# SCOTTISH SCHOOLS SCIENCE

# EQUIPMENT RESEARCH

# CENTRE

Bulletin No. 109. December, 1978.

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# Introduction

Our cost index of consumable apparatus for which the baseline is 100 in May, 1974 now stands at 195.7. This is an increase of 11.1% since November, 1977 and of 3.6% over the past six months.

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The Centre will be closed from 23-26 December, and from 30 December - 3 January, 1979, all dates inclusive.

# Physics Notes

The timing sockets on the <u>Griffin and George</u> and <u>Philip Harris</u> scaler/timers require to be shorted for their start or stop function to operate. In fact, if one puts a variable resistance between the sockets it will be found that a resistance of about 1250Ω or less will constitute such a 'short'. Also, the non-grounded terminal of the pair is about 4.7V negative when the sockets are on open circuit.

Recently we have experimented with methods of driving these sockets from t.t.l. This would increase the versatility of the timer when photo-electric timing is being used. At present, blanking out the light beam to a photo-electric unit e.g. by the passage of a card attached to a linear air track vehicle can be used to start the count, which will stop when the beam is restored. There are advantages in a system wherein an initial blanking pulse starts the count, which continues after the blanking has finished, and it requires a second blanking pulse to stop the count. One such application is the measurement of g by free fall. By placing two photo-electric units one above the other, the falling ball starts the count when it interrupts the first beam and stops it on passing through the second. This measurement by itself will not give g, because there is an unknown quantity, the initial speed of the ball when it interrupts the first beam. However, if two such determinations are made, by altering the separation distance between the p.e. units by moving only the lower of the two, this unknown can be eliminated.

Again, one may wish to stop the count of the falling ball photo-electrically, when this has been started mechanically as we described in Bulletin 8. With the normal arrangement the count will stop momentarily as the ball is passing through the light beam, but how to 'freeze' it so that it does not start up again when the ball moves on, thus allowing it to be read? T.T.L. provides one solution. A flip-flop such as SN7473 will 'toggle' if J,K, and 'clear' inputs are all made high, and a positive going pulse is applied to the clock input. Then each successive pulse flips the system into its opposite state, but it holds that state when the clock pulse has stopped.

The circuit we give below will operate either the start or stop sockets. SN7401 is a quad dual input NAND gate with open collector outputs, so that a resistor is required between the gate and the positive supply rail. Because the scaler live socket is negative to ground, the positive rail of the t.t.l. power supply is connected to chassis, and the -5V rail, normally called 'ground' is floating. Driving the input low will produce a short on the scaler sockets. The power supply itself should be floating and preferably not mains derived, e.g. a battery of four Nife cells.

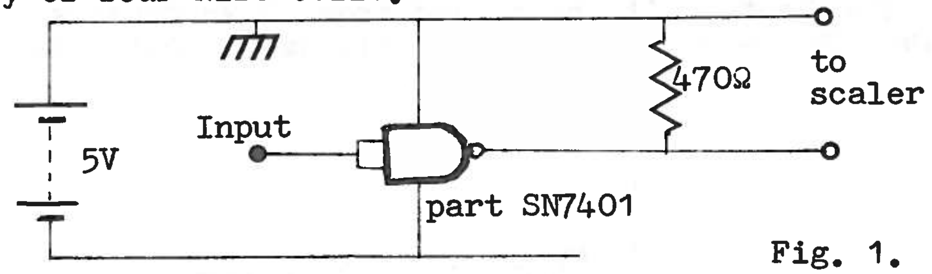



Fig. 1.

Coupled to a flip-flop for 'one-way' triggering of the scaler, the full circuit becomes that shown in Fig.2. The sensor here is the Griffin and George photo-diode assembly, XKS-440H. With this arrangement, each momentary interruption of the beam will switch the timer to its opposite state, i.e. it will stop if it is already counting, or start the count if it is not.

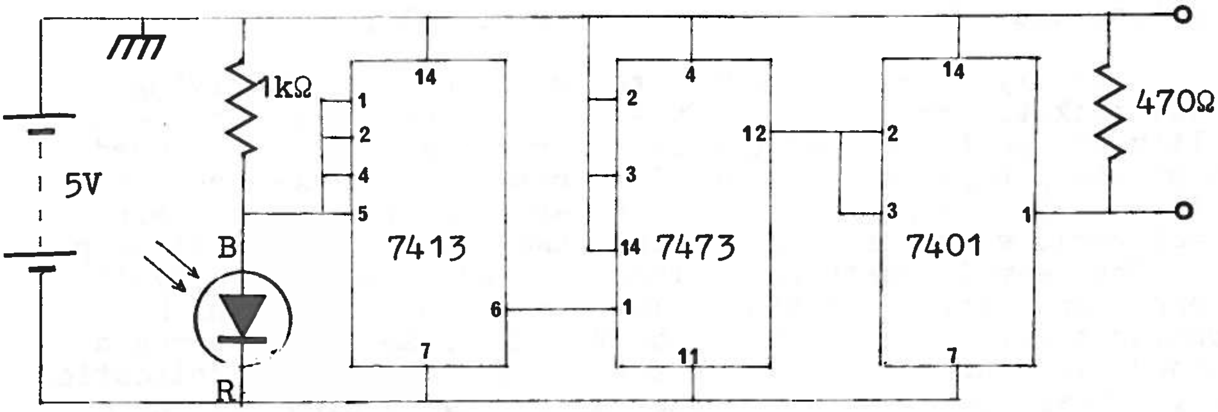



Fig. 2. Photo-diode triggering of scaler. R and B are the red and black terminals of XKS-440H.

For those who do not have XKS-440H, a 2N5777 photo-transistor may be used instead. The base is left unconnected, collector connects to point B and emitter to point R in Fig. 2. The transistor costs 45p from Technomatic. It will need to be fixed in some light-proof box, such as a film can or medical pill box with a 5mm dia. hole at the bottom to admit light. The light source can be a 24W raybox lamp bulb placed 8-10cm from the hole. Fig. 3 shows one possibility.

For a 1.55m drop we found an average time of 560ms, which gave $g = 9.90 \pm 0.13 m/s^2$. If results do not come up to scratch one should seek the source of error in the scaler's internal oscillator. Timing the frequency against a clock, instead of assuming a frequency of 1kHz, accounted for three-quarters of the possible error given above. The same circuitry will not operate the Panax scaler because the shorting link between the 'make to count' sockets transmits the 1kHz pulses from the generator to the counter.

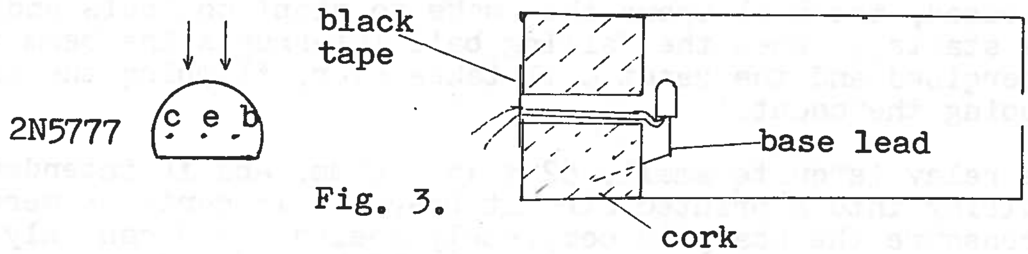



Fig. 3.

The solution for those with a Panax scaler, and this will work with any scaler/timer, is to use the latching relay we advertised under Item 919 in Bulletin 107, and of which we still have a good quantity in stock. These were taken from an early variety of computer so that they are a high speed type. Measurements of g by free fall using one of these have failed to show any delay which could be attributed to the closure time of the contacts.

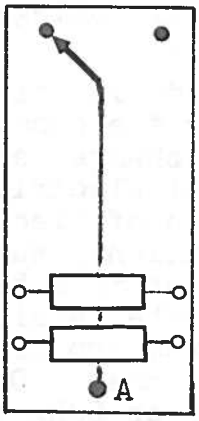



Fig. 4.

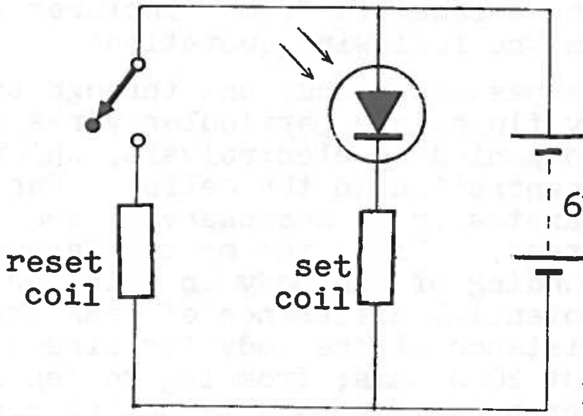



Fig. 5.

The relay configuration is shown in Fig. 4. It has two coils, both polarised, and a single, change-over contact with a common terminal marked A. Unfortunately after testing a number of these relays we have found some where the polarity is the reverse of that marked, but this is an easy matter to determine with a 6V battery and a continuity tester on the relay contacts.

A momentary current pulse from a supply of 5V or over will flip the relay into its opposite state, and this will be held until a similar pulse is fed to the other coil. If both coils are energised, the one which receives current earlier will control the state of the relay, despite the fact that the opposing coil is also energised. In this condition, if the controlling coil is de-energised, the relay flips to the opposite state and holds it, even if the first coil is re-energised. It is this type of operation that is used in Fig. 5.

The reset switch is a normally closed type, and can be push button as it needs to open only momentarily to reset the relay. The Griffin photo-diode, or the 2N5777 transisitor, are both conducting when illuminated, so that the set coil is energised. To ensure that the set coil is controlling the relay, the reset switch is opened momentarily. Then in this state the two closed contacts of the relay are connected to the 'make to start' sockets of the scaler, so that it counts.

The count is stopped by closing the 'make to stop' sockets through the ball itself using any of the methods we have already described. When released, the ball opens the 'make to stop' contacts and counting starts. When the falling ball interrupts the beam the coil is de-energised and the reset coil takes over, flipping the circuit and stopping the count.

The relay is quite small, 52 x 15 x 20mm, and is intended for direct wiring into a printed circuit board. It contains mercury - but to reassure the scary is completely sealed - and can only be used in the upright position, so that it should be mounted on some sort of baseboard with its terminals brought out to 4mm sockets. The cost of a relay is 10p and as this offer is unlikely to be repeated, anyone who would like to try the method would be well advised to get two or three.

* * * * * * *

Since reporting in Bulletin 107 on body resistance to a.c. and d.c. we have received from a lecturer in Jordanhill College of Education the following quotation:

> "The passage of current through the human body is, since the body fluids are particularly responsible for the conduction, accompanied by electrolysis, which produces changes of concentration in the cells. For the user of electric apparatus it is necessary to know the dangers of electric current. Under the most unfavourable conditions, such as grounding of the body in moist or wet soil, or in a bath tub a potential difference of less than 115V may be fatal. The resistance of the body for direct current from arm to arm is about 2000 ohms; from leg to leg it is 3000 ohms. On the other hand, for an alternating current of 50 or 60Hz these values are reduced to 400 and 600 ohms respectively. A current of 0.02 amp. is dangerous; one of 0.1 amp. is fatal. The passage of a current in the body disturbs the heart function, producing a rapid, irregular contraction of the heart muscle instead of the regular diastole and systole, the expansive and compressive motions of the heart muscle. If this fibrillation of the ventricles has not begun, prolonged artificial respiration is usually successful; if it has begun, immediate intracardiac injection of camphor and heart massage must be undertaken". *

If indeed Bluh and Elder did intend it, they should have made it clearer that the resistance figures they quote refer to the most unfavourable conditions which they specify. If they mean that the figures they give for body resistance should apply independently of any stated conditions, as the writers of Memo 26 have taken them, then I question their truth, and they should serve as a warning not to accept everything one reads in print.

* Bluh and Elder, Principles and Applications of Physics, Oliver and Boyd, 1955.

* * * * * * *

There is a need in schools for a general purpose timer, which is not a stopclock or a scaler, but simply a device which indicates seconds and minutes so that pupils can time experiments like the measurement of pulse rate and breathing rate. Many teachers use the wall clock if it has a large seconds hand, and some have voiced their complaint when the authority has refused to instal one, because of the cost of employing electricians to knock holes in the plaster and lay conduit wiring. This seems to us an example of stereotyped thinking; there is no reason why wallclocks have to be mounted on walls, and it is easy to fit one on a piece of hardboard, and use it in any position as any other piece of portable mains equipment.

We bought a standard clock movement, with minute and seconds hands to fit, from a local watchmaker for £5.35. The radial length of both hands was 13cm. The movement was fitted to a piece of 3mm thick white perspex, measuring 32cm square. This will add about another £1 to the cost, and white-painted hardboard could be used instead. A base was made by glueing two 20mm wide wooden struts one at each side of a plywood sheet 10 x 32cm, and the lower two corners of the clock face fit into 30mm deep slots in the struts.

Seconds divisions, 10mm long and standing on a 125mm radius circle were scratched on the perspex and marked with Indian ink. Thicker markings were made every fifth division, and every tenth division was numbered using Letraset, varnishing over these transfers to make them permanent. Provided a sufficiently long mains lead is fitted, the clock can be placed anywhere in the lab. to obtain good visibility for the class. It can be used, semi-stopwatch fashion, to start a time interval by holding the seconds hand still while the mains is switched on. The teacher can then give a count down to the pupils and release the hand on the count of zero.

Others have considered the need for a general purpose timer, and <u>CLEAPSE</u> have produced an applications note, APP28, on how to convert a commercial digital clock kit to give a continuous seconds count up to a maximum of 9min 59s. APP28 can be borrowed from SSSERC by writing to the Director.

A digital version of the timer is simple in principle and it is mainly a question of making the most of the facilities and keeping the cost down. Even so, the cost will be at least twice that of the mechanical clock, and only two points can be offered in its favour; a digital display has a 'with it' appeal lacking in the common clock, and it is sometimes easier for younger pupils to react to a step-wise display than to a pointer which is rotating continuously. What we mean by this latter point is that our own in-built sense of time or rhythm can be brought to synchronise with the steps of the display, so that we are ready and able to perform whatever action is needed almost instantaneously on the appearance of 0.00 on the clock. By contrast, the divisions of the clock scale are being swept continuously by the seconds hand, and it is not so easy to synchronise with the coincidences of the hand and the scale divisions, if only because the divisions may not be so clearly seen.

We built the CLEAPSE version, but found difficulties - through no fault of CLEAPSE - because the firm producing the kit, which comes in both 'alarm' and 'non-alarm' versions, sent the wrong printed circuit board so that the diagrams on APP28 did not relate to the hardware we had. The cost of the kit vis-a-vis that of individual Series 74 chips is very similar, and the labour of conversion likewise to the work of do-it-yourself, but what finally persuaded us to d-i-y was the facility for lengthening the maximum time to 40min as we describe below.

The requirement for good visibility means that the 'jumbo' size - DL747 - of seven-segment display must be used, and these now cost over £2 each. To economise, we limited ourselves to three of these, so that the maximum time displayed is 9 min. 59s. However, by using a simple code based on the decimal point which each DL747 possesses, the time interval can be extended to 40 min., which should be more than enough for experiments which require this accuracy.

The schematic diagram of the timer is shown below:

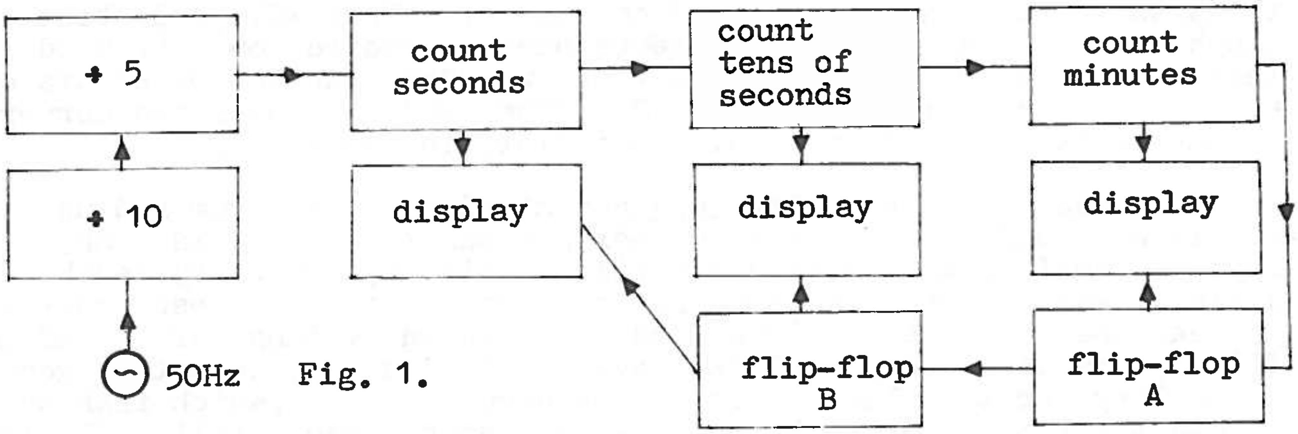



Fig. 1.

The counting system from 50Hz mains is straight-forward. A SN7492, which has a divide-by-twelve count symmetrical on both halves, is used to count the tens of seconds, and by leaving its D output unconnected, the count reverts to zero at the end of the first half, i.e. at 59s. The reset pins on the '92 are thus left free for manual resetting. The D output of the minutes counter drives flip-flop A, which in turn drives flip-flop B. A drives the minutes decimal point; B drives both decimal points of the seconds display. After the first ten minutes therefore, one decimal point comes on; after the second cycle of ten minutes two decimal points come on, and during the fourth cycle all three decimal points are on. This produces an easily remembered code by which timing can be extended to 40 minutes. A push-button reset can be used to set all the counters and the decimal points to zero.

The power supplies, $V_{cc}$ and $V^*_{cc}$ in Fig. 2 are both 5V, and are obtained from a low voltage transformer (RS Components 196-296) which has two 6V windings. One of these, marked xy, provides the 50Hz input for the timer. The power supply diagram is shown in Fig. 2.

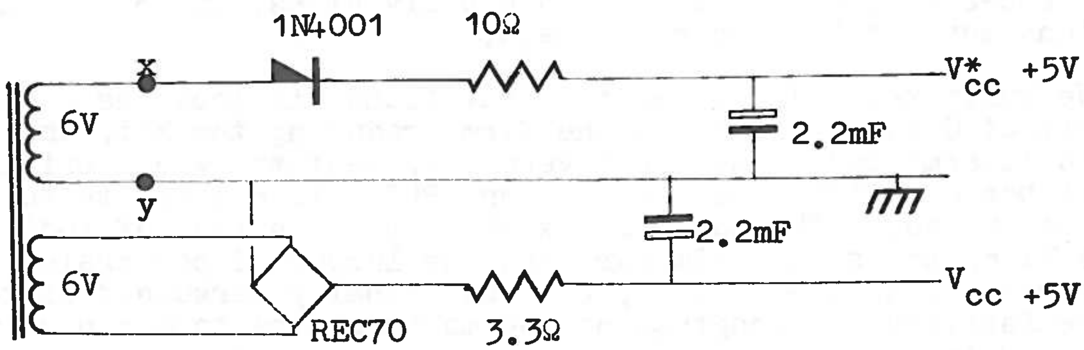



Fig. 2. Power supplies.

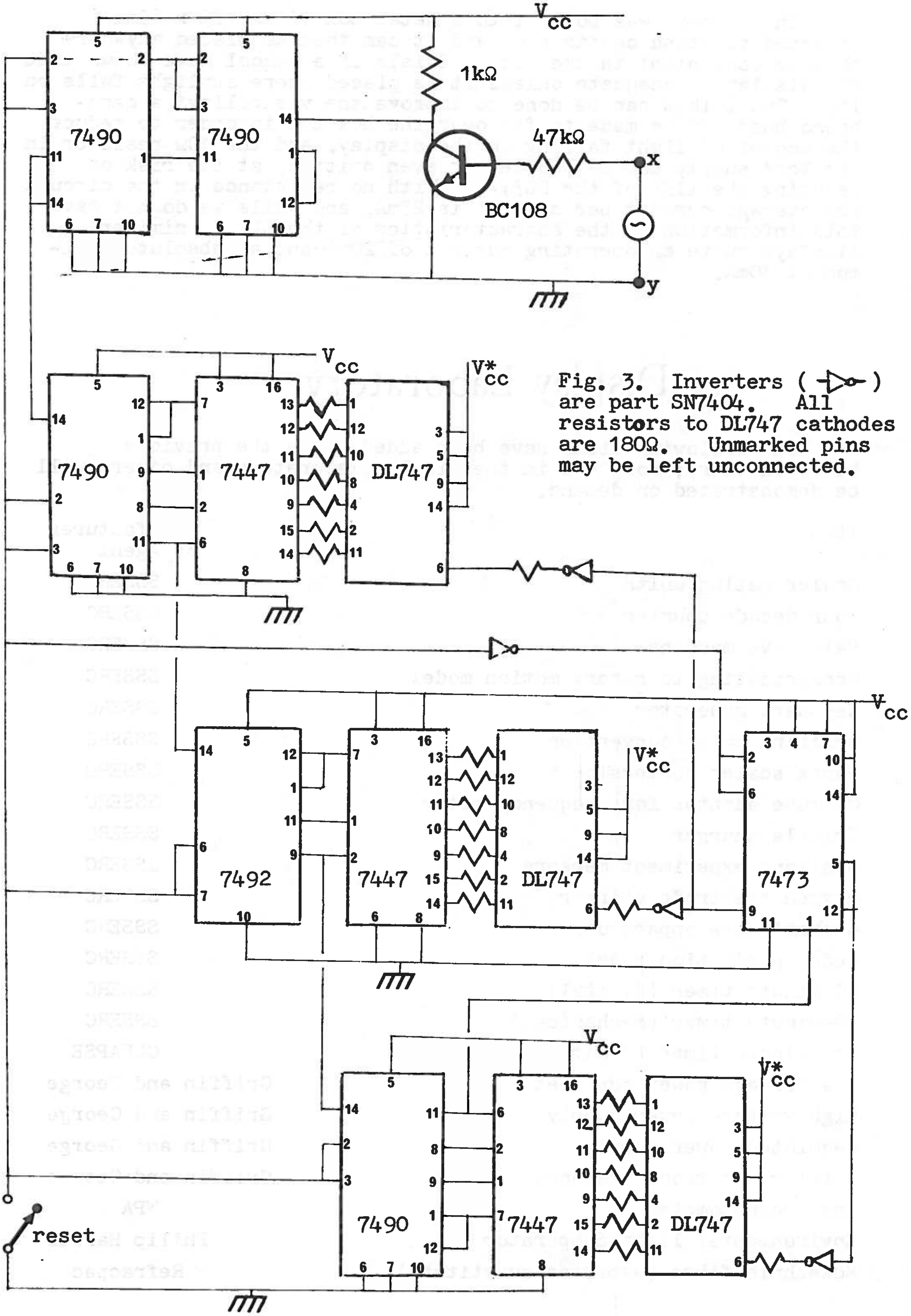



Fig. 3. Inverters ( —▷o— ) are part SN7404. All resistors to DL747 cathodes are 180Ω. Unmarked pins may be left unconnected.

The circuit was built into a metal box 180 x 125 x 65mm designed to stand on its end, and it can then be placed anywhere that is convenient in the lab. Trials in a school have shown that the display is adequate unless it is placed where sunlight falls on it. Two things can be done to improve the visibility: a cardboard hood can be made to fit over the box top in order to reduce the amount of light falling on the display, and the 10Ω resistor in the Vcc* supply can be reduced or even omitted, at the risk of reducing the life of the DL747. With no resistance in the circuit the average current per segment is 25mA, and while we do not have this information on the characteristics of the DL747, similar displays quote an operating current of 20mA and an absolute maximum of 30mA.

# Display Laboratory

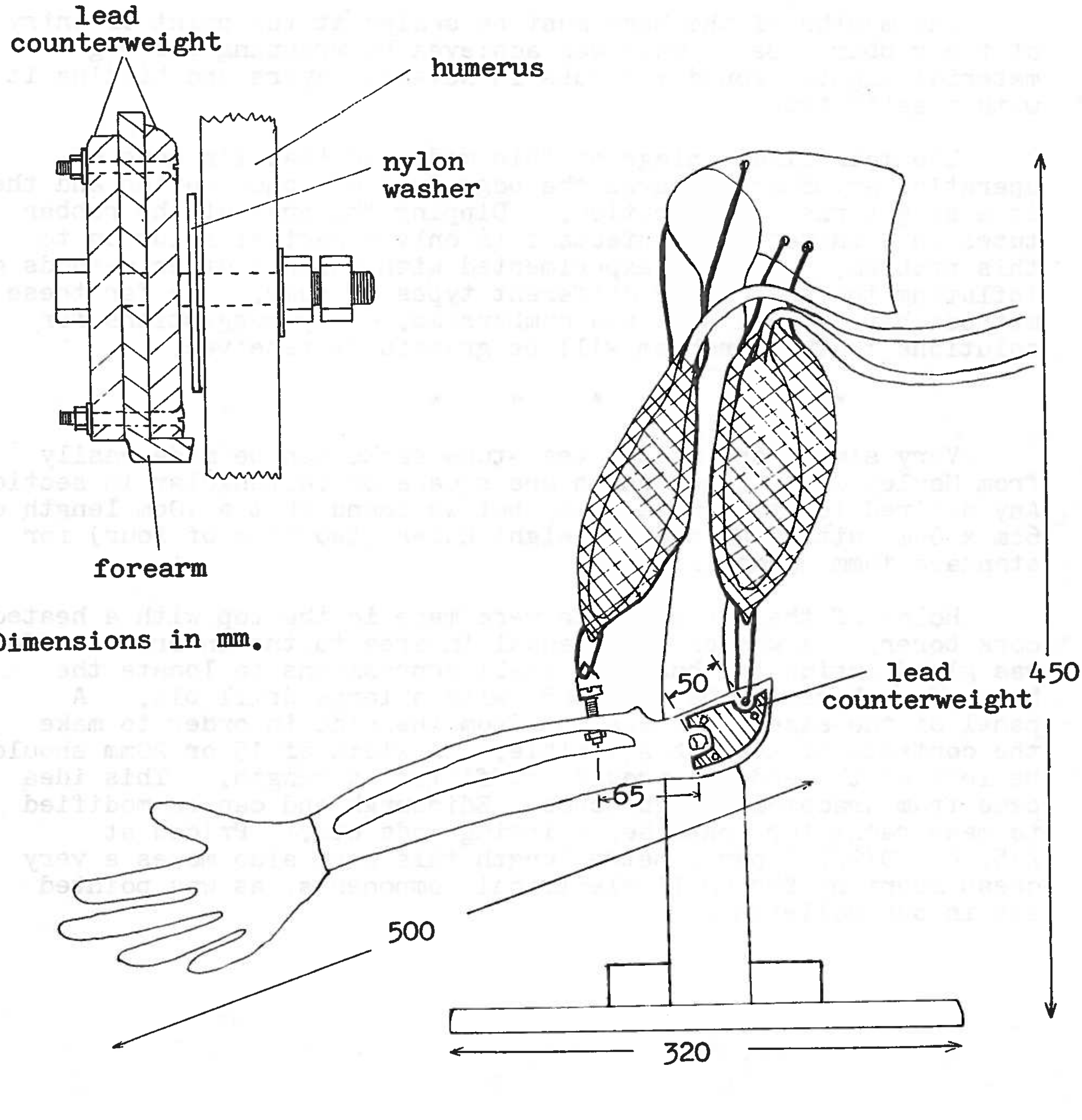
The following items have been added since the previous bulletin entry; most are in the display laboratory and others will be demonstrated on demand.

| Item | Manufacturer or Agent |
|---|---|
| Scaler gating units | SSSERC |
| Four decade counter | SSSERC |
| Haig wave machine | SSSERC |
| Reciprocating to rotary motion model | SSSERC |
| Keyboard generator | SSSERC |
| Griffin scaler conversion | SSSERC |
| Panax scaler conversion | SSSERC |
| GM tube adaptor for frequency meter | SSSERC |
| Trickle charger | SSSERC |
| Stations experiment markers | SSSERC |
| Oxygen electrode stirrer | SSSERC |
| Graham's Law apparatus | SSSERC |
| Redox prediction model | SSSERC |
| 40-minute timer (digital) | SSSERC |
| 60-minute timer (mechanical) | SSSERC |
| Ten-minute timer (digital) | CLEAPSE |
| Low voltage power supplies | Griffin and George |
| High voltage power supply | Griffin and George |
| Regulated power supply | Griffin and George |
| Mettler electronic balance | Griffin and George |
| Spectrophotometer | WPA |
| Environmental light comparator | Philip Harris |
| McKechnie fibre (asbestos substitute) | Refracpac |

# In The Workshop

Working models of the human arm were described in this section of the Bulletin as long ago as issues 24 and 13. Over the past year we have exhibited a third design, from Liberton High School, Edinburgh, which has aroused much interest, sufficient to justify the publication of the details of its construction.

This model employs polythene bags inside plastic mesh ones of the type used by supermarkets for packing apples etc. The mesh bags are connected to the bones by string tendons. Inflating a polythene bag, by blowing air in through a rubber tube, shortens the mesh bag 'muscle' so that it contracts. Allowing the bag to deflate slowly, and so relax, as the other bag in the antagonistic pair is inflated gives a fairly realistic demonstration of muscle action.



The bones are cut from 11mm plywood with the radius and ulna cut from one piece using a fretsaw. These lower arm bones and the 3mm hardboard hand, swivel on 1/4" Whitworth bolt passing through the humerus. The piece of ply forming the humerus is extended below this pivot and is fixed to a softwood block which is pinned and glued to a 320 x 150 x 12mm blockboard base. The humerus and scapula are cut from one piece of 11mm plywood, with the head of the humerus and the ball and socket joint drawn on. We have given the main dimensions of the model, which was made to be approximately life size, in the drawing.

To counter the weight of the forearm and hand, two pieces of lead, total mass about 270g, are fitted on either side of the plywood arm to the olcranon process (the point of the elbow) with three 6BA bolts. That on the inside (i.e. nearer the humerus) is recessed into the plywood to permit movement of the joint. A side view of the detail of the joint in this region is shown.

The lower string tendon of the biceps is fixed to a stiff wire hook on the head of a 4BA bolt passing through a hole drilled in the radius. This allows minor adjustments to be made without continually untying and retying the string.

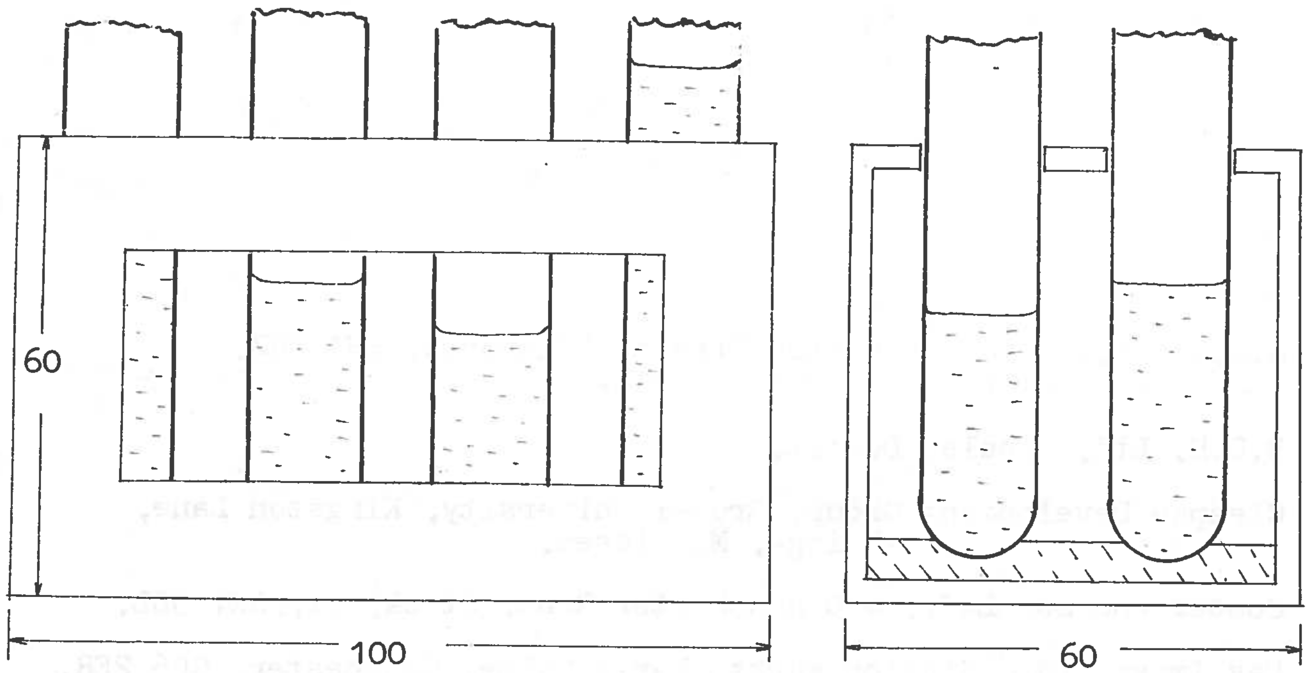
The mouths of the bags must be sealed at the point of entry of the rubber tube. This was achieved by wrapping the bag material tightly round the tube in several layers and binding it with plastic tape.

The main disadvantage of this model is that its mode of operation at present leaves the bags full of condensation and there is a slight risk of infection. Dipping the ends of the rubber tubes in a suitable disinfectant is only a partial solution to this problem. We have experimented with various other methods of inflating the bags using different types of pump. So far these methods have proved slow and cumbersome. Any suggestions for solutions to this problem will be gratefully received.

* * * * * * *

Very simple and stable test-tube racks can be made easily from Marley drain pipes which are square or rectangular in section. Any desired length can be used, but we found that a 10cm length of 6cm x 6cm gutter can provide eight holes (two rows of four) for standard 15mm diameter tubes.

Holes of the correct size were made in the top with a heated cork borer. A wooden strip equal in area to the internal surface was glued inside the base and small depressions to locate the base of each test-tube were made with a large drill bit. A panel of the size shown was cut from the side in order to make the contents of the tubes visible. A width of 15 or 20mm should be left at the ends to provide sufficient strength. This idea came from Gracemount High School, Edinburgh and can be modified to make racks for spatulae, stirring rods etc. Priced at £15.16 (20/9/78) per 4 metre length this pipe also makes a very cheap mounting for small electrical components, as was pointed out in our Bulletin 42.




# Trade News

We apologise to those schools who have been trying to contact Mr. Scrimgeour of Watson MEL in order to arrange to have their microscopes serviced. We have only recently learned that Watson MEL have ceased trading. However, another former employee of Watsons, Mr. Easson, has gone into business on his own account and will service and repair a wide range of school microscopes. His service charge for a monocular instrument with plain stage is £2.50, and with mechanical stage £3; binocular instruments cost £4. It is emphasised that these are service charges and are for labour only. Actual repairs are charged on a time plus parts basis. Travelling time is included in the agreed price and is not charged separately.

A number of firms supplying schools have changed their addresses to those given overleaf. They are:
GBI Labs., suppliers of general biological materials;
A. R. Hoare, makers and suppliers of fume cupboards;
Russell pH, makers of pH electrodes;
Comber and Son, mentioned in Bulletin 101 as suppliers of laboratory glassware at competitive prices.

BDH, whose products can be obtained in Scotland from Macfarlane Robson, have introduced self-adhesive hazard warning labels. Each pack, costing £2.20, contains 90 labels all of the same type, viz. Corrosive, Highly Flammable, or Toxic. The labels are useful for flasks of solutions and other containers into which the school may dispense chemicals. Hazard phrases as required by the Packaging and Labelling of Dangerous Substances Regulations 1978 and safety information are included in each pack.

A bi-metallic strip thermometer which would seem to be ideal for Section 1 of the integrated science course can be obtained from Day Impex at £1.60 for 10. It has a plastic case 55mm diameter, and both C and F scales. The bi-metallic strip is clearly visible, and the only drawback to their use we can see is the ease with which they could be pocketed.

CSERC 24 BERNARD TERRACE EDINBURGH EH8 9NX TEL 031-668 4421

B.D.H. Ltd., Poole, Dorset.

Cleapse Development Group, Brunel University, Kingston Lane, Uxbridge, Middlesex.

Comber and Son Ltd., 490 Manchester Road, Stockport, SK4 5DL.

Day Impex Ltd., Station Works, Earls Colne, Colchester, CO6 2ER.

Mr. W. B. Easson, Microscope Servicing Co., 35 Polmaise Crescent, Fallin, Stirling, FK7 7EA. Tel. 0786 812795.

G.B.I. Labs. Ltd., Shepley Industrial Estate, Audenshaw, Manchester M34 5DW.

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

Philip Harris Ltd., 34-36 Strathmore House, Town Centre, East Kilbride, Glasgow, G74 1LQ.

A. R. Hoare Ltd., 42 Croydon Road, Penge, London, SE20 7AE.

Macfarlane Robson Ltd., Burnfield Avenue, Thornliebank, Glasgow, G46 7TP.

Refracpac Ltd., Beechwood, Fore Road, Kippen, Stirling, FK8 3DT.

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

Russell pH Ltd., Station Road, Auchtermuchty, Fife, KY14 7DP.

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

Walden Precision Apparatus Ltd., Shire Hill, Saffron Walden, Essex.