

SCOTTISH SCHOOLS SCIENCE
EQUIPMENT RESEARCH CENTRE



Bulletin No. 146

June 1985

A D D R E S S L I S T

SSSERC, 103, Broughton Street, Edinburgh EH1 3RZ Tel. 031-556 2184 or 031-557 1037.

BDH Ltd., Broom Road, Poole BH12 4NN Tel.(0202) 745520
[Scottish Agents - Macfarlane Robson, MacKay and Lynn amongst others).

BOC Ltd., Gas Sales Dept., Erskine House, 1 North Avenue, Clydebank Business Park, Clydebank G81 2DR
Tel.041-941 3344.

Camlab Ltd., Nuffield Road, Cambridge CB4 1TH Tel.(0223) 62222.

Farnell Electronic Components Ltd., Canal Road, Leeds LS12 2TU Tel.(0532) 63611.

Gerrard Biological Centre, Worthing Road, East Preston, West Sussex BN16 1AS Tel.(0903) 772071.

Griffin & George Ltd., Ealing Road, Alperton, Wembley, Middlesex HA0 1HJ Tel.041-248 5680 or
01-997-3344.

Kodak Ltd., - for information on scientific and technical applications, contact your local Kodak Sales
Centre (see Telephone Directory).

Ilford Ltd.,Mobberley, Knutsford, Chesire WA16 7HA Tel.(0565) 50000.

Mendascope Ltd., Otter House, Weston Underwood, Olney, Bucks. MK46 5JS Tel.(0234) 712445.

Metragram Instruments Ltd., Radlett House, West Hill, Apsley Guise, Bucks. Tel.(0908) 582262.

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

The Royal Society of Chemistry, Burlington House, London W1V 0BN.[Grant Applications - f.a.o.
Mr.S.S.Langer].

Scopex, 117 Knowle Road, Mirfield, West Yorkshire WF14 9RJ Tel.(0924) 49638.

UVP Ltd.,Science Park, Milton Road, Cambridge CB4 4BN Tel.(0223) 355722.

Visijar Tuckers Ltd., 8 Napier Way, Wardpark Industrial Estate, Cumbernauld. Tel.(02367) 32814.

© SSSERC 1985

(Copyright is held to be waived only for bona-fide educational uses within Scottish schools and colleges in current membership of SSSERC).

INTRODUCTION

S.S. Susan Goodbye!

Looking for a new sobriety test, an alternative to the "Leith Police....."? Try this:

"Sadly, after seven years, SSSERC says "Sianara" to Susan Smith as was".

SSSERC customers and regular attenders at our workshops and exhibitions will be sorry to hear of the departure from the staff of Mrs Susan Barnett (nee Smith). She was made an offer she couldn't refuse - a chance to escape! Mrs Barnett is now engaged in the business of selling equipment instead of testing it, leaving the Centre towards the end of April to work for Metragram Instruments. We are sure that readers would join us in wishing her the very best in her new career.

We seem, in recent months, to have used a lot of this introductory space in saying farewell to folk. However when we look back at the record we have, over the years, done remarkably well in the technical and scientific staff turnover stakes (touch wood). In the last few years two such members of staff have retired and now one has left after seven years with the Centre. The question is, do we only recruit loonies or do you get that way inclined after only a short sojourn at SSSERC? After some twelve years on the staff myself, this is beginning to prey on what now passes for my mind.

Summer Saturdays

Sorry about the heading. That's the trouble with alliteration, you can get hung up on it. Like all sweet, sickly things it tends to stick to tongue, teeth and typewriter (computer keyboard - pleads poetic licence).

We hereby give notice that, in accordance with custom, the Centre will not be open on Saturday mornings in July and August. Saturday morning opening will thus recommence on the 7th of September. Thereafter we will follow the usual pattern of weekend opening, 9am to 1pm on the first two Saturdays of each month until further notice.

Normal, 9am to 5pm, weekday hours will be kept right through the summer break. So if you wish to risk life and limb, pushing past the tourists, to come and visit us please do so. If you wish to see a particular specialist on the staff, please telephone first because we will be taking leave on a rota basis.

Royal Society of Chemistry Research Fund

Once again the RSC Research Fund is making available a number of grants in an arrangement which takes in schools and FE colleges. The purpose is to assist members in their research by providing funds for example, for the purchase of chemicals, equipment or for the running expenses of chemical education research. For 1986 a limited number of grants, each of approximately £300, will be available. Applications for innovative projects in chemical education and chemistry are particularly welcomed. The closing date for applications is 1st November, 1985. Application forms, together with copies of the regulations governing the fund, may be obtained from Mr.S.Langer at the address given on the inside front cover of this Bulletin.

Erratum Bulletin 145

In the "Trade News" section of the last Bulletin, we made an announcement on behalf of Gerrard Biological of a change of telephone number. In the "Address List" section we then gave the old number! Not content with that, having made a statement to the effect that Griffin & George's number had not changed we misquoted it. That was

about the time when the whole of a database on electronic balances printed out as so much garbage and, on two occasions, a printer started up printing merrily away; with no-one within 5 metres of it nor the computer. It was those Gremlins I tell you.

Gerrard's new telephone number is:

(0903) 772071

Griffin & George's numbers should have been:

Via Glasgow - 041- 248-5680

London direct - 01-997-3344

Cost Index

Our cost index for consumable items is sampled twice yearly, in May and November. The 100 baseline was set in May, 1974. Our reports of a downward movement during the period November, 1983 - May, 1984 and of a virtual standstill (+0.7%) from May to November, 1984; triggered a certain amount of correspondence, complaints even.

We received comment recently that whatever the basis of our shopping basket, its price movements certainly did not reflect the immediate experience of our correspondents. We think that this is partly explained in terms of a time-warp. What we reported in Bulletin 144 was history. Our correspondents were complaining that our figures did not mirror their recent requisition pricing experiences. They were right, as our report for the last six months will show. The other difficulty was a misunderstanding of the nature of our shopping basket and the procedure for pricing it.

Remember that keen competition, high-powered marketing and price cutting in 1983-84? It has worn off. The Accountants with their return-on-assets and profitability calculations have apparently duffed up the marketing managers. The index is back up over the 300 mark at 339. In November, 1984 it stood at 276.54. That represents a staggering increase of 22.7% over the six months and 23.5% for the year May, 1984 - May, 1985.

These figures do broadly agree with our correspondents' figures and which were the basis of their complaints. Differences in findings were largely due to different methods of pricing a consumables package. One correspondent, for example, had used a random sample method. He took the bottom item on a number of randomly opened pages in one major suppliers' price lists and also added in all the items of stationery and writing implements etc. from another of his suppliers. We calculate our index on a different, consistent, if not more accurate or reliable basis.

For many items we obtain at least two prices from major suppliers. Where we have a choice, we take the lowest. This is in the interests of consistency. That is how the basket was priced in May, 1974 and in order to compare like with like we have to stick with this method. Also, the list of items is always the same list and is weighted as to quantities of certain items. This weighting was arrived at by applying certain criteria to a larger list of commonly requisitioned consumables. The raw data for this were obtained from a number of school science departments' purchasing records and major suppliers' sales figures.

We do accept however that 1974 was a long time ago. Some SSSERC staff still had hair then. Purchasing patterns have changed. We are actively seeking ways (bureaucratic phrase meaning we are unsure what the h..l to do?) to update and improve the basis of the index. We are also looking at the possibility of designing an index for capital equipment. Is there anybody out there with bright ideas as to how we might go about it?

By way of a postscript, we thought readers (and educational administrators) might be interested in another set of figures from the raw cost index data. These show the effects of shopping around, of being tied to one supplier and worst of all being tied to a more expensive supplier. What we did was to recalculate the price of our basket using not always the lowest figure (i.e. the cost index way) but:

- (i) Most items from the same supplier "A" plus a fixed element of those items with one specialist source or locally obtained recommended selling price.

(ii) As on the previous page but variable element from supplier "B".

(iii) The corollary of the cost index method, where there was a choice take the dearest.

The observed range is of considerable interest:

Cost index method - £653.29

Method (i) - £661.09

Method (ii) - £775.32

Method (iii) - £806.29

Retiral Tribute

J. A. R. Hughes OBE BSc

John Hughes entered full retiral earlier this year when he gave up his part-time Secretaryship to the Committee on Technology. He had retired from his post as Director of the SCDS Dundee Centre in 1982. However we continued to work with him closely because he then went on serving Scottish education as, supposedly part-time, Co-ordinator of the Microelectronics, Computing and the Curriculum Project. We did not feel we could let the occasion of John's retiral pass without some note of appreciation in these pages.

After graduating from the University of Wales, more or less at the outbreak of the war, John then spent the next seven years in the army rising to the rank of Captain in REME. He then trained as a teacher at Moray house and thus began an unbroken thirty eight years serving Scottish science and mathematics education. His long and varied experience included 18 years as a science teacher 6 years training physics teachers at Jordanhill College of Education and 11 years as Director of the Scottish Curriculum Development Service, Dundee Centre. As well as the two posts he held after retiral from SCDS, John has also had spells with the Scottish Examination Board as one of the first examiners and setters for 'O' grade Physics and then as the first Principal Examiner in CSYS Physics.

To those achievements have to be added work with the British Council and other bodies in Malaysia, Hong Kong, Netherlands, USA, and Brunei.

Looking at that track record with its breadth and depth of experience, one appreciates why John's counsel was so often heeded. It also explains why we enjoyed working with him on things like the CSYS physics experimental guides, the MCC project and many other tasks. We would also record our appreciation of the quiet work he did behind the scenes in pursuit of aims, shared with SSSERC, in the interests of improved science and technology education in Scotland. We wish John a well deserved, long, full and healthy retirement. We also wish him many happy hours devoted to his other great interest - amateur radio, although in his case "amateur" is a misnomer.

C L E A P S E G u i d e s

We have recently received the following new or revised guides from our sister organisation, "CLEAPSE School Science Service". Copies of these publications may be borrowed for up to one month on application to the Director of SSSERC:

L104 "Digital Multimeters" (Revision)

L153 "Interfacing Laboratory Equipment to Computers". Part C of this guide. It describes some seven experiments which have been used and evaluated in CLEAPSE interfacing workshops for teachers.

L172 "Oxygen Meters"

* * * * *

BIOLOGY NOTES

Pollution - a practical pot-pourri

Abstract

A number of more recently developed Scottish curricular materials suggest some novel experimental and analytical techniques. This short note deals with two such activities, the effects of air pollution on plants and the detection or demonstration of lead pollution.

relatively sensitive subjects such as peas or sweet peas are used. In the case of the latter we found that fumes from an exposed 90 mm Petri dish of 5% metabisulphite solution were fatal to young sweet pea plants within 24 hours. Usually symptoms are not quite so drastic. Look for scorching of the leaf margins and wilting of leaf petioles.

Air pollution and plants

The effects of common pollutants such as sulphur dioxide and ethylene are easily and simply demonstrated. One commonly used set-up is to enclose a suitable plant subject (see Fig.1.) in a polythene tent made from a plastic bag with a simple supporting frame. In the experimental chamber is a source of the pollutant, the control chamber either containing a harmless substitute for the pollutant or a reagent which will absorb or otherwise remove it. The supports are indispensable. Their purpose is to keep the inner surface of the plastic enclosure off the plant. Otherwise the surface of the bag, moist with condensation, in contact with leaf surfaces may itself cause damage and encourage fungal and/or bacterial infections in experimental and control plants alike. We used plastic covered wire bent into hoop shapes. However short, thin canes or a semi-cylinder of climbing plant support (e.g. heavy-duty 'Netlon') work equally well.

(a) sulphur dioxide

Here the most convenient source of the pollutant is a metabisulphite solution (See Fig.1). Concentrations as high as 5% (W:V) of sodium metabisulphite are recommended in some texts [1]. However this will produce sulphur dioxide levels much higher than those normally encountered, even in grossly polluted air. It is worth experimenting with a range of lower concentrations especially if

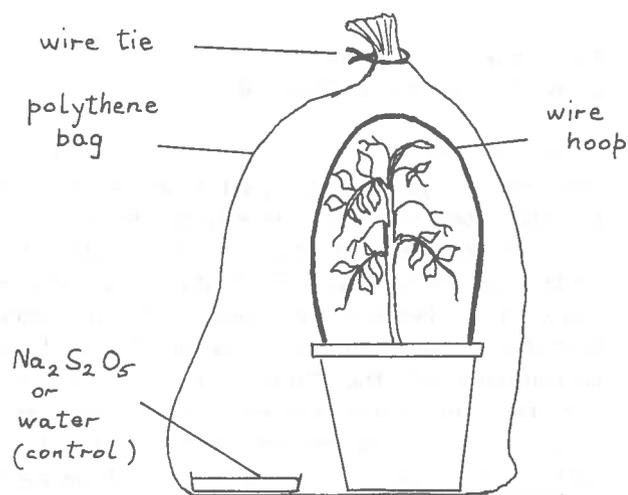


Fig.1.

We have also used that classic, easily grown standby, cress. More recently we have read that alfalfa sprouts are particularly good for this application. Alfalfa apparently is now being widely recommended as a suitable subject for air pollution bioassays.

If all you seek is a quick qualitative demonstration then we would recommend young peas or sweet peas in 3 or 4 inch pots; with a Campden tablet in an open, 90 mm Petri dish of distilled water in the experimental. For the control use an identical set-up but miss out the Campden tablet.

(b) ethylene

Ethylene is a component of pollution from car exhausts. It is also well documented as a 'plant hormone'. Its effects as a pollutant are thus of particular interest. Here the same type of experimental enclosure can be employed. A sample of car exhaust can be carefully collected in a plastic bag. However, we recommend the use of the cut surface of an apple as a source of traces of ethylene. This clever idea was suggested by the Chelsea College "People and Resources Project" team [1, 2]. We admit that we were doubtful at first, but it does work. The use of the apple is based on the fact that ripe and ripening fruit actually produce ethylene. For the control chamber, either miss out the ethylene source altogether or use an open Petri dish of potassium manganate (VII) [potassium permanganate] solution as an effective absorbent which will remove it from the atmosphere inside the bag.

Tests for lead

The detection of lead ions in aqueous samples is called for in one of the exemplars for the Standard Grade Science Core Topic "Man and the Environment". In our exhibitions and courses we normally show two simple, small scale tests:

(a) potassium chromate (vi) solution

This relies on the detection of a yellow precipitate of insoluble lead chromate. Heavy metal chromates however are classed as "A2 carcinogens". Therefore reagent concentrations and test sample volumes, have to be kept to the minimum and the waste precipitates disposed of carefully. In theory, given the very low solubility product of lead chromate ($1.8 \times 10^{-14} \text{ mol dm}^{-3}$) very dilute test reagents should suffice. Also lead ions should be detectable at very low concentrations. In practice however, we found that levels of the order of 10^{-2} to $10^{-3} \text{ mol dm}^{-3}$ were required to produce a yellow precipitate which would be detectable by pupils. In our own 'in vitro' demonstrations we use 1 or 2 cm^3 test samples of 10 M lead nitrate solution and dropper quantities of the chromate reagent.

(b) dithizone reagent

Dithizone is a somewhat more sensitive reagent than potassium dichromate solution. However the solvent used should be the less harmful 1,1,1, trichloroethane rather than the tetrachloromethane (carbon tetrachloride) usually quoted in texts. We also suggest that you ignore the advice, given in a number of texts, to use cyanide ions to mask the effects of other heavy metal ions. Dithizone in 1,1,1, trichloroethane gives a green solution. On addition to an aqueous sample polluted with lead it forms a distinct red upper layer. Once again only very small volumes of test sample and reagent (drops) are required. A suitable concentration for the dithizone solution is 3 mg in 100 cm^3 . A little will thus go a long way and we recommend purchase of only 1 g. or so of 'Analar' grade (e.g. BDH Cat.No. 10104 2U 1 g. £3.30). The reagent bottles of dilute dithizone solution should carry an "Irritant" hazard warning label.

Despite the toxicity of the reagents used; with dilute solutions, small scale methods and common-sense precautions, these lead testing activities are, in our view, acceptable at school level.

Reference:

- [1]. "People and Resources - Teachers' Guide", Evans, 1975, ISBN 0 237 29098 7.
- [2]. "Breathing Space" - People and Resources Series, Evans, 1975, ISBN 0 237 29095.

* * * * *

SAFETY NOTES

Hydrogen cylinder incident

The timing of events is often odd enough to make one believe in the supernatural. Just as the work on the "Chemistry Notes" article, which follows and which concerns the burning of hydrogen was being concluded; there came a report from a school of an unpleasant incident involving a hydrogen cylinder.

An experienced technician was filling balloons with hydrogen from a cylinder when the stream of gas ignited to produce a large flare. There had been no obvious sources of ignition in the room.

Subsequent examination showed the regulator to be quite dusty and to have traces of a black oily substance coming out of it. BOC were contacted and they re-emphasised the need for careful storage and use of regulators. Dust particles in a fast stream of hydrogen can give rise to static which will ignite the gas. Valves should be opened only slowly.

Fortunately no-one was hurt by the flame, but a patch of paint on the wall opposite was blistered. We would emphasise that even in this incident there was little hazard other than that of fire. The access to the cylinder valve was not impeded by either the flame or by furniture and the technician simply turned off the supply of hydrogen. Similar incidents have occurred with piped gas supplies when the bunsen tubing came adrift at either the tap or the burner. Is methane any less flammable or explosive than hydrogen?

Incidentally BOC supply excellent data sheets on the handling of hydrogen, oxygen, nitrogen, carbon dioxide and many other gases. These are available from your nearest depot or from the address supplied on the inside front cover.

* * * * *

CHEMISTRY NOTES

The burning of hydrogen

This single activity has, over the years, repeatedly hit the headlines as occasionally things went awry. The reason for burning hydrogen is usually either to produce and identify the product of combustion or to safely remove the excess of hydrogen during the reduction of metal oxides. In nearly every case these activities are carried out as a teacher demonstrated experiment.

The cause of the explosions is almost always the incomplete displacement of that air initially present in the apparatus, or by the accidental introduction of air through a poor connection e.g. via a badly fitting bung which may become momentarily dislodged. The use of a thistle funnel on the generating flask can lead to the entrainment of small bubbles of air during addition of acid and the use of a dropping funnel has been recommended by some.

Metal and acid (impure zinc + dilute sulphuric acid) mixture does not produce hydrogen at a high rate. By the time the air has been displaced and the hydrogen lit at the end of the combustion tube, the rate of reaction will have fallen. The small flickering flame does not then inspire great confidence in the safety of the arrangements. Some additional acid is needed to boost the flow rate.

Most Education Authorities south of the border do not permit the burning of hydrogen unless it has come out of a cylinder. The thinking behind this is that the faster flow achievable from a cylinder will flush out any air and thus overcome such problems associated with using "chemically generated" hydrogen. This does seem eminently sensible. The penalty is the need for the extra precautions in use and storage of hydrogen cylinders. [See previous column for a report of an accident involving a hydrogen cylinder].

If your Regional or Islands Authority does not permit the use of hydrogen cylinders and your only

source is the reaction of zinc and acid, then there are a number of simple steps which can be taken to reduce the likelihood of a flashback and in the event of an explosion, of containing any debris and shrapnel.

1. Use two safety screens -one for you as well as one for the pupils.
2. Bungs must snugly fit the flask mouth; those with a steep taper are more easily dislodged.
3. As much as possible of the glassware and certainly the gas generating flask should be contained in a strong wooden box as shown in Fig.1. A round-bottomed flask will certainly be stronger than a flat-bottom type. A simple ring support for this can be fashioned from an old waste sheet of expanded polystyrene or from the base of a plastic 'Coke' bottle.

Containment box

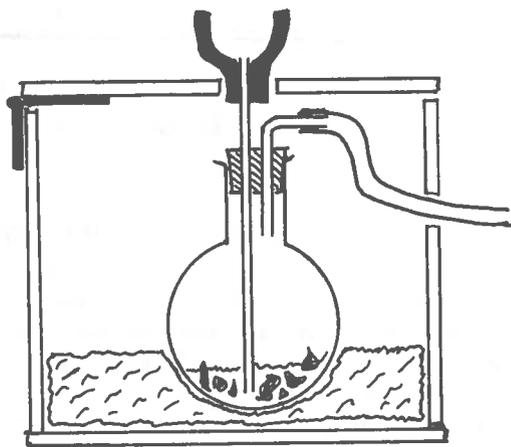


Fig.1.

Perspex window(s) 6mm thick give a front, and if required a rear, view of the reaction flask. The only part of the generator outwith the box is the soft 'polythistle' funnel and in the event of an explosion this would fly harmlessly upwards. The delivery tube is of either rubber or plastic tubing and exits through a small hole in the side;

care is needed to ensure that this tubing is not accidentally nipped.

The dimensions are not critical but should be made to fit the flask you are using -probably a 100 cm³ or 250 cm³ flat bottomed pyrex type. Given here are the dimensions for a 100 cm³ RB flask. The walls, apart from the perspex or better still a polycarbonate window, were of 6 mm ply, 125 mm wide X 150 mm high. The floor and lid were 125 mm square and four internal corner pillars were fitted. A small hole made in the side of one wall takes the delivery tube. A 12 mm diameter hole in the centre of the lid allows the Polythistle funnel to be fitted after the lid has been closed.

Access to the flask is by means of a hinged lid. When this is closed, the stem of the funnel tube is sited just below a hole in the lid through which the polythistle tube can be fitted.

The thistle funnel is used here in spite of the criticism made of it above, because the alternative is a glass dropping funnel which would protrude well above the flask. In investigations carried out in the Centre it was found that the occasional, very small bubble which was carried into the generating flask did not produce any explosions. The author, and many other teachers over the years, has used thistle funnels whilst generating hydrogen without any catastrophe. Polythistle funnels are available from several suppliers e.g. Griffins (Cat. No.FPM-970-G and priced at £3.40 for 6).

4. Even if a plastic bottle is used it should still be enclosed inside a strong container. Small flying pieces of plastic which may become embedded under the skin can give rise to later health complications.

Floppy or flexible plastic bottles have another disadvantage in that any slight movement may slightly compress them and the subsequent re-inflation may draw in some air.

5. A faster flow of hydrogen can be obtained if (i) a generous amount of 'coppered' zinc is used to give a larger surface area and (ii) the strength of the acid is increased. 3M sulphuric or 6M Hydrochloric acid are suitable strengths.

Software

That part of the software which waits for a button being pressed has been written in assembly language in order to take advantage of the speed of execution to be able to discriminate between two buttons being pressed at almost the same instant.

Three of the user port's data lines (PB0, 1 and 2) are configured as input lines, three (PB3, 4 and 5) as output, and two are unused, but are also configured as outputs. The software which does this is

```
?&FE62=&F8
```

where the hexadecimal number &F8, representing a binary number 1111 1000, is written into the data direction register B (DDRB) at address &FE62 (in line number 30). Also at this line number 0000 0000 is written into the output register B (ORB) to ensure that the indicator lights are off at the beginning of the program.

The label 'store' is given to a memory address (&0071) where a temporary record of which button had been pressed is passed from the assembly language to the BASIC program. The code used to identify each house is as follows

house name	binary value in 'store'	decimal value of 'X'
Charteris	0000 0001	1
Douglas	0000 0010	2
Wemyss	0000 0100	4

What technical interest there is in the system exists in the assembly language part. This is described on a separate page.

In operation you will find that the switches are disabled for five seconds after one has been pressed. In the event of two being pressed simultaneously, two lights will go on together, but in practice this has only been observed when contestants hold down the switches continuously over a long period.

Sources of components from two suppliers are given below.

item	Farnell	£	RS	£
darlington driver	ULN2003N	1.14	307-109	1.30
bulb, MES, 6.5V, 0.3A	G501	0.139	586-194	1.60 for 10
pushbutton switch	146-244	0.97	336-747	0.89
cap for switch	146-245	0.039	not required	

Assembly language program The execution of this program is explained by means of a particular example; in the example the first button pressed is Douglas, that is the button connected to the VIA input register bit 1 (PB1). Therefore bit 1 is cleared, bits 0 and 2 remain set.

The contents of the accumulator are shown against each instruction. The "&" symbol represents a "#".

instruction	accumulator	notes
.loopLDA &FE60	x x x x 1 0 1	read the VIA input register (IRB at address &FE60); the contents of this register are copied into the accumulator
AND &&07	0 0 0 0 0 1 0 1	perform a logical AND on the accumulator using bit pattern 0000 0111 as the mask; this lets us ignore bits 3 to 7
CMP &&07	0 0 0 0 0 1 0 1	the zero flag (Z) in the processor status register is set if the difference between the accumulator and 0000 0111 is zero (if zero then Z=1; if non zero then Z=0); in this instance the difference is non zero, therefore Z=0
BEQ loop	0 0 0 0 0 1 0 1	branch to loop on Z=1; therefore branch not followed
EOR &&07	1 1 1 1 1 0 1 0	perform a logical EXCLUSIVE-OR on the accumulator using bit pattern 0000 0111 as the mask; this inverts bits 0, 1 and 2
AND &&07	0 0 0 0 0 0 1 0	perform a logical AND on the accumulator using bit pattern 0000 0111 as the mask; this clears bits 3 to 7
STA store	0 0 0 0 0 0 1 0	save record of which button was pressed for future use in the program
ASL A	0 0 0 0 0 1 0 0	shift the accumulator left by one bit
ASL A	0 0 0 0 1 0 0 0	as above
ASL A	0 0 0 1 0 0 0 0	as above
STA &FE60	0 0 0 1 0 0 0 0	write this bit pattern into the VIA output register (ORB at address &FE60); this sets bit 4 of ORB and thereby puts on an indicator light for Douglas

Listing - BASIC program

```
10 MODE7
20 DIM input 40
30 ?&FE62=&F8: store=&71: ?&FE60=&00
40 PROCassembly
50 PROCintroduction
60 REPEAT
70   PROCmonitor
80   UNTIL FALSE
90 END
100
110 DEFPROCassembly
120 FOR pass=0 TO 2 STEP 2
130   P%=input
140   [ OPT pass
150   .start SEI: LDA &00: STA store
160   .loop LDA &FE60: AND &07: CMP &07
170   BEQ loop
180   EOR &07: AND &07: STA store
190   ASL A: ASL A: ASL A
200   STA &FE60: CLI: RTS
210   ]
220   NEXT pass
230 ENDPROC
240
250 DEFPROCmonitor
260 CALL start
270 CLS: X=?store
280 IF X=1 THEN X$="Charteris" ELSE IF X=2 THEN X$="Douglas" ELSE X$="Wemyss"
290 PRINT TAB(16,8) "first is ";X$
300 SOUND 1,-15,X*40,10
310 PRINT TAB(4,20) "To end program - press <escape> when light is on"
320 pause=TIME+500
330 REPEAT UNTIL TIME>pause
340 ?&FE60=0
350 PRINT TAB(4,10) "Ready for next question"
360 ENDPROC
370
380 DEFPROCintroduction
390 CLS: PRINT TAB(2,8) "The system identifies the first on"
400 PRINT"the button"
410 PRINT"Ready to respond - if wired up"
420 ENDPROC
```

PHYSICS NOTES

The fine-beam cathode ray tube

An American journal, "The Physics Teacher", has run a series of articles on investigations with a Teltron, fine-beam, cathode ray tube. We would like to draw your attention to this series because the description of the effects which can be studied is so simple and clear and yet imbued with interesting physics that the series could be extremely useful even to schools who do not possess this apparatus.

There are eight articles in the series (one unpublished at the time of writing this Bulletin article). Topics covered include:

- why is the beam fine?
- an investigation of the strength and direction of the earth's magnetic field
- two methods for the determination of e/m
- electromagnetic focussing
- the confinement of charged particles with a description of how to "put a cork on a magnetic bottle" such as to confine a plasma
- spectroscopic analysis of the beam

As it is not widely available in this country photocopies of the series on the fine-beam cathode ray tube can be obtained from SSSERC, price £1.50, by interested teachers in Scotland.

Permission to offer this service has very kindly been granted by the author, John Le P. Webb, of the University of Sussex. He does ask the teachers concerned, however, that they restrict their own copying from the supplied photocopies to the specific details required for any one lesson or project. That is to say he does not want class sets of the entire notes handed out, but a class set of notes on the measurement of e/m would be OK.

Nuclear emulsions

We recently had an enquiry on nuclear sensitive film. Such special films are supplied by Kodak and Ilford, but are more or less unsuited to school use on account of cost, long delivery delay and short storage life, in that they become fogged after a few months by cosmic radiation.

There is, however, one approach in this field that schools might realistically enter. Ilford produce a range of nuclear sensitive gels from which one can prepare film or plates for experimental research. The minimum quantity these are supplied in is 50 ml with 2-3 week delivery and 3-6 month shelf life. Its not cheap at £41.65 for 50 ml, but SSSERC would be willing to purchase this emulsion at the beginning of a session and sell it off in smaller batches if there was a demand from schools. We await requests for this service.

A useful product information booklet called "Nuclear research materials" is available, free, on request from Ilford. This booklet, as well as outlining procedures for working with nuclear gels, provides information on applications. In particular there is a description of the process called autoradiography, the study of fluid transport within living substance by means of a radioactive tracer. However this subject, interesting though it is, would involve the use of open sources and is thereby impractical in schools.

Nicad cells - Help required

From time to time we are asked for advice on nickel-cadmium (nicad) cells; such enquiries asking whether the initial outlay in cells and chargers is likely, as data sheets would indicate, to pay off against the continual replacement of non-rechargeable cells. In order to be in a position to give sound advice we require the statistical evidence based on a large sample.

We would be very grateful, therefore, if you have experience of operating nicads, especially in Sl electricity, to find the time to write in to us with details.

ELECTRONICS NOTES

Shaft encoder circuits

Abstract

A technical description of two shaft encoder systems is given. Whilst being useful in their own right as notes on instrumentation the main purpose is as applications of some common electronics principles.

The obvious version of the encoder, with straight binary coding, is found to work poorly and a Gray-coded version is introduced to get over this difficulty.

Introduction

When the analogue and digital S.C.D.S. memoranda (Refs. 1 and 2) were published, there was sufficient material therein which was new to most teachers that the lack of applications may not have mattered overmuch. However we are now, two years after publication, getting requests from teachers for applications for both these courses and the purpose of this article is principally to meet, in part, this demand.

An optical shaft encoder is a transducer which gives a digital output which corresponds to angular position. Two applications are motor position control and wind direction indication.

Standard 74 TTL logic chips can be used in the circuits which are described. However this family has become outdated and in consequence is getting expensive. We therefore recommend the use of the 74HCT series; these are CMOS devices which operate at TTL speed and at TTL switching threshold levels.

One can in fact mix 74HCT and 74LS TTL devices in circuits; this is one of the design features of the 74HCT family.

In the text and diagrams reference is uniformly made to the 74HCT series, but it should be

understood that the circuits will work perfectly well with standard 74 TTL components. However 74LS devices, another series altogether, should not be used to drive the bar graph displays unless you can tolerate very low light levels. The reason is that the 74LS series has a low, maximum recommended, sink current of 8 mA (compared with 16 mA for standard 74 TTL and 13 mA for 74HCT). The bar graph display is driven at 13 mA in our circuits, a current which is somewhat under the 20 mA recommended specification for such a display.

Both circuits can be constructed either temporarily, on prototype board, or permanently; if the latter then preferably by wire wrapping, for ease of construction. This technique has been described in SSSERC Memo 1 (Ref.3).

System 1

A primitive shaft encoder can be fashioned out of the binary to decimal decoder, 74HCT42, (Ref.2 p.25). A block diagram of the system is shown in Figure 1.

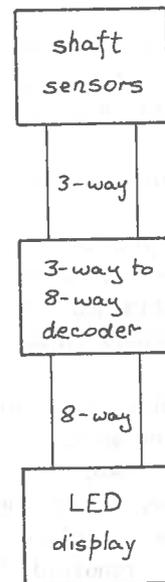


Fig.1 - System 1 block diagram

Examining the function table of the binary to decimal decoder (Table 1) it can be seen that it may be used to give 3-bit resolution. Each of the eight possible combinations of input levels makes one of the eight outputs low, while the other seven outputs are high.

inputs				active output low
D	C	B	A	
L	L	L	L	0
L	L	L	H	1
L	L	H	L	2
L	L	H	H	3
L	H	L	L	4
L	H	L	H	5
L	H	H	L	6
L	H	H	H	7

Table 1 - part of 74HCT42 decoder function table

Input A is the least significant bit. Input D is the most significant bit and is unused in this application. It is therefore tied low.

In the schematic diagram (Fig.2) of the 74HCT42 the outputs are marked by a small circle. This signifies that they go low when active. That is at any one time nine of the ten outputs will be in a quiescent state at +5 V, the tenth output will be active and at a potential of 0 V.

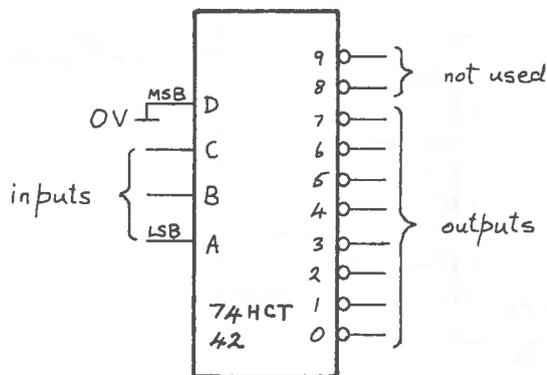


Fig.2 - 74HCT42 decoder schematic

Thus the 74HCT42 can be used to drive a L.E.D. bar graph display directly, only one L.E.D. being on at any time. The active output of the decoder goes low, sinking the current from the lighted bar.

The rotating shaft has three circular vanes (Fig.3), labelled according to the inputs of the 74HCT42, mounted on it. These vanes, from most to least significant, have respectively 1, 2 and 4 slots, the slots being carefully aligned when the vanes are being assembled on the shaft.

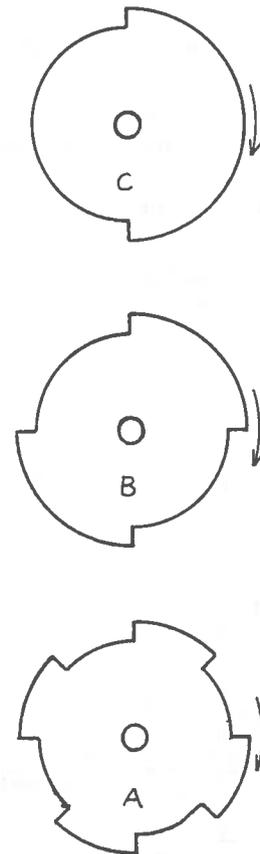


Fig.3 - encoder vanes

The rotating shaft with vanes is thus a "concrete" example of analogue to digital conversion.

Slotted opto-switches are used as sensors of vane position, three being required. Again care is

required to align these sensors with respect to one another and the vanes.

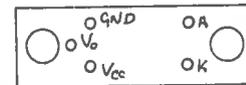
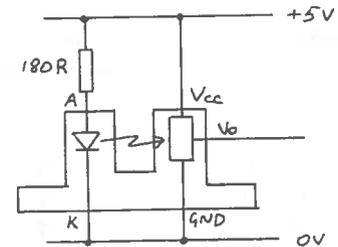
Of the two types of slotted opto-switch in the RS catalogue, that with logic (stock number 304-560) is preferable in that it interfaces directly with TTL or CMOS digital chips.

The only additional component required with the device is a dropping resistor to connect in series with the light emitting diode. The technical specification of this diode is:

- forward voltage at $I = 20 \text{ mA}$ 1.5 V
- maximum forward current 50 mA

From these figures, we can calculate the resistance, R , of a suitable dropping resistor. The power rail voltage is 5 V . With a p.d. across R of 3.5 V and a current through R of 20 mA , the resistance is $3.5/0.02 = 175 \text{ ohms}$. The nearest preferred value is 180R .

Both pin-out and wiring diagrams for a slotted opto-switch are shown in Figure 4.



pin view of sensor

Fig.4 - slotted opto-switch (RS no. 304-560)

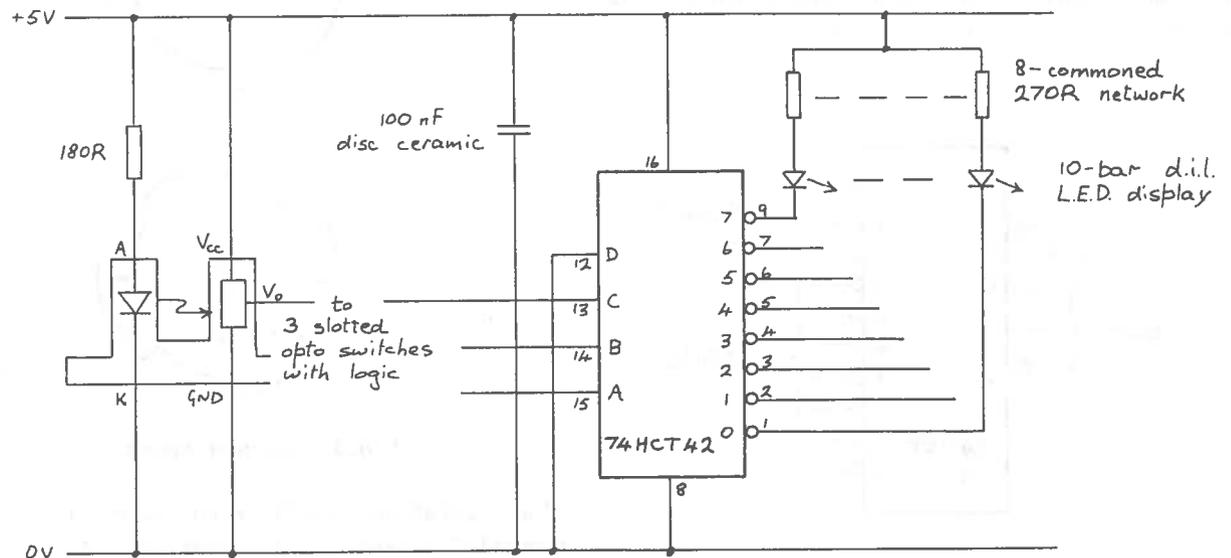


Fig.5 - System 1 circuit diagram

The outputs from the three slotted opto-switches should be taken directly to the respective inputs, A, B and C, of the binary to decimal decoder, 74HCT42.

A 10 bar d.i.l. array with 10 individual L.E.D. elements is used as the output display. Dropping resistors are required for each element of this display and the optimum value can be calculated by the method shown above. 8-commoned resistors may be used to save time during construction and the suitable preferred value is 270R, which gives a typical forward current of 12.5 mA.

The L.E.D. array should be mounted in a 20-way d.i.l. socket. The anode is marked by a chamfer, but for those who are not good at chamfer spotting, and this one is subtle, we suggest inserting it any-way-round; if it doesn't light turn it the other way round.

A schematic diagram of the circuit is shown in Figure 5. Power should be taken from a 5 V regulated supply. The 100 nF decoupling capacitor is there to remove transients on the power rail.

In practice the system cannot be used as a working device. Its defect is that it relies on simultaneity at transitions between one position and another. For example when changing from 101 to 110 the data input may temporarily become either 100 or 111 depending on whether bit 0 or bit 1 changes first. Thus the output either flips to 4 or 7 in between changing over from 5 to 6.

This defect is overcome by using a different form of coding on the rotating shaft. Instead of using straight binary, one has to use **Gray code**. The distinguishing feature about Gray code as opposed to straight binary is that only one digit changes when a transition is made from one encoded value to a neighbouring value.

System 2

The second system uses a 4-bit Gray code sensor of shaft position. The block diagram is shown in Figure 6.

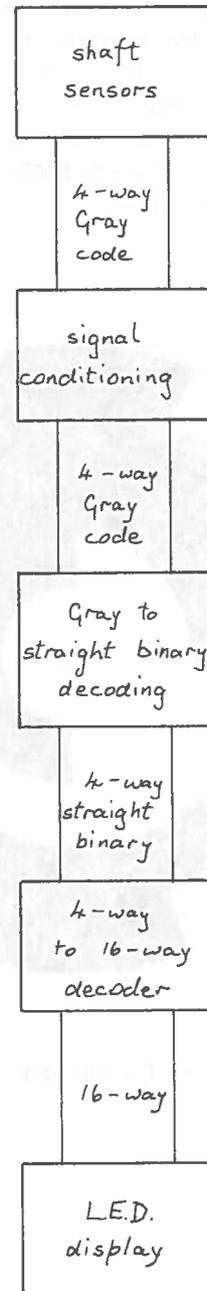


Fig.6 - System 2 block diagram

Sensor

The sensor consists of a disk mounted on the rotating shaft and four miniature, reflective opto-switches. The switches face the disk at an optimum distance of 1.2 mm. The disk is opaque with black and white markings (Fig.7) and the diameter is 80 mm as shown. We suggest, if wanting to make such a disk, you photocopy our drawing and paste the paper cutout on a suitable backing.

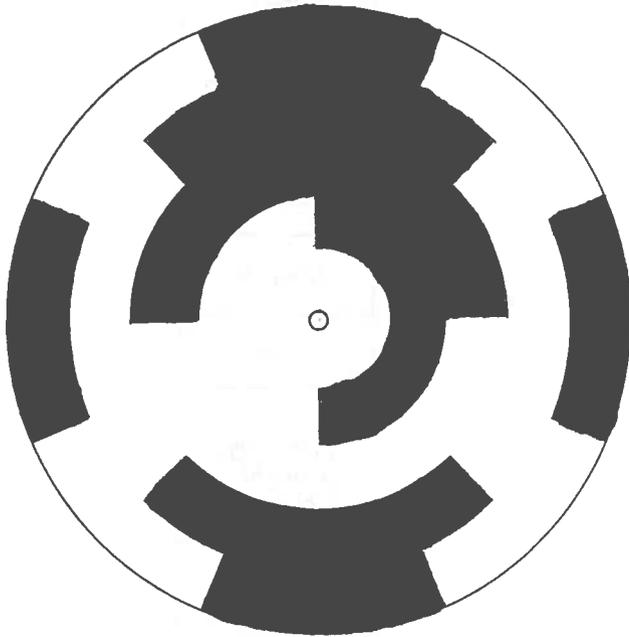


Fig.7 - encoder disk

The reflective opto-switch contains an infra red L.E.D. and phototransistor sensor. The relevant specifications for the L.E.D. are

forward voltage	1.4 V
Maximum forward current	50 mA

In this application, with the opto-switch facing paper, we have chosen to drive the L.E.D. quite hard at 30 mA, so the dropping resistor works out at 120R (again +5 V power rail). The collector current of the phototransistor is kept low by using a 10K resistor between the collector and +5 V rail.

The pin-out and wiring diagrams for the reflective opto-switch (RS stock number 301-606) are shown in Figure 8. Switch logic is

facing white paper	output is low typical value is 200 mV
facing black paper	output is high typical value is 3 V

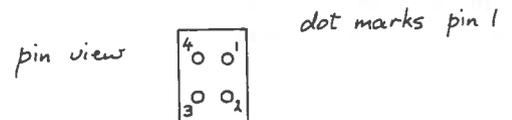
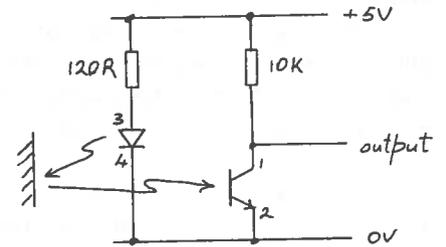


Fig.8 - reflective opto-switch

The output voltages from the sensor depends on several factors: reflectivity of surface, separation distance between opto-switch and reflector, angle of mounting. These factors influence each opto-switch signal in a different way, dependent on the mounting of the switches and the particularities of the disk surface.

At a signal transition there is a gradual rather than sudden change in voltage.

Signal conditioning

Whilst the output from the reflective opto-switch is in a sense digital, it is not suitable for driving either TTL or CMOS digital devices (the following notes refer solely to TTL switching levels and therefore are applicable to the 74HCT family).

When taking a TTL input low the signal must be below +0.8 V; when taking a TTL input high the signal must exceed +2.0 V. The extreme limits are 0 V and +5.2 V. The output from a reflective opto-switch cannot be guaranteed to, and in all probability will not, keep out of the prohibited band between +0.8 V and +2.0 V. We therefore require a signal conditioning stage between the sensor subsystem and processing subsystem where once again HCT devices, which operate at TTL switching levels, are used (Fig.9).

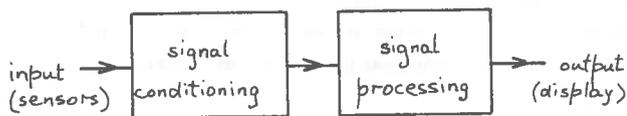


Fig.9 - subsystems block diagram

The signal conditioning subsystem is analogue, the signal processing is digital.

A Schmitt trigger based on an operational amplifier is used for signal conditioning

(Fig.10). Readers may wonder why not use a digital Schmitt trigger, e.g. 7413 or 7414. However the threshold levels of these, typically 1.7 V and 0.9 V, are not suitable because the output voltage from an opto-switch may, in some circumstances, not travel through one or other of these thresholds.

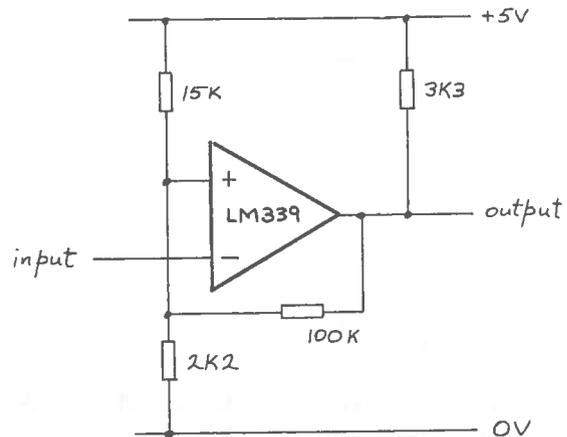


Fig.10 - Schmitt trigger circuit diagram

A comparator-type op amp is used, LM339N. This is a quad device in a 14 pin d.i.l. package. It has an open collector output and requires a pull-up resistor on the output. The other point to note is that it runs off a single rail supply, in this case 5 V. Thus when the output saturates it will be at either +4.8 V or +0.25 V and is therefore compatible with TTL switching levels.

The threshold voltage is set at +0.64 V by means of 2K2 and 15K resistors in a potential divider network. The non-inverting input is connected to this point and the input signal is applied to the inverting input. When the input is below the threshold voltage the output is high (+5 V); when the input is above the threshold the output is low (0 V).

A large value resistor is connected between the output and non-inverting input. This modifies the threshold point and can be explained by potential division as follows.

Suppose the input signal is 0 V. The comparator output is therefore high and the potential divider network which controls the threshold voltage is equivalent to the circuit shown in Figure 11.

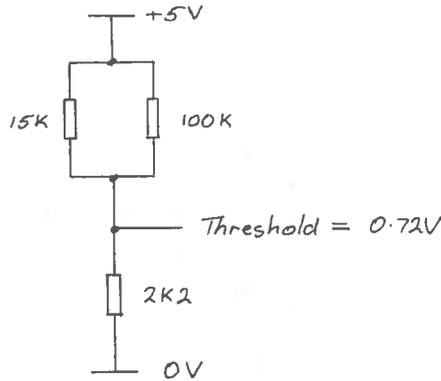


Fig.11 - equivalent circuit of threshold network with comparator output high

The threshold voltage can be seen to be 0.72 V.

When the input rises above this 0.72 V threshold the comparator output goes low and the equivalent circuit for the potential divider network changes to that shown in Figure 12.

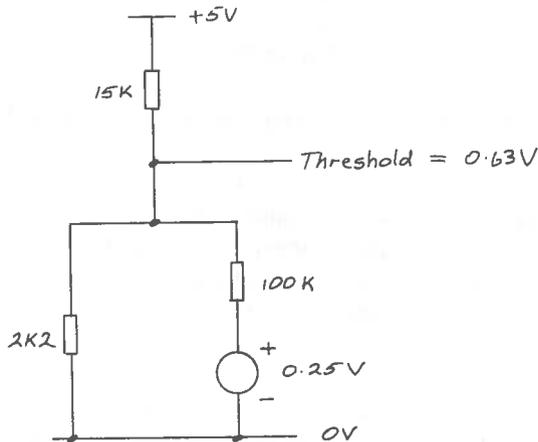


Fig.12 - equivalent circuit of threshold network with comparator output low

A simplified equivalent circuit might show the 100K resistor tied directly to ground. However, because the threshold is very close to ground, it seems necessary to include the effect of the 0.25 V voltage source at the output of the op amp in our equivalent circuit.

This makes the analysis of the network not so simple. The threshold voltage, by measurement, is 0.63 V.

The system displays an effect called **hysteresis**. This effect prevents multiple triggering when a slow changing or noisy signal moves through the threshold because a rising signal encounters a higher threshold than a falling one. It should be obvious that the proportional size of hysteresis is controlled by the respective values of the potential divider and feedback resistors.

The signals from the four reflective opto-switches each require signal conditioning. Therefore all four elements of the quad comparator are put to use as Schmitt triggers and their outputs are ready for signal processing.

Signal Processing

The signal from the signal conditioning stage is 4-line Gray code. There are two processing stages:

4-line Gray code to 4-line straight binary

4-line to 16-line decoder

Gray code has the property that only one bit changes at a change of encoded value (Table 2). This does not necessarily happen with straight binary.

decoded value	Gray code	straight binary code
0	0000	0000
1	0001	0001
2	0011	0010
3	0010	0011
4	0110	0100
5	0111	0101
6	0101	0110
7	0100	0111
8	1100	1000
9	1101	1001
10	1111	1010
11	1110	1011
12	1010	1100
13	1011	1101
14	1001	1110
15	1000	1111

Table 2 - Gray and binary encoded values

Three exclusive-OR gates are used in the Gray to binary, encoding conversion. The output of the ex-OR gate (Fig.13) is 1 if the input states are different (Table 3).



Fig.13 - exclusive-OR logic diagram

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Table 3 - exclusive-OR truth table

A 74HCT86 quad, 2-input, exclusive-OR package is used. The conversion schematic is shown in Figure 14. Readers might like to devise 2-, 3- and 5-line Gray codes and a method to convert into straight binary.

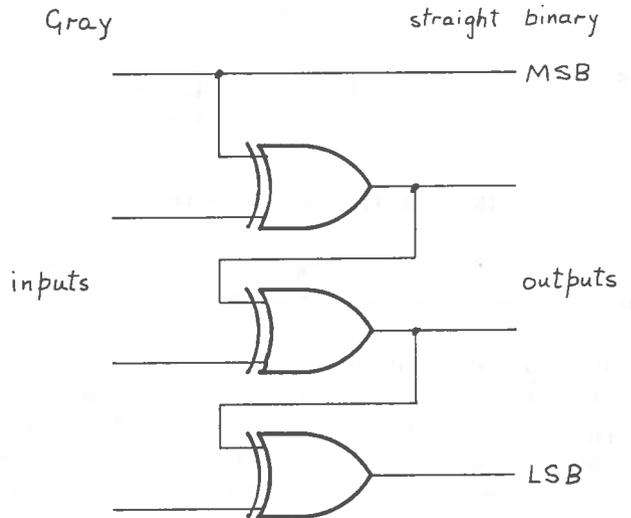


Fig.14 - 4-bit Gray to binary schematic diagram

The 4-bit, straight binary output is decoded using a 74HCT154 4-line to 16-line decoder. This is in a 24 pin d.i.l. package.

The four inputs of the device are labelled A, B, C and D, A being least significant and D being most. Two additional inputs, G1 and G2, disable the device if any one is pulled high.

The outputs are high in their quiescent state and low when active. This is suitable for sinking current from an L.E.D. display (Fig.15).

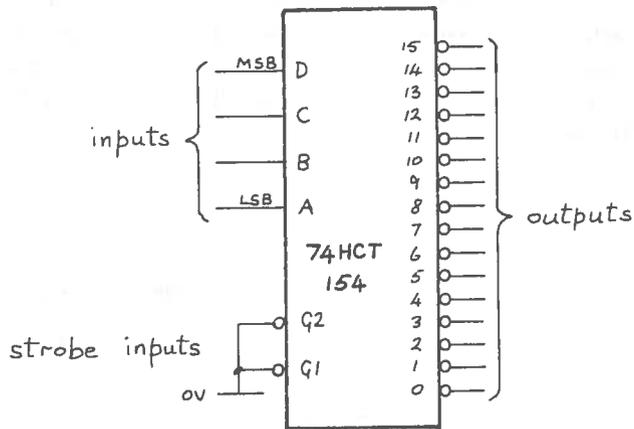


Fig.15 - 74HCT154 decoder schematic

Two 10-bar, d.i.l. arrays with L.E.D. elements are used for the display, mounted end on.

The complete circuit for the shaft encoder system is shown in figure 16. A 5 V regulated supply should be used for power and a 100 nF disk ceramic capacitor should be connected between the power rail and ground to suppress transients in the supply.

Final comment

It is characteristic of courses on electronics that digital is separated from analogue. It is often the case though, and here we are writing from hard-won experience, that both branches are jointly used in many electronic systems. This is a point worth bearing in mind for the planning of courses and project-based work.

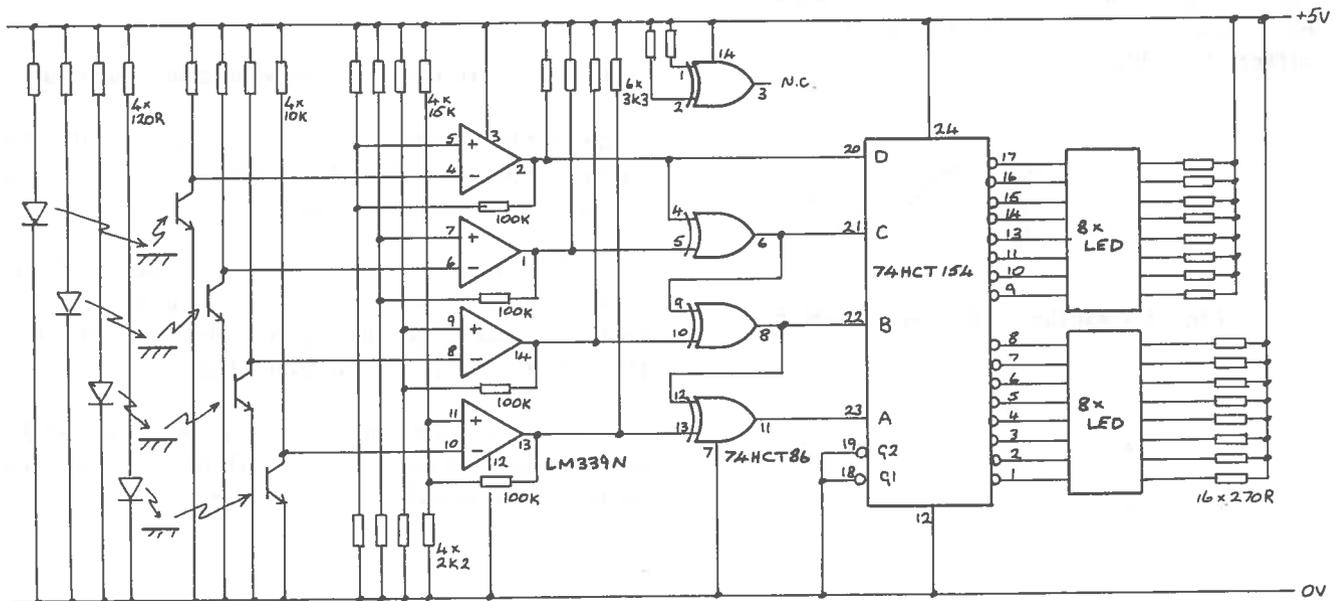


Fig.16 - System 2 circuit diagram

Components

Two suppliers are given, Farnell and RS Components. Items are noted once, under the cheaper supplier at the time of writing.

item	cat.no.
Farnell	
B.C.D.-decimal decoder, 74HCT42	PCF74HCT42P
exclusive-OR, quad 2-input, 74HCT86	PCF74HCT86P
decoder, 4 to 16 line, 74HCT154	PCF74HCT154P
quad comparator, LM339N	LM339N-NSC
8-commoned resistors, 270R	143-833

RS Components

slotted opto-switch with logic	304-560
miniature reflective opto-switch	301-606
10-bar d.i.l. L.E.D. array	588-027

Please note that 74LS devices are not suitable for directly driving the L.E.D. displays mentioned above.

References

1. "Analogue Electronics for Higher Grade Physics", Memorandum no. 53, SCDS.
2. "Digital Electronics for Higher Grade Physics", Memorandum no. 59, SCDS, 1983.
3. SSSERC Memo 1, SSSERC, 1984.

* * * * *

TRADE NEWS

New CRO

New from Scopex is a dual trace oscilloscope, 14D-15, which features d.c. to 15 MHz bandwidth, 5 mV sensitivity, and 5 inch tube (100x80 mm display).

Of especial interest is the facility to add a function generator, which is bolted underneath the 'scope chassis, and regulated, dual power supply, +1.5 V to +15 V, 1 A; this latter item being bolted on top of the 'scope chassis. One thus has the basis of an electronics workstation all within one instrument.

Prices (sigh) of these options are

Scopex dual trace CRO, 14D-15	£325
Scopextra FG, 14D-15 with function generator fitted	£425
Scopextra FG.PS, 14D-15 with function generator and dual power supply	£545

'Scope repairs

New to us is the firm Mendascope who specialise in the repair and recalibration of all makes and models of oscilloscopes including Scopex, Safgan, older Tektronix and Telequipment. The firm uses a specialist carrier who, it is claimed, will collect the instrument 3 days after you make a 'phone call to Mendascope. A free estimate is sent out and on agreement, repair and recalibration are carried out followed by a 24 hour soak test. Mendascope are located in Bedford but claim a "nationwide" coverage. Further information and indications of typical charges, should be available from the address given on the inside front cover.

Polycarbonate sheet

This is a relatively expensive material but very useful for making explosion screens (see "Chemistry Notes" for one such application). It is also handy for re-glazing fume cupboards. Design Note 29 "Fume Cupboards in Schools" recommends 4 mm thick polycarbonate for explosion screen glazing of fume cupboards.

One of the cheapest sources we have found for such materials is Visijar Tuckers Ltd. of Cumbernauld, who were brought to our attention by the Rudolf Steiner School, Edinburgh. 4 mm thick sheets sell at ca.£35 per square metre and are available in a variety of sheet sizes viz: 3 x 2.05 m, 2.44 x 1.22 m and 2.05 x 1.25 m. This firm also sells Perspex in imperial sheet sizes at competitive prices by commercial standards. Their 4 mm thick Perspex is about £20 per square metre and the 6 mm ca.£30. However this represents a good buy only if you require large sheet sizes, other sources are cheaper for offcuts.

Ultra-violet news

Camlab's latest chromatography catalogue contains details of a 3 W, 'pocket', UV lamp. This has the major part of its UV output in the short wave, 254 nm, region with some long wave at 367 nm. Product code number for the battery powered model is UVP 020B at £22.90. A mains model, UVP 010 is also available at £17.50.

More powerful lamps for chromatographic uses are on offer from UVP Ltd. Their shortwave, 254 nm, UVG-11 model is currently £95 with the dual, 254/365 nm UVGL-15 type costing £73. Also available is a very neat lamp stand for these models. Coded as J-124, this stand costs £20.

* * * * *

CONTENTS

JUNE, 1985

	Page
Introduction	
-S.S. Susan Goodbye!	1
-Summer Saturdays	1
-Royal Society of Chemistry Research Fund	1
-Erratum Bulletin 145	1
-Cost Index	2
-Retiral Tribute J.A.R. Hughes OBE BSc	3
Cleapse Guides	3
Biology Notes	
-Pollution - a practical pot-pourri	4
Safety Notes	
-Hydrogen cylinder incident	6
Chemistry Notes	
-The burning of hydrogen	6
Interfacing Notes	
-Quiz game control	9
Physics Notes	
-The fine-beam cathode ray tube	13
-Nuclear emulsions	13
Electronics Notes	
-Shaft encoder circuits	14
Trade News	24