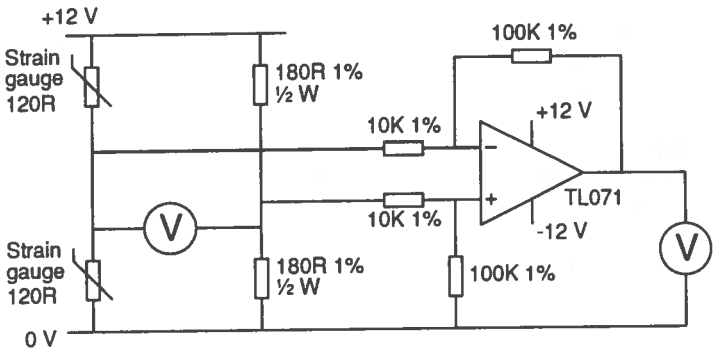


Figure 13. Circuit diagram of resistor bridge with strain gauges and differential amplifier. Gauges mounted on opposite sides of cantilever.

Because the gauge resistance is only 120 Ω, quite a lot of resistive heating can be expected. To prevent the gauges from cooking, the voltage across the bridge should be limited to 12 V. Of course you don't want too small a supply voltage, because that would reduce the sensitivity to a very low level. It is small enough as it is with a bridge supply of 12 V.

The bridge output is connected to a differential amplifier (Fig. 13). The common mode voltage on both inputs is 6 V. From a theoretical analysis [12], the linear working region of the cantilever is expected to give an out-of-balance voltage swing of ±10 mV. Looking at the data obtained from loading the cantilever (Table 3), the output signal is a linear function of load, with offset, the system being capable of resolving loads to a precision of 0.5 g across a range of 250 g. Had the common mode voltage not been got rid off, then this same 250 g load would have shifted the 6 V output by a mere 6 mV, too small a change to measure at all, far less measure accurately, with school meters.

Load on cantilever (g)	Out-of-balance bridge voltage (mV)	Amplifier output (mV)
0	3.2	9.8
20	3.7	14.6
40	4.2	19.5
60	4.6	24.3
80	5.1	29.3
100	5.6	33.7
120	6.1	38.6
140	6.5	43.4
160	7.0	48.4
180	7.5	52.9
200	8.0	57.9
220	8.4	62.7
240	8.9	67.6

Table 3. Effect of loading cantilever arm : Values of out-of-balance voltage and amplifier output versus load. Note linear relationships between quantities. Offset voltage under zero load is due to mismatch of resistors, lead resistances and non-ideal op-amp performance.

Part	Supplier	Stock number	Qnty.
Strain gauge, linear, 6 mm, 120 Ω, per pack of 10, from Measurements Group:			
steel		CEA-06-240UZ-120	
aluminium alloy		CEA-13-240UZ-120	
Hacksaw blade with pair of strain gauges	SSERC	751	1
Op-amp TL071	Rapid	TL071	2
Resistor 180R, ½W, 1%	RS	163-476	2
Resistor 10K, ¼W, 1%	RS	148-736	2
Resistor 100K, ¼W, 1%	RS	148-972	2

Table 4. List of parts for cantilever arm and strain gauge amplifier.

The constructional details [13] (Table 4) (Fig. 14) show an aluminium alloy cantilever and gauges temperature compensated for aluminium. Spring steel with suitably compensated gauges may be substituted. Information on how to fasten gauges to metals can be found in an earlier issue [14]. Our Surplus item number 751, hacksaw blade with pair of strain gauges, is a suitable cantilever for those wanting ready mounted gauges.

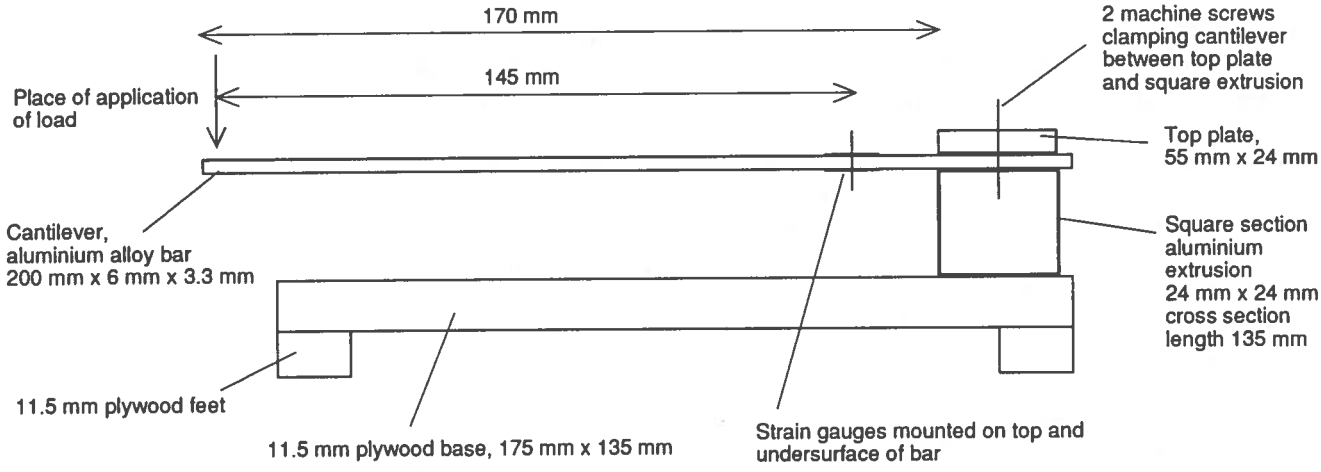


Figure 14. Construction details of the cantilever from which results were obtained. Specifications are for guidance rather than for making an exact copy. Sectional view.

Concluding remarks

The purpose of the differential amplifier is to differentiate between two signals. It does this by subtraction. This manipulation removes algebraically the common mode signal on both inputs revealing, unobscurely, the superposed, requisite signal.

We have illustrated the differential amplifier with three applications : the removal of mains hum from an ECG signal, the removal, again, of mains hum from a microphone lead, and the removal of an overbearing DC offset superposed on the tiny signal drawn from strain gauges.

All our applications use the basic diff-amp circuit unadorned with any bells and whistles. This simplicity is deliberate, so as not to confuse with superfluous detail. Properly designed instrumentation circuits would be more complex. However exploring such refinements is beyond the scope of our article.

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1. *Teachers guide for Higher Grade Technological Studies*, SCCC, 1990, Appendix IV, *Op-amps*, p 8.
2. *Ibid.*, p 14.
3. *Higher Physics : Electricity and electronics*, Curriculum Support Series No 2, SCCC, 1991, pp 48-51, 33, ISBN 1 871707 45 5.
4. Cackett G, Lowrie J and Steven A, *Higher core physics*, Oxford, 1992, pp 115-118, ISBN 0 19 914324 2.
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11. IEC 1201 : 1992 *Extra-low voltage (ELV) - Limit values.*
12. *Strain gauges*, Bulletin 171, SSERC, October 1991, pp 8-10.
13. *Teachers' Guide for SSERC Case Studies in Higher Grade Technological Studies*, SCCC and SSERC, 1991, pp 20-21.
14. *Strain gauge installation*, Bulletin 171, SSERC, October 1991, pp 10-12.

TECHNICAL ARTICLE

More ways of timing projectiles

The Unilab Digital Scaler Timer can be triggered to start and stop timing by microphone. Different methods of using this facility to measure the time of flight of a projectile are compared.

Following our article on timing projectile motion [1], we had an interesting letter from Mr Foggarty, PT Physics at Brechin High School, on the use made by him of the Microphone Input on the Unilab Digital Scaler Timer (512.023). It provides a very simple method of timing a projectile. Because, as Mr Foggarty adds, many schools now have this Unilab instrument, the idea is certainly worth publicising.

Using the method described by Mr Foggarty, the timer is started by the steel ball (19 mm diameter) breenging through the foil switch as it leaves the runway and is stopped when the ball strikes the floor, the vibrations of the impact being sensed by the microphone linked to the timer (Fig.1). The foil switch consists of two 30 mm strips of foil taped to the lip of the bench, there being a 5 mm gap between the strips. The ball passing through the gap has been found to make the switch with complete reliablity. Because our laboratory floor is not level, and because it consists of screeded concrete with a covering of cushion vinyl, a wooden board was laid level under the trajectories to act as a strike board. The microphone (Unilab 035.141) was taped to this. We found it to be a wholly reliable means of stopping the timer. The runway was as described earlier [1].

Two other means of starting the timer were also investigated. In one, a second microphone (also Unilab 035.141) was dangled over the end of the runway. As the ball leaves the runway, it gives this microphone a glancing blow, which triggers the timer. In the other (Fig. 2), timing is started when the projectile breaks a light beam set up at the runway end.

Flight times from these three methods have been tabulated together (Table 1, Columns 1 to 3, 4 to 6 and 7 to 9). Additionally, data published in Bulletin 183 obtained with Type SV1 Vibration Sensors at the runway and floor is shown for comparison (Table 1, Columns 10 to 12). Comments on each of the methods follows :

Foil switch

1. This system worked very reliably but was not as nifty as the Vibration Sensors' method because the foil switch had to be reset by hand.
2. Because foil work-hardens at the fold after repeated flexing, it becomes impossible to reposition accurately. It tends to spring into some unique position after each reset. This leads to errors when the projectile is moving with a slowish horizontal

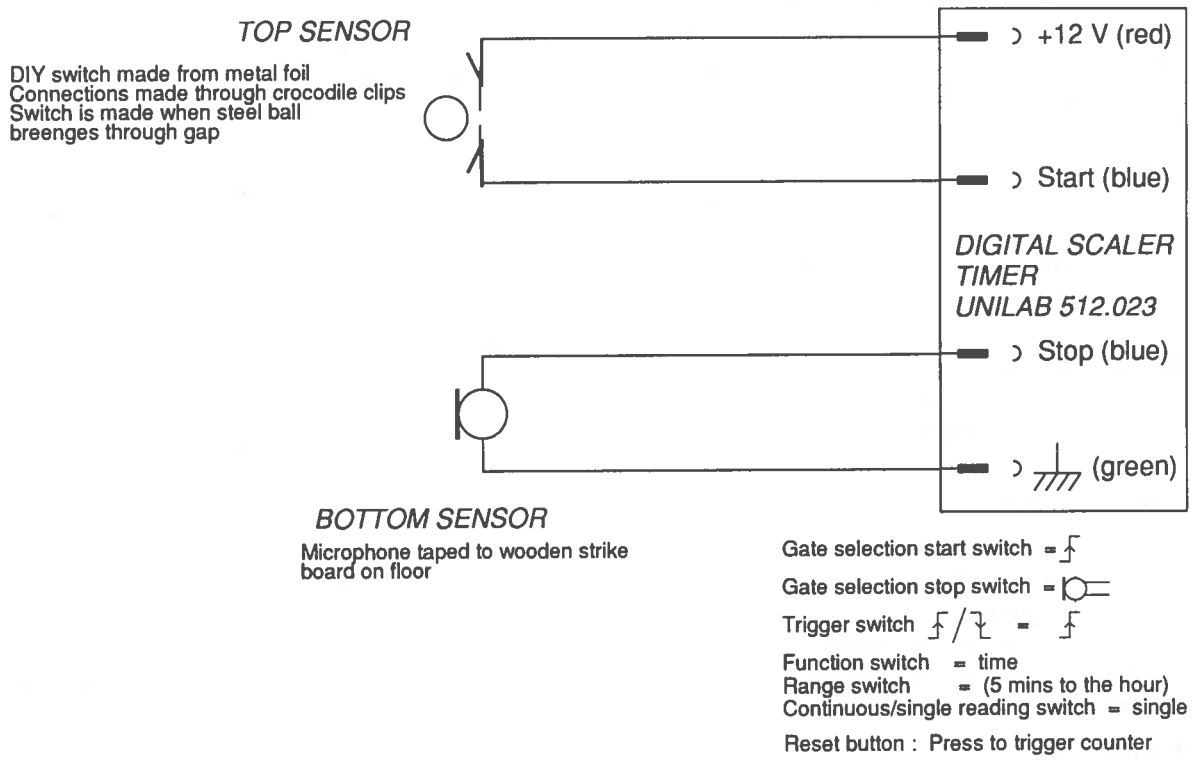

Figure 1. Circuit diagram with sensors connected to Unilab Digital Scaler Timer for timing projectile motion. Top sensor is a foil switch. Bottom sensor is a microphone.

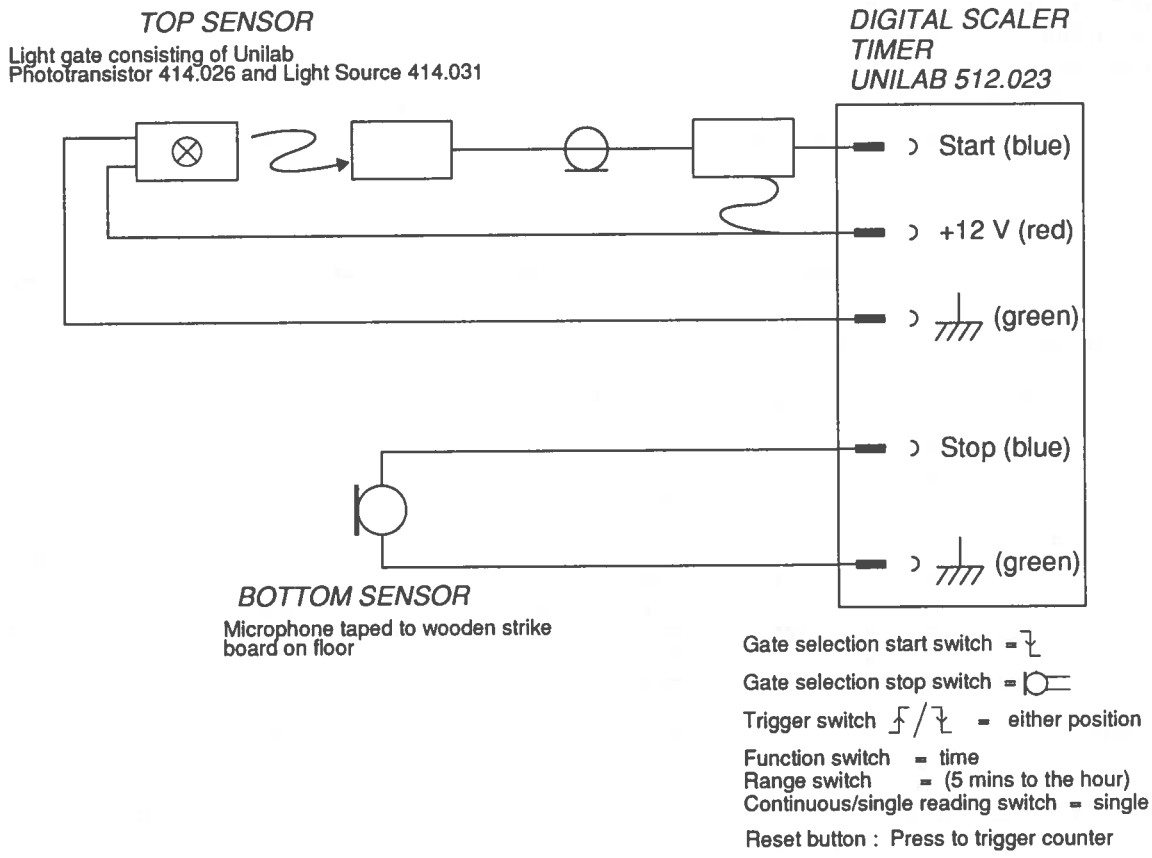

Figure 2. Circuit diagram with sensors connected to Unilab Digital Scaler Timer for timing projectile motion. Top sensor is a light gate. Bottom sensor is a microphone.

velocity component. This is shown by the large distribution in values in Column 1. The uncertainty in the mean value is far larger than obtained with any other circumstances. Also the mean value seems to have a systematic error, being 12 ms lower than the values in Columns 2 and 3.

3. The values in Columns 2 and 3 show excellent agreement between themselves and between values obtained with the Vibration Sensors (runway left unchanged from when data in Table 1 in our earlier article [1] had been obtained).
4. This indicates that this method of timing is sound provided that the projectile has an appreciably large component of horizontal velocity.

Microphone switch :

1. This system also worked very reliably but was not quite so nifty as the Vibration Sensors' method because the suspended microphone had to be steadied by hand during periods of continual use. However the method was more nifty than the foil switch method because the microphone was easy to steady.
2. The mean values of drop times are somewhat inconsistent. Specifically the fact that the 95% confidence limits for release heights of 10 mm and 20 mm do not overlap indicates that something is awry.
3. The steel ball undoubtably receives a significant impulse when it collides with the suspended microphone. This impulse is probably non-horizontally directed. This would explain why the mean values have significant differences.
4. The microphone switch method is therefore unsound.

Light gate switch :

1. As with the other systems, this too works very reliably. Because no manual resetting was needed, it was as nifty as the Vibrations Sensors' method to operate.
2. It was however the hardest to set up. As with all such systems, its positioning is critical. It is easier to position a switch that operates on mechanical contact than one which is operated by light.
3. The mean values were consistent with one another and in agreement with the values from the Vibration Sensor method and the better values from the foil switch method. The uncertainties were of the same order as these other two methods. This indicates that the light gate switch method is inherently sound.

In conclusion, the foil switch method is as good as the Vibration Sensor method provided that the projectile has an appreciable horizontal velocity component. However it does not seem to give good results when this condition is not met. The microphone method is flawed because it gives an impulse to the projectile. The light gate method is also as good as the Vibration Sensor method, but is harder to set up than any of the other methods.

As to other technical difficulties, all three methods with a floor positioned microphone and Unilab Digital Scaler Timer are easier to wire up than the Vibration Sensor method described in Bulletin 183. Thus each of these schemes have their respective merits and drawbacks.

Reference

1. *Timing projectile motion*, Bulletin 183, SSERC, Winter 1994, pp 18-23.

	Foil switch			**Microphone switch**			**Light gate switch**			**Vibration Sensor switch**		
Runway switch type	*Aluminium foil*			*Microphone*			*Light gate*			*SV1 Vibration Sensor*		
Floor switch type	*Microphone*			*Microphone*			*Microphone*			*SV1 Vibration Sensor*		
Height of release (mm)	**1**	**10**	**20**	**1**	**10**	**20**	**1**	**10**	**20**	**1**	**10**	**20**
Drop time values (ms)	433	419	425	443	444	451	425	422	424	422	422	423
	414	425	427	457	442	456	425	425	424	423	424	423
	389	424	426	450	446	455	426	425	424	424	422	423
	399	424	424	444	448	454	425	422	424	424	423	424
	417	423	425	447	446	455	428	424	423	426	421	423
	415	428	424	452	442	452	425	423	423	425	422	425
	399	427	424	444	435	451	422	423	424	421	425	424
	419	425	424	440	446	452	425	423	423	424	422	425
	419	426	425	458	443	452	425	424	426	422	421	423
	418	422	418	442	448	455	426	423	423	422	424	423
Mean values (ms)	412	424	424	448	444	453	425	423	424	423	423	424
Uncertainty in mean values (ms) (95% confidence limits)	± 10	± 2	± 2	± 4	± 3	± 2	± 2	± 2	± 2	± 2	± 2	± 2

Table 1. Values of drop time against release height on ramp. Time measuements made with a Unilab Digital Scaler Timer for the Foil, Microphone and Light gate Switches, and a Unilab Motion QED for the Vibration Sensor Switch.

Sulphur dioxide canisters

In Bulletin 177 [1], we reported that the familiar, wee yellow, aluminium SO_2 canisters originally sold by BDH in the 500 g size were being withdrawn from the market. Merck, BDH's successor company, have substituted a much more expensive stainless steel container. The older aluminium containers, because they held the SO_2 as a liquid under pressure were also known as SO_2 syphons. These were a cheap and cheerful source of the gas, not only for general use in chemistry teaching but as a fairly controllable source of an acidic gas in challenge tests on the filters of recirculatory fume cupboards.

The only problems we had encountered were those occasionally reported to us by schools and colleges and usually involved seizure of the valve. The root cause of that problem was nearly always poor storage conditions with syphons being held in poorly ventilated spaces or in cupboards alongside acids (including - naughty, naughty! - fume cupboards). We were somewhat suprised therefore when the decision to withdraw the aluminium syphons seemed to be based on concerns over the integrity of the thin-walled aluminium container itself.

Sulphur dioxide in the newer, stainless steel canister is now costing almost £150 per 500 g. Because of this expense we published the basis of an alternative means of generating SO_2 for filter challenge-testing [1]. This method, based on burning elemental sulphur, has since been adopted by a number of fume cupboard manufacturers as well as by CLEAPSS who have also refined it somewhat. More recently we have come upon an alternative, inexpensive source of liquified SO_2. You guessed it - under pressure in an aluminium container.

The firm Prolabo sell such a canister in a 1 kg size for only £23.40. Prolabo's catalogue number for this item is 21 415.290. We have obtained a sample for testing and are currently evaluating it for effectiveness and for health and safety purposes. Although the canister apparently presents good value in terms of pennies per gramme of sulphur dioxide we have already identified a couple of potential problems :

a) Although the canister is larger and heavier than a typical camping gas container its walls are of a similar, relatively lightweight construction and we are uncertain of their ability to resist puncture,

b) The Prolabo canister, unlike the old BDH syphon, doesn't come with a proper control valve. Instead it is fitted with a self-sealing valve of the type found on aerosol containers. The gas is emitted when a small button is depressed so unseating this valve. As a result, the flow of gas is not always readily controlled. Because of this - and because the SO_2 is liquified under pressure - quickly, or just fully, depressing the button may result in a sputtering of drops of liquid SO_2.

The latter is less of problem for general chemistry teaching since, as with an aerosol container, the nozzle can be extended by fitting a short length of plastic tubing (one being supplied with the canister). By this means the drops of SO_2 may be directed and brought more under control. A gas jar may thus be filled with sulphur dioxide merely by squirting a drop of liquid into it and waiting for a few seconds for the air to be displaced before fitting a lid. Similarly if a few drops of the liquid are squirted into a conical flask fitted with a one-hole bung and delivery tube, this can then be used a source of the gas. When this secondary SO_2 generator is finished with, the end of the delivery tube can simply be placed under some water in a beaker and suck-back allowed to occur. The small amount of sulphurous acid which results from this may, greatly diluted, be disposed of to waste.

Much trickier is the business of producing a controlled flow of gas from either the syphon itself or from a secondary generator. This would be particularly useful for the purposes of fume cupboard testing. We have a number of ideas under development some new and at least one recycled from early SSERC work on re-fillable oxygen cylinders. Some of that old work is now coming round again for the third time. "Déja-vu, again" - as we on the Celtic fringe might say.

Conclusions

The Prolabo sulphur dioxide canister has potential as a less expensive source of the gas than the new stainless steel containers. There are still some uncertainties over the integrity of the container itself. There are also difficulties in obtaining controllable flows and these are particularly desirable for fume cupboard monitoring. Anyone who has bought or is considering buying a Prolabo syphon is advised to handle it with due care, in a fume cupboard and to wear the relevant personal protective equipment. Storage should be in a well ventilated, but secure, location. Because of the geometry of the container it is not especially stable. A secondary supporting container is thus useful.

Should we successfully develop our idea for a suitable, add-on control valve, we shall publish the details in the Bulletin a.s.a.p. Meanwhile we would be very interested to hear from anyone else who has experience of using this particular source of the gas, either for general teaching purposes or in testing and monitoring work.

Reference

1. *Monitoring of recirculatory filters*, Bulletin 177, SSERC, June 1993, p.22.

SOFTWARE NEWS

SSERC Graphics for PCs

The SSERC Graphics Collections, originally developed for use on Acorn's RISC platform are now available in a format accessible to users of IBM PCs and compatibles. The collection has been put onto fourteen 1.44 Mb floppy discs which can be loaded into Oak Draw for Windows a full-function, vector based drawing and graphics editing package. We have negotiated a special deal with Oak Solutions which allows us to sell Oak Draw for Windows at a heavily discounted £65.80 (single user, but inclusive of VAT).

A description of the features of Oak Draw for Windows is provided below. An indication of the range and quality of the graphics in our collection is given by the line drawings and other figures published in these pages over the last three years or so. Nearly of all these were assembled from graphics components of our library of objects. A full list of titles of the 14 discs currently available in Oak Draw compatible formats is available on request from SSERC. Each 1.44 Mb disc costs £14 including a site licence and VAT.

Oak Draw for Windows

OAK DRAW® for WINDOWS® is an object-oriented drawing package for Windows® on the PC. It is designed to be simple enough for use by children (and teachers!) in schools but also has powerful features which meet many of the needs of professional users. Object-oriented (a.k.a.. vector-based) drawing packages can produce much clearer diagrams than pixel based (painting) packages. The quality of object oriented diagrams is always determined by the resolution of the monitor screen or printer and is not limited to a fixed number of pixels.

Within Oak Draw, the drawing area is specified in paper sizes up to A0 and either imperial or metric working units can be chosen. The apparatus in the SSERC PC Graphics Collections has been drawn to a set scale corresponding to a 1 mm grid. If this grid is configured before any graphics are loaded in, then all horizontal and vertical lines will sit on that grid. This means that graphics can be easily ungrouped and edited to the user's own requirements. Electronics symbol graphics are configured to a 1/10 inch grid. Conducting lines can then easily be drawn to join the components.

Drawings are made up of a series of objects which are either paths (lines & curves), text or embedded bitmaps. Path objects can have their own line and fill colour specified separately. The line thickness can be anything from a thin line (one pixel wide) to however many units are required. The start and end of lines can be square, rounded or triangular (for arrows). Line joins can be mitred, round or bevelled.

File compatability with Acorn

Oak Draw provides a similar set of tools to Acorn's !Draw application - including lines, curves, text, circles and rectangles. You can produce a Drawfile on Oak Draw running under Windows and then transfer it from the same DOS disc by reading it in the high density disc drive of your A3020, A4000, A5000 or RISC PC . It can be loaded directly into the Acorn !Draw application. Oak Draw also comes with its own extra disc packed full of example clip-art. Oak Draw can export Windows Metafiles (.wmf), bitmaps (.bmp), DXF (.dxf) or Drawfiles (.aff). Therefore, as well as exporting to the Acorn platform, other applications in the Windows environment of the PC such as DTP, word processors and spreadsheets can accept your graphics.

Apple Mac

Mac users needn't feel left out. SCET are now putting the finishing touches to a Gold or pilot version of an Apple CD ROM of our graphics. This will have better search facilities than the Acorn SSERC CD. SCET have used a modified version of their front-end for the Glasgow Herald CD archives as the search-engine for the SSERC Graphics. Once trials have been held with a few Gold copies, the final versions will be pressed in numbers for distribution and be offered for sale. The price is yet to fixed but will be somewhere around the £80 to £100 mark.

Note: Educational Computing & Technology

Some readers may have seen a recent review of our CD ROM based Graphics Collections in the above named magazine and thus may be a tad sceptical about our claims for the quality of the graphics. Strangely this was but one of many aspects that the so-called reviewer neglected to mention. The bulk of the EC&T review was taken up with a nit-pick over the use of "times" for a singular occurrence the absence of one specific piece of chemistry glassware (never mind the umpty other megabytes of chemistry apparatus) and a misunderstanding based solely on total failure to read the right instruction manual. The slagging we got over the cost was also unjustified since it was based on the original launch price - last year's. Strangely, it was also all that time ago that we first sent in a sample CD to Educational Computing & Technology for review.

We have just got our reminder for our subscription renewal for the magazine. You can imagine the exotic plans which have been made for that paperwork. Certainly if we do - instead - renew, and if all their reviewers are as objective and fair minded as the one who looked at our CD, I am certain SSERC shall be taking any of their future software evaluations with a 50 kg bag of salt. This is also because, in 1992, the same magazine gave the original Graphics Library (only 3 discs then) a rave review describing it as an excellent resource. But, then again, if the editors don't even bother to read their own magazine, why should we pay for that somewhat doubtful privilege?

NEWS REPORTS

Biology '95

This year the Institute of Biology (IOB) held their National Conference in Edinburgh to co-incide with two days of the International Science Festival programme. I could only make it along to the Saturday morning session in the Royal Scottish Museum, but was glad to have made the effort. The general theme for the session was the public understanding of science and in particular of some aspects of modern biology, such as the so-called New Genetics. What made the morning so interesting was a deliberate mix of disciplines in the panel of speakers. Biologists were minority contributors to a multi-disciplin ary examination of the question set from the Chair by Dr Bernard Dixon of the IOB and the Edinburgh Science Festival Programme Planning Committee : ***Making sense of science - What does the public believe?***

This question was addressed in the broad contexts of biotechnology and the *New Genetics* as well as of specific biomedical questions by a panel of speakers. This included a biologist who is a 'teacher educator'; two sociologists, one of whom is a member of the Glasgow University Media Unit and the other a researcher into the sociology of social policy and of science; then a research psychologist and, just to round things off, one individual geographer turned biology teacher, micro-biologist, biotechnologist, geneticist and now Head of Communication and Education at the Wellcome Foundation. (and, no, he wasn't called "Jack"). Unusually for some of these sessions there were also a lot of directly relevant contributions from the floor (no, I didn't). The conclusions reached were also uncharacteristically useful.

The three major points which got hammered home are worth bearing in mind by any science or technology teacher. The first of these is that mechanisms for understanding scientific and technological issues, especially the most controversial ones, have to be part of a two way process. That is, for them to promote public understanding scientists must first understand the nature of the public.

The second, and related, point is that there is no such thing as a General Public (i.e. the proverbial on the top of the Clapham whatsit). This is where the multi-disciplinary nature of the presentations proved stimulating. The sociologists and the psychologist had lots of evidence to convince us that there is not just one public, but many different publics, with all of which scientists, technologists and engineers may have to learn to communicate (just as with pupils' understanding and differentiation really).

The third point is a consequence of the other two. The speakers collectively and comprehensively demolished the old idea that for the public to learn to love science, and all of her works, then all we have to do is give them more information - the "Ve haf vays to make you love science!" approach.

I had three minor objections to the programme. The first was that there was no philosopher to keep us on the ethical straight and narrow. I would like to have discussed a central problem of teaching about controversial issues. which is that of intrinsic objection. This is where your particular public has deep seated and absolute objections to a practice. They can never be swayed by extrinsic arguments based on ideas such as the balance between, say, possible suffering of a few animals on the one hand and veterinary or medical benefit to many other animals or humans on the other. They just happen to believe that any and all exploitation of animals is inherently wrong and thus totally indefensible. For them you can put your cost-benefit analyses anywhere rude, they're just not on. I would have like to have had the cheek to invert the famous conference question in David Lodge's *It's a Small World!*. I did nearly ask "What happens if we never agree?" I chickened out, but in a free-range kind of a way.

My second objection was that if one more platform speaker had used what is obviously now the conference buzz-phrase : "And, I suppose, the take-home message has to be . . ." I swore to a Pantheon that I would invade the pitch. My third point, and probably the most serious, is that every conference session always seems to end with some trainspotter emphasising three major points.

What is a derivative?

After the collapse of Barings merchant bank in February the media made many half-baked attempts at trying to explain what a derivative is. Here is the only description I have seen which has the ring of truth about it. According to Peter Rogers writing in the April issue of *Physics World*, a derivative is a security whose price is derived from something else. Futures and options are both derivatives. In 1973, mathematician Black and economist Scholes showed that although stock and options prices varied randomly, they were related by a partial differential equation :

$$\partial V/\partial t + \tfrac{1}{2}\sigma^2 S\, \partial^2 V/\partial S^2 + rS\, \partial V/\partial S - rV = 0$$

where $V(S,t)$ is the value of the derivative, t is time, σ is the volatility, S the price of the underlying asset and r is the risk-free credit.

According to *Physics World*, the City uses its Recruitment Section to attract young mathematicians and physicists out of theoretical science into international finance. Can we expect future undergraduate physics courses soon to include a topic on methods of solving the Black-Scholes equation?

No comment

We understand that Jim Jardine is on the Rotary lecture circuit. The title of his deliverance - Rotary motion!

ASE (Scotland) Annual Meeting Practical Workshops

We have already reported on other aspects of the meeting elsewhere in this issue (p.2). Also of particular interest to us however were the three sessions on practical work and investigations. That on Practical Investigations in Science at the Standard Grade is particularly topical in that we understand that the various science panels at the SEB have been looking again at some of the problems in the management of the assessment of investigations.

The Bannockburn session on Practical Investigations was led by Johanna Carrie of Portobello High and James Dorward of Gracemount High (both Edinburgh schools). The various demonstrations and management hints and tips in this session were rounded off with group work followed by - that rare phenomenon - a short, but useful, plenary session. Johanna and James were kind enough to collate the significant points and main requirements of practitioners to come out of that session and to send them to us. The more important ones are listed, somewhat cryptically, below and not in any particular rank order :

- consistency across the sciences, both marking schemes and the numbers of investigations required must be the same with more account taken of difficulties with multivariables;
- means of managing one half of the class at a time to allow space for the practical work and suggested means of occupying the other pupils so that their demands on the teacher overseeing the investigatve work are minimised;
- pupils used to working in pairs are then required to work alone and this noticeably affects the confidence of some;
- how far is it justifiable to prepare for and 'package' the investigations, for example are pupils to be made aware beforehand of the kind of jargon they can expect to meet in the assessment booklet? How important and acceptable is practice, for example in the use of measuring instruments?
- other aspects of the generative phase were raised in discussion including the help that some pupils get by picking up ideas from others in a group. In terms of learning and teaching practices this may be very useful but what, if any, is its place in assessment?
- should reference books be made available (since we are not supposed to be assessing knowledge and understanding)?
- there is a general problem of shortage of time, which breaks down into issues such as the amount of time to prepare for and carry out a single investigation, the proportion of that time out of the overall allocation to teach an already demanding syllabus. Specific mention was made by several teachers of the unrewarding effect of replicating results, where up to double the time may be spent for one extra mark.

Despite all of these questions and difficulties nearly everyone present was broadly in favour of retaining investigative work and was of the opinion that it could assist in promoting learning in science. Thus most concerns were with the effects of the formal assessment of such work and less with its usefulness for learning. It will be interesting eventually to learn the outcome of any review by the Board and its panels.

As to the more general purpose and role of practical work in science education, there was time barely to scratch the surface. It would be our wish here at SSERC, and that of a number of participants in the ASE Workshops, to have a whole day or more on this subject. It would seem that this is a theme for a national conference which is long overdue.

Other spin-offs from this session were a number of practical hints and tips for investigations and projects. Some of these we were very taken with and will be trying out one or two with a view to publicising them more widely. For example, we saw an intriguing and colourful alternative method for assaying urea and the use of sections of dandelion flower stalks to demonstrate the effects of plant growth substances. Both of these are the work of Tony Sellars and his pupils in the Biology Department at Monifieth High School - more on which anon.

DNA Technology News

For some years both the National Centre for Biotechnology Education (NCBE) and the Science and Plants for Schools Project (SAPS) have been working separately to bring low cost practical work on DNA to schools and colleges (see SSERC Bulletins 180 and 183). It has become clear to both organisations that closer collaboration would be mutually beneficial to both agencies and would also allow them better to assist teachers, pupils and students. NCBE and SAPS have thus announced that they are co-operating in the joint production of a DNA kit which will cover the Lambda protocol developed by NCBE as well as the SAPS procedure for the extraction of plant DNA together with similar procedures for other DNA sources.

NCBE and SAPS have also acknowledged the receipt of two generous grants from the Gatsby Foundation one of which has allowed them to buy a large quantity of room-temperature stable enzymes for use in their kit. The other grant is being applied to allow teachers who attend a SAPS DNA workshop to apply for sponsorship to help them buy a DNA kit for their school. According to a SAPS information sheet this sponsorship "will be subject to certain criteria as not all schools will be able to be (so) funded". This leaves considerable uncertainty for agencies like SSERC who have been promoting and assisting such initiatives since before the Scottish National Symposium on Biotechnology in 1988. More recently we have been running successful courses based on the original NCBE kit. If that last wee bit sounds like sour grapes - well - that's because, probably, it is (or "they are"?).

TECHNICAL ARTICLE

Protected MOSFET transistors

New fully-protected power transistors have been developed. Being nearly idiot-proof, they would seem to be very suitable for use in teaching electronics and control technologies in schools and colleges.

In any applications in electronics where transistor switching is required, there will be a risk that the transistors will get damaged. The frequency of abuse in elementary education can be expected to be high. We all have to go through a stage of incompetence before finding out how things should properly be done. By the nature of this stage, young persons handling electronic devices are bound to be incompetent - at least for some of the time. Therefore the advent of fully protected power MOSFETs is good news. These devices, designed as they are for applications where extreme operating conditions can be expected, would seem to be tailor-made for bench work.

We know of two manufacturers who have recently introduced these n-channel transistors. International Rectifier have called their product the SmartFET. The rival Philips' products do not have a tradename, but are in their TOPFET group of PowerMOS transistors (Table 1). They all offer the following :

- Over temperature protection
- Over current protection, including protection against short circuiting the load
- Active drain to source clamp, including protection against inductive spikes
- Electrostatic discharge protection

The SmartFET is in the standard TO-220 package (Fig. 1). It can be used in switching or linear applications. Philips list ten different types of protected MOSFET. They are intended for switching applications. The two described in this article are also in TO-220 packages. The SmartFET and BUK100-50GS can be used at any logic input level between 5 V and 10 V. The BUK100-50GL has been specifically designed for use with 5 V logic. Reference data are tabulated (Table 2). A simplified schematic diagram illustrates their functions (Fig. 2).

These protected MOSFETs are interchangeable with many other n-channel power MOSFETs. They can be used in any new design requiring this type of transistor. They can also be retrofitted into many old designs where there has been a history of transistor failures. For instance they may be fitted into the transistor switch boards of electronics kits.

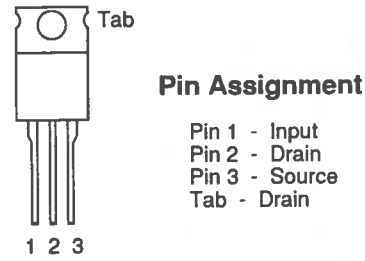

Figure 1. Pin configuration of TO-220 package. Front view. Tab to rear.

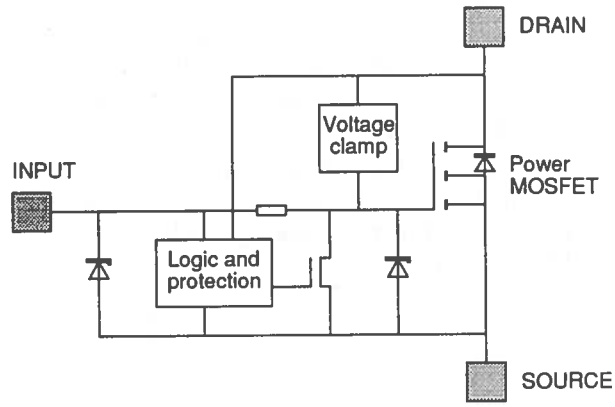

Figure 2. Functional block diagram of protected MOSFET's internal structure.

Manufacturer	International Rectifier	Philips	Philips
Product name	SmartFET	SOT-263 TOPFET	SOT-263 TOPFET
Manufacturer's list number	IRSF3010	BUK100-50GS	BUK100-50GL
Supplier	Farnell	Farnell	Farnell
Supplier's order code	541-369	291-651	291-640
Price (£) 1+	3.05	2.29	2.29
25+	2.15	1.99	1.99

Table 1. Fully protected n-channel power MOSFET transistors. Each type in 3-pin TO-220 package.

Parameter	IRSF3010	BUK100-50GS	BUK100-50GL	Unit
Maximum drain to source voltage	50	50	50	V
Maximum continuous drain current	11	15	13.5	A
Drain to source on state resistance	80	100	125	mΩ
Maximum threshold junction temperature	155	150	150	°C
Maximum power dissipation	40	40	40	W
Minimum input threshold voltage	1.5	1.0	1.0	V
Maximum input threshold voltage	2.5	2.0	2.0	V
Input clamp voltage	10	11	6	V
Typical input supply current	0.3	0.4	0.2	mA

Table 2. Maximum ratings and characteristics of protected MOSFET transistors.

In the event of current through the power switch exceeding 14 A (typical), or the junction temperature exceeding 165°C the switch is turned off instantly. For both types of protection the switch is reset by applying a negative going pulse to the input taking the voltage level to logic 0.

In addition to protecting against overvoltage, these transistors can absorb energy in the form that might occur during the switching of an inductive load.

The following notes should help you get the best usage from these transistors:

- Use in applications requiring an n-channel power MOSFET. The devices to choose from are:

SmartFET IRSF3010	switching and linear
BUK100-50GS	switching (5 V - 10 V input logic)
BUK100-50GL	switching (5 V input logic)

- Applications include driving inductive loads such as solenoids, d.c. motors and relay coils, and driving passive loads such as lamps and heaters. The transistors can comfortably switch currents of 10 A.
- If using digital logic, these transistors can be driven directly from the output stage of any standard logic device (Fig. 3) in the following families : LS, HC, HCT, or 4000.

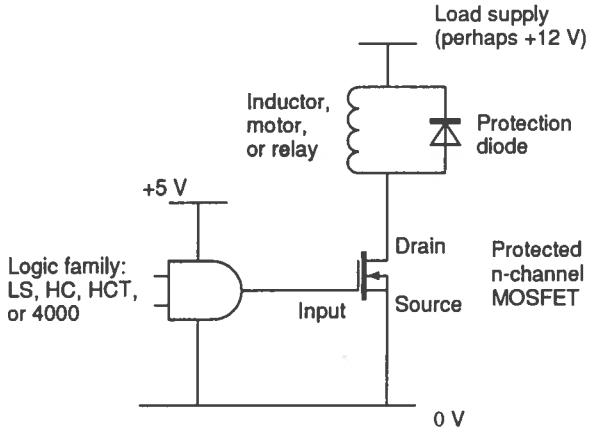

Figure 3. Digital switching : Protected MOSFET transistors may be driven directly from the output stage of logic devices in LS, HC, HCT, or 4000 families.
The protection diode across an inductive load is not generally necessary with these transistors (see text).

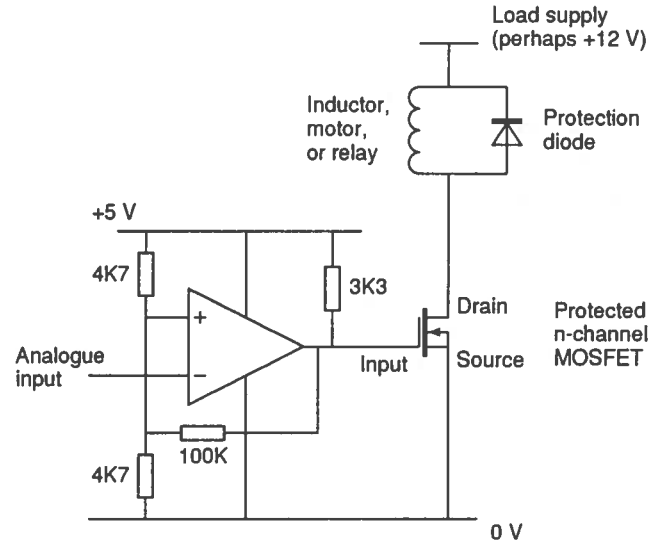

Figure 4. Digital switching from a comparator drive. Suitable comparators include LM311N and LM339N.
The protection diode across an inductive load is not generally necessary with these transistors (see text).

- If using op-amps, the recommended drive would be through a comparator with hysteresis (Fig. 4). By using a comparator, the transistor is operated in its digital rather than in its analogue mode. By adding hysteresis, the output cannot jitter about the set point.
- There is minimal internal heating provided that the FET is switched completely on or off. In this type of application it may be used with a small heatsink, even the small clip-on type (e.g. RS 402-260).
- Unless you specifically wish to operate the FET as a linear device, the input voltage should not be allowed to linger at, or come near to, the threshold voltage (for a Philips type: between 1.0 V and 2.0 V; for a SmartFET: between 1.5 V and 2.5 V). Always stay well above or well below the threshold if at all possible.
- For analogue applications, the preferred way of controlling the brightness of a lamp, or speed of a motor, is pulse width modulation. Digital switching causes minimal internal heating within the transistor.

- If however you do modify lamp brightness or motor speed by controlling the gate voltage, you will find that the transistor gets very hot - and needs to be fitted to a very large heatsink, where it still gets very hot. However don't worry about the transistor. Because it is protected against over temperature, it will look after itself. It's your own and your pupils' fingers that are not so protected!
- If using pulse width modulation, the pulses must be clean with no analogue component (Fig. 5), otherwise the MOSFET's temperature will rise.
- A protection diode needs to be placed across an inductive load only if more than 400 mJ of inductive energy is generated (Figs. 3 and 4). In general for small motors, relays, or solenoids, no protection diode needs to be fitted.
- Use one power supply for the processing and a separate power supply for the load (Figs. 3 and 4).

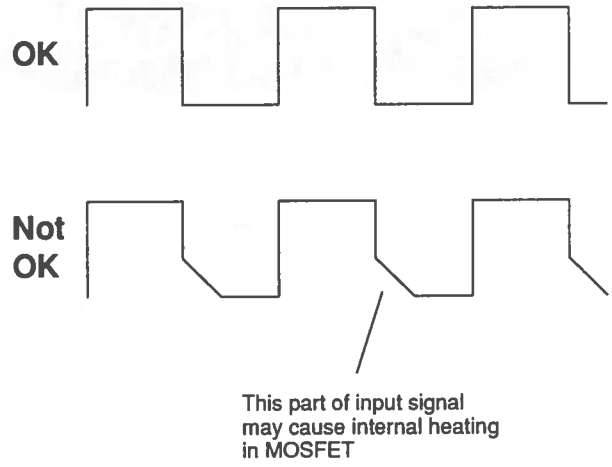

Figure 5. Transistions on input signals should not dally in the threshold region.

Performance trials

From performance trials on protected transistors the failure record on the three types is :

International Rectifier SmartFET	no failures
Philips BUK100-50GL	1 failure
Philips BUK100-50GS	1 failure

It does unfortunately seem, from our samples at least, that the protection Philips have added to their transistors does not live up to expectation. However our samples of the rival SmartFET from International Rectifier have proved to be wholly reliable and indestructible.

SAFETY NOTES

Laser pointers

We have had a report from a military training establishment of a dangerous occurrence with a laser pointer. An instructor left his pointer lying in the base tearoom. Shortly later another person was seen to pick it up, switch it on and flash it around. After the pointer had been recovered by a 'responsible person' it was found to be marked Laser Class 3A to an American classification scheme. In fact its class was equivalent to 3B in the BS and IEC scheme and so was sufficiently powerful to injure an eye from a specular reflection. Continuing with the tale, the responsible person then removed the battery, repositioned the laser in the tearoom and waited to see what might happen next. Within a short space of time it had been picked up by several people, who had tried to switch it on and play with it. One person was even seen peering into the aperture from a distance of 10 cm.

It doesn't take much imagination to translate this incident with squaddies in a canteen to kids in a classroom. The story illustrates that laser pointers would seem to offer significant risk in places like schools. Young persons have a natural propensity to be curious and inquisitive, or to indulge in horseplay. The only safe avoidance may thus be abstinence. As was advised in an earlier issue : "It would seem prudent for schools to refrain from buying them - even those in Class 2".

Be Safe! - Scottish Edition

Over recent months a Working Group convened by ASE (Scotland) has been working on a Scottish version of the ASE's well respected publication on safety in science and technology in Primary. This has now been better tailored to meet the requirements of the Scottish 5-14 curriculum. A number of drafts have been circulated for consultation and comment. The final text should soon be ready to go forward to ASE headquarters for approval by the Safeguards in Science and Publications Committees. It is hoped to have the Scottish Edition printed and available in time for the early part of next session.

SSERC Safety Courses

The Centre has a number of Health and Safety training courses dealing with a range of topics from COSHH through electrical safety and on to newer matters such as the implementation of the Management of Health and Safety Regulations. Recently we have been offering places on open courses in SSERC on a first-come first served basis. We only have a few places left on our Management of Safety in Science Departments course in September but will consider repeating it should we receive sufficient enquiries. We shall soon trial a version of this course for Principal Teachers in Technology departments. Assuming that it is as well received as was that for Science we shall advertise it more widely in time for next session.

PRODUCT AND TRADE NEWS

Dry ice supplies

This hardy perennial's time has come round again as suppliers play their latest game of musical market sectors. Distillers, after a move of "Pure Genius" and Guinessian wisdom, are no longer our recommendation. If it's dry ice you're after, then the thing to go for is known as a *liquid withdrawal* (the mind boggles!) CO_2 cylinder. This kind of CO_2 cylinder differs from the standard type in having a special colour code with a distinctive white stripe overlaid on the normal CO_2 black (a sort of designer or go-faster gas?). It is specifically intended for use with a dry-ice attachment and is available from BOC. The capacity of this cylinder type is 34 kg of gas. It may rented at £38.20 per year (payable in monthly instalments) and each refill costs £13.92 (see Address List inside rear cover for further details).

Pipette fillers

We have had a number of enquiries of late on sources of pipette fillers such as *Pi-pumps*. Our records of sources and prices are thus fairly up-to-date and the results of our mini-market comparative survey of standard 10 cm^3 fillers are tabulated below.

Supplier	Cat. numbers	Price (£)	Notes (Quantities etc)
Camlab	PPD200/10	8.67	each 5 or more min.order £25
Griffin	PMR-336-051H	12.35	each no min.quant
Harris	Y40542/8 Y40542/82	11.25 10.12	each 1-9 each 10 or more
Hogg	J3704 fast release only	9.20 or 8.28	each 1-9 each 10 or more
McQuilkin	241/3983/03 fast release only	10.35	each
Radleys	F37898	8.47, 7.63	1-4, 5 or more mln. order £30.

If their minimum order is not a hindrance, and ignoring any contractual discounts, then at the time of our survey the cheapest source of Pi-pump type fillers would seem to be Radleys Laboratory Equipment & Scientific Glassware. Their address and those of the other suppliers is listed on the inside rear cover of this issue.

Ken Holyoake

To Mr Holyoake, well known gentleman, angler and raconteur, erstwhile Philip Harris Sales Manager for Scotland and Northern Ireland and now at Marr College :

Nice one, Ken! Good luck and awra best!

Autoclave bags

Not a few schools now have modern, automatically controlled, portable autoclaves capable of operating at 126 °C rather than the 121 °C achievable with a pressure cooker or older model of autoclave. It then becomes necessary to check that any autoclavable disposal bags bought for use with these devices will withstand the somewhat higher operating temperature. For example : when purchasing bags from Philip Harris the type needed is of high density polythene for use up to 130 °C, catalogue number R16600/3, size 670 x 305 mm, currently £19.29 per pack of 200 bags. In contrast the smaller (220 x 280 mm) disposal bags Philip Harris reference R16610/6 (£11.66 per 100) are intended only for use with older autoclaves and pressure cookers operating up to 121 °C. Also worth trying are plastic roasting bags purchased locally. These work fine especially where large amounts of microbiological work aren't the norm. Several brands of roasting bag which we have used for disposal purposes are capable of withstanding more than 126°C.

Dispensing bottles

We have had a number of enquiries as to sources of small, inexpensive, plastic bottles with built-in dispensing devices. These are widely used in class sets of reagents or kits prepared for specific chunks of several courses. We have located one Scottish source of such bottles which have pivoting nozzles providing a controllable dropping device. The company is called Johnsen & Jorgensen and is based in Glasgow (see inside rear cover for full address). The products are known as *Poly* bottles. They come in two densities and with a variety of closure types including an ordinary dispensing closure or a pivoting nozzle.

Prices are quoted per 1,000 but the bottles may be purchased in minimum lots of as few as 1 dozen. The basic prices work out at about 12p to 21p each depending on size, plus the cost of the closure which varies from about 3p for a plain cap up to 13p for a proper dispensing closure or about 5p for a nozzle. The company also sells ordinary dropper bottles made in PVC in 10 and 20 ml sizes but these are somewhat more expensive at roughly 35p each.

Storage cabinets for flammables

One source of moderately priced metal cabinets for the storage of flammable liquids is the Shropshire firm of W.H.Dixon (see Address List).

More Trade News etc. on page 32, facing inside rear cover.

Vitamin C and phenol oxidases

In this section of the last issue we posed an open-ended question intended, in the main, as a stimulus to further investigative work on a fascinating complex of enzymes. The question was based on the observation that the browning of cut surfaces of plant tissues is more effectively inhibited by citrus fruit juices than can be explained by their low pH alone. Lemon juice and orange juice are rich in ascorbic acid. So, we asked ;

"Ascorbic acid (vitamin C) has a direct effect on these reactions. What effect might that be?"

We are very grateful to Jim Boyd of Crookston Castle Secondary School in Glasgow who took the trouble to write in and tell us. We have to confess that we did already have the answer, but none of the accounts we had seen were as graphically succinct as Jim's. Here it is, but don't give it to your students - make them work for it through some simple investigations.

Dear Sir,

In Bulletin 184 "Looose Ends", you ask what effect Vitamin C might have on phenol oxidative coupling reactions.

These enzymes function by producing peroxides which oxidise the phenols so producing phenyl peroxides which then cleave to produce the phenoxy radical with its tautomeric forms (Fig. 1). Such radicals will then couple in a large variety of ways. The resulting mixture of biphenyl compounds leads to the formation of even more varieties of combinations. A very complex polymeric phenolic resin is the result.

Ascorbic acid (vitamin C) is involved in many reduction reactions. It is easily oxidised by such radicals and so mops them up by hydrogenation (Figure 2). In living tissues, or in-vitro simulations, this effect of ascorbic acid need not be stoichiometric. A large number of other substrates in living material are capable of reducing the de-hydro form back to vitamin C whereafter it can re-enter the phenol oxidase reaction mopping up phenoxy radicals before they polymerize and so again blocking it.

Yours etc . . .

and . . there's more!

So, the effects of citrus juices on the browning reaction arise partly from a lowering of pH but probably more importantly from a blocking of the oxidation and polymerisation chain by vitamin C itself.

What about sulphites? These used often to be added as food preservatives both for their bacteriostatic and anti-oxidant action and thus also their ability to prevent browning. They even used to be added to fresh fruit salads etc. in the 'States until a small percentage of the population was found to be allergic to them [1]. They may be used still in certain food processing industries. Here then, are some more *loose ends* : How do sulphites "work" in this context? Are their effects and mechanism different from those of ascorbic acid, and if so how? Devise experiments using apple or potato slices to investigate.

And, by the way, why is green or China tea green and black, or Indian, tea black?

Reference

1. *Inhibition of Enzymatic Browning by Sulfite*, Hie-Joon Kim, 1995, J.Chem. Ed., Vol. 72, 3.

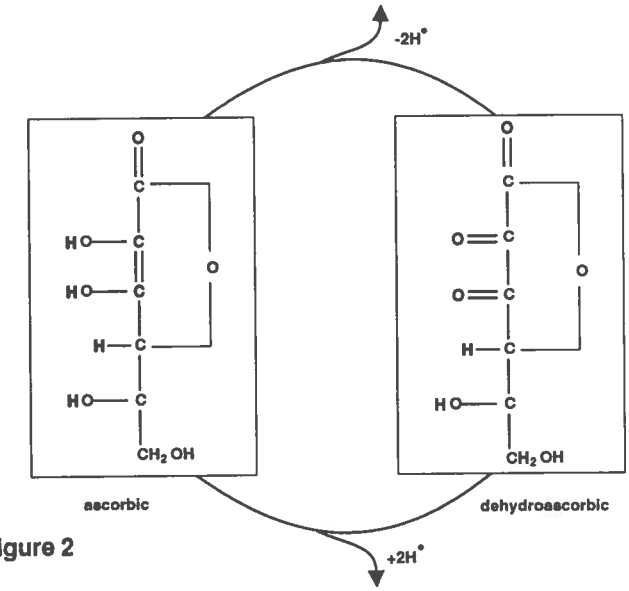

Figure 2

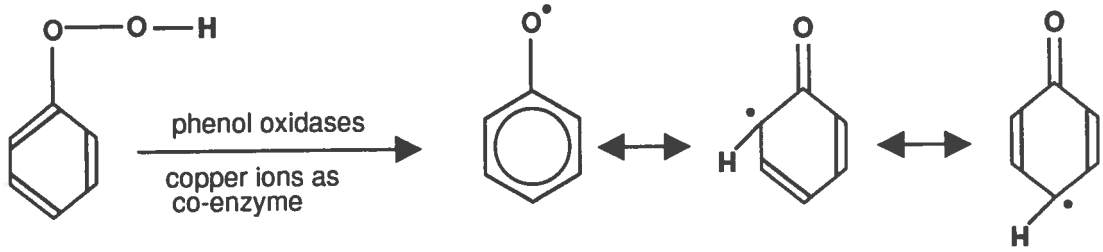

Figure 1 Oxidation of phenols to phenoxy radical in various forms

TRADE NEWS

Information on paints

We have had a number of enquiries lately about the science, especially the chemistry, of paints and their components. A number of the enquirers were seeking a Trade Association as a central source of information. One might expect such an association to be called the British Paint Manufacturers' Association and at one time they probably were called just that or something very close. These days however they like to be known as :

The British Coatings Federation

May they never cross over to the Dark Side and, unless or until they do, their address details appear opposite on the inside rear cover.

Changes of address

Note that both *Irwin Desman Limited* and *Sensor Technologies Limited* have recently moved. Their new address details are listed opposite.

Change of owner

Fisons Instruments, the parent company of Griffin & George, has been bought by Thermo Instruments. What effects, if any, which this change of ownership may have on Griffin and its educational activities is at present unclear.

Changes of personnel

As noted on page 30, Ken Holyoake is no longer with Philip Harris Education. Robert Anderson who previously covered parts of Scotland as well as a patch in Northern England has we understand now taken over Ken's Scottish bits. He can be contacted either directly or at Harris' Clydebank office or via Shenstone.

SSERC, 24 Bernard Terrace, Edinburgh, EH8 9NX; Tel. 0131 668 4421, Fax. 0131 667 9344.

ASE (UK, HQ), College Lane, Hatfield, Herts., AL10 9AA; Tel. 01707 267411 Fax. 01707 266532.

ASE (Scotland), Secretary, Mr. S. Farmer, 28 Balfour Road, Alford, Aberdeenshire, AB33 8NF; Tel. 01975 563060.

British Coatings Federation, James House, Bridge Street, Leatherhead, Surrey KT22 7EP; Tel. 01372 360660.

British Oxygen (BOC), Head Office, The Priestley Centre, Guildford, Surrey. Free 'phone 0800 220400 for information on local BOC gas and equipment supplies or see Yellow Pages.

British Standards Institution, Linford Wood, Milton Keynes MK14 6LE.

Camlab Limited, Nuffield Road, Cambridge, CB4 1TH; Tel. 01223 424222 , Fax. 01223 420856.

Dr. Peter Craig, Northern College, Aberdeen Campus, Hilton Place, Aberdeen AB9 1FA; Tel. 01224 283500, Fax. 01224 487046. (Distance learning - Electronics).

W.H. Dixon, Uni Works, Cockshutt Lane, Shropshire, TF12 5DF; Tel. 01952 882332 Fax. 01952 884404.

Griffin & George Limited, Bishop Meadow Road, Loughborough, Leicestershire, LE11 0RG; Tel. 01509 233344, Fax. 01509 231893.

Philip Harris Education:

2 North Avenue, Clydebank Business Park, Clydebank, Glasgow, G51 2DR; Tel. 0141 952 9538;

Lynn Lane, Shenstone, Lichfield, Staffordshire, WS14 0EE; Tel. 01543 480077, Fax. 01543 480068. (Note that Mr Robert Anderson, who already covered part of the territory will now be Philip Harris Education's Scottish Representative).

Hogg Laboratory Supplies, Sloane Street, Birmingham, B1 3BW; Tel. 0121 233 1972, Fax. 0121 236 7034.

HSE Books, Customer Services Department, PO Box 1999, Sudbury, Suffolk CO10 6FS Tel. 01787 881165 Fax. 01787 313995. (Cash with order if you don't have an account - and quote the ISBN of the publication).

Johnsen & Jorgensen (Glasgow Ltd), 15 Jessica Street, Polmadie, Glasgow, G42 0PG Tel. 0141 423 3066 Fax. 0141 423 1365.

Irwin-Desman Limited, Eurocrown House, 23 Grafton Road, Croydon, CR9 3AZ; Tel. 0181 680 2058, Fax. 0181 681 8429.

McQuilkin & Co., (Scottish Distributor BDH, Merck), 21 Polmadie Avenue, Glasgow, G5 0BB; Tel. 0141 429 7777, Fax. 0141 420 1223.

Measurements Group UK Limited, Stroudley Road, Basingstoke, Hampshire, RG24 0FW; Tel. 01256 462131, Fax. 01256 471441.

National Centre for Biotechnology Education (NCBE), Department of Microbiology, University of Reading, Whiteknights, Reading RG6 2AJ; Tel. 01734 873743, Fax. 01734 750140.

Oak Solutions Limited, Dial House, Chapel Street, Halton, Leeds LS15 7RN; Tel. 01132 326992 Fax. 01132 326993.

Prolabo, Liverpool Road, Eccles, Manchester, M30 7RT; Tel. 0161 789 5878, Fax. 0161 788 8279. (Scottish Customer Enquiries : Tel. 0161 787 3350).

Radley's Laboratory Equipment & Scientific Glassware, Shire Hill, Saffron Walden, Essex, CB11 3AZ; Tel. 01799 513320, Fax. 01799 513283.

Rapid Electronics Limited, Heckworth Close, Severalls Industrial Estate, Colchester, Essex CO4 4TB; Tel. 0206 751166, Fax. 0206 751188.

RS Components Limited, PO Box 99, Corby, Northamptonshire, NN17 9RS; Tel. 01536 201201, Fax. 01536 201501.

SAPS (Science and Plants for Schools) Project, Scottish Office : The Royal Botanic Garden, Edinburgh, EH3 5LR; Tel. 0131 552 7171, Extension 465 Fax. 0131 552 0382.

SATROSPHERE, 19 Justice Mill Lane, Aberdeen, AB1 2EQ; Tel. 01224 213232.

SCCC, Gardyne Road, Broughty Ferry, Dundee, DD5 1NY; Tel. 01382 455053, Fax. 01382 455046. (Comments on Technology Education Framework f.a.o. Dr. D. Stewart, Director).

Sensor Technologies, 9 Southgate, Green Lane, Heywood, Lancashire, OL10 1ND; Tel. 01706 625060, Fax. 01706 625961.

Unilab Limited, The Science Park, Hutton Street, Blackburn, Lancashire, BB1 3BT; Tel. 01254 681222, Fax. 01254 681777.