SCOTTISH SCHOOLS SCIENCE EQUIPMENT RESEARCH CENTRE

Bulletin No.119. March, 1980.

Contents

Introduction

We have recently embarked on what is a new area of work for us, the organisation of practical workshops for technicians. We have held two of these, one on microscope repair and maintenance, and one on building integrated circuits, both for Lothian Region. In the first, the technicians brought along a few simple tools, and a microscope from their school. Under our guidance the microscope was taken apart and re-assembled. Some organisation was necessary to ensure that everyone did not bring the same model, and we probably learned as much as the technicians as a result of having first hand experience of the things that can happen to a microscope in a school.

The workshop on integrated circuits attempted to show technicians how a circuit diagram using integrated circuit chips can be converted to a working piece of hardware, using the Veroboard system of wiring. Again the technicians brought along tools, chiefly a soldering iron and wire cutters, and the region is expected to pay £1 per participant for the cost of the components. Experience suggests that it is not realistic to expect that the group will achieve this task in a single two hour session, and in the case of Lothian Region we have arranged a follow-up session, to complete the project. The objective is to give technicians the confidence to tackle Veroboard wiring, and in the longer term to have the satisfaction of making something which works. At the time of writing two six formers have just won the Young Scientist of the Year competition with a stage lighting control circuit which interfaces with a PET computer, and we know of at least one Scottish school which is building a computer from a kit. It should not therefore be beyond the capability of a school physics technician to wire up a half dozen integrated circuit chips to form a working piece of apparatus.

By the time this bulletin appears in print we hope to have another workshop session available for technicians, on the maintenance and repair of the Serviscope Minor, and the OS12 oscilloscopes.

Both types are obsolete, and present pupil(?) oscilloscopes are edging towards the £100 mark. Eventually they will all have to be replaced - for example the tube which these oscilloscopes use is no longer made - but anything which slows down their rate of demise is to be applauded. We suspect that there may be oscilloscopes in schools which are not being used because the region has selected servicing as an area for financial pruning, and the technicians lack the ability or experience to tackle the job themselves.

The workshops we have held in Lothian region were not done with any intention of favouring the technicians on our doorstep, but so that we should have the experience of what was needed while still being near enough our home base to make quick changes if necessary. The workshops are equally available to any region where the SSSERC service operates, and if a science adviser, or other person involved in the training of school technicians thinks that we can help by holding one in his area, he is invited to contact us.

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The Centre will close from Good Friday to Easter Monday, 4th-7th April inclusive.

Biology Notes

Over the years we have received a number of enquiries about hazards associated with biological stains. This has also arisen in questions following our in-service training sessions on safety. It is a difficult area. This is partly because of the use of several different trivial names for what is basically the same compound and partly because what hazards there are, frequently arise out of possible contamination of the dyestuff rather than from the substance itself. This latter point was made in our 'Hazardous Chemicals Manual' and was touched on in the article on carcinogens (1) reprinted from 'Education in Science' in Bulletin 117.

Suspicion naturally falls on microscopical stains and many other biological reagents for the very reasons that have made them useful to biologists. Any biologically active compound that combines with or acts on cellular contents or components might reasonably be treated with some suspicion. The difficulty lies in deciding what degree of hazard exists and whether it is sufficient to justify discontinuing the use of some stains and reagents. The results of our own enquiries suggest that there is no significant risk attendant on reasonable use of the stains commonly used in school biology. However we do feel that there may be insufficient awareness of the potential hazards and of the simple precautions which are needed before the use of stains could be described as 'reasonable'. A lot of stains and dyes used in biology are derivatives of aromatic amines and many are azo compounds. As the ASE convened working group on materials and processes have pointed out (1) "some azo compounds are carcinogenic but the generalisation that all are is unfounded". Most water soluble dyes and indicators are not recognised carcinogens.

However there is a possibility with some dyes that there may be contamination with carcinogenic starting materials or by products. For example, congo red is prepared using benzidine as a starting material, and impure samples of diphenylamine may contain the potent carcinogen 4-biphenylamine. Similarly the dye magenta (basic fuchsin, rosaniline) used in Feulgen staining and other procedures has not shown itself to be carcinogenic but could contain impurities which are. (The manufacture of magenta is controlled under the 1967 regulations but its use is not).

There is also the possibility that stains not hazardous in themselves may yield substances that could be harmful. For example p-phenylenediamine used in the identification of lichens (as well as in hair dyeing and colour photography) is not itself thought to be carcinogenic but could yield oxidation products (nitrosamines) that are. In any case, risks of dermatitis in sensitive subjects, and of poisoning by skin absorption, mean that this substance should be handled with care.

The examples given above point to the first rule defining 'reasonable use'.

STAINS AND INDICATORS SHOULD BE PURCHASED IN AS PURE A FORM AS POSSIBLE.

However we should not let these somewhat speculative suspicions of carcinogenic effects blind us to the more definite hazards of toxicity. A number of substances used to stain tissues and in

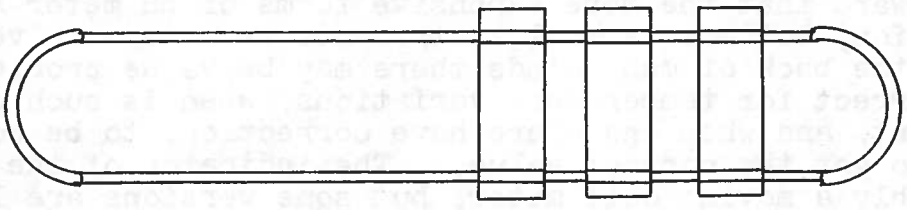
microchemical tests are toxic or irritant. Add to this the fact that they may be made up in organic solvents which degrease the skin and ease penetration, or in acid or other solvent mixtures which are themselves corrosive and we have other good reasons to handle many biological reagents with care. For example benzene-1,3,5-triol (phloroglucinol) used as a specific stain for lignin is toxic by skin absorption as well as by ingestion and is mixed with hydrochloric acid in the lignin test. Other examples of toxicity of active ingredient or solvent mixture or both can be cited - lactophenol used in the cotton blue/lactophenol recipe for testing fungal cellulose; phenol in the carbol fuchsin or Ziehl Neelsen stain; picric acid in the aniline blue-picric acid double stain. Responsible suppliers provide warnings in their catalogues on these and several other stains. However we suspect that these warnings are not always read. As yet there is no requirement for labelling these mixtures and in any case the Packaging and Labelling of Dangerous Substances Regulations 1978 are anomalous to say the least (see Bulletin 112).

It is therefore probable that many biological reagents and stains are not always treated with the respect they deserve. This leads us to our second basic rule defining reasonable use and it is an obvious one. It applies equally to other biologically active compounds such as hormones and certain enzyme preparations:

SKIN CONTACT WITH THESE COMPOUNDS SHOULD BE AVOIDED BY WEARING GLOVES AND BY USING SOUND MANIPULATIVE TECHNIQUES.

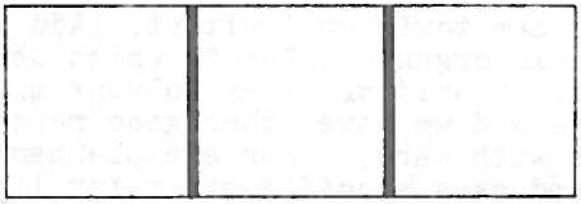
When using stains on slide mounted specimens there are two very simple aids, which can be used. These are a staining rack and a chinagraph pencil. The use of these in staining procedures has been fairly well publicised (2) but in our own experience their use is still fairly uncommon.

The staining rack consists of nothing more than two pieces of glass tube or rod of equal length joined at their ends by rubber tubing of suitable internal diameter, see below.



The length of rubber tubing used should be 80-100mm. They are adjusted to so space the glass tubes that standard 75 x 25mm microscope slides will sit comfortably across them. The length of the rack is not critical and depends upon the dimensions of the laboratory sink. The rack is placed across a sink and slides that are to be stained placed on it. In this way any excess stains go into the sink where they can be washed away and not onto the bench where they may contaminate skin or clothing.

The use of the chinagraph pencil is also extremely simple. It is used merely to draw two wax lines on either side of the central part of the slide where the smear or specimen should be mounted. The hydrophobic wax lines repel the aqueous stain and confine it to the area of the specimen. In this way the ends of the slide are kept free of the stain and a great deal of mess is avoided.



If, despite all these precautions, stains are spilled on the skin they should be washed off immediately using soap and water. Resist the temptation to use an organic solvent. The use of such a solvent may only facilitate the penetration of material absorbed on the outer layers of the skin. Unfortunately, because they are 'biological', many compounds are very difficult to remove and are often left merely to wear off. This presumably is why Baird and Tatlock have marketed the biological stain remover described in the 'Trade News' section of this Bulletin. However it proves simpler, safer and cheaper to avoid skin contact with stains, which thought prompted the writing of this article.

References

(1) 'Possible carcinogenic hazards in school science' Education in Science No. 84 September 1979.

(2) 'Micro-organisms' 1977, P. Fry, Educational Use of Living Organisms series, published for the Schools Council by Hodder and Stoughton.

Chemistry Notes

Measuring pH is a familiar routine for most teachers and technicians, as most schools possess some form of pH meter. Complications occur if the solution temperature is anything far removed from 20°C. Most users will be aware that the more expensive forms of pH meter have temperature compensation, but most school instruments seem to work very well without it. In the back of many minds there may be vague problems of how one should correct for temperature variations, when is such correction significant, and when and where have corrections to be added or subtracted to get the correct value. The indicator of the instrument is recognisably a moving coil meter, but some versions are left hand zero, so that when no current is flowing they read OpH, while others are centre zero and read 7pH when at rest. It is to lessen some of the confusion that this article has been written.

A pH meter consists of three parts; an electrode which produces a direct potential difference which is linearly related to the pH of the solution, an amplifier, and an output indicator which, ignoring digital forms of meter which are usually too expensive for a school, is a moving coil milliammeter. The relation between the input voltage V of the combination electrode, and the current i in the indicator is of the form:

$$V = m.i + c$$

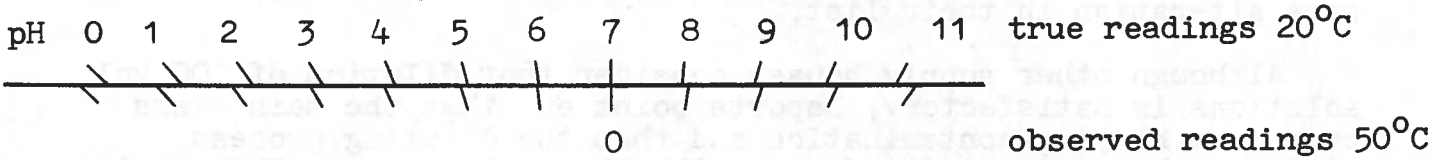
m and c are both 'constant' in mathematical terms although one or both can be varied by means of pre-set controls in the pH meter. The constant c is controlled by the buffer control, so that the value of i

can be correctly set using a buffer solution of known pH. The expensive pH meter allows one to vary the constant m, through the temperature compensation control, which makes m continuously variable. The uncompensated meter has one fixed value of m, or, if it measures mV as well as pH it will have two fixed values of m, selected by the function switch. Using a temperature compensated instrument the measurement of pH is straightforward; one simply sets the compensation control to the temperature of the solutions to be examined, and buffers as normally. It is not necessary to have the buffer solution at the elevated temperature, if one is measuring warm solutions.

In an uncompensated meter, m is fixed, and the amplifier is so arranged that every change of 58.1mV on the electrode will alter the indicator current by one unit of pH. The value of 58.1mV occurs from the constants of the Nernst equation and is true at a temperature of 20°C, at which most pH meters are calibrated. (Occasionally a pH meter is calibrated to be true at 25°C, and the manufacturer's instructions should indicate its 'base' temperature). At anything other than the base temperature the indicator scale will not be true because the redox potential which the combination electrode measures is proportional to the absolute temperature. At any temperature, a neutral solution at pH7 will have no voltage across the electrode. A solution of pH8 at 20°C will have 58.1mV across the electrode, but if the same solution is warmed to 50°C, the potential difference across the electrode becomes

$$\frac{58.1 \times 323}{293} = 64.0\text{mV}$$

The amplifier, sensing a change of 64.0mV in its input changes its indicator by 64.0/58.1 = 1.1 units of pH, i.e. the scale is now 10% in error. The amount of this error, and therefore the correction that has to be made to obtain the correct pH, will be greater the further one is from the buffer point. The difference may be clearer with the aid of a diagram of the meter scale.



The meter has been buffered at pH7, and the upper half of the scale shows the meter readings in pH. If we now place the electrode in different solutions at 50°C, the scale will move 0.1pH further than it ought to do for every unit of pH we go away from the buffer point of 7pH. The meter pointer will therefore occupy the positions shown on the lower half of the scale, instead of the 'true' values of the upper half. The effect of raising the temperature has been to expand the scale concertina fashion in both directions about the buffer point. In alkaline solutions, the pointer position will be too far to the right, and a correction must be subtracted from the observed reading to get the true pH. In acid solution, the pointer will be too far to the left, and a correction must be added to the observed reading to get the true pH.

The same is true for buffering at any other point on the scale. If the pH value being measured is to be the right of the buffer calibration point, a correction must be subtracted: if the value is to the left of the buffer point, the correction must be added. To refer again to a concrete example, suppose we have buffered the meter to pH10, and then put it in a solution of pH4 at 50°C. The solution is then 6 units of pH away from the buffer point, and the

observed reading will be 1.1 x 6 units to the left of the buffer, giving a reading of 3.4pH. A correction of 0.6pH must therefore be added to the observed reading. Similarly, if we had buffered at pH4 and were using a pH10 solution at 50°C, the observed reading would be 10.6pH, and 0.6pH would be subtracted to get the true pH.

Finally, and to confuse you still further, all the above is reversed if the solutions are below the base temperature of 20°C. Additions become subtractions and vice versa. Again it is perhaps easier to think in terms of the concertina scale, where now the concertina has been compressed about the buffer point. In going away from the buffer point the scale now does not go far enough in either direction, so that to the right of the buffer point the correction must be added.

None of these precautions is required when using the mV scale on instruments which have one. There the value of m is adjusted so that the values 0-14 on the scale correspond to voltages from 0-1400mV on the input, which is usually supplied with separate input terminals. If the meter has a 'set mV' position, this can be used like a buffer control to set the indicator pointer to any desired position with the input terminals shorted. The meter will then read 100mV per scale division from the zero position. Some meters also have a x2 scale so that the readings go from 0 - 2.8V, at 200mV per pH division.

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One of the entries in our Chemicals List dated February, 1979 suggested using 100 volume hydrogen peroxide and diluting it five times on receipt. In the light of the recent correspondence with Laporte, the principal manufacturers of hydrogen peroxide in the U.K. we intend to remove this alternative and ask teachers to make the same alteration in their list.

Although other supply houses consider that dilution of 100 vol solutions is satisfactory, Laporte point out that the main risks come from heating/contamination and that the diluting process gives another opportunity for possible contamination. They state that it would be preferable to purchase the material in the same concentration as that in which it was to be used.

The literature reports that the risk of decomposition of stronger solutions of hydrogen peroxide is less than for weak solutions. This means that 100 vol solution would be a more stable means of storing peroxide. However we feel that in any case no more than a year's supply should be kept and should a bottle of 100 vol solution start to decompose the potential risk would be much greater. The latest edition of Bretherick (1) reports the explosion of a screw capped Winchester of 35% peroxide solution after two years owing to the internal pressure of liberated oxygen. Some suppliers used to make a small vent hole in the plastic screw cap, but this might have allowed access of dust. Leaving the cap slightly loosened would seem to be a better answer.

(1) Bretherick, Handbook of Reactive Chemical Hazards, Butterworth, 1979.

Physics Notes

These circuits, produced in Portobello High School, could be a useful construction project for the radio or electronics club. It is designed for the panel game situation - e.g. Ask the Family - where two teams compete in answering questions and have to beat each other to the bell to have the right to answer the question. The circuit must ensure that the loser produces no effect when his bell is pressed. A second slightly more complex circuit is used for the 'all-against-all' situation, shown in this case for four independent contestants. Both circuits are self-resetting, i.e. after a certain time, which can be varied to suit the game, the circuit resets ready for the next question.

The circuit uses a monostable multivibrator SN74121. It has one stable state, and can be flipped into the other, unstable state by either of two inputs which we call A and B. If the B input is high, a negative-going edge applied to A will flip the '121, and if the A input is low, a positive going edge applied to B will flip it. The time for which it remains in the unstable state is determind by a CR time constant which can be adjusted externally. The '121 has complementary outputs Q and $\bar{Q}$; Q goes high during the unstable state. There is one further state used in the quiz game circuit; if B input is low the outputs lock in with Q low, irrespective of the state of the A input.

For the two team game, the circuit could hardly be simpler:

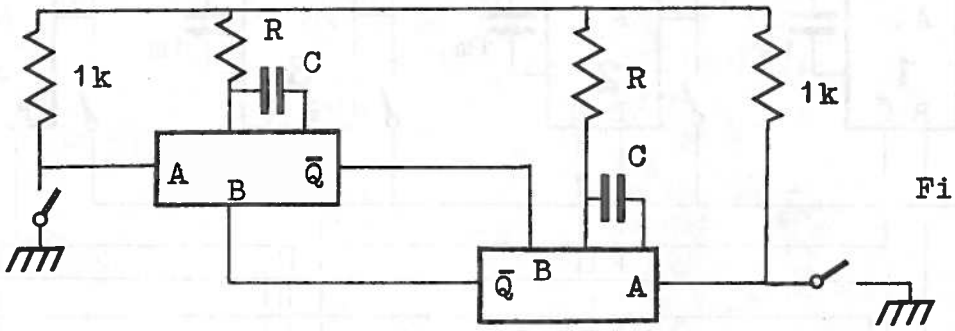


Fig. 1.

The teams are provided each with a normally open push button switch. Both multivibrators are in the stable state, i.e. both $\bar{Q}$ and both B are high. When one team presses the button A goes low, flipping the '121. Its $\bar{Q}$ output goes low, which means that the B input of the other '121 goes low, and this is a locked state so that pressing the other A input has no effect. This state persists with neither A input having an effect until the end of the unstable state, when the circuit resets. Details of a practical circuit are shown in Fig. 2 overleaf.

The Q outputs of the two multivibrators connect to two inputs on the SN75492, which is a hex. inverter driver capable of sinking 250mA. Hence the winning output can be shown on a 4.5V, 0.3A low voltage lamp bulb. The two 3.3Ω resistors are used to keep the lamp current down to 250mA, which is the absolute maximum for the driver. The CR timing components are 12kΩ and 1mF, which give a reset time of about 10s. In the 'ready' state both lamps are off; when one of the push

buttons is pressed, the lamp goes on and remains on for 10s independent of how either button is pressed.

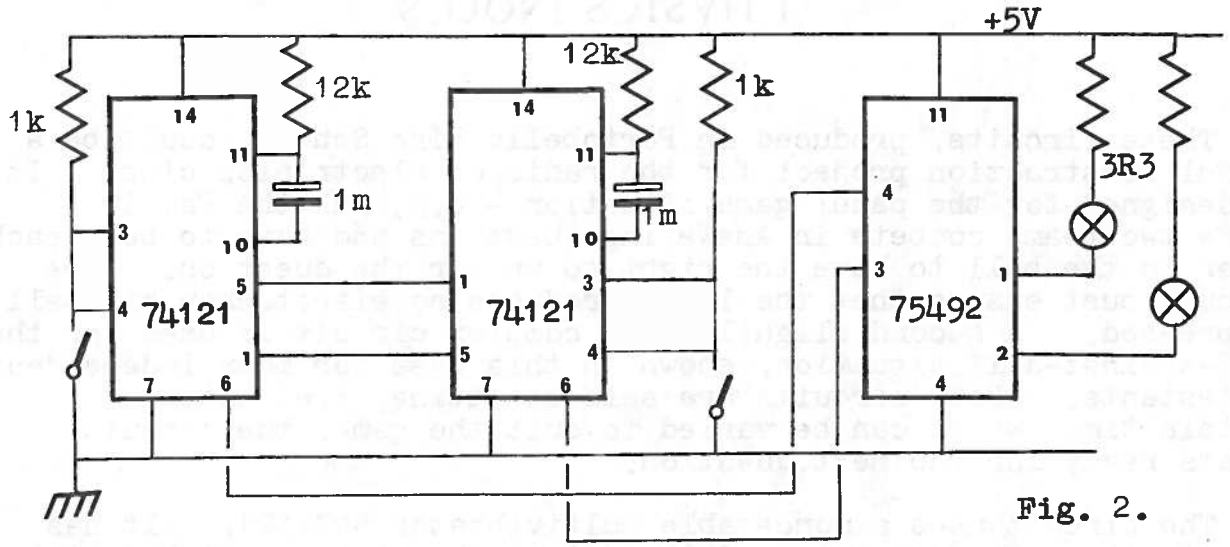


Fig. 2.

The circuit for the 'all-against-all' situation is similar, (see Fig. 4) but every competitor must now have its own push button and indicator lamp. The interconnection between the $\bar{Q}$ outputs and the B inputs is also more complex using a multi-input AND gate for each competitor. The principle of the design, for four competitors is as follows:

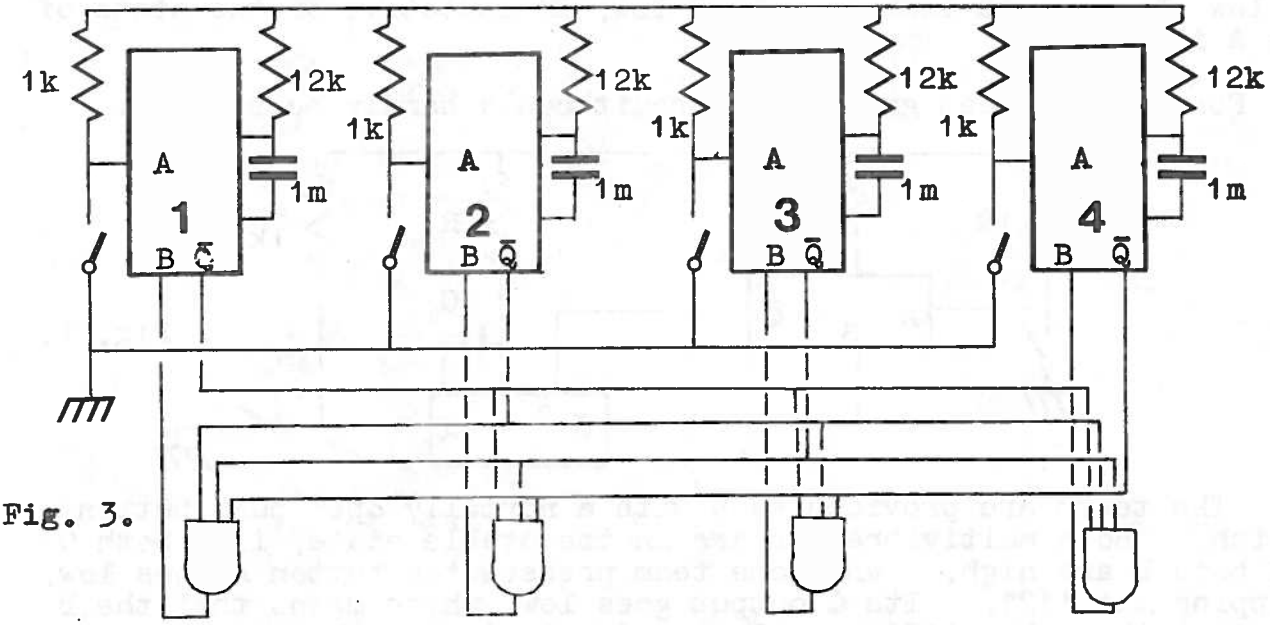


Fig. 3.

The output of each AND gate goes to its own B input. The inputs to the AND gates are the $\bar{Q}$ outputs of all the gates except its own. In the ready state, all the A and $\bar{Q}$ are high, so that all the AND gates are on, and all B are high. When the first button is pressed, say the first at the left hand side, this '121 flips, making its $\bar{Q}$ low. This turns off all the AND gates except its own, so that the B inputs of Nos. 2,3, and 4 go low, into the locked state where they cannot flip. This state persists until the '121 resets as before. The chance of a mistake occuring, so that two '121s flip over is real but not very probable. It could happen if the second A input to be pressed - the mistake - were so close to the first that its B input, which of course has to go through an AND gate and the correct '121, had not yet gone low. A typical delay time for the '121 and an AND gate is 70ns.

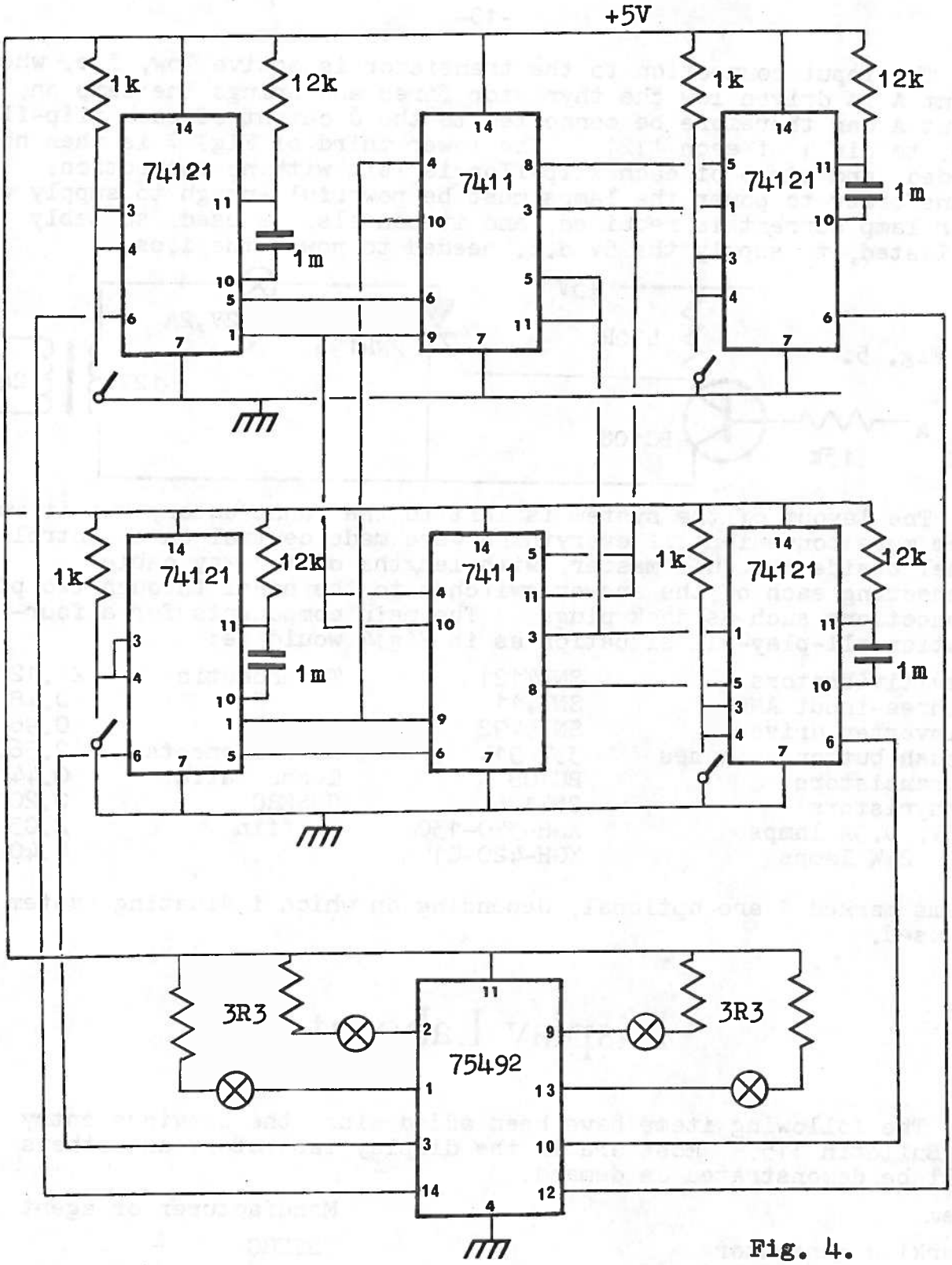
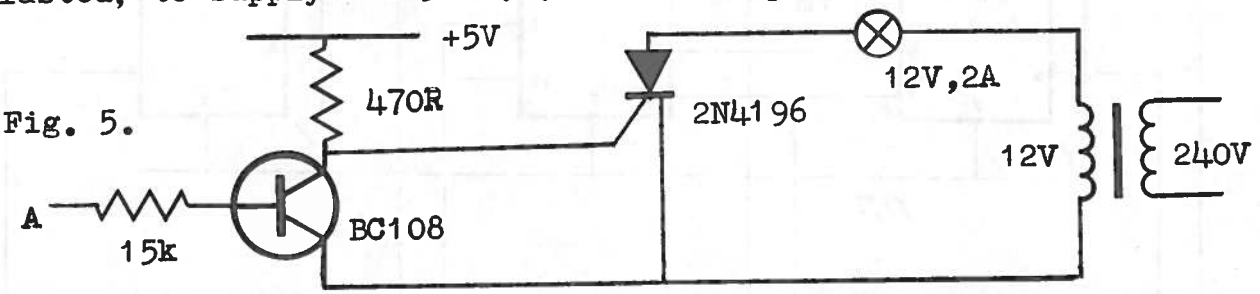


Fig. 4.

As in the previous case, the indication is given on a 4.5V, 0.3A low voltage lamp bulb. If something more powerful by way of an indicator is wanted then thyristors or triacs are the answer. Because we do not like direct connection between t.t.l. circuits and mains voltage, and because we have a large number of 100V thyristors going cheap, we experimented with circuits which would drive a raybox lamp. The circuit shown (in Fig. 5) has been tested and found to work.

The input connection to the transistor is active low, i.e. when point A is driven low the thyristor fires and brings the lamp on. Point A can therefore be connected to the $\bar{Q}$ output of each flip-flop, i.e. to pin 1 of each '121. The lower third of Fig. 4 is then not needed, and pin 6 of each flip-flop is left with no connection. The transformer to power the lamps must be powerful enough to supply whatever lamp current is required, and it can also be used, suitably ballasted, to supply the 5V d.c. needed to power the i.cs.

Fig. 5.



The layout of the system is left to the constructor, but it would seem more convenient if everything were made central on a control panel beside the quiz master, with lengths of two-way cable connecting each of the answer switches to the panel through two pin connections such as jack plugs. The main components for a four-station all-play-all situation as in Fig.4 would be:

4 multivibrators	SN74121	Technomatic	£1.12
4 three-input AND	SN7411	"	0.48
*4 inverter drivers	SN75492	"	0.96
4 push button switches	337-914	RS Components	2.36
*4 transistors	BC108	Technomatic	0.44
*4 thyristors	2N4196	SSSERC	0.20
*4.5V, 0.3A lamps	XGH-340-130S	Griffin	2.05
*12V, 24W lamps	XGH-420-010L	"	4.40

Items marked * are optional, depending on which indicating system is used.

Display Laboratory

The following items have been added since the previous entry in Bulletin 115. Most are in the display laboratory and others will be demonstrated on demand.

Item	Manufacturer or agent
Sparking generator	SSSERC
Deflagrating spoons	SSSERC
Test-tube anti-splash guard	SSSERC
Magnetic flux density unit	Unilab
"Blue chips"	Unilab
Gravitron E balance	International Electronics
22CH balance	Philip Harris
Experimenter's centre	Philip Harris
Dual trace oscilloscope	Philip Harris
Dialmeters	Philip Harris

Data memory respirometer	Philip Harris
Data memory potometer	Philip Harris
N.E.C. laser	Philip Harris
Student microscope	Philip Harris
Biosystem kit	Griffin and George

The following items have been returned to their respective manufacturers since the Bulletin 115 entry.

Mettler PC440 balance	Griffin and George
Precisa 300-3000D balance	European Instruments
Bosch P115 balance	European Instruments
HC22 balance	Oertling

Trade News

Baird and Tatlock have recently marketed 'Camco' biological stain remover. The remover is rubbed into the stained skin and then rinsed off with water. It is claimed that stains disappear in seconds and that there is no irritation. The remover is available from B and T's agents in Scotland who are Asschem. It comes in either a cream or liquid form; Erada-stain cream, order code 4056.50 6oz tube £4; Erado-sol liquid, order code 4056.55 12oz bottle £4.40 and 32oz £8.80.

The remaining items are some of the new apparatus unveiled at the recent ASE meeting in Hull.

Philip Harris have a combined dual trace oscilloscope/signal generator/power supply, which we suggest be dubbed the fiddler centre, for £280. The oscilloscope has 10mV/cm sensitivity, d.c. to 1MHz, timebase 10μs/cm to 100ms/cm; the signal generator is 10Hz to 100kHz sine or square wave, 3V at 50-100Ω output impedance; the power supply gives ± 9V at 0.5A; +5V, and 12-0-12V a.c.

Also from Philip Harris, what they call dialmeters, which are ammeters or voltmeters with a difference. A fixed pointer scale (like a potentiometer control knob) is adjusted until a light emitting diode just ceases to flash, when the pointer position gives the required measurement. The accuracy claimed is 2%, and advantage of the system is its robustness. Seeing them, we thought there was an opportunity for someone to replace the flashing light with an earphone, and scale the meter with Braille numbers. The dialmeter ranges are 5,15V or 1A d.c. and the price is £13.75.

Griffin and George had a nanocomputer - no doubt someone is already working on a picomputer - with an external breadboard which allows machine code programming to be done from wire connectors to the outside. The catalogue number is CRA-200-010M and the cost £445. There is extensive documentation to enable to learner to work the machine. The output is on a calculator type keyboard, but a television driver unit which allows the nanocomputer to drive a domestic television set is available for about £250.

S.S.S.E.R.C., 103 Broughton Street, Edinburgh EH1 3RZ.
Tel. No. 031 556 2184.

Asschem Ltd., Redding Industrial Estate, Falkirk.

Baird and Tatlock Ltd., P.O. Box 1, Romford, Essex RM1 1HA.

European Instruments Ltd., 80-82 Desborough Road, High Wycombe, Bucks.

Griffin and George Ltd., Braeview Place, Nerston, East Kilbride, Glasgow G74 3XJ.

Philip Harris Ltd., 34-36 Strathmore House, Town Centre, East Kilb Kilbride, Glasgow.

International Electronics Ltd., Ewood Bridge, Haslingden, Lancs.

Laporte Industries Ltd., P.O. Box 2, Moorfield Road, Widnes, Cheshire WA8 0JU.

Oertling Ltd., Cray Valley Works, St Mary Cray, Orpington, Kent.

RS Components Ltd., P.O. Box 427, 13-17 Epworth Street, London EC2P 2HA.

Technomatic Ltd., 17 Burnley Road, London NW10 1ED.

Unilab Ltd., Clarendon Road, Blackburn, Lancs BB1 9TA.