BERNARDS

ELECTRONIC GADGETS & GAMES

BY

B. B. BABANI

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Although every care is taken with the preparation of this book the publishers will not be responsible for any errors that might occur

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TREASURE TRACER

Let's start at the beginning: Some months ago we were intrigued with the idea of a so-called "hum sniffer" which was featured in a well-known American electronics magazine. Basically this device was nothing more than a transistor amplifier with a small loudspeaker connected to its output and a ferrite cored coil, at the end of a lead, connected across its input.

The device was said to be effective in locating "hum" fields and paths in a chassis and it could thus be used for orienting power transformers and chokes for minimum hum transfer to, say, the input stage of an amplifier. The device could also be used to route AC wiring for paths of minimum hum - so the story said.

It was also suggested that the "sniffer" could be used for searching out hidden power lines and for locating power leaks. As the final clincher, it was suggested that the amplifier, with suitable AF and RF probes, would make a very handy signal tracer for testing transistor radios and the like.

The device, as described, used a ready-made 5 transistor amplifier, and, since we had one of these units on hand and were rather interested in the possibilities of the "sniffer," we constructed a "carbon copy" of the original unit.

Our unit worked very well and proved quite capable of locating hum fields around turntables and other items of this nature in our laboratory. It could also locate reasonably well, by means of the 50-cycle field surrounding them, electrical cables and conduits buried in the wall of our office building.

At about this time we came across another article which stated that buried water pipes and the like could often be located by the hum fields induced in them from surrounding electric mains. We decided, accordingly, to test our unit's capabilities in this direction.

Our first test was at the author's home. In this location, no difficulty was experienced in tracing the buried water pipe from the kitchen and bathroom through to the meter at the front fence and thence to the main located some 10 feet from the meter.

The true location of the pipe was verified by probing with a metal rod and we were delighted to find that our unit had located the pipe with almost pinpoint accuracy. The tests may have been influenced, however, by the fact that the electricity lines were almost directly over the pipe for most of its run.

We decided, accordingly, to run further tests on the unit at the home of a staff member in a completely different type of location. Here, unfortunately, the story was ratner different.

In this location, it was found that the general hum level in the ground was so high that exact location of the pipes was extremely difficult, if not impossible. This contrasted strongly with the previous location where hum could only be heard when the "probe," connected to the input of the amplifier, was pointed directly at the overhead power lines or at the water pipe buried in the front garden.

We were at something of a loss to explain the huge difference in residual hum levels between the two locations, but, whatever the cause, it seemed obvious that the device could locate pipes - but only under certain ideal conditions! In many locations it would be a dismal failure.

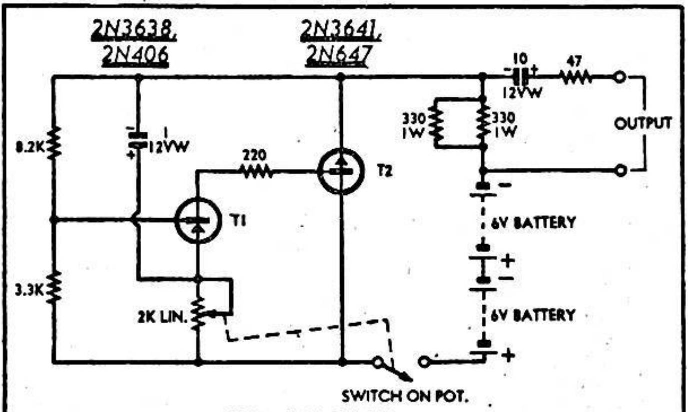
Since our problem, at this stage, was one of general hum masking the hum signal we were interested in, we wondered what would happen if we deliberately introduced a signal into the pipe at a frequency well separated from the 50cps of the mains frequency.

As a first step, we constructed a simple multivibrator type of oscillator which had a small transistor output transformer as the collector load for the two transistors. Output from this oscillator was taken from the nominal 15-ohm secondary of the transformer, while the values of coupling capacitors and base resistors in the oscillator were chosen to run the device at approximately 1000cps. We first tested this unit in the location where AC hum was exceptionally heavy and found that, with one side of the oscillator output connected to a tap in the garden and the other connection made to the upright of a rotary clothes line (a convenient "earth" point), we had little difficulty in locating the pipe by means of the signal introduced into it. Unfortunately, however, our generator was not putting out a strong enough signal for us to trace the pipe over its full length, the signal fading out at about 20 to 30 feet from its source.

The results we had achieved so far, however, were sufficiently encouraging for us to go ahead and try various other generator designs with the idea of being able to radiate a signal from the pipe which would enable it to be traced for a distance of at least 150 to 200 feet from the source.

The final and most successful circuit was that shown in detail elsewhere in this article. This oscillator produces a substantially square-wave output with an amplitude equal to the full battery voltage and a frequency coverage, adjustable by the 2000-ohm potentiometer, from approximately 200cps to 12KC.

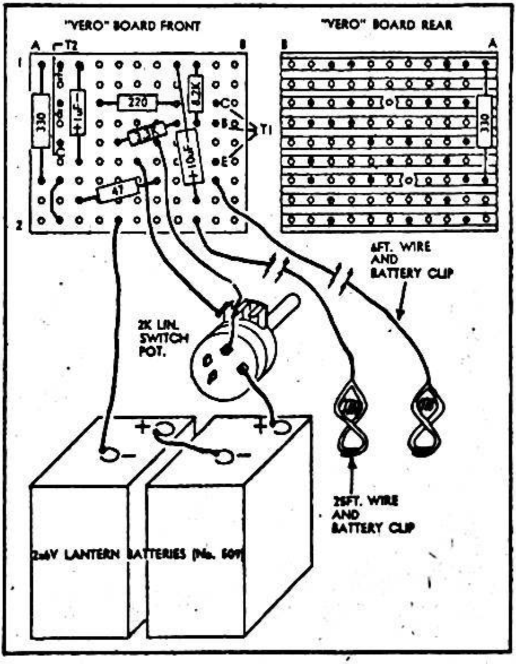
For those interested, the circuit is, basically, an astable multivibrator using a PNP and an NPN transistor in a complementary-symmetry arrangement. This circuit has advantages over the more conventional "Eccles Jourdan" type of multivibrator in that both transistors switch on and off simultaneously so that the average current drawn is reduced. The frequency control is also simplified and only a single potentiometer is needed to change frequency while, at the same time, preserving a fairly even mark-space ratio of the output waveform.



TONE GENERATOR

Our tone generator is simple in circuitry but functions extremely well. It produces a 200cps to 20KC square wave output with an amplitude equal to almost the full battery voltage. Its output frequency will vary with loading but should be peaked up on each occasion to coincide with the resonant frequency of the search probe.

This wiring diagram of the tone generator is included for those who might have some difficulty in following the schematic. It shows the layout of all components on the "Veroboard" chassis. It could alternatively be assembled on board of another variety.



The two parallel connected 330-ohm resistors in the negative lead from the battery form the "load"across which the square-wave output is developed and also limit the maximum current drawn by the NPN transistor. The value of the resistors is chosen to ensure than none of the transistor types listed for use in the circuit will be operated at current drains beyond their maximum ratings. Under no-load conditions, the peak current drawn by the NPN transistor will be approximately 70 milliamps and average current drawn by the whole unit will be 40 milliamps. The heaviest drain condition would be a short-circuited load (the two output leads joined together) and under these conditions the 47-ohm resistor in series with the 10uF electrolytic capacitor serves to limit the peak current ot just under 100 milliamps.

In experiments performed under actual conditions, we determined that the higher the frequency fed into a water pipe, the easier it was to trace. Higher frequencies also appeared to carry further along the pipe, thus extending the range of the unit.

The practical limit to the frequency used depends on ears, loudspeakers and environment and we found that 4 to 5KC was about the highest usable range when in the open air and under possible noisy conditons.

In the original sniffer design an untuned probe was used to "seek out" the 50cps electromagnetic fields. In experimenting with this probe we found that resonating the probe coil by means of parallel capacitance to the operating frequency of our generator increased the sensitivity by quite significant amount.

In the course of these probe experiments we tried various designs of ferrite and iron-cored coils and finally settled for an iron-cored unit as being most suitable to our requirements. Many of these coils were hand wound in out laboratory, but our final design, with an eye toward duplication by the reader, utilises the primary winding and a portion of the core from a standard "over the counter" transistor driver transformer.

Perhaps at this stage we might examine the construction of our "sniffer" commencing with the detector-amplifier portion of the system.

This unit is housed in a standard metal case measuring 6½ by 4½ by 2 inches and consists of the amplifier board, a 2¾in diameter loudspeaker, an output meter with bridge rectifier, volume control and on/off switch, two input sockets and one output socket and a small 9-volt battery.

The amplifier is a ready-made unit which is commonly available at a quite reasonable price and it has colour coded connecting leads which agree with the details given on our circuit. For those interested in constructing their own amplifier the details of this unit are as follows: three stages of amplification driving a transformer-coupled class-B output stage, power output being appriximately 350 milliwatts for an input signal of 300 microvolts.

This amplifier is mounted, by two small angle brackets, on its side and in the approximate centre of the case.

The unit should be orientated so that the transformers on the amplifier board are to the top of the case and nearest the loudspeaker.

The small loudspeaker used has no mounting holes and must be retained in the case by means of an aluminium bracket which folds across the speaker's magnet and bolts to the case at either side of the speaker. A 4in square of perforated steel placed in front of the loudspeaker protects its cone against accidental damage.

The meter mounts in the opposite corner of the case and has the four diodes of the bridge rectifier mounted on a four-lug tagstrip which is soldered to the meter terminals. These components should be mounted on the meter before securing the unit in the case.

The two input sockets and the external speaker socket are mounted in a line immediately beneath the loudspeaker. When wiring in these sockets, be careful to run the leads to the "external speaker" socket well away from those of the input sockets, otherwise the amplifier will suffer from feedback whenever the gain control is advanced towards the "full on" position.

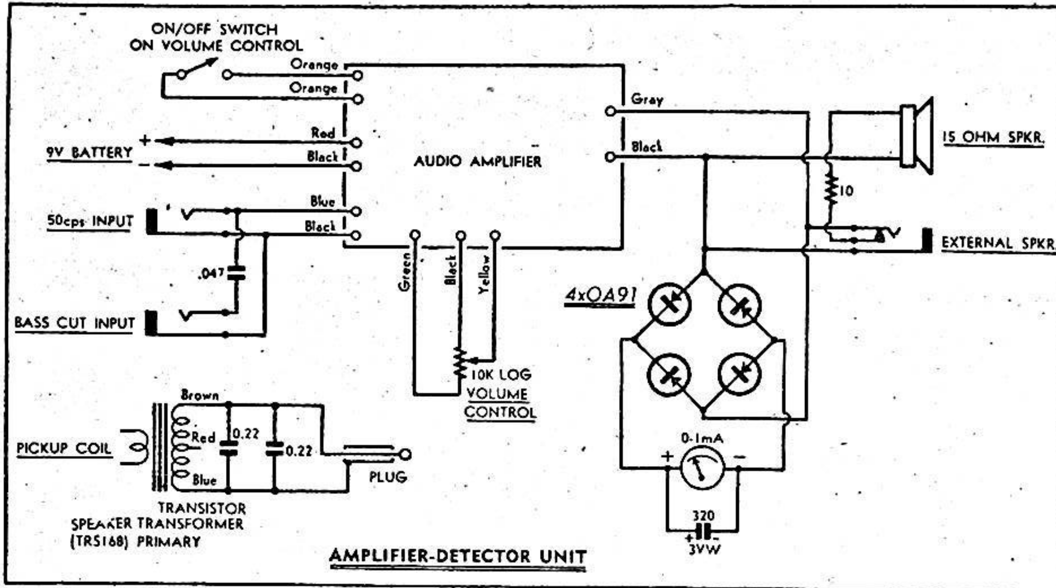
The battery a nine volt unit, fits snugly between the speaker magnet and the end of the case. To prevent the terminals of this battery from accidentally shorting to the base, several layers of insulation tape must be placed over them. To further retain the battery in position a layer of foam plastic, 1in in thickness and approximately 4in square, was glued to the rear lid of the case and at the end nearest the battery.

It will be noticed that our circuit included a 10-ohm resistor which is permanently in series with the in-built loudspeaker. This resistor is necessary to ensure a good indication on the meter and the drop in audio level from the speaker is hardly noticeable. When an external speaker is used the resistor is not in circuit and full power output may be realised.

The two input sockets connect to the first transistor in the amplifier, the difference between them being that one is a direct connection while the other has a series .047uF capacitor in circuit. The direct connection allows the full frequency response of the amplifier to be utilised while the series capacitor connection will produce a fairly drastic cut in bass response.

Although our probe is resonant at 4.5KC, it will still produce a quite useable output on 50cps hum fields and, when used for tracking hum, it would need to be plugged into the direct input connection. If used for locating pipes in conjunction with the tone generator, however, it should be plugged into the "bass cut" input, when the reduction in bass response will reduce the sound from any hum fields which might otherwise mask the sound from the tone generator.

If the unit is being constructed purely as a pipe locator, then the input and output sockets could be dispensed with



AMPLIFIER-DETECTOR UNIT

Our search amplifier uses a ready made, printed circuit board amplifier which has colour coded input and output leads that agree with the markings on this diagram. In fact, any amplifier having a sensitivity of 300 microvolts input for 350 milliwatts output could be used in the circuit, provided its drain is within the capacity of the supply battery.

in the interest of reliability and the lead from the probe connected directly through the capacitor to the input of amplifier.

To complete our amplifier-detector unit we added a chrome handle to one end of the case so that the unit could be easily held with the speaker in close proximity to the operator's ear, the normal operating position of the unit when locating pipes, power cables, etc.

Because our "sniffer" will be most useful in the hands of a plumber we formed mental pictures of it, in use, being thrown into the back of a utility truck along with sundry pipes, sections of cisterns, monkey wrenches and the like. For any electronic device to stand up to this kind of wear and tear it must be robustly packaged.

We have, accordingly, constructed our tone generator in one side of a strong metal suitcase purchased from the hardware department of a city store. The case is sufficiently large to also accommodate the amplifier-detector unit and the probe plus the lengths of wire needed to connect the generator to a water pipe and ground stake.

The particular case we used measured 10 by 8½ by 4 inches, which is just about the minimum size needed to accommodate all of the necessary components.

The tone generator plus its batteries is in the left-hand corner of the case and a wooden partition down the approximate centre of the case separates it from a felt-line compartment at the right-hand end used to house the amplifier-detector.

We used ordinary heavy felt to line this compartment and also the lid of the case but a layer of ½in-thick foam plastic might have some advantages of this in providing additional vibration protection for the units in the case.

Since the tone generator might be required to run for considerable periods of time during the pipe location work, we equipped the unit with two large 6-volt batteries in the interests of economy and to obviate the nuisance of having to continually change batteries.

The batteries are mounted with a gap of approximately 1in between them, into which the tone generator itself is fitted. The spacing of this gap is maintainted by the potentiometer and switch at one end and a small wooden block at the other, the tone generator being packed in a slip of felt and placed between the two.
To hold the batteries and tone generator in place, we fashioned a cover from a piece of tinplate measuring 9¼ by 3½ inches. This cover bolts to the back and bottom of the case.
A small hole drilled in the centre of this plate and immediately above the tone generator allows the two output leads to be brought out through a small rubber

grommet. One of these leads is approximately 5 feet in length and the other measures 25 feet. Both leads terminate in a large battery clip to facilitate their connection to water piptes, taps, etc.

It might be noticed that the longer of the two leads is wound around an aluminium plate to facilitate packing the case for transport. This plate measures 6½ by 3½ inches and fits neatly above the tone generator section in the case.

A small cutaway in the wooden partition and near the handle end of the case allows the pickup probe to be placed lengthwise in the case for transport.

The construction of the probe presented some difficulties since we realised it must be robust in order to stand up to a considerable "bashing" and, at the same time, must be adequately protected against moisture and other hostile environments. Our method of solving these problems was to encapsulate the whole of the coil plus its resonating capacitors in a sold block of epoxy resin.

For those interested in duplicating exactly, the probe we constructed, the method is as follows:

Take a transistor output transformer and strip it down to its component parts of the coil plus a number of "E" and "I" type metal laminations. Take the "E" laminations and cut through them.

These laminations can either be cut individually with a pair of tinsnips or collectively by bunching them together in a vice and cutting them with a hacksaw. In the latter case we suggest using a fine toothed hacksaw blade since the laminations are quite hard due to the heat treatment process to which they are subjected during manufacture.

Place the cut laminations back in the coil. Cut the red, black and green leads off at the coil, leaving only the blue and brown leads intact. Cut the blue and brown leads at 1½in from the col and strip ½in of insulation from each lead.

Take two 0.22uF-30 volt polyester capacitors and twist their leads together so that they are parallel connected. Place the capacitors on the top of the coil core and twist the wire of the brown lead around one lead of the capacitors and the blue lead around the remaining end of the capacitors.

Take two 4in lengths of 18-gauge tinned copper wire and solder one end of each to the ends of the capacitors and the coil. Place a small length of insulation tape over each soldered joint.

Now take a piece of cardboard tube of approximately 1¼in inside diameter and at least 4in in length (the inside section of a toilet paper roll is ideal for this job). Place the cardboard tube against any flat surface, a small square of tinplate for instance, and run some wax around the outside of the join between the tube and the tinplate. Lightly coat the inside of the tube with vaseline or silicon grease. The purpose of this is to prevent the epoxy resin from sticking to the tube and marring the finish of the completed job.

Now take a small package of "Araldite" epoxy resin and mix together the entire contents of both the blue and black tubes contained in the package. Place about two teaspoonsful of the mixture in the bottom of the cardboard tube and push the coil plus its attached capacitors to the bottom of the tube. Note that the laminations should, during this process, be orientated so that their length is parallel with the sides of the tube.

Take a 7in length of ¾in diamter wooden dowel rod and insert it into the tube until it just touches the top of the coil and its capacitors. Temporarily tape the two lengths of tinned copper wire connected to the coil to the outside of the dowel rod. Support the rod so that it is in a straight line with the tube and pour the remainder of the epoxy resin into the tube. Allow to stand in this position for at least 12 hours while the epoxy resin sets hard. Full "curing" of the resin is completed in 24 hours.

When the resin has set, the two protruding lengths of tinned copper wire can be cut short (about ½in from the resin) and a 5-foot length of shielded wire can be soldered to them. Some plastic tape can be wound around the handle to cover this joint and secure the shielded lead along about 3in of its length to the handle.

The probe with its short wooden handle is ideal for searching out pipes or conduits in a wall, but really needs a longer handle for convenience in locating pipes buried in the ground. We solved this problem by drilling a ¼in hole through the wooden handle approximately 2in from the tope, and placing a 1½in by ¼in bolt fitted with a wing nut through the hole. An extension handle made from a 3-foot lenth of ¾ ID aluminium tube and with a slot cut in one end can now be fitted over the handle and retained by the bolt and wing nut.

To complete the outfit we added a "ground stake" made from a 2ft 6in length of ½in OD copper tube with one end cut to a point and the other fitted with a brass cap.

To round off this article we might now make a few observations on the use of our "sniffer."

To trace a buried pipe, the short lead from the tone generator should be clipped to an accessible part of the pipe, e.g., a tap in the front garden. Make sure that the clip makes a good connection with the metal of the pipe and is not insulated by paint, rust, etc. Drive the copper stake into the ground at least 15 feet from the tap and at right angles to the anticipated direction of the buried pipe. Connect the clip on the long lead form the generator to this stake.
With the probe lying on the ground in the vicinity of the tap, switch on the amplifier and advance its gain control to approximately ¾ on. Switch on the tone generator and adjust its frequency control to produce a maximum reading

on the amplifer meter. This latter adjustment sets the frequency of the generator to the resonant frequency of the probe and ensures maximum sensitivity from the system.

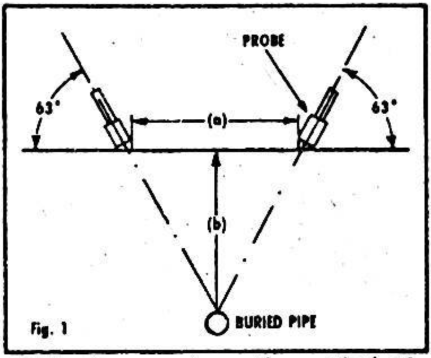
To locate the buried pipe, simply walk over the area where you suspect the pipe is buried with the probe held close to and pointing directly at the ground. when you pass over the pipe and, in fact when the probe is pointing directly at the pipe, the tone heard in the loudspeaker and the reading on the meter will both go into a deep "null," or drop in intensity.

This null will be quite sharp and will virtually "pin-point" the position of the pipe. If, for instance, the probe is held to point straight downward when the null occurs, then it will usually be possible to drive a spike into the ground at this point and actually strike the pipe.
Using the probe, it is also possible to determine the exact depth of the pipe in the ground. Our drawing of figure 1 shows how this is accomplished.

The probe is held so that its handle forms an angle of 63 degrees to the ground and moved around until a null is heard. Mark this position on the ground and, still holding the probe at 63 degrees, move it across and take another null reading from the other side of the pipe. The distance, measured on the ground, between the positions at which the two null readings were obtained is, within very close limits, the distance at which the pipe is buried.
It is suggested that, as a start, the reader should acquire a measure of skill in locating pipes by practising on those which he knows the location of at the start of the experiment.
To locate pipes hidden in the wall of a building it is necessary to connect the leads from the tone generator to either end of the pipe. In a typical example, one lead from the tone generator might be connected to the tank of a hot water system and the other lead connected to the hot water tap in the bathroom.
With this set-up it would be possible to trace the pipe from the tank to the tap by the same procedure of looking for a null as was used with the buried pipe. It should be noted, however, that with this set-up most of the other pipes in the dwelling will also carry a signal which is easily heard in the amplifier and it could happen, that in starting to trace a hot water pipe from the tank to the bathroom the user may wind up at a cold water tap in, say, the kitchen.

With just a little practice this sort of thing is easily avoided, but it is something to watch for.

It must be fairly obvious that the same technique used for tracing water pipes can also be used for tracing gas pipes and electrical conduits. The only requirement is that the pipe or conduit to be traced must be made of metal. It is not a bit of use trying to use this system on tile or asbestos pipes.



This diagram shows the method of angling the probes to check pipe depth. At the null points, the distances (a) and (b) are virtually identical.

Parts List
Resistors .

1 10 ohm ½ watt
1 47 ohm ½ watt
1 220 ohm ½ watt
2 330 ohm 1 watt
1 2kohm switch potentiometer
1 3.3kohm ½ watt
1 10kohm potentiometer
1 8.2kohm

Capacitors

1 .047uF 25-volt ceramic.
2 .22uF 30-volt polyester
1 1uF 12-volt electrolytic
1 10uF 12.volt electrolytic
1 320uF 3-volt electrolytic

1 2N3638,2N406 transistor, RS276-2021, TIS50 AC122-125-151
1 2N3641, or 2N647 transistor, RS276-2009, BCW36-2N 5449-1306
1 1¾" by 1½" piece of "Veroboard"
4 germanium diodes, RS276-1102-1136, AA117-132-144. 1K38-55-63
1 amplifier board.
1 2¾" dia. 15-ohm loudspeaker
1 transistor output transformer.
1 9-volt battery.
2 6-volt lantern batteries.
1 0-1 mA meter.
3 Miniature sockets (optional- see text).
1 Miniature plug (optional - see text).
1 suitable amplifier case (see text).
1 metal suitcase (see text)
2 small knobs.
2 Large battery clips.

1 Pkt. "Araldite" epoxy resin glue. 2 yds shielded wire, 8 yds figure-eight plastic flex, qty. felt or foam plastic (case lining) 7in of ¾in dia. dowel rod, 1 yd ¾in ID alumium tubing, 2ft 6in of ½in OD copper pipe, ½in ID brass cap, 4in square of 1in thick foam plastic, 1½in by ¼in whitworth bolt and wingnut, bookup wire, etc.

6V TO 12V CONVERTER

Here is an ingenious DC-DC converter circuit which doubles its battery input voltage and does not require any diodes to rectify its output. It can be used to power 12V car radios and stereo cartridge players from a 6V battery.

While the number of cars with 6V batteries is now a minority and confined to Volkswagens five years old or more, we still have readers who write for just such an inverter circuit. And we felt the circuit was unusual enough to be of general interest. Readers will undoubtedly find other applications for the idea.

We can't claim that the novel circuit used is original. It is of Japanese origin.

Refer now to the simplified circuit in Fig 1. It shows the converter as consisting basically of two power transistors and a transformer with two centre-tapped windings.

One of the transformer windings has each "leg" connected to a transistor collector while the other winding has each "leg" connected to a transistor base. The transistor emitters are connected together and thence to the minus 6V supply rail from the battery. The centre-tap of the collector winding connects to the positive rail (OV) from the battery while the centre-tap of the base winding becomes the negative output lead (minus 12V). Thus the 12V output is taken from between the two centre-tap connections of the transformer windings.

The mode of operation is as follows: Consider that Tr1 and Tr2 are functioning as a typical transformer coupled multivibrator with both transistors switching alternately between "cut-off" and "saturation". Now consider Tr1 "on" and Tr2 "off". This place minus 6V directly across the Tr1 collector's half winding, so that plus 6V appears across the other half, by transformer action. In total, 12V or double the battery voltage appears across the whole collector winding.

For the purpose of our explanation, we have neglected the small "saturation" voltage from collector to emitter of Tr1 and we will also neglect the base-emitter forward-bias voltages of the transistors.

Now, at the same time as the conduction of Tr1 places 12V across the collector winding, transformer action causes slightly more than 12V to appear across the base winding in the opposite direction, so that the base of Tr2 is minus 12V (approx) with respect to the minus 6V established at the other end by the base of Tr1 (conducting). This means that the centre tap of the base winding is now minus 12V with respect to the OV line.

When the transistors switch over so that Tr2 conducts, the same process occurs so that the base of Tr1 becomes minus 18V with respect to OV and again the centre-tap is minus 12V with respect to OV. This means that while ever the transistors are switching, the centre tap of the base winding is maintained at minus 12V with respect to the positive battery line (OV).

Thus, the transformer's output does not require any rectification The base current is supplied via the load connected between the two centre-tap connections. Indeed under normal conditions, the inverter will not function without a load. The transformer's slight "step-up" from collector winding to base winding is to compensate for losses in the transformer and in the transistors.

Referring now to the complete circuit diagram, readers will note that it contains additional components: two silicon diodes and two large electrolytic capacitors. The transistors are the easily available silicon NPN power type 2N3055. The purpose of the capacitors is to provide filtering of the input and output lines so that "switching hash" is heavily attenuated.

Two important functions are served by the diodes connected in series with each transistor base. First, they prevent damage to the transistors which is possible because of the reverse voltage applied to the transistor base (when the transistor is "cut-off") with respect to its emitter. Second, the diodes prevent spurious operation of the converter which is possible when no load is connected - the unit may then run without any apparent base current supply. What apparently happens is that leakage via the reverse-biased transistor is sufficient to enable the other transistor to conduct.

As the circuit stands, with diodes incorporated, it needs a load before it will operate. This is a desirable feature as it means no power is drawn from the battery unless it needs to be. It also means that the unit can be wired into circuit and does not require a power switch - the power switch on the car radio or cartridge player it powers is sufficient.

Minimum load current for reliable operation of the circuit is of the order of 100 milliamps. It may be used at lower currents with somewhat less reliable starting and running.

With a 6V input, maximum output current at 12V is about 750mA. At this load, input current is about 1.8A. Heavier loads can be connected but the output voltage drops somewhat and losses in the small transformer core become excessive.

We have incorporated a fuse in the circuit to limit the input current to less than 3 amps. This is to protect the diodes, which are rated at 1 amp each but will in fact withstand more than this for a short period. The fuse also protects the base-emitter junctions of the transistors which are rated at 4 amps. In fact, the ratings off all components in the circuit will not be exceeded provided that the load current does not exceed more than about 800mA.

Note that one side of the output is connected to chassis (of the motor car). As shown, the circuit is suitable for use with cars having a "positive earth" electrical system. At the same time, it must be used with car radios or stereo tape players which also have a "positive earth" chassis.

If the unit is required to operate in a vehicle with a "negative earth" electrical system, the battery polarity is reversed so that the negative electrode connects to chassis. At the same time, several circuit changes must be made. First, the polarity of the diodes and electroytic capacitors is reversed. Second, PNP transistors are substituted. Suitable PNP silicon power transistors are the AY9149 or AY9150. These are very robust transistors which have similar ratings to the NPN 2N3055.

Now a few words on the construction. We housed our unit in a diecast case measuring 120 x 95 x 55mm which are available at quite an attractive price. There is no reason, however, why it cannot be housed in smaller case, provided all components fit. Heatsink requirements of the transistors are very modest and the diecast case is more than adequate for the purpose. The main source of heat in the circuit is the transformer, and this does not become overly warm at the maximum recommended load current.

Use mica washers and plastic bushes to mount the transistors so that they are insulated from the case. Since the transistors each dissipate relatively small amounts of power, it is really not necessary to use silicone jelly to improve heat transfer.
Wiring layout is not at all critical and provided solder joints are made properly, the circuit should work without any trouble. Remember that a load must be connected otherwise it will not operate. If it does not operate at first try, swap over the orange leads to the collectors of the transistors.

We found that when the unit is used to power a typical dash-mounting car radio, hash generated by the inverter was not a problem - there was only a very slight buzz from the speaker even when the volume control was at maximum setting. However, if it is used to power a radio or stereo tape player with inadequate internal interference suppresion components, audible hash and whine could be a problem.

In this situation, a worthwhile reduction in "hash" and whine can be obtained by connecting an LC network to filter the output of the converter. It consists of an inductor in series with the "hot" output lead and then a shunt capacitor across the output leads of about 500uF, rated at 16V or more.

A suitable inductor can be made as follows: Start by winding a layer or two of plastic insulation tape on a 50mm length of 10mm (approx) ferrite rod. If a full length rod has been purchased it can be cut by filing a groove around the circumference of the rod and then snapping it as if it were glass.

Close wind a layer of 22 B&S enamelled copper wire over the insulation tape, and finally wind insulation tape tightly over the wire to anchor it all. Then tin the ends of the wire prior to soldering.

We used an in-line type of fuseholder but there is no reason why a panel-mounting type cannot be used.

While the primary use of the circuit is to obtain 12V from a 6V battery to run a car radio or tape player, we have no doubt that readers will come up with other applications. It can be used at input voltages of 12V, but losses are higher and heat-sinking of the transistors becomes more stringent.

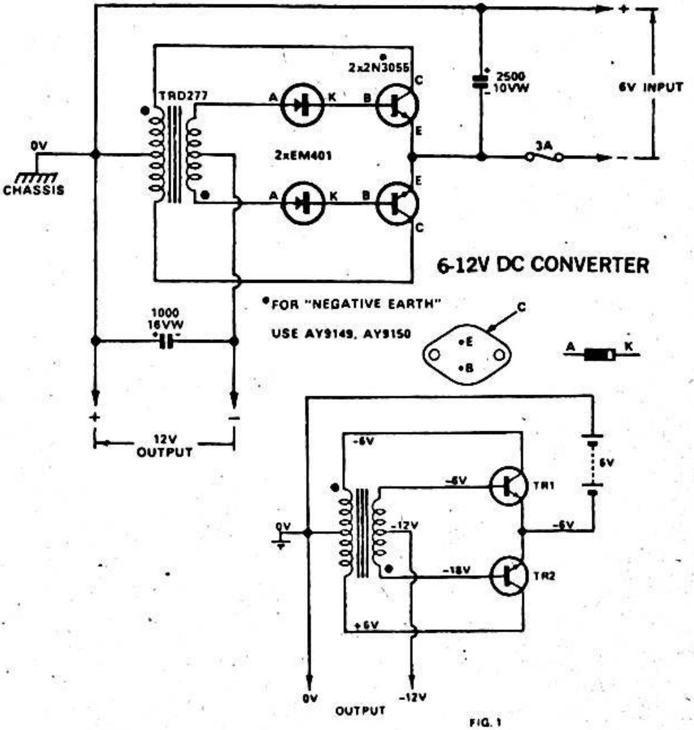


FIG. 1

A simplified circuit of the converter.

PARTS LIST

1 diecast box, 120 x 95 x 55mm.
1 inverter transformer
12V Primary 12V Secondary - both centre tapped to carry 2 Amps (Ratio 1:1)
2 silicon NPN power transistors, 2N3055 (for "positive earth" version) - BDY20.
2 silicon PNP power transistors, AY9149 or AY9150 (for negative earth version). or 2N3789-3792, BDX 18.
2 silicon power diodes, EM401 or RS276-1139, IN4006, BY127
1 1000uF/10VW electrolytic
1 2500uF/16VW electrolytic
1 in-line fuseholder
1 3A fuse
1 2-pin polarised socket and plug
2 7-way tagstrips
MISCELLANEOUS
Mica washers and plastic bushes to mount transistors, solder lugs, hook-up wire, screws, nuts lockwashers, solder.

A METAL BENDER FOR YOUR WORKSHOP

Although not strictly an electronics project, this metal bender should find ready application with a great number of electronic project enthusiasts. The time and effort spent in building up the project will obviate the enthusiast's reliance on commercial companies for the metal work for many electronic projects, and will provide the enthusiast with chassis and bracket making facilities for projects of his own design.

The metal bender described here is not difficult to make, and a lathe is not a must for its manufacture. The prototype was made some twelve years ago, and since then has seen constant use in the school workshop. This has been a hard proving ground,and maintenance over the years has been negligible.

The maximum width of material which can be folded by the machine is 400mm, and 18 gauge aluminium is recommended as the heaviest gauge of metal to be used in the bender. On one occasion a student bent a piece of 125 x 3mm steel plate in the machine, but this was most certainly carried out without the author's permission.

The accompanying diagrams, together with the text given below, should make construction of the metal bender a relatively straightforward process. Basically, the device consists of three lengths of angle iron, two hinges, a locking clamp assembly, and a suitable wooden base. No doubt, many constructors will already have the necessary materials stashed away in their "junk" box.

The logical place to begin construction would be to make up the three pieces of angle iron, as illustrated in Fig 3, according to the accompanying metal work diagram. Angle iron measuring 50 x 50 x 6mm was used in the prototype, although 45 x 45 x 5mm diameter holes are drilled in parts A and B (one at either end) to take the locking pins.

Fig 1 shows the locking handle assembly in the "clamp" position. The 4mm pins used to secure the handles to the locking pins are left loose so that they may be removed when bending awkward work, or changing to a slotted clamp bar. Furthermore the locking handles can be rotated through 180 degrees, enabling them to lock in the outer position. This is a most useful feature when long narrow trays are being folded. Some "fitting" of these handles will be required to achieve the best locking action.

A section through the machine is shown in diagrammatic form in Fig 2. The hinges used in the prototype were 90 x 50mm butt hinges which are secured to both ends of part C (Fig 3) by four 18 x 6mm round head bolts and nuts. It will be necessary to enlarge the holes in the hinges in order to accommodate these bolts.

The other section of each hinge is fastened to the wooden base block by four 160 x 6mm bolts which pass right through the timber and through a 3mm thick steel plate let into the wood at the rear. It is essential that the centre of

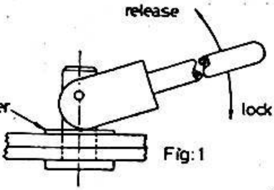


Fig:1

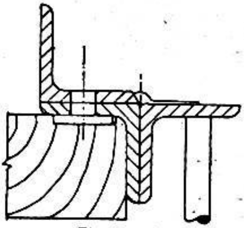


Fig:2

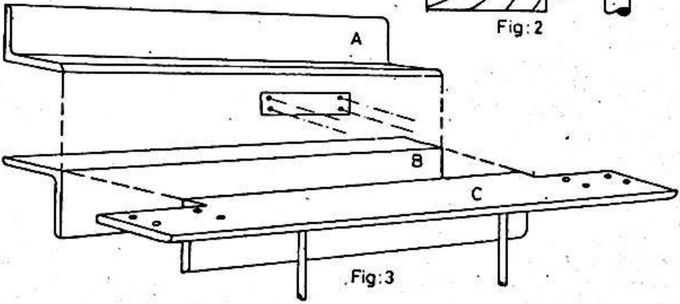


Fig:3

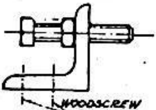
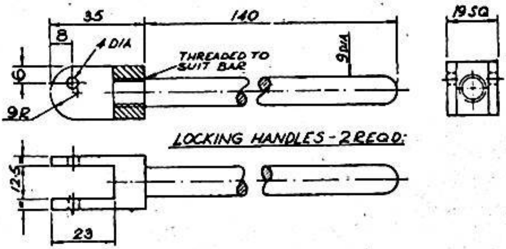
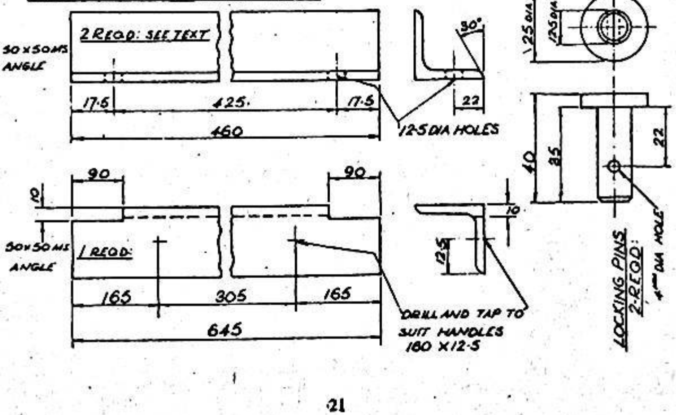


Fig:4



LOCKING HANDLES - 2 REQD:

ALL DIMENSIONS ARE IN MMS:



the hinge pin is aligned with the junction point of all three pieces of angle iron used in the construction of the metal bender (see Fig 2). Note that it will be necessary to provide some 6mm of packing material between each hinge and the wooden base block in order to allow for the thickness of part B.

A general arrangement of the major parts is shown in Fig 3. Part "B" is secured to the wooden base block by nine 30mm No. 10 countersunk woodscrews, four in the top section and five in the bottom section. The positioning of these screws is left to the individual constructor.

Parts A and B must be a matched pair with respect to the positions of the 12.5mm holes through which the locking pins are passed (see Fig.2). The 30 degree bevel, which is on part A only, may be ground or filed. Where access to a lathe is not possible, bolts of appropriate sizes may be used to make the locking pins, the locking handles, and the 160 x 12.5mm handles which are screwed into part C (Fig 3). The slot in each 19 x 19 x 35mm locking handle assembly is produced by drilling a hole, cutting with a hacksaw, and filing to fit the locking pins.

By now, the purists will have noted that the clamp bar (Part A) is not adjustable to accommodate metal of various thicknesses. Should this facility be required, it will be necessary to elongate the 12.5mm locking pin holes (in part A only) and mount adjustable stops on the wood at the rear of the clamp bar. A suitable stop arrangement is detailed in Fig. 4.

Where it is required to bend shallow trays or fold edges on boxes, a slotted blade, as shown in Fig. 5, will be most useful. The slots may be spaced at regular intervals for bending standard size boxes, or spaced to suit each constructor's individual requirements. The slots can be formed by drilling, cutting out with a hacksaw, and filing to a smooth finish (hard work, but worth it in the long run).

Whilst on the subject of chassis, the easiest and most economic method of constructing them is illustrated in Figs 6 and 7. The ends may be secured with PK screws, pop rivets, semitubular rivets, or just ordinary bolts and nuts.

Two alternative methods of mounting the completed metal bender are suggested. The first, most obvious, suggestion is to fasten the bender by bolting the wooden base block to the workbench. However, the author has found it more convenient to secure the bender to the bench using two G clamps. This enables the device to be removed when not in use, thereby enabling more efficient use of available bench space.

The dimensions shown in the accompanying diagrams are as measured from the original prototype, and may be varied to suit each individual's requirements and the materials on hand. For those people who have access to full workshop facilities, deluxe improvements would be to grind the working

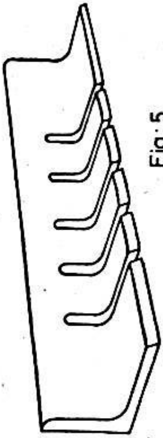


Fig: 5

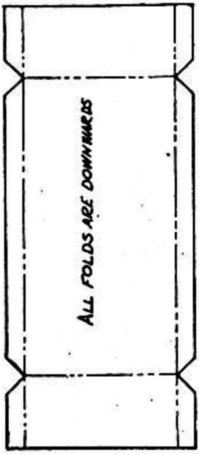


Fig: 6

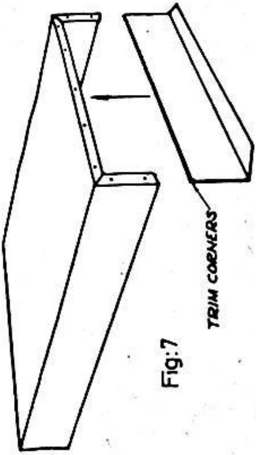


Fig: 7

surfaces of parts A and B and have the bevel of part A cut on a milling machine.

At the beginning of this article, it was stated that the metal bender is not difficult to construct. This is correct, but a a fair amount of time and some adjustments will be required to achieve optimum results. Once completed, it will give good service, becoming an asset to anyone willing to spend the time making it.

PARTS LIST

1 piece of hardwood, 700 x 150 x 50mm
1 645mm length of 50 x 50 x 6mm angle iron
2 460mm lengths of 50 x 50 x 6mm angle iron
2 35mm lengths of 19mm sq steel bar
2 150mm lengths of 9mm dia steel rod
2 40mm lengths of 25mm dia steel rod
2 160mm lengths of 12.5mm dia steel rod
2 20 x 4mm round head steel rivets
2 90 x 50mm butt hinges
8 16 x 6mm round head steel bolts and nuts
8 160 x 6mm bolts and nuts
9 30mm No. 10 steel wood screws
2 12.5mm dia steel washers
2 90 x 50 x 3mm steel plates

Note: the above list specifies those parts used in the prototype. Of necessity, some of these parts required machining. Alternative materials may be used by those constructors without access to a lathe (see text).

DECORATIVE LIGHTS "PLAY" WITH THE MUSIC

Almost all families who treat themselves to a Christmas tree decorate it with low voltage bulbs wired in series and operated from the power mains. This is a reasonably effective arrangement, but there is always the nuisance of one bulb failing and putting the whole system out of action until it is located and replaced. There is also the hazard that this simple system may create a dnagerous situation if it is damaged or mishandled in any way, or if any attempt is made to use it out of doors.

For these reasons I saw fit to purchase a twin filament transformer which, with the two windings in series, supplies 12.6 volts. The existing socket leads were trimmed to about three inches long and connected in parallel across light duty "figure eight" flex connected to the transformer.

Many homes also have recorded Christmas music playing to add to the atmosphere, and added effect is obtained if the Christmas tree lights are "modulated" by the music., I found that this can be done quite simply and, more importantly, quite cheaply. The simplest arrangement devised is shown in the circuit diagram.

It consists of a very simple amplifier/modulation arrangement, using tow power transistors and an assortment of parts, all of which are relatively easy to obtain.

The amount of modulation is governed largely by the setting of the 60 ohm 5W potentiometer, but the level from the amplifier through which the recordinfs are played is also a factor, since the modulation unit is driven from the speaker voice coil (A 7W amplifier provides enough drive for the unit).

The unmarked resistor in series with the input lead is required to prevent undue; and possible dangerous, loading on the amplifier output when the 60 ohm pot is turned right down. It should be at least somewhat higher than the norminal impedance of the voice coil.

A number of variations on the above circuit are possible. A simple mixing circuit may be used to bring two stereo channels into the unit, or two separate units may be used, with two separate light circuits, to give added effect.

A spectacular effect may be obtained by splitting the sound into three separate frequency ranges (low, middle and high) and feeding them through separate modulators to separate colour runs. A suitable frequency dividing network is illustrated. While this may be a little adventurous for a Christmas decoration, it has many other uses. For example, imagine the effect of using guitar amplifiers to modulate spot lights of differing colours, according to the frequency of the sound.

The output from each of the divider networks, marked "X" would connect to the input terminal of each amplifier/modulator unit. The control of large lamps, as in a spotlight, would require the development of suitable thyristor control circuits

A basic phase modulating circuit, which is essentially a split load type phase splitter, is shown at right. A detailed explanation is given in the text.

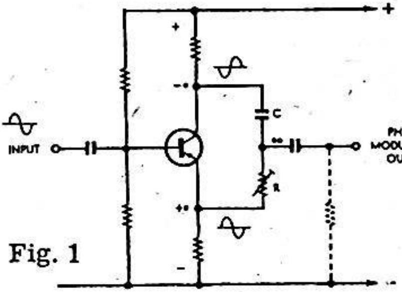
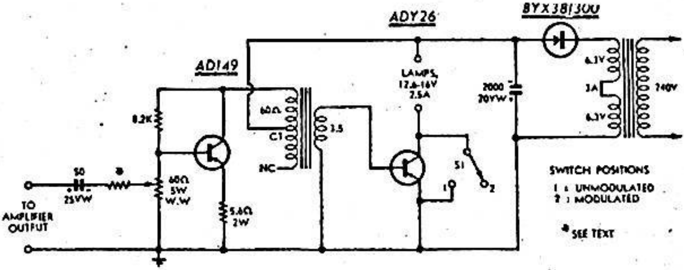
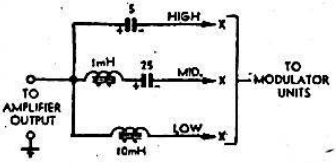


Fig. 1



Circuit of the light modulation unit. All the components are readily available standard items.



A frequency dividing network to permit lights of different colours to be controlled by the low, middle, or high frequencies.

Construction of the unit is not critical, requiring only that the transistors used be provided with adequate ventilation and/or heat sinks. A suitable chassis is a metal box measuring approximately 6" x 5" x 4". The majority of the components may be mounted inside the box but a cutout is necessary for the power transformer. The AD149 mounts directly on the outside of the case, and this makes an adequate heat sink. The ADY26 must be fitted with a "U" metal heat sink, and this may be fabricated from a strip of blackened aluminium 3" x $1\frac{1}{2}$".

Additional holes are needed in the box to accommodate two toggle switches and a potentiometer, and also to ventilate the power transformer. Any standard socket may be used for the light circuit connections. A four-pin speaker plug and socket serves the purpose well.

UPDATE YOUR HELIUM-NEON GAS LASER DESCRIBED IN BERNARDS RADIO BOOK NO: 207

The original laser tube used in our very popular experimental laser design is no longer available. This note gives details of a cold cathode tube of more recent design which is suitable for the project and describes the minor circuit changes which it requires.

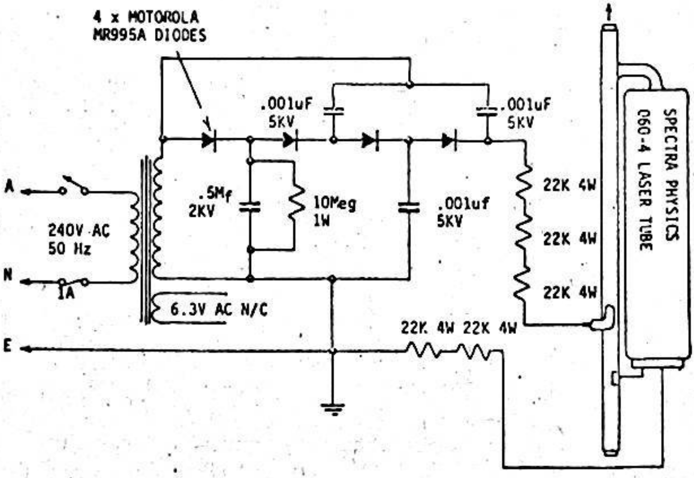
Although the laser tube used in the original design was far from cheap, the project was a remarkably popular one. A considerable number have been built up by schools, technical colleges, universities and by a number of enthusiastic hobbyists. A newer type of laser tube is now available. This is the type 060-4 from Spectra Physics.

The 060-4 tube is very similar in its performance to the original tube, yet costs only a little more than half the original price. Like the original tube it has a nominal light output of 0. 5mW.

The main difference between the two is that the new tube is of the cold cathode type and does not need heater excitation. Apart from this the only circuit change required is an additional 22k/4W resistor in the ballast chain. We recommend that the chain be split in two, as shown, with two of the resistors in the cathode return. This is to reduce lead capacitance and assist in staring, particularly when the tube gets very old.

We used GE controlled-avalanche A14P 1000V diodes in the original circuit, with three in series per multiplier leg. These diodes are still available and would still be quite suitable. However, we have suggested using four of the Motorola MR995A diodes which are now also available. These are rated at 4kV PIV and 250mA average current.

The only other point of interest is that the 060-4 tube is physically rather different from the original tube, consisting of a narrow-bore laser resonator with a larger cathode tube alongside. This will call for a rather different method of tube mounting and also for a slightly longer case. Overall tube length is 28. 3 cm



LEARNING MORSE IS NOT SO DIFFICULT

THIS CHAPTER, WRITTEN FROM THE VIEWPOINT OF PRACTICAL EXPERIENCE, WILL HELP YOU MASTER THE MORSE CODE AND OPEN UP A NEW LANGUAGE FOR YOU. YOU MUST PASS A TEST IN MORSE WHEN YOU SIT THE P.M.G.'S EXAMINATION FOR YOUR AMATEUR OPERATOR'S CERTIFICATE

The Morse code is essentially a sound language, therefore the only way to learn it is by sound. It follows, therefore, that the "opposites" method and others of a similar type are not the best. By their use, the student learns to "see" Morse symbols as they are heard, and pictures so many dots and dashes on paper, instead of relying on the rhythmical sound of each symbol. He is then faced with the necessity of converting his visual picture into a sound picture before he can achieve any real speed. The logical thing, therefore is to concentrate on sound right from the start.

Before attempting to "take" Morse or send it, the student must first memorise the code. Printed herewith is a copy of the Morse code. It will be observed that the letter itself is written after the actual sound. The student should learn that "d' dah" means "a" and not that "a" is "d' dah."

The first step is to memorise the code by singing each letter - then say the letter, e.g.,

"d' dah (pause) a"
"dah d' d' dit (pause) b"
"dah d' dah dit (pause) c"

Dashes are called "dah," and dots are called either "d" or "dit," depending on their relative position in the symbol, e.g., if a symbol ends in a dot, the dot is called "dit." If the dot precedes a dah or another dot, it is called "d."

Generally speaking, the rules for spacing are as follows:

The "dit" is the unit upon which the spacing is made.

1. Dah = 3 dits.
2. Space between any two elements of a letter = 1 dit.
3. Space between any two letters or figures forming one group = 3 dits.
4. Space between groups or words = 5 dits.

The whole code should be sung through, slowly at first, and, then, as each symbol "sticks" in the memory, speed will automatically increase. By this method, it is possible to learn how each symbol would sound on a buzzer or oscillator, even though the student has never heard one.

When a student has memorised the code, even at a slow speed, he will have passed the most difficult stage. It does not require much work. A quarter of an hour a day will embed it in the memory, but the person who really wants to learn the code as quickly as possible would put more time into it - and learn much faster.

The ideal method of carrying on from here is to get some operator to send to you at a rate equivalent to 20 words a minute, but with a long break between each letter. By taking this type of Morse, even though some of it will be missed, the beginner will hear each symbol at its correct speed, and in its correct rhythm.

In the early stages of training the student should try as far as possible to receive code groups in preference to plain language. The reason for this procedure is that with reception of plain language the beginner involuntarily starts to "journalise" and the system is defeated.

To illustrate the point: If the sentence, "He went away," is being sent, he would receive, "He went aw...," and before the "ay" was sent the student would have written it down.
Other traps for the beginner are such words as "formed-forming" and "stayed-staying", where "ed" has been written down before the final part of the word is sent, and often the wrong suffix is added.

Code groups are groups of five letters with five dots' space between them. By using these for practice, the student does not know which letter is coming next. Later on, these groups may also contain figures, but it is advisable for the student to master the letter groups first.

At the bottom of the alphabet are shown the 10 primary figures used in Morse. These are not as hard to master as at first may appear. To begin with, the 26 letters of the alphabet are made up from one to four units. The figures all have five units and to determine from figure 1 to figure 5 merely count the dits. That will be the number. The balance of the five units is made up of "dahs," so that the figure 2 has 2 "dits," followed by the three "dahs" necessary to make the units up to five.

From 6 to 0 is exactly the opposite. By counting the number of "dahs" appearing, we have either 6, 7, 8, 9, or 0. The balance here is made up of dits.

For example, if "dah dah d' d' dit" was sent, merely say: Six, seven d' d' dit" (to yourself), and write down 7.

After mastering the alphabet and the figures, the student may now spend some time on plain language. This is done in ordinary handwriting, but care must be taken to ensure clear, legible characters in the early stages, so that when speed does come the student will not tend to scrawl.

After some practice it will be possible to keep one letter behind the sender, so that if the work "coming" is being sent the student will be writing "c" as the "o" is being sent and at the end of the word, while the operator is pausing before the next word, the student will be writing the "g."

Experienced operators are able to write several letters behind the transmitting operator and even work three or more words behind without being troubled.

Once the student has mastered the rhythm of Morse signals by receiving practice, he may take the key. But it is useless for him to try and send unless he knows how each symbol should sound.

The good Morse operator sits upright in his chair, with both feet flat on the floor. The left hand is placed comfortably on the table in readiness for turning a page.

There are many different methods of keying, but one of the most successful is to hold the key between the ball of the thumb and the forefinger. The second finger is placed on the right of the key towards the bottom.

Then, instead of pressing down with either the fingers or the whole arm, the wrist is held horizontal and dropped whenever a symbol is made. The upward and downward movement of the wrist is the method of keying.
This method is recommended because it reduces "arm fatigue" over long periods of operating.

The tendency is, however, to stray from this method and attempt to "nerve send." The student is advised to pay particular attention that this does not happen and that slovenly habits do not creep on him and ruin his operating.

Many people will argue that the "wrist-movement" method is cumbersome and that it is impossible to reach any high speeds. Countless operators have disproved this theory by passing the 30 wpm rate by "wrist" action alone.

Of course as speed increases, the wrist action becomes less noticeable, but the beginner should allow his wrist to drop the full distance while sending at low speeds. By "following through," even though contact is made by the first movement of the wrist, greater key control is obtained.

The key chosen for practice should be a good quality one, particularly if it is likely to become a standard item in the ham shack after a licence is granted. Keys do not appear to be in very good supply at the moment, although some dealers have indicated that some good quality imported types may be available later. In the meantime, the disposals sources may have a few to offer.

Electrical contact is made by the front stop of the key and its anvil. The distance between these two points is called the "GAP," and should be equal to the thickness of a sheet of notepaper folded once. The spring tension is supplied by the spring at the back of the key, and should be just tight enough to cause the key to return to the open position after the key is pressed, but not too tight to cause actual operating fatigue.

When operating, keep the fingers arched and the muscles loose.

The beginner should sing through the alphabet and lower his wrist to keep in time with the units.

Some common faults with beginners are:

1. Slurred characters.
2. Clipped dashes.
3. Bad spacing.
4. Running words together.
5. Sending too fast.

From this stage on, all that is needed is practice and more practice. A little each day is worth more than a lot once a week. Handbooks on Morse will carry the student further on in the subject but, if he is prepared to work, the data given in this chapter will put him in the speed category in a matter of a few weeks.

Taken on average, the hardest letters for the beginner to memorise are:

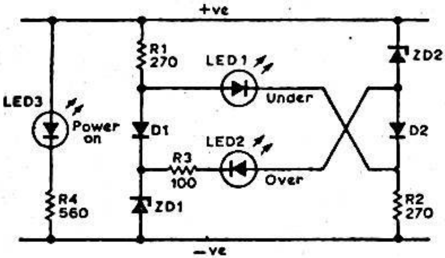
D B F G W L Q Y K R P X

Remember that practice makes perfect. Make up your own chart, stressing the letters that YOU find most difficult. Keep at it until you have mastered them.
We would stress again the importance of listening to the code at every opportunity. Get yourself a short wave receiver, and look round the short waves for commercial stations sending at a reasonable speed. You can often strike such stations sending code groups at often less than 20 words per minute, frequently repeating each group after it has been sent. This is good practice, because you have an opportunity to check on your first attempt.

As you progress, you can pick out a station sending at a higher speed. Do not develop the complex of despair if you find yourself receiving only a portion of what you hear. Take this philosophically, trying to develope an attitude of mind which refuses to be "rattled."

LEDs MONITOR SUPPLY VOLTAGE

Yet another use of LEDs turns up in an item by Marvin J. Moss in "Electronic Design". This is in the form of a voltage monitor for 12V supplies, indicating both over or under tolerance voltages. Using three LEDs the user can see at a glance whether power is on, over-voltage or under-voltage. This is achieved by means of a balanced bridge that uses zener diodes ZD1 and ZD2 in the bridge's opposite arms and back-to-back LEDs between the mid-points of the bridge arms.



If the input voltage does not exceed the two zener breakdown voltages (2 x 6.8V = 13.6V), LED1 lights. But above 13.6V LED1 becomes reverse biased and remains off. When the input voltage increases to the extent that at the junction of ZD2 and D2, it exceeds the zener voltage of ZD1, plus the LED voltage of 1.6V, then LED2 is turned on, with R3 limiting the current through the LED. By mixing of silicon and germanium diodes, etc., it might well be possible to decrease the voltage tolerance. The total drain of the circuit as shown is of the order of 50mA, which is not excessive for car batteries or mains units although would have to be considered for dry battery operation.

DECIMAL READOUT FOR THE ELECTRONIC DICE DESCRIBED IN BABANI PRESS BOOK BP15

In the original article on the Electronic Die or Dice we intimated that we would publish a later article on a decimal-readout system. This article describes an economical readout system of this type, one which may also be used as the foundation of a readout system for other more elaborate devices.

The nucleus of the readout is an XN3 side-viewing numerical indicator tube made by Hivac Limited.

As some readers are probably aware, the numerical readout tube is a development from the simple neon glow tube. It is currently the most commonly used of all digital readout devices, offering bright, easily interpreted display, mechanical simplicity and high reliability. This particular tube is a side-viewing type as opposed to other types which are viewed from the end or "top". The two methods of construction each have certain advantages regarding numeral size, suitability for close mounting of tubes, etc.

The tube is basically a multi-cathode neon tube in which the cathodes are stamped in thin metal sheet in the shape of the desired numerals - in this case, from 0 to 9. The common anode is fine wire gauze through which the cathodes may be observed. When a selected cathode is made negative with respect to the anode by about 150 volts it glows with the familiar pink neon aura. This aura surrounds the cathode so that the desired numeral is easily recognised.

The tube has an envelope about the same size as a 12AX7 but instead of being used with a valve socket it is fitted with eleven flexible leads so that it can be soldered directly into the circuit. A base diagram showing lead connections is shown on the circuit diagram.

In the Electronic Dice only six numerals of the ten are used, from one to six. Each numeral is controlled or "driven" by a separate transistor which, in turn, is turned on or off by the output from the appropriate "AND" decoding gate. The four unused cathodes are left "floating" electrically.

The driver transistors we have used are BSX-21, or RS276-2008, made by Mullard. They have a collector-emitter breakdown voltage Vceo of 80 volts and are thus ideal for high voltage switching of this nature. They are, in fact, intended as a driver for numerical indicator tubes. They are mounted in a TO-18 case, with the collector connected to case.

In their data sheets for the BSX-21 Mullard indicate that the transistor can be used with its collector connected directly to the cathodes of the indicator tube. At first thought, this could mean tragedy. This is because the "unstruck" cathodes of the indicator tube will acquire a potential of between about 60V and the anode sustaining voltage of the tube - which, in the case of the XN3, is nominally 140V at the typical cathode current of 1.5mA. The actual potential acquired by an unstruck cathode depends on its distance from the glowing cathode and the collector leakage of the transistor. This means that the Vceo of the transistor can be exceeded when it is "off", depending on the above conditions.

Happily this is not as serious as it may sound because Mullard state that the transistor can be used in the "avalanche" or "breakdown" mode up to 160V, provided the total power dissipation does not exceed 100mW at an ambient temperature of less than 85 degrees Centigrade. These conditions would normally be fulfilled in this case and the transistor would be within its ratings.

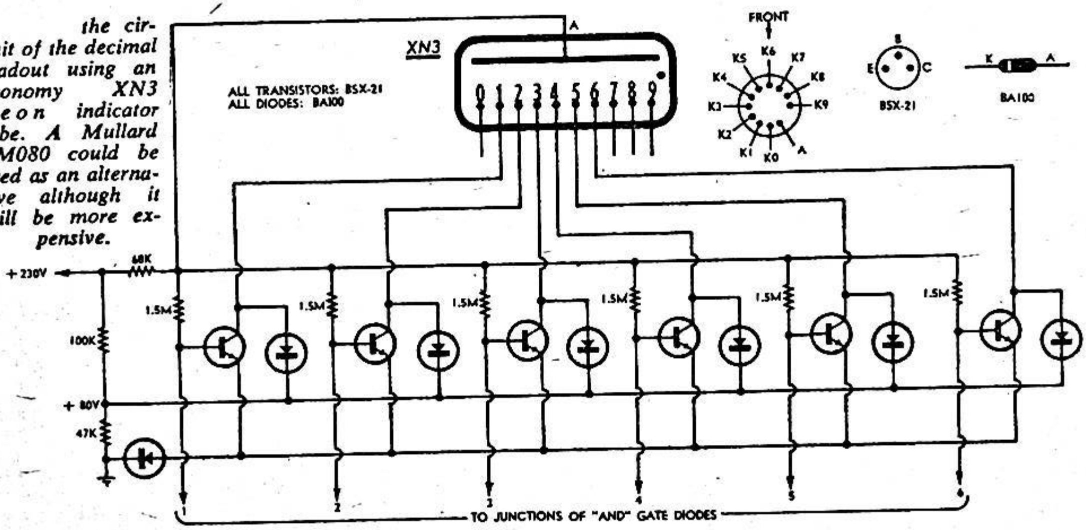
All the above assumes that one cathode of the indicator tube is conducting and thus the maximum voltage on the "unstruck" cathodes is less than the tube sustaining voltage. If, for some reason such as an open circuit transistor or other fault, the tube is not conducting, then all cathodes will rise in potential to the supply voltage. This is normally much higher than the tube sustaining voltage, due to the desirability of operating the tube under approximately constant current conditions. In our case the supply voltage is around 230V DC, which would probably mean the demise of at least one transistor, and perhaps all of them, if they all went open circuit at once.

To eliminate this possibility we have arranged that all transistor collectors are "clamped" to a potential of around 80 volts by means of BA100 or RS276-1102 silicon diodes. The 80 volt potential is obtained from a voltage divider across the 230 volt DC supply, using a 100K and a 47K resistor. This ensures that the voltage rating of the transistors cannot be exceeded no matter what the "state" of the tube.

For the benefit of readers who are not familiar with the principle of clamping a short explanation follows. Briefly, it is a method of tying a point in a circuit to a certain reference voltage, using a diode, so that this point will not be less than the reference voltage. In this case we have six diodes, connected with cathodes to the reference voltage and anodes to each transistor collector. If any collector voltage tends to exceed 80 volts its associated diode will conduct - holding the collector substantially at the 80V reference. When the transistors are conducting (i.e., collectors at near zero potential) or non conducting but have assumed a voltage below 80V, the appropriate diodes will be reverse biased and non-conducting.

Readers who feel that this "insurance" of the transistors is not worth the small cost of the six diodes and two resistors may omit these components, but we do not advise this unless the constructor is quite sure that the counter and decoding sections of the device are operating correctly and reliably.

The driver transistor emitters are connected to earth via a common BA100 or similar low power silicon diode. The current of about 1.5mA induces a voltage of approx. 0.5 volts across the diode and thus holds all the emitters at 0.5 volts above zero potential. This ensures that all non-operative transistors have their bases relatively more negative than their emitters and are thus positively "cut-off". The omission of this diode could mean that the circuit of the decimal readout using an economy *XN3* neon indicator tube. A Mullard ZM080 could be used as an alternative although it will be more expensive.



DECIMAL READOUT FOR ELECTRONIC DICE

cathodes which were supposed to be non-operative might glow slightly, due to slight conduction of their associated transistor.

We point out that, if for some reason none of the transistors are conducting, the tube may still emit a slight glow, due to leakage through the clamping diodes and the 47K resistor to earth. This is because the anode voltage will rise above the normal maintaining voltage of about 140 volts so that the potential difference between the anodes and the cathodes, which are all clamped at 80 volts, may be in excess of the nominal extinction voltage of 125 volts.

In the original article on the Electronic Dice we suggested the use of a small power transformer with an additional secondary to supply HT for decimal readout which had a 6.3V winding as well as multi-tapped 150 volt winding at a nominal 30mA DC. Since the HT current used here represents very light loading the transformer in the prototype actually delivered about 175 volts AC which was then half-wave rectified to give about 230 volts DC.

Construction: All the components comprising the decimal readout section are mounted on the lid of the original case using a piece of Veroboard. The circuit diagram has been laid out to facilitate the wiring of the Veroboard. The horizontal lines on the circuit diagram can be imagined as the copper strips of the Veroboard. We used a piece 3-1/8in long with 9 strips of copper running lengthwise. Referring to the photograph of the internal details of the Dice it can be seen that all but the indicator tube and the diode common to the driver emitters are mounted on one side of the board. Thus reference to the circuit diagram and the appropriate photograph should eliminate any difficulty in layout.

The Veroboard is mounted to the front panel on an aluminium bracket which, in turn, is held to the front panel by means of the "Toss" button securing nuts. The aluminium bracket should be made and positioned so that the Veroboard and its associated components do not foul the power transformer or circuitry inside the case.

Referring again to the circuit diagram it will be seen that the base of each driver transistor connects to the junction of the appropriate "AND" gate diodes. Readers refering to the original circuit diagram of the "AND" gates will see that the AND gate consists of a 4.7K resistor and two diodes. Both diodes must be reverse-biased by the inputs before the AND gate output can be positive. In the decimal readout case the resistor is 1.5M.

The AND gate diodes are mounted in the case, strung between the terminals of the flip-flops and a tagstrip, while the gate resistors are mounted on the Veroboard on the case lid.

The lead from the junction of each pair of diodes to the bases of the transistors are numerically colour coded by means of the wire insulation. This avoids confusion when making connections. The leads are bound together in a cable

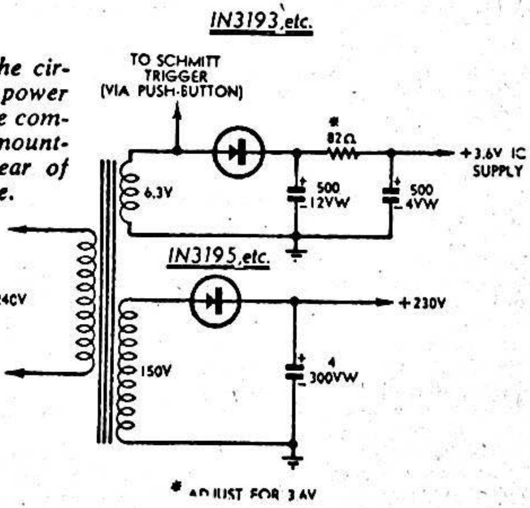
The unused cathodes of the tube are tied together, insulated with a piece of nylex or cambric sleeving and left floating. The tube is held upright by a close-fitting (but not tight) bracket of aluminium, which is screwed to the front panel using countersunk screws. Since we used the same panel for the decimal readout as we had for the incandescent readout we had to make a "dress" panel to cover the holes. This we made of aluminium, with a brushed finish and sprayed with a clear lacquer.

Interposed between the two front panels is a piece of red celluloid which improves the contrast under high ambient light conditions. With a single panel the celluloid may be clamped between the tube and the panel rear.

The only components which have not been mentioned at this stage are those of the high and low voltage power supplies. These are mounted on a tagboard at the rear of the case. The 82ohm resistor in the low voltage power supply may need to be varied to obtain the necessary 3.6 volts for the ICs. This, as you may remember, is adjusted for 3.6 volts under operating conditions.

So there it is. A readout system which is the final "gilding of the lily" for a project which, although rather impractical economically, is one which we hope has been of value both as tuition and perhaps, entertainment. The readout system could also be used in other instruments of a more serious nature.

At right is the circuit of the power supply. These components are mounted in the rear of the case.



INTERCOM USES STANDARD AMPLIFIER

Disappointed in the performance of many cheap intercom units available on the local market, a reader evolved a system of his own, based on an existing 3W amplifier. He finds it is capable of a high order of performance.

Here is a high quality low-priced intercom system. It uses one extra transistor in a grounded base mode as a combination impedance matching transformer/amplifier, replacing the more familiar (and costly) audio stepup transformer for matching the low impedance of the speaker to the high input impedance of the amplifier.

For a given speaker cone and magnet size, the voltage produced, when used as a microphone is directly proportional to the impedance of the voice coil. The higher the impedance, the higher the voltage output. As 15 ohm voice coils are readily available, this intercom has been designed for this impedance. It will work satisfactorily with voice coils of either 8 or 4 ohms impedance, although the gain control will need to be advanced to compensate for decreased output.

The microphone pre-amplifier stage consists of a BC109 grounded base transistor which matches the low impedance speaker voice coil to the high input impedance of the main amplifier and gives a voltage gain of around 250. This high gain is necessary as a 15 ohm speaker generates only about one millivolt when spoken into from a distance of two feet.

Although the input impedance presented by the pre-amplifier may not exactly match the impedance of the speaker (in the role of a microphone) the design is a compromise between low noise performance and adequate gain.

The 0.047uF capacitor across the 1000 ohm emitter resistor effectively by-passes radio frequency signals and is essential if one does not wish to hear the local radio station blaring out the receive speaker. The unshielded wires between the two units form an excellent broadcast band aerial!

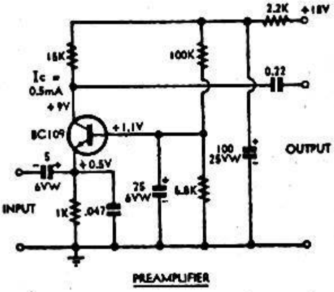
The design values of the electrolytic coupling capacitors should be adhered to. They provide ample gain at voice frequency whilst limiting low frequency audio feedback which may exist if any two units are situated in adjacent rooms.

The gain control follows the pre-amplifier to avoid overloading the power amplifier. In use, it requires only about one third rotation for adequate output.

A press-to-talk switch is provided on the master unit, permitting continuous monitoring of the remote slave unit. On the prototype, the switch is a two pole micro switch which gives positive action. Alternatively, an Oak type switch may be used, but only if it is fitted with non-shorting (break before make) contacts. This requirement is necessary to avoid short circuiting the output of the amplifier.

The master unit may be mains operated or powered by two nine volt batteries connected in series. Although the prototype was only a two-unit intercom, the system lends itself to more elaborate switching arrangements. Using a 5" speaker on the master and a 3" speaker on the slave, reproduction is remarkably clear and free from distortion, with a quality sadly lacking in commercial units.

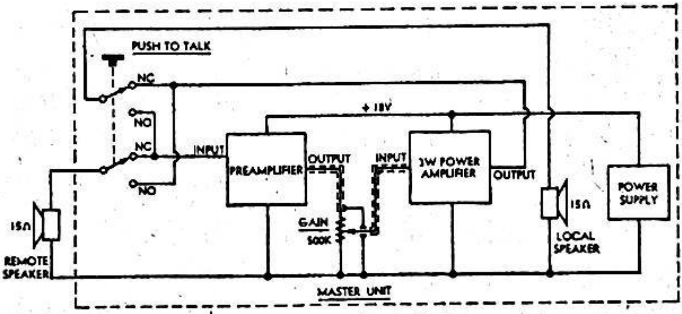
Note: Adequate power output is an essential requirement in any intercom system if distortion is to be avoided. It is this characteristic which many cheap commercial units lack. As a result, they distort badly as soon as they are required to handle a signal marginally louder than normal.



Above: The preamplifier and impedance matching unit.

BC109=RS276-2009/2031, BC149-169-209-319.

complete intercom system.



INTERCOM CONNECTION DIAGRAM

KEEP YOUR COOL WITH THE TEMPER TIMER

Whether you're a high powered executive, a harassed housewife, or just prone to losing your cool, this little gadget should be just what you need. Whenever your pulse rate starts to rise, puch its button. On your behalf it will then count to ten and "blow its top", relieving the tension in a satisfying and harmless way.

In appearance, the Temper Timer is a small box with a pushbutton on top and an audible signal source on one side. When the switch is pressed, a series of short bleeps are emitted, at about pulse rate. These are followed by a continuous tone, which does not stop until the switch is turned off. Counting the action of pressing the switch to start the device as the first bleep there are nine bleeps before the continuous tone starts.

Construction is very simple, and for a small outlay, anyone should be able to build it, providing of course they don't lose their temper in the process! Once completed though, the Temper Timer should help prevent any future loss of control.

The Temper Timer has other used as well. For instance, it is a useful reinforcement of "If you don't get out of my sight in ten seconds I'll ..... (deleted expletives)". It can be used as a conversation piece, as an aid to counting and last but no least, as an interesting way of learning about digital electronics.

The Temper Timer circuit can be considered as three main sections, a clock, a decade counter and the output logic. Turning first to the clock, this consists of a 555 type timer, connected as a free running oscillator with a period of one second and a mark / space ratio of 0.066.

This is all achieved using only a single capacitor and two resistors. The capacitor is initially charged through both the 100k and the 22k resistor. When the voltage at pin 6 reaches two thirds of the supply voltage, an internal flip-flop changes state, and pin 7 is grounded.

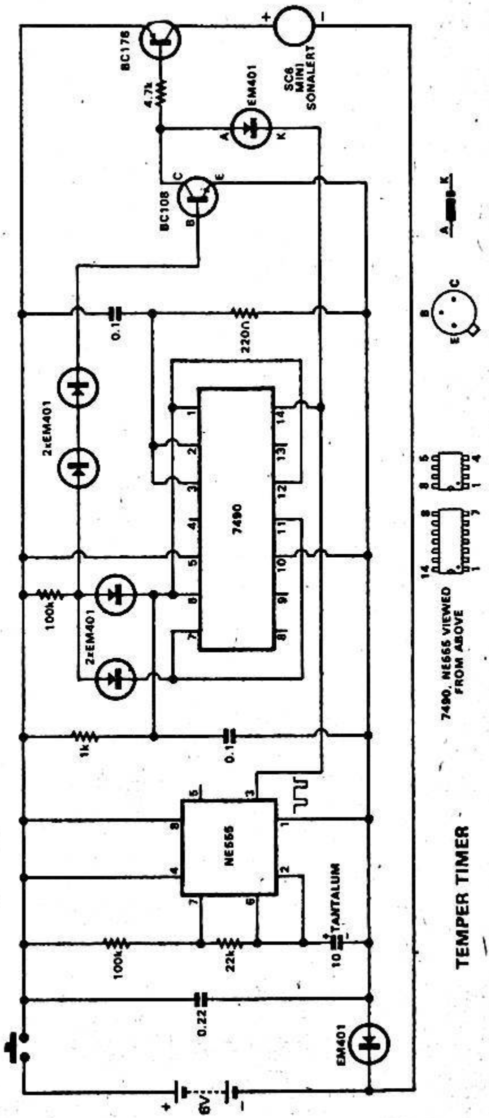
This discharges the capacitor through the 22k resistor. When the voltage on pin 2 reaches one thrid of the supply voltage, the flip-flop is reset to its original state, and the cycle starts again. The output is obtained at pin 3, which is high during the charge time and goes low during the discharge time. Since the capacitor must initially charge from zero volts, the first high time is always longer than the following ones.

The decade counter is formed from a 7490 type TTL device. This has facilities for being reset either to BCD "O" or BCD "9". We use both of these reset facilities.

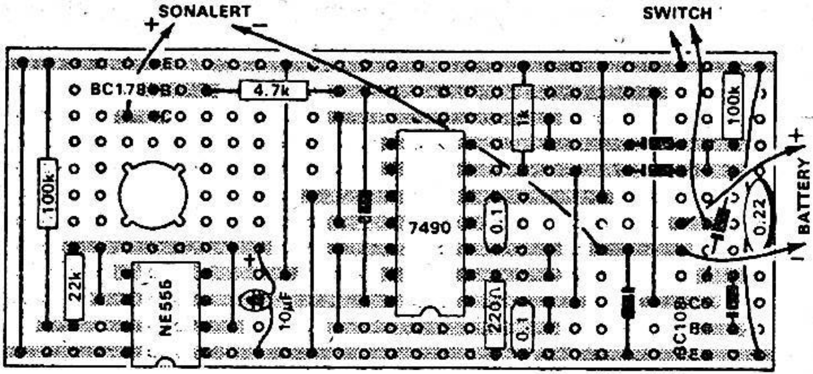
When power is first applied to the circuit, the 0.1uF capacitor in conjunction with the 220 ohm resistor momentarily sends the two reset "O" inputs (pins 2 and 3) high, while at the same time the second 0.1uF capacitor in conjunction with the 1k resistor send pin 6, one of the reset "9" inputs, low. This resets the counter to BCD "O".

Subsequently, input pulses from the 555 timer are applied to pin 14, and this starts the counting action. Note that pin 12 is connected to pin 1, as required to form a BCD counter.

In order to stop the count when it reaches "9" we have used the reset to "9" facility. This is the reason for the connection between pins 11 and 7 and pins 12 and 6. Pins 11 and 12 go high when a count of "9" is reached, and by applying them to the reset-to-"9" inputs, we can force the counter to reset to "9". Since it is already at "9", this causes the count to stop,



TEMPER TIMER



This wiring diagram should make construction a simple process, provided that you don't lose your temper.

until the device is retriggered by turning off and then on again.
The remaining section of the Temper Timer is the output logic. The mini-Sonalert, which is used as the output device, is controlled by the PNP transistor. This will turn it on whenever the base resistor is taken low. The bleeps during the count are obtained by connecting this base to the 555 output via an isolating diode.
A simple AND gate is formed by two diodes in conjunction with a 100k resistor. This is used to sense the "9" count, which occurs at the end of the count. The base of the NPN transistor is held low by the AND gate until the count of "9" is reached. When this occurs, the NPN transistor shorts the base resistor of the PNP transistor to ground, turning on the Sonalert.
The Sonalert then remains on until the power is removed. The total current drain of the complete circuit is about 25mA. A 5V supply is required for the 7490 counter and a 6V supply for the Sonalert. The 555 timer will operate satisfactorily from any voltage from about 4V to 18V. We used four penlight cells as a power supply, giving a nominal voltage of 6V. We placed a diode in series with the supply for the logic, to limit the voltage to a safe level. However, the Sonalert is connected directly to the battery, to enable a higher sound level to be obtained.
Our prototype was constructed on a small piece of Veroboard, and fitted into a small plastic case. The layout of the Veroboard is as shown in the diagrams. Note the area intentionally left clear of components so that the switch could be used to hold it to the case. The Sonalert is a push fit into a suitable sized hole in the side of the box, while the batteries when fitted into their holder, are also a push fit.
Care is required when soldering the components to the Veroboard, as it is very easy to bridge between the tracks. Do not fit the integrated circuits until last, as they may be damaged by excessive heat. Make sure that all the diodes are fitted with the correct polarity as well as the tantalum capacitor.
If you have succeeded in restraining your temper during construction and have actually completed the Temper Timer, now is the time to conduct tests. Carry it around in your pocket and if at any time you start to get hot under the collar, press the switch and count to ten. At the end of this period, you should be back in control of your temper.

PARTS LIST

1 7490 decade counter or RS276-1808. FLJ161-165. FJJ141
1 555 timer or RS276-1723
1 NPN transistor, BC108 or RS276-2009. BC168-208.
1 PNP transistor, BC178 or RS276-2023. BC153-205-252.
6 Silicon diodes, EM401 or RS276-1136. BA219. 1N4002.
1 Mini Sonalert, SC6 Transducer (Plessey)
1 Push-on, push-off single pole switch.
4 1.5V penlight cells 1 Holder for above penlight cells
1 Piece Veroboard, 0.1 in spacing, 12 x 29 holes

RESISTORS

1 x 220 ohm, 1 x 1k, 1 x 4.7k, 1 x 22k, 2 x 100k

CAPACITORS

2 0.1uF LV polyester
1 0.22uF LV polyester 1 10uF 6VW tantalum

MISCELLANEOUS

Tinned copper wire, solder, hook up wire

SIMPLE WIDEBAND TUNER

This little tuner is a spin-off from development work I have been doing on a new Homodyne tuner. Stripped of an IC and sundry other bits and pieces, we still have a tuner in its own right, simply by taking the audio from the voltage doubler diode rectifier used for the AGC system. The circuit is a very simple superhet with one tuned circuit at signal frequency ahead of a self-oscillating mixer. This is followed by an over-coupled pair of IF transformers. There is one stage of IF amplification before the diode detector. Audio recovered from the detector is fed via a 10kHz whistle filter to a 500k preset level control.

The DC negative voltage developed across the detector load is used to control a junction FET between the aerial input and the primary winding of the aerial coil. The source and drain of the FET are maintained at zero DC potential but at the same time, the same two elements are kept at a medium impedance level for signals by the 10k resistor in the source and the coil primary winding in the drain circuit. An RC filter consisting of a 1M resistor and a 0.1uF capacitor feeds into the gate of the FET. The varying negative DC potential with signal level at the gate has the effect of causing a varying resistance in series with the aerial circuit, so controlling the effective signal input to the first stage.

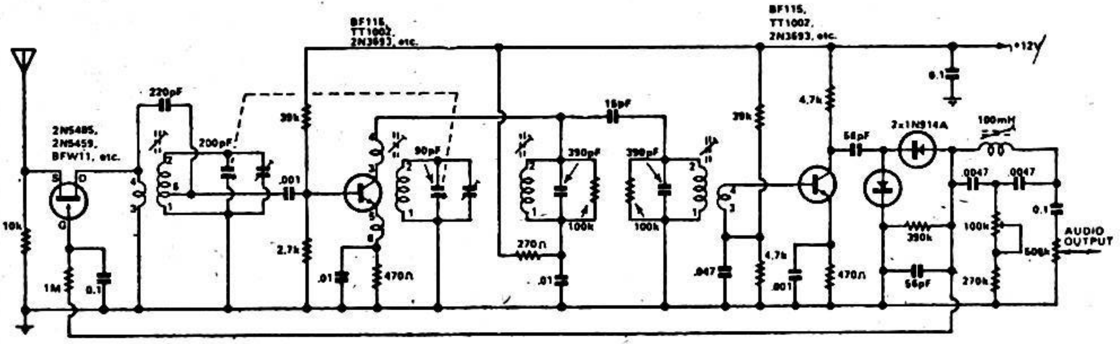
The overall bandwidth of the tuner is such that the recovered audio is down only from 3-6dB at 10kHz. This means that at night, 10kHz heterodyne whistles would be intolerable without the 10kHz whistle filter. The filter gives a deep notch at this frequency but has virtually no other effect on the overall frequency response. The sensitivity of the tuner is of the order of 400uV, which means that it is for local reception only, the best aerial being found by experiment.

Aerial, oscillator and IF coils are types S203, S201 and ST45C or 7155, 7348 and 9185 made by Aegis and Transcap respectively. A whistle filter is made by RCS Radio and which uses the circuit values as shown or a transcap coil may be used in which case the .0047uF capacitors should be replaced with .047uF and the 100k trimpot and 270k resistor replaced with 1k each.

If you wish to save a little, you may wind your own IF coils. It is important to change the two 390pF capacitors with 330pF when using the home wound coils. The coils are wound on Neosid type E adjustable inductance assemblies. The tuned winding consists of 130 turns of 39/40 s.w.g. enamel copper wire and the second unit requires a second winding consisting of 15 turns of the same wire.

Alignment follows the normal procedure for superhets but an additional point must be observed when aligning the two IF coils. Shunt one tuned winding with a 4.7k resistor while the other one is adjusted and vice versa. Do not forget to remove the resistor when alignment is finished. The 100k shunting resistors must be left in circuit. A power supply capable of delivering about 35mA at 12 volts is required.

A Simple Wide-Band Tuner



BFW11=2N5459-5485, RS276-2028, 2N4416
BF115=RS276-2009, 2N3693, TT1002, BF117-122-173-184-194, 2N915-2952
1N914A=RS276-1102, BA211, BAY38-61, BAW76, 1N451-4446.

A TWO-WAY MOBILE TUNING AID

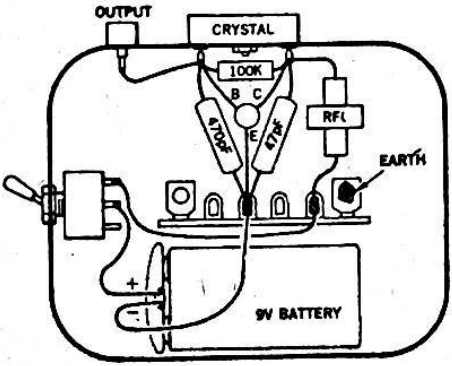
It is not certain just how widely this little unit is known, but I have found it invaluable for tuning up two-way mobile receivers after the front end has been modified from the original frequency.

The circuit specifies a type 2N3964 transistor and a 2.5mH RF choke. I am successfully using a BF115 or RS276-2009, BF117-122-173-184-194, 2N2952-3693 transistor and a smaller value of RF choke which I salvaged from a scrapped TV receiver.

Our Assistant Editor, has made up one of these units for his own use and a detailed drawing is shown herewith. It is built into a tin which measures 3¼in x 2½in x ¾in and includes a battery, switch, crystal socket and miniature coax socket to take an aerial. The aerial consists of a 7in length of stiff hookup wire soldered to a miniature coax plug.

This unit has been used to tune up modified two-way mobile receivers for both the 52 and 144MHz bands, using the crystal from the companion transmitter. It is also invaluable for tracking down interference on an FM receiver, such that the required signal level can be provided in the receiver, while steps are being taken to trace and remedy the interference.

The required signal strength for adjustment and alignment purposes may be obtained by the simple expedient of varying the distance between the receiver and the oscillator. It was observed that with the lid on the oscillator case and without the aerial, a signal could not be detected beyond a few inches from the receiver aerial input.



PULSER PROBE

A low frequency pulse generator for trouble-shooting logic circuitry

Using just one IC and a few other low cost components, this simple pulser probe is intended for trouble-shooting in digital logic circuits using TTL devices. It is housed in a transparent probe case and clips directly into circuit, and makes a good comparison for the logic probe.

In testing equipment using digital logic circuitry, it is often useful to apply a low speed pulse signal to the input and then check the circuit operation, stage by stage with a logic probe. It is very convenient to have a simple pulse generator probe which could inject the pulse stream into any part of the circuit. This is not nearly as simple as it sounds, but the simple probe described in this article is a good compromise for trouble-shooting TTL circuitry.

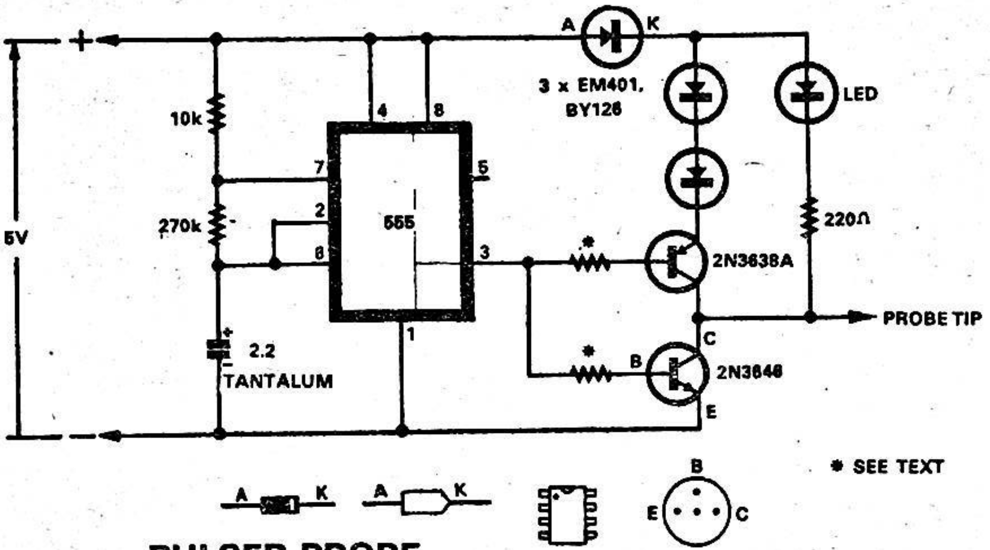
If the probe is to be able to inject pulses into any part of the circuit, it must be able to "pull" a high level output to low, and a low level output to high. In the former case it has to short-circuit the output of an element, while in the latter case it has to pump current in, to force the output high.

To see what this requires, let us examine the circuit of a typical TTL NAND gate used in 7400 series devices (see Fig 1). When one or both inputs are low, current flows through the base-emitter junction of Tr1 and the base of Tr2 is held low, turning it and Tr3 off. Tr4 is turned on and supplies current to the output via diode D1. Although only intended to supply a maximum of 400uA at an output voltage of 2.4V, Tr4 can supply up to 55mA when the output is short-circuited to ground.

In the case of higher speed TTL devices, the short circuit current is much higher; 100mA in the 74H series and as much as 225mA in the 74S140 buffer.

When both inputs of a 7400 series NAND gate are high, Tr2 is turned on by current through the forward-biased base-collector junction of Tr1. Tr2 turns off Tr4 and drives Tr3 into saturation, so that the output is low. When the output is low, the output voltage will be Vsat of Tr3. This is less than 400mV for a maximum fan-out current of 16mA. However the output will sink much higher current than this in the low state. In fact, a 7400 series TTL gate output will sing 50 to 130mA before coming out of saturation at a voltage of about 2.0V.

The input voltage threshold of a TTL gate is at about 1.4V varying between about 1.1V and 1.6V with temperature. A pulse generator must therefore be capable of supplying to, or sinking from the output of a driving gate sufficient current to change the gate output voltage from below this range to above it, or vice-versa, if the following gate



PULSER PROBE

is to be switched correctly. To do this with normal 7400-series TTL we would strictly need to source about 130mA and sink about 100mA; for 74H and 74S devices these figures would be considerably higher.

Manufacturer's data shows that for the 7400 series, no more than one gate output in a package can be shorted to ground without exceeding the dissipation ratings. For the 74H series, the short-circuit cannot be maintained for longer than one second; for the 74S series, not longer than 100mS. The maximum current that can be safely pulled out of any output is therefore about 50mA average.

These problems can be overcome, but fairly complex circuitry is required. Since the most common form of TTL device is the 7400 series, it was decided to build a simple pulse generator compatible with these devices but offering protection to the faster 74S and 74H series if inadvertently used on their outputs. The probe can sink an average current of 50mA (100mA peak) and source an average current of 75mA (150mA peak). This means that for standard 7400 devices it can pull a high output low or a low output high.

Refer now to the circuit diagram of the pulser probe. Heart of the unit is a Signetics 555, an integrated circuit timer. Here, the timer is connected to function as a square wave generator. The time constant components are the 2.2uF capacitor and the 10k and 270k series charging resistors. The capacitor charges to 2/3 Vcc via the 270k and 10k in series and then discharges to 1/3 Vcc via the 270k resistor. This cycle of events repeats itself ad infinitum. Operating frequency is about 0.8Hz and the duty cycle 50pc

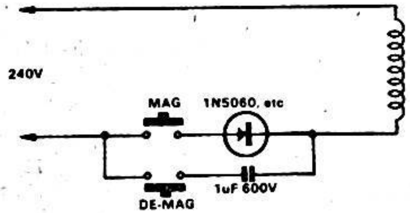
Two transistors are arranged as common emitter amplifiers working in a push-pull class-B mode. The basi resistor of each transistor is chosen to limit the sink or source current to the figures specified above. The transistors specified are the 2N3646 (NPN) and the 2N3638A. These are both ideal for the job as they are fast switching transistors with low collector-emitter saturation voltages. The base resistor of the 2N3638A is chosen to limit the peak source current to 150mA while the base resistor of the 2N3646 is chosen to limit the sink current to 100mA peak or less. Since the square wave output of the 555 has an approximate 50pc duty cycle, the average source current will be 75mA while the average sink current will be 50mA.

The value of the base resistors are dependent on the beta of each transistor and should be selected during construction.

SIMPLE MAGNETISER OR DEMAGNETISER

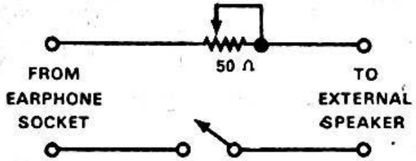
A magnetised screwdriver can be useful for fishing a steel nut out of an inaccessible place, or for holding a nut while screwing it up. Alternatively, a magnetised tool is a menace when adjusting tape-heads or when it becomes covered with iron filings. This simple arrangement for magnetising and demagnetising tools can be very useful. The main item is a field coil of 100 ohms or so, salvaged from an old loudspeaker, transformer or choke. The rest of the circuit is self-explanatory. The tool is inserted into the hole of the field coil and the appropriate button pressed. When magnetising, the coil is fed with pulsating DC. When demagnetising, a capacitor is introduced in series with the coil, producing a strong alternating field. The tool must be withdrawn slowly from the coil while the demagnetising button is held down.

1N5060(400V at 1. 5A)=RS276-1154/44/49. BYX83. 1S154. 1N1118-5174-5395. BY194-252.



REMOTE TV VOLUME CONTROL

If you would like a remote volume control on your TV set, but hesitate to tamper with the wiring of a commercial set, the following tip may help. Many TV sets are fitted with an earphone socket, which usually cuts out the main speaker when the earphone is plugged in.



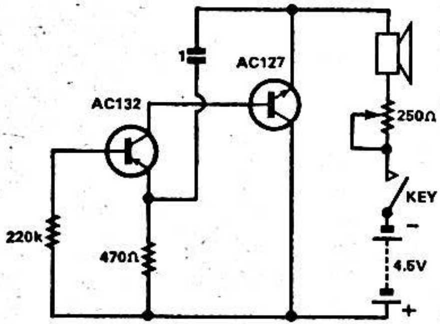
If an extension speaker is plugged into this, it can be fitted with a simple volume control and, if you wish, a switch as well. The volume control's function is obvious, while the switch can be used as an "ad killer".

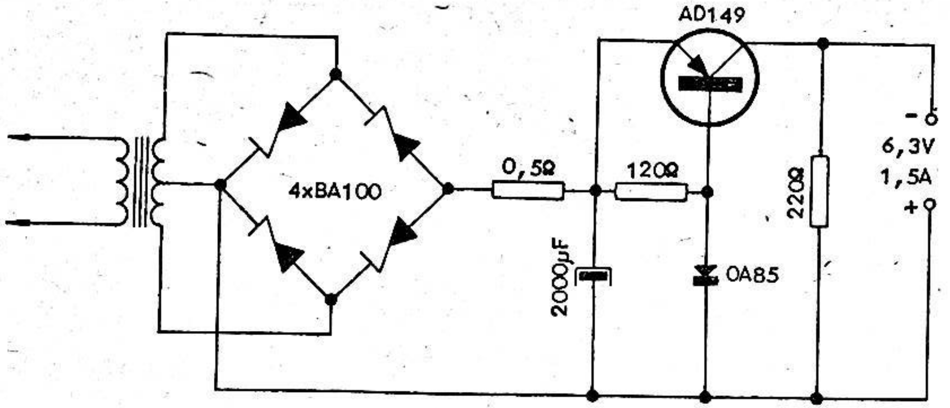
My unit was built into a small plastic case and has about 20ft of cord from it to the TV set.

MORSE CODE PRACTICE OSCILLATOR

Here is a circuit for a morse code practice oscillator. The circuit is self-explanatory and some modifications may be made to accommodate other types of transistors which may be more readily available.

AC127 = RS276-2001. 2N647-1304. SK3010. AC176-179-181
AC132 = 2N1008-1924-2613. SK3004. AC122-131-162-173.





REGULATED 6. 3V SUPPLY

Transformer is 240 volts in 13 volt output centre tapped 15 Watts.
AD149=RS276-2006, AD140, ADY27-28, 2N1530-2143-2836
BA100=RS276-1102, BA108-127-128-147, 1N457-914-4446/7/8/9
OA85 = RS276-1139, OA90-91-95, 1N618, AA118-133

THE TERMINOLOGY OF MEDICAL ELECTRONICS

Articles concerned with medical electronics are appearing with increasing frequency

Because of their application to the medical field, many of the instruments to be described have high sounding names, but nearly all contain familiar circuits. The electroencephalograph, for example, consists of a low-frequency amplifier and a pen recorder; a cardiac pacemaker is essentially a blocking oscillator; and a phonocardiograph is a microphone-amplifier-oscilloscope combination for displaying heart beats. These and other instruments are described below in terms familiar to the reader with a knowledge of electronics.

Ballistocardiograph (bah lis toe kar dee o graf): Each time the heart muscle contracts, it sqeezes blood through the circulatory system of the body. Like the ballistic recoil of a rifle when the bullet is ejected, the ejection of blood from the heart produces a movement of the body along the head-foot axis. A person standing on a sensitive scale can sometimes observe this effect by noting the slight deflection of the scale pointer during each heartbeat. The ballistocardiograph (BCG) is an instrument that records these body movements.

Recordings of the ballistocardiograph are accomplished with the patient reclining on a specially constructed table. The top is mounted on springs or rollers so that it is free to move along the head-foot axis. Ballistic motion of the patient's body is therefore imparted to the table top, and a sensing device such as a phototube, strain gauge, magnetic pickup coil, or movable-core inductor responds to this motion. Output of the sensing element is amplified and fed to an oscilloscope or a pen-type recorder. The resulting waveform, known as a ballistocardiogram, can be evaluated by trained personnel to reveal information about the heart and circulatory system.

Cardiotachometer (kar" de o tack kom e ter): The cardiotachometer is a form of frequency meter used to indicate the heartbeat rate. The sensing element may be a microphone responding to heart sounds, a pressure transducer responding to the pulse, or metal electrodes picking up the voltage produced by the heart. In any case, the output of the sensing element is amplified and applied to a pulse-shaping circuit. These standardised pulses, one for each heartbeat, are then applied to a metering circuit to indicate the rate of heartbeat.

Defibrillator (de fib" ri la' tor): Fibrillation is a condition in which the muscle fibres of the heart contract in a random, un-co-ordinated sequence. The heart, therefore, loses its effectiveness as a pump, and the condition is fatal within a few minutes if normal heartbeat is not restored. By shocking the heart electrically, the defibrillator causes simultaneous contraction of all muscle fibres. This produces a condition of cardiac standstill from which the heart often recovers spontaneously, resuming a normal beat.

The output of the defibrillator is often a 50Hz sine wave obtained through a transformer from the power lines. Voltage is adjustable in the range of 50 to 200 volts. Contact with the patient is established by means of two metal electrodes placed on the chest, and the duration of the shock .1 to .3 second, is controlled by a time-delay circuit.

High-voltage DC may also be used. Capacitance-discharge defibrillators supply a 2,000 to 2,500-volt pulse for time durations of less than 20mS. In addition, defibrillators have been synchronised with electrocardiographs for treatment of fibrillation—the device is then similar to the pacemaker.

Diathermy (di' ah ther" me): Diathermy employs RF energy to produce heat in the deep tissue of the body. Equipment consists of a high-power RF oscillator whose output is applied to a pair of metal electrodes (insulated to prevent electric shock to the patient). These electrodes, known as applicators, are positioned on the patient's body so that the tissues to be heated are between the applicators; the patient thus becomes the dielectric of a capacitor. Proper choice of size and position of the applicators permits heating of a selected region of the body. Typical frequencies of operation are in the 13-, 27- and 40-MHz bands, but some units operate in the microwave region around 900 or 2300MHz.

Electrocardiograph (e lek" tro kar' de o graf): The electrocardiograph (ECG) records the voltage produced by the heart as it alternately contracts and relaxes. This voltage is picked up by means of metal electrodes strapped to the arms, legs, and chest of the patient. At the electrodes, the voltage is approximately 1 millivolt peak and must be amplified to a level sufficient to drive a recording pen which writes on a paper chart. The amplifier must have excellent low-frequency response because the input pulses from the electrodes have a basic frequency of approximately 1Hz (the heartbeat rate). For this reason, ECG amplifiers, generally employ either direct coupling or capacitive coupling with relatively large values of capacitance – 2 to 10uF.

Although the low-frequency response of the ECG amplifier must extend below 1Hz, high-frequency response is not critical. Few electrocardiographs (including the pen mechanism) will respond above 100Hz, and response may be deliberately limited to less than 50Hz, to attenuate stray pickup from the power lines.

The recording mechanism is essentially a D'Arsonval movement fitted with a lightweight pen instead of the usual pointer. The pen writes on a long paper chart pulled through the machine by a constant-speed motor.

Electroencephalograph (e lek" tro en sef' ah lo graf): The electroencephalograph (EEG) records the electrical activity of the brain. Like the electrocardiograph, this instrument consists of a high-gain amplifier and a pen-type recorder. The brain-generated voltage is picked up by small metal electrodes on the surface of the scalp. The waveform is roughly sinusoidal and the amplitude at the electrodes is in the microvolt region. The dominant frequency component, known as the **alpha** rhythm, is approximately 8 to 12Hz.

Research and clinical electroencephalographs are multichannel instruments to permit simultaneous recording from different areas of the scalp. Typically, the instrument consists of eight identical amplifiers feeding eight recording pens. All pens write on the same (wide) chart so that the waveforms are recorded in correct time relationship.

Electromanometer (e lek" tro man om' e ter): The electromanometer is a pressure-recording device. A typical instrument employs a transducer such

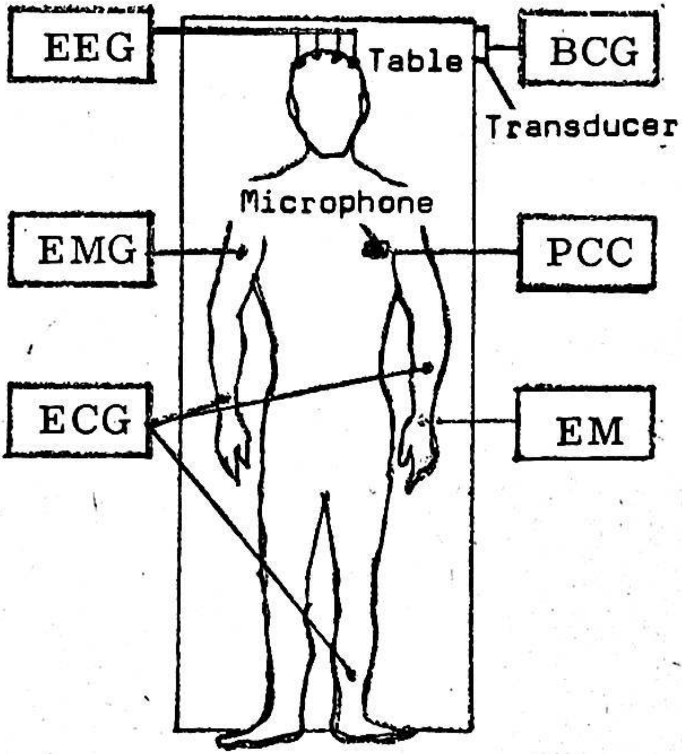


Diagram showing where some of the instruments described in the article are used. EEG records brain voltages; EMG records muscle voltages; ECG records heart voltages; BCG records movement of body when blood is ejected from the heart; PCG records waveforms of heart beats; electro manometer records blood pressure waveforms.

as a strain gauge for sensing variations of pressure. The transducer is mounted in a hypodermic syringe which is inserted into the blood vessel whose pressure is to be monitored. The strain gauge varies in resistance according to pressure changes and is connected in a bridge circuit. The degree of unbalance of the bridge then varies according to pressure changes. Output of the bridge is amplified, and the resulting waveform is either displayed on an oscilloscope or applied to a pen-type recorder. Some electromanometers employ surface-type transducers such as capacitor microphones for measuring pulse pressure.

Electromyograph (e lek" tro my o graf): The electromyograph (EMG) records the electrical activity of muscle. A needle-shaped electrode is inserted into the muscle to be studied and picks up the voltage pulses produced when the muscle fibres contract; these pulses are amplified and displayed on an oscilloscope. (Pen-type recorders do not have frequency response generally required for electromyography.) Most electromyographs include an audio amplifier and loudspeaker to make the muscle pulses audible. To the trained diagnostician, these sounds are as meaningful as waveforms on the oscilloscope.

Oximeter (ok sim' e ter): The oximeter is a device for measuring the oxygenation of the blood. The blood sample is placed between a light source and a photocell, and the light transmitted through the sample is a measure of the oxygen content. Output of the photocell is amplified and displayed on a meter. Some oximeters employ an ear-clip so that measurement can be performed without drawing a sample of blood. The ear-clip contains a miniature light bulb and photocell to measure light transmission through the ear lobe.

Pacemaker: The pacemaker is a pulse generator used for restarting the heart after a condition of standstill (cardiac arrest) has occurred. By means of electrodes placed on the chest, or directly on the heart during surgery, pulses of current are passed through the heart at regular intervals. Each pulse causes the heart muscle to contract, restoring normal heartbeat. The pulses are 1 to 2 milliseconds in duration and are variable in repetition rate from approximately 20 to 200 pulses per minute. A few heart patients require continual electrical stimulation, and miniaturised pacemakers are implanted surgically in their bodies.

Phonocardiograph (fo" no kar' de o graf): The phonocardiograph (PCG) records the waveforms corresponding to the sounds produced by the heart. The sounds are picked up by a microphone held against the chest, and the signal is fed to a high-gain, low-noise amplifier. Amplifier output is either displayed on an oscilloscope or is applied to a pen-type recorder. A headset or loudspeaker is also included for aural monitoring of heart sounds.

The waveforms recorded by the phonocardiograph convey diagnostically useful data not obtainable by use of the ordinary stethoscope. The acoustical stethoscope (and the doctor's ears) does not respond to many important heart sounds, which are low in both frequency and intensity.

Crystal and capacitor microphones are often employed in phonocardiography. In a variation of the basic technique, a subminiature microphone can be pushed through a blood vessel until it is inside the heart. This permits monitoring of sounds within the chambers of the heart, and these sounds can be interpreted in terms of blood flow, valve action, leakage, or other desired information.

THE DAUBLE 9 NOTE DOOR CHIME

The jarring sound of a front door bell or buzzer is about the least desirable way to announce a visitor's presence. The door chime is a step in the right direction, but its repertoire is limited, to say the least. If you want something that is gentle, melodious and distinctly personal – try the Dauble.

The Dauble will play a sequence of nine tones which can be pre-selected. There is no current drain until the doorbell button is pressed. The Dauble peals out its message the pre-set number of times then switches off at the end of a sequence. There are a number of variations which can be implemented using an extra component or two.

Nearly all the circuit functions are performed by three ICs: a 556, a 7490 and a 7441.

The 556 is a combination of two 555 timers, and is considerably cheaper than two of these latter devices. The left half of the 556 generates a series of rectangular waveform pulses which, ultimately, initate the series of tones, one for each pulse. The rate at which the pulses are generated is variable by adjusting P2.

The right half of the 556 generates the actual tones. Resistor R5, together with any one of the pots P3 to P11, form a voltage divider which controls the frequency generated at any particular time.

The 7490 counts the pulses generated by the left half of the 556 and gives out a binary count in BCD form, resetting to zero after each ninth pulse.

The 7441 decodes the bindary count in a number from 0 to 9. More specifically, it connects the pin representing each number to the negative rail via pin 12. Thus R5 and the selected pot (P3–P11) form a voltage divider between the positive and negative rails.

The 7441 was chosen because it is the cheapest 1 to 10 decoder with open collector output, i.e., any output can be connected to any trimpot, P3–P11, without risk of blowing gates or upsetting other settings.

The whole sequence of events is iniated by operating the press button S1. This energises the relay which connects the battery negative terminal to the negative rail. In doing so it locks itself up via R1.

Immediately the negative rail is energised, C1 commences to charge through P1. Initially, the base of Q2 is at negative rail potential, before C1 commences to charge. As it charges, Q2 base moves towards the positive rail until, after a prescribed time, Q2 is biased on – or would be if its emitter was connected to the negative rail. Assuming for the moment that it is, when Q2 conducts, Q1 is biased on, and shunts the relay winding. The relay drops out and the sequence finishes.

In fact, the base of Q2 is not returned directly to the negative rail, but to pin 16 of the 7441. With this arrangement the emitter is isolated until the 7441 goes through zero. Only then does it go to the negative rail and the relay drop out. This ensures that a sequence, once commenced, will be completed, regardless of random time variations, as determined by C1, P1.

Another operation initiated by S1 is to set the 7490 to zero. The network C4, R4 performs this function as it is connected to the negative rail.

Values for R5 and R9 are selected to ensure that if there is no pot in any of the positions 3 to 11 the control voltage on the right half of 556 is held above the voltage to which C5 can charge. As a result, oscillation is stopped.

In its elementary form, the circuit produces a continuous output switching directly from one tone to the next. If a pause between tones is preferred, oscillation can be stopped by holding the reset pin (10) low. Since the output of the left half (pin 5) alternates between high and low as it generates the square pulses to feed the 7490, it is a logical source to also control oscillation of the right half. When the output goes high, the right half will oscillate; when it goes low, it will not.

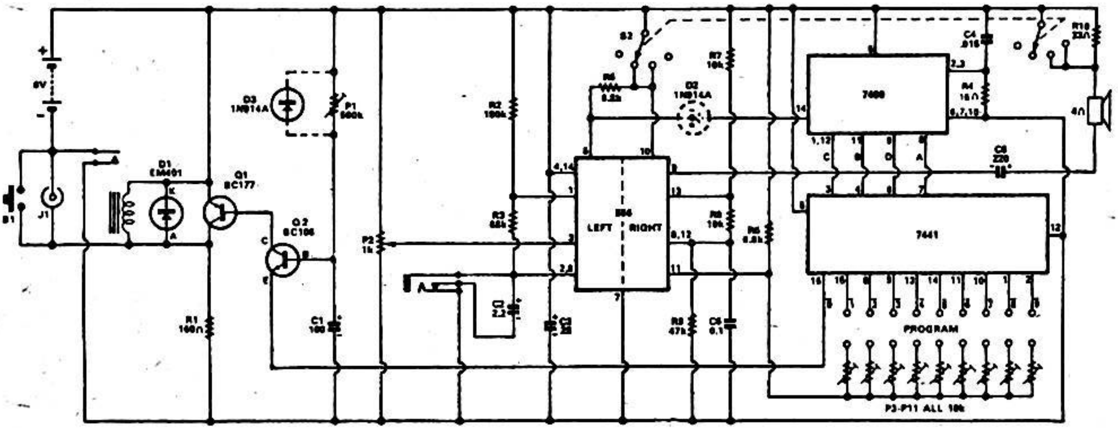
If spaces are not required, pin 10 can be held high by connecting it to the positive rail. Switch S2 provides switching between these two functions, R6 providing isolation of pin 5 and permitting a simple switching arrangement.

Diode D1 is, fairly obviously, a protective diode to suppress any inductive spikes generated in the relay winding when its associated circuit is opened.

Diode D2 is part of an optional modification for 12V operation. It is not otherwise required.

Diode D3 across P1 provides a rapid discharge for C1 after each operation. Without it, a second pressing of the button may produce only one peal, rather than the normal five or six. This may be either an advantage or a disadvantage, according to circumstances. Restricted repetition is certainly an advantage when visiting children lean on the button in sheer delight at what may no longer be a novelty to anyone else. Thus D3 is shown dotted – it is entirely optional.

Switch S2 has already been mentioned as providing either intermittent or continuous operation, but it also provides a choice of two volume levels by either removing or including R10 from the speaker circuit.



The complete Double circuit. The relay and associated timing circuits are on the left, the pulse and note generating circuits in the centre around the 556, the binary counter (7490) and the binary decoder (7441) circuits on the right.

556 LEFT	556 RIGHT	555	FUNCTION
7		1	GROUND
6	8	2	TRIGGER
5	9	3	OUTPUT
4	10	4	RESET
3	11	5	CONTROL V
2	12	6	THRESHOLD
1	13	7	DISCHARGE
	14	8	Vcc

(Editorial note: In the original design, S2 was fabricated from a trimpot but, while ingenious we feel that most constructors would prefer to use either a standard two-pole switch, or two simpler, separate switches.)

Most of the circuit is accommodated on a printed board. This is really two patterns in one; the main, or larger, portion, and a smaller auxilliary board on the right-hand side. This auxilliary board is to accommodate two 555 timers in place of the 556. This will be appreciated by constructors who already have 555s on hand, or in the event of a shortage of 556s. There is also provision for adding power transistors to the output.

The prototype was constructed in a plastic junction box measuring 4in x 4in x 2½in. These are available from most electrical trade warehouses for about $1.40. They are usually grey but also come in "electrical trade orange". The walls are 5/32in thick.

The accompanying diagrams give a good idea of the general construction, although this may have to be varied slightly to accommodate components of varying size.

The lugs of pots P1 and P2 must be bent at right angles so that they lie flat on the board. This area of the board lies under the back of the speaker, so a minimum profile is required. It is recommended that the 0.015μF capacitor (C4) be installed at the same time as the 120 ohm resistor (R4). The capacitor lies flat over the resistor, once again in the interests of low profile.

Pots P3 to P11 should be fitted last to avoid damage during other wiring operations. To avoid fouling the relay it may be necessary to trim the lugs of these pots close to the copper pattern.

Pins 9 and 11 of the 7490 connect to pins 4 and 6 respectively of the 7441 directly across the top of the board. Bend the pins outwards, once only, not too sharply, just above where they narrow.

Programming the unit involves two steps; adjusting each of the pots to create one note of the musical scale, then making the necessary interconnections to provide the required note sequence.

In the prototype the required notes were obtained by setting the pots to the values shown in the accompanying table. However, these can only serve as a guide. Final tuning may be by ear, if one has the musical ability, or with the aid of a frequency meter if one is available.

The note sequence is programmed by appropriate connections between the 9 pots and the 9 output pins of the 7441. Any output can be connected to any pot, regardless of whether there is a previous connection to it or not.

Initially, interconnections may be made directly on the board, using jumper leads. Once a tune has been selected, the jumper leads may be shortened to permanent links, if it is not expected that the tune will need to be changed.

A more flexible arrangement is to extend both the pot connections, and the 7441 output connections to an external socket into which may be inserted any one of a number of plugs interconnected to give a particular tune.

A number of socket arrangements are possible. The minimum requirement is 18 pins (9 pairs) but the prototype also had pins 5, 10, and 11 of the 556 plus the positive and negative rails brought out.

One suggestion is a pair of 14 pin DIL sockets. Another is a single 24 pin DIL socket which would at least accommodate the pot connections. Yet another is a 24 way edge connector, with a strip of suitably spaced Veroboard as a plug.

In the prototype, preliminary interconnections were made using jumper leads fabricated from short lengths of wire soldered to plastic headed pins. The pins are then inserted in the DIL sockets to provide the necessary connections.

TUNING GUIDE

B	1	987.8 Hz	7.8k
C	2	1046.4	7.3k
D	3	1174.8	6.1k
E	4	1318.4	5.3k
F	5	1396.8	4.8k
G	6	1568.8	3.9k
A	7	1760.0	3.0k
B	8	1975.6	2.5k
C	9	2092.8	2.0k

A more permanent arrangement was made as follows. The DIL socket was covered with plastic tape, then the pins inserted and the correct sequence established. The wires were trimmed and dressed to occupy minimum space, then a small cardboard mould erected around the assembly. Finally, the whole set up was potted in Plastibond. The result is a plug providing a particular sequence.

If at first switch-on, the circuit fails completely, check these points. Rail voltage on all three ICs. That the ICs are the right way round. That the pins connecting directly together across the top of the board are soldered. A wire link is required on the component side of the board between pin 4 of the 556 and the positive rail. Check that it has been fitted.

A voltmeter between either supply rail and pin 5 of the 556 should show a changing voltage at pulse frequency. the ABCD outputs of the 7490 can be similarly checked. The 7441 outputs can be checked by measuring the voltage between the positive rail and each output, preferably with a meter with poor sensitivity. Each output should drop to about 4.5V progressively. The right side of 556 can be tested by connecting any one of the pots, P3 to P11, directly to the negative rail rather than via the 7441. Varying the pot should vary the frequency.

It is also likely that the circuit will work but that some functions may not perform correctly. One possibility is that the relay may lock on permanently or drop out immediately the button is released. This will call for adjustment of R1, such that the relay is just held on after the button circuit opens. If the relay resistance differs from that used in the original, or if a 12V relay is being used with the 12V modification (described later) a different value of R1 will be required.

If, when none of the pots P3 to P11 are selected, there remains a low frequency oscillation, decrease R9. R5 and R9 adjust the voltage at which oscillation stops, while R5 adjusts the loading which pots R3 to R11 can provide. R9 controls the total frequency range. There is a rough balance to be struck between these factors, but nothing critical.

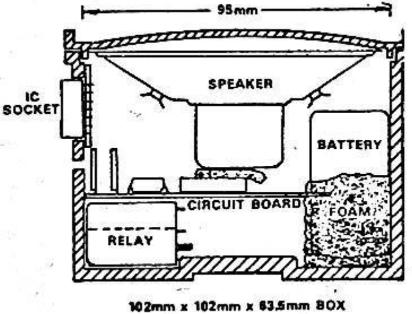
If the circuit does not start with P3, or resets during operation, the combination of R4 and C4 is probably wrong. There must be enough time delay to hold the reset input high momentarily after switch-on, but not so much capacitance that heavy audio spikes can reset the 7490 during a cycle. Physical size limits C4 and R4 must be under about 250 ohms.

There are several modifications to the basic circuit which readers may care to try, once this is working.

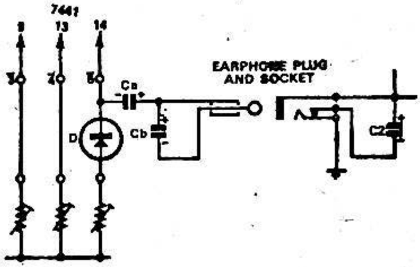
Try varying the value of C5. This will change the waveform of the note, the main limitation being a reduction in volume if the value is increased too far.

The unit can be operated from 12 volts, with the advantage that the tone level from the 556 will be increased. The disadvantage is that the circuit must be modified to provide two positive rails; 12V for the 556 and 6V for the 7490 and 7441. The relay will also need to be a 12V type. The relay will also need an extra set of contacts to switch the positive 12V rail. Separation of the positive rails can be provided by cutting the copper pattern at the point marked "H".

The 556 has not been tried with a 4 ohm speaker at more than 12 volts. Under these conditions one end gets warm after repeated playings. The input to the 7490 from the 556 must be diode isolated – hence D2 shown dotted in the circuit.



Assembly of the system within the box. Some care is necessary to ensure that everything fits readily into place.



How to lengthen a single note. The normal pulse rate is determined by Cb but, for tone 5, by Cb and Ca in parallel. Ca, Cb and the diode are encapsulated in the brick.

(Editorial note: Strictly speaking the 7490 and the 7441 should not be operated above 5 volts. A diode in series with the supply rail to these units would bring the voltage closer to that recommended, and probably close enough for intermittent operation.)

The following are a few suggested note combinations:

Westminster chimes	A F G C n/c C G A F
Twinkle Twinkle	C C n/c G G n/c A A G
Dragnet theme	A A A B C'C' A A
On Top of Old Smokey	C C E G C'C'C'A A A
From Beethoven's sixth	A A A F F F F F F

Note: Where letters are shown close up it is intended that the outputs be linked to give a continuous note. Spaces between letters indicate the normal break provided in the intermittent mode. The notation n/c indicates an output left blank.

Joining two or more outputs together to lengthen a note can introduce a variation in tone when switching from one output to the next. An alternative approach is to change the pulse rate of the left side of the 556 for that particular note. More specifically, the value of C2 is changed for that particular note.

To facilitate this C2 is connected to a miniature shorting type jack mounted alongside the DIL socket into which the programming modules are plugged. Inserting a plug into this jack will remove C2 from circuit and substitute whatever capacitor is connected to the plug.

A bonus feature of this arrangement is that the length of all notes can be changed by simply connecting a larger or smaller capacitor to the plug. Miniature electrolytic capacitors, larger in value than C2, can be accommodated inside the plastic plug housing, making a very neat arrangement.

To lengthen a particular note an additional capacitor is used and switched in parallel with the main capacitor (substitute for C2) when the particular note is selected. For example, in the auxilliary diagram, the normal pulse rate will be determined by Cb, but, for tone 5, it will be due to Cb and Ca in parallel, Ca being connected to the negative rail via output pin 5. The diode provides the necessary isolation.

A minor problem is that the diode will lower the frequency of the note involved. This may be overcome by adding resistors, or diodes, to all the other notes to lower them also, or connect the diode to a note further up the scale which, hopefully, will be close enough to the one required when lowered by the diode.

If the exact note cannot be obtained in this way, a note can be selected which is too high, then lowered by the addition of resistance in series with the diode.

All these modifications can be incorporated in the module, including a plug on a short flexible lead.

Soldering to ordinary household pins may present problems using conventional flux as used in electronic work. Something stronger, such as "Baker's Fluid", will usually be required. After soldering, and before encapsulation, all traces of such fluxes should be carefully removed, otherwise they can cause conductive bridges between the pins.

No doubt constructors are thinking of their mown modifications by now. In any case, why restrict the idea to a doorbell? What about a child's toy, chime for an electronic clock, alarm for a clock, dinner bell, TV program reminder . . .

This project has been a delight to design, and an absorbing toy to play with.

May your doorbell be musical, and may you have many visitors.

Parts List

1 Plastic box (4 x 4 x 2½in)
1 Printed board
1 Speaker, 3.4 or 4 ohm to fit box
1 Relay, Siemens V23027-130001-A101 or V23154-D0412-K104 or V23154-C0717-B104
1 Press button switch. Switch or switches for S2 function. See text.
1 25mm plug and socket
1 24-pin DIL socket or 2 x 14-pin DIL sockets. See text.

ICs
1 SN7441AN or RS276-1804
1 SN7490N or RS276-1808
1 NE556 (DIL)

TRANSISTORS
1 BC108, BC108 or BC109 or RS276-2031
1 BC177 or 2N3638A or RS276-2021

DIODES
1 EM401 or EM4004 or RS276-1139

RESISTORS (all ¼W)
1 33 ohm
1 120 ohm

1 160 ohm
1 6.8k
2 10k
1 47k
2 68k
1 180k

POTS
9 10k
2 1k
1 500k
Soanar type. Must not exceed 11mm wide.

CAPACITORS
1 0.01µF 100V greencap
1 0.1µF 100V greencap
1 2.2µF electrolytic
1 25µF electrolytic
1 100µF electrolytic
1 220µF electrolytic
All electrolytics suitable for board mounting.

QUIZ CONTEST-CAPTURE SYSTEM

This simple lamp and buzzer circuit may be treated as an electronic game in its own right, in which contestants can compare their reaction times, or it may be used as an accessory to popular quiz games to determine who has first right to answer a question.

It was inspired by watching the TV quizzes where contestants have to push a button to sound a buzzer and light a lamp to earn the right to answer the question. Some mental gymnastics are necessary as pressing the button to gain the right to answer also carries a penalty if an incorrect answer is given.

On a more dedicated note, the device allows practice, beforehand, by quiz contestants in a TV show. This can really hot up the competition.

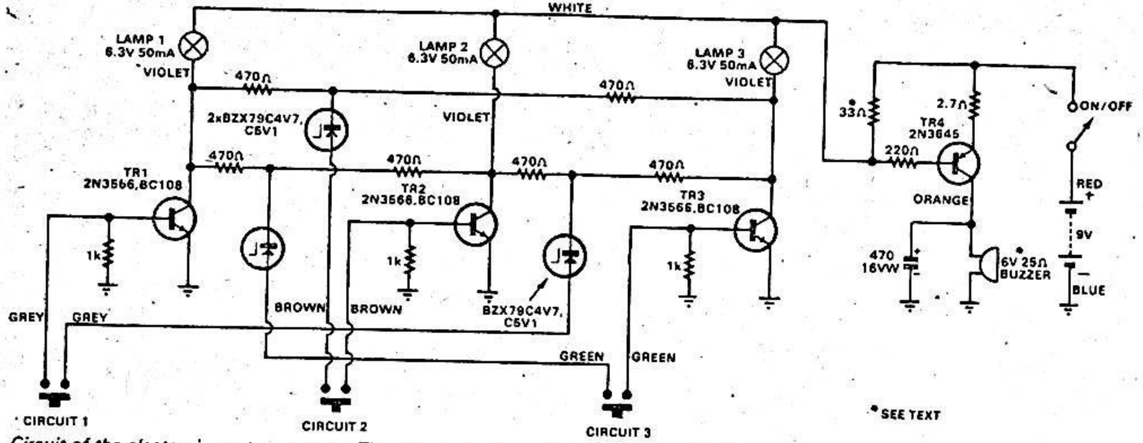
The circuit provides the facility to sound the buzzer, and to both light a lamp for the first button pusher, and to remove the capability of the other two buttons to actuate their respective lamps. Thus the quizmaster knows to whom the question is to be addressed.

Electrically, there are three similar circuits – each of one transistor (TR1, 2, 3), and associated resistors, with a 50mA, 6V lamp in each respective collector circuit. All three transistors are NPN silicon general purpose types, fed from a common positive supply rail. This rail in turn is supplied via a 33 ohm resistor from 9V battery.

When any one transistor conducts, 50mA flows through this resistor producing about 1.7V across it. This voltage is applied to the emitter/ base circuit of a PNP transistor (Tr4) through a protective 220 ohm resistor. This 220 ohm resistor guards against untoward connections and happenings in the buzzer, pushbutton or lamp circuits.

The 1.7V turns on TR4, which is normally off. Its collector is connected to the buzzer, thence to negative. A 470uF 16V electrolytic is fitted across the buzzer to absorb the buzzer surges, which could cause sufficient battery voltage disturbance to affect the other three stages. The capacitor also reduces buzzer voltage spikes which could damage Tr4.

All three transistors (Tr1, 2, 3) are held normally off by a 1K emitter/base resistor for each. Now one (say Tr1) may be switched on by that contestant's pushbutton, which connects the base to a source of positive voltage. For each transistor, the source is a voltage divider of two 470 ohm resistors, across the collectors of the other two transistors. The control power is fed in each case through a 4.7V or 5.1V zener diode from the divider points to the pushbutton concerned.



Circuit of the electronic capture system. Three sections, involving TR1, TR2 and TR3, are virtually identical and the first one triggered disables the other two. Simple circuits are possible, but are usually limited to two push buttons.

As Tr1 conducts, its collector drops to about 1 volt positive, while the collector rail, and hence the collectors of the other two, drop by 1,7V, as previously explained, to 7.3V positive. Under these conditions the voltage available to the other two pushbuttons is only 7.3 + 1 (No. 1 collector) x 0.5 (voltage divider of 2 x 470 ohms) = about 4.1 volts. However the 4.7V or 5.1V zeners in the respective pushbutton circuits will not conduct at this figure, so both Nos. 2 and 3 circuits are inoperative.

This condition is set up virtually instantaneously, being in the conduction time – of some nanoseconds – of Tr1 (or Tr3 or Tr2). Thus, the aspect of a dead heat by the button pushers, with a reaction time of several hundred milliseconds, is of little more than academic interest. As it happens, a true dead heat would favour the circuit with the fastest transistor turn-on time, but it is worth considering that the margin is less than the time delay in hearing the quizmaster's voice, if the contestants are seated so much as one inch more distant that each other from him.

It is necessary to use good zeners, and not "specials" (with high loss currents), as this will indeed give one contestant an advantage. In this case switch-on will be achieved under any conditions, which will also extinguish an earlier set-up of one of the others.

The buzzer may be any unit that will work in the 4 to 6V range, but should not be less than about 25 ohms. This is to ensure that Tr4 is not overloaded, and also that large surges are not superimposed on the battery rail, to the detriment of the lamp seize circuits. If a suitable buzzer cannot be obtained a relay can be turned into a buzzer by connecting the operating winding in series with a break contact on it.

If lamps other than 50mA are used, the 33 ohm resistor will have to be varied to retain about 1.5 to 1.7V across it. Also, if such lamps are used, a check on Tr1, 2 and 3 ratings would be required.

Layout is not critical. The circuit proper is best wired on a piece of veroboard. The writer used a 2¼in length, cut from a 4¾in wide veroboard, having 21 perforated conductor strips. The 2¼in length provided 11 holes, which proved adequate. The diagram shows the layout adopted. Only one cut is needed in one copper strip, as shown. About 10 to 12 square inches of board are required.

PARTS LIST

1 Box
1 piece of Vereboard, 4⁶ in wide, 2² in long (21 strips)
3 NPN transistors, BC108, RS276-2009 or similar
1 PNP transistor, 2N3645, RS276-2021 or similar
3 4.7V or 5.1V zener diodes, BZX79, C4V7 or similar

1 470µF electrolytic capacitor
3 1k resistors
6 470 ohm resistors
1 220 ohm resistor
1 33 ohm resistor
1 2.7 ohm resistor (¼ W)
3 6V, 50mA lamps complete with bezels
1 9V battery
1 Battery plug to suit
3 Push buttons
1 Buzzer, 6V, 25 ohms or higher. (See text)
10yds insulated hookup wire. (See text re colours)
12 4BA x 1in machine screws with nuts

When the circuit board is wired, the 13 leads to it are best run in various colours, to minimise connection errors. A suggested colour coding is indicated, both on the layout diagram, and also on the circuit diagram. The writer found this double colour guide almost indispensable.

There are no real problems in mounting all parts in a small box. The writer used a wooden box, having inside dimensions of 4½in x 5in x 2¾in. The size of the buzzer, and the veroboard used will determine the box shape requirements. If the small relay shown in the parts list is used, plus the battery specified, the box listed should accommodate all items.

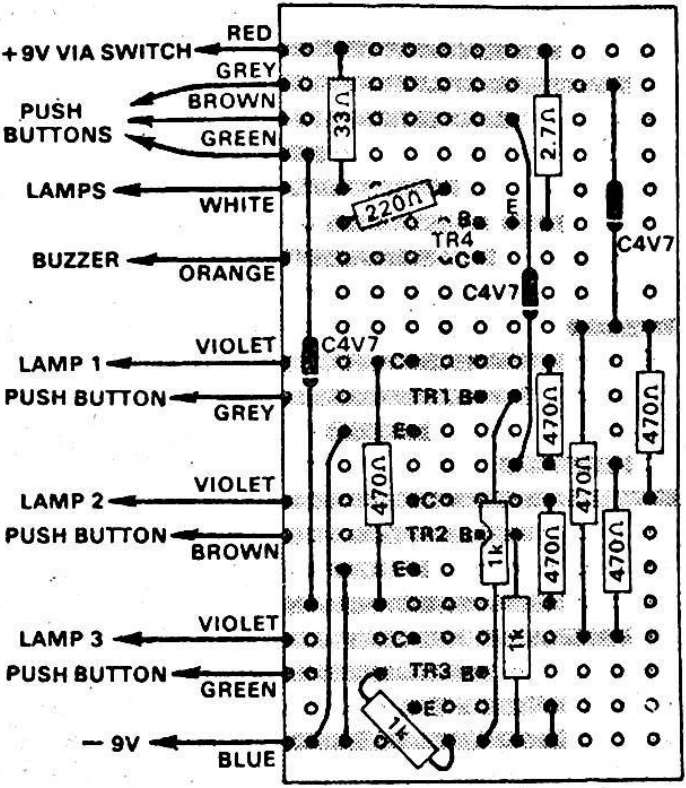
The three bezels can be mounted on the lid of the box or, if desired, can be extended by hookup wire to be associated with the pushbutton concerned. All leads leaving the box need anchoring inside the box. Plus and sockets are another, tidier, way of terminating the pushbutton leads. The writer used antenna plugs and sockets. The on/off switch mounts on the box lid.

The 9V battery may be fitted inside the box, as noted above, or externally if it is desired to avoid having to open the box at intervals. A sizeable battery is necessary to prevent buzzer surges having an unwanted coupling on the lamp seize circuits.

Three pushbuttons are required, and can be mounted on small wood blocks, like older electric switch blocks, or on small folded aluminium boxes, made from scraps of metal. The connecting leads must be anchored at the button end to avoid strain on the button terminals.

Well, that's about the lot! If it is made with reasonably good components, and does not work, it just has to be a faulty connection, or a flat battery.

The writer made the original available to the local school to practice for a TV quiz show. The result? A request for two more! It has also proved an entertaining device in the teenager area in the family. There is no known solution though, for the main problem – wear and tear on parents!



The Veroboard layout,

AN AUTOMATIC LAMP DIMMER USING THE "TRIAC" AC SWITCH

At the flick of a switch, this unit will automatically dim a bank of mains-voltage incandescent lamps smoothly up or down at an adjustable rate and over an adjustable range. The basic design handles up to 2 Kilowatts, but details are also given for both lower and higher power versions. Easy to build and modest in cost, it is ideally suited for movie, slide-show and live theatre presentations.

The "Auto-Dim" unit described in this article acts rather like a "third-hand" in situations where the mains supply to a bank of lamps or a heater must be turned up and down. Once the operator has turned the appropriate knob, the unit takes over and performs the desired fast or slow glide smoothly and automatically.

With the component values shown in the basic circuit the dimming time is adjustable from about one to fifty seconds. However by altering the value of one of the components the maximum time may be extended to more than ten minutes with some reduction in setting convenience for the shorter times. A fixed maximum dimming time of approximately 30 minutes is also available, although only for "downward" dimming.

With the more restricted time range the dimming time is easily adjusted to produce the slow "fade-up" and "fade-down" of house-lights so essential for a polished and professional theatrical presentation. Further features which make it eminently suitable for such applications are the provision for emergency "fast on", and the provision of an adjustable intermediate level between full-on and full-off. The latter is ideal for providing a "twilight" condition until the audience has settled into its seats.

Apart from its fairly obvious applications in movie, slide-show and live theatre work, both for house-light and special-effects dimming, the unit should also find many uses in other fields where lamps or heaters must be dimmed smoothly and/or slowly.

One likely application which suggests itself is for the control of a night-light for children who tend to be afraid of the dark. With the unit modified for maximum dimming time, the night-light will be dimmed smoothly and imperceptably over a period of 30 minutes – after which period the child is usually asleep, having been gently and subtly relaxed by the artificial "sunset" effect.

Other possible applications are in photographic studios, both "still" and movie, for producing special lighting effects; in industrial processes, where heat or light must be applied and removed at a controlled rate; and in applications where expensive lamps must be operated on a "soft start" basis to minimise surge failure and prolong life.

Aside from such "direct" applications of the unit as described, there may be applications for the high-gain power amplifier which forms its greater part. As this section of the unit requires a DC input of but a few microamps to control AC output currents of up to 10 amps RMS, it might well form the basis of an economical high-power AC function generator or servo amplifier, or perhaps a high-power regulated DC supply.

Enough of such speculation, however; surely sufficient has been said to more than justify the appearance of the design and this article. Let us now pass on to a discussion of the operation of the unit.

At the heart of the design is a "Triac" silicon AC control device, a development by General Electric of U.S.A. and a close relative of the thyristor or "SCR".

For a fairly detailed description of the Triac and its principles of operation readers are referred to either the above article or to the "Keeping Up With Semiconductors" article of last month. However for the following discussion it may be sufficient to visualise the Triac as virtually two thyristors in inverse parallel, sharing a common gate electrode and a common case.

Like the Vari-watt, the Auto-Dim circuit employs phase control to vary the conduction of the Triac for each half-cycle of the AC supply. However, whereas the Vari-watt uses a simple R-C phase shift circuit and silicon breakover diode to produce the required adjustable-phase trigger pulses, the Auto-Dim uses a unijunction transistor relaxation oscillator coupled to the Triac via a small pulse transformer. The unijunction may be a G-E economy type 2N2646, a type 2N2160 or similar.

The operation of the circuit is as follows: The Triac is connected directly in series with the load socket across the mains. Also across the mains is a bridge rectifier circuit using four 400V rating silicon diodes; the output of this bridge therefore consists of unidirectional pulses of 340V peak amplitude (240 x 1.414), corresponding to the half-cycles of the input AC.

A regulator-clipper connected across the rectifier output is used to produce a clipped version of this pulse voltage, to operate the low-voltage transistor circuitry. The regulator consists of a 15K 10W resistor series arm and a shunt arm comprising a nominal 12V zener diode (OAZ213 or similar) in series with approximately two forward-biased silicon diodes (BA100 or similar).

The principal function of the forward-biased silicon diodes is to allow convenient adjustment of the transistor supply voltage, which in turn controls the maximum obtainable output power in a manner to be explained shortly. The exact number of diodes required thus depends upon within-tolerance variations in other components.

A secondary function of the diodes is to provide temperature compensation for the voltage regulator. As forward-biased semi-conductor diodes have a negative temperature coefficient, they tend to counter the positive temperature coefficient of the zener diode.

The nominal 13V peak clipped output of the regulator is used as the supply voltage for the unijunction transistor. It is also used as the supply for a cascaded-emitter-follower or "Darlington pair" transistor amplifier using two silicon planar NPN transistors (type BC108, 2N3565 or similar), whose purpose has yet to be explained. And finally, it is used to provide a source of charging current for the 100uF capacitor marked C1.

In addition to the regulator-clipper circuit connected across the bridge rectifier output there is a 3.3M resistor, connecting to the unijunction emitter and thence to negative via a 0.1uF capacitor. The resistor and capacitor form a charging circuit whose time-constant is such that, in the absence of any current contributed by the Darlington transistor pair, the capacitor voltage ONLY JUST reaches the conduction point of the unijunction at the end of each mains half-cycle.

As it is the unijunction conduction which supplies a current pulse to transformer T1 to turn on the Triac, under these conditions the Triac is effectively "off" for all but a very small portion of the mains half-wave. The effective current passed is far below that required to produce a visible glow from an incandescent lamp or discernible heat from a radiator.

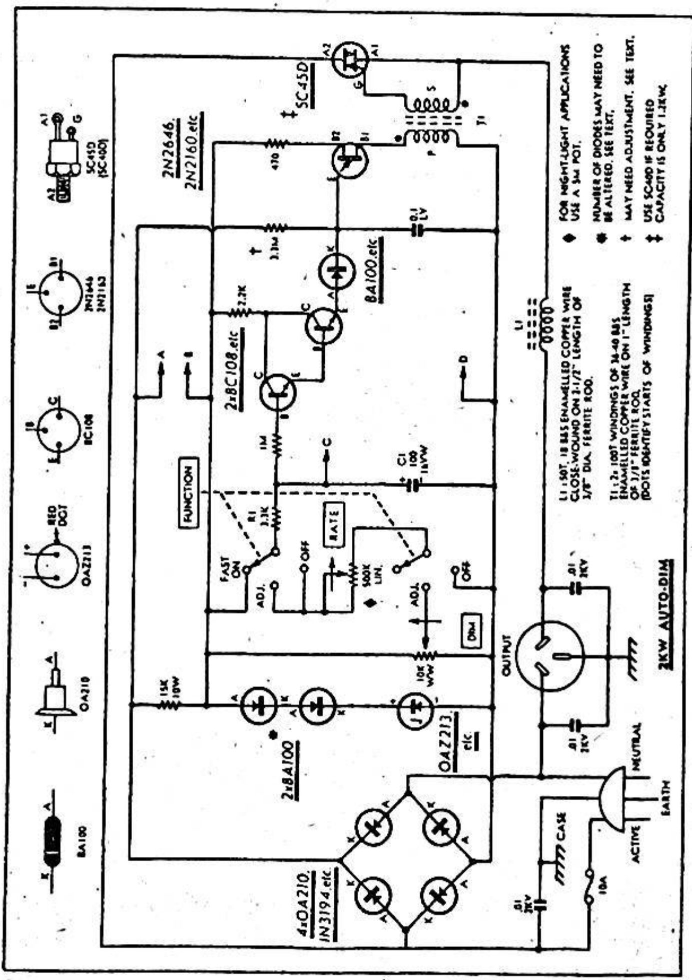
To turn the Triac on for increasingly greater proportions of the mains half-cycles, it is simply necessary to advance the conduction of the unijunction. This is done by using the Darlington pair to apply an increasing "bootstrap" DC voltage to the 0.1uF capacitor, so that the total capacitor voltage reaches the unijunction conduction level at earlier and still earlier phases in the half-cycle.

When the applied DC is itself only just short of the conduction level, the unijunction and Triac conduct almost at the start of each half-cycle. This is the "full on" situation, where the Triac delivers virtually full power to the load.

To slowly reduce the load power for "dimming down", the DC bootstrap voltage applied to the 0.1uF capacitor is simply reduced at the required rate. This produces the converse of the dimming-up operation: with each succeeding mains half-cycle the unijunction and Triac conduct at later and later phases until finally they are conducting at almost the end of the half-cycles as before.

The DC control voltage applied to the 0.1uF capacitor is generated by the circuitry associated with the 100uF capacitor C1. It is actually the voltage across C1 during adjustable charge and discharge which forms the increasing or decreasing DC voltage.

The Darlington transistor pair is simply a means of reproducing this voltage at the 0.1uF capacitor while presenting very light loading across C1. As a cascaded-emitter-follower, the pair has a very high input impedance, low output impedance, high current gain but unity voltage gain.



The circuit of the unit. The high-gain power amplifier section may also find use in other applications, as suggested in the text.

To produce a rapid increase of load voltage for the "emergency fast on" function, C1 is charged quickly from the 13V line via the 3.3K resistor R1. This resistor also determines the shortest rise and fall times in the remaining positions of the function switch. However in both these positions the dimming rate can be extended considerably by inserting additional series resistance with the Rate potentiometer.

The 500K value shown for this pot provides a maximum time of approximately 50 seconds, as noted earlier. Naturally enough if it is desired to increase the maximum time still further, the pot value can be increased; however, if the value is raised much above a few Megohms the maximum available power output on UPWARD dimming starts to fall.

The reason for this is that while the Darlington transistor pair has a very high input resistance, its input resistance is still quite finite – approximately 7M, in fact. And this input resistance is effectively in parallel with the capacitor C1.

When the Rate pot is increased so that its value becomes comparable with the Darlington input resistance, for "upward dim" the two form an effective voltage divider across the 13V supply. The result of this is that C1 cannot charge up to the full 13V, but only to a value determined by the divider. Hence full output is not reached.

Contrary to what one might expect the effect of the Darlington input resistance is far less drastic on downward dimming. This is because for downward dimming the Darlington resistance is simply in parallel with the discharge resistance, and thus merely sets a limit on the maximum available dimming time.

Very likely most applications requiring an extended automatic dim function will be interested mainly in the downward operation. This being the case there is no reason why the Rate pot cannot be increased considerably, providing the user remembers that for full output the Rate pot must either be turned well up or the switch turned to the "fast on" position.

A pot value of 5M might well be satisfactory for applications such as nightlight dimming, as with this value the maximum downward dimming time is almost 15 minutes.

Those who are interested in obtaining the maximum dim time may care to fit a four-position switch, using the fourth position as a "dim down" position in which the end of R1 is simply left floating. When this is done the Darlington input resistance is the sole discharge resistance in circuit, giving a dimming time of close to 30 minutes.

As may be seen from the circuit, there are normally two function switch positions apart from the "fast on" position; in both of these the Rate pot is in circuit. The first is the "dim" position, and the second is the "off" position.

In the Dim position the charging supply voltage may be varied anywhere from zero to the full 13V. This provides both a manual dim control (with the Rate control at maximum), and also an adjustable intermediate level to or from which the charging circuit can operate.

Thus if the unit is required for virtually manual dimming, the switch is simply turned to the central position, the Rate control adjusted to give the highest rate (shortest time), and the "Dim" pot used in the same fashion as the control on the Vari-watt manual dimmer.

For automatic operation, the Dim pot is set to a convenient "twilight" level and the Rate pot set for a convenient dimming time. Then the load can be dimmed either up from zero or down from maximum to this "twilight" level, and also dimmed from the level either down to zero or up to maximum.

It may seem that the unit is thus quite flexible, and may be used to provide quite a variety of different effects and functions, the foregoing should also provide sufficient insight into the basic circuit operation to enable readers to modify the circuit to provide for special requirements.

At this stage, it should not be too difficult to see why the transistor supply voltage must be adjusted by varying the number of silicon diodes in series with the zener. If the supply voltage is too low, the voltage at C1 and hence the bootstrap voltage at the unijunction cannot rise far enough to provide maximum output; alternatively, if it is too high, control may be lost because the DC bootstrap voltage itself can exceed the conduction level of the unijunction.

The correct supply voltage is that which at "full on" allows the unijunction and Triac to fire at about 6 degrees or so after the start of each mains half-cycle—a phase corresponding to about one-tenth of the peak value of the mains half-cycle as viewed on a CRO. Higher supply voltages and correspondingly earlier conduction phases tend to make the unit unduly susceptible to line surges, causing the unit to produce violent flashing and other undesirable effects when turned to maximum.

Adjustment of the minimum output of the unit is carried out by varying the value of the nominal 3.3M resistor connecting to the unijunction emitter. If the resistor is too small, the emitter voltage will rise too quickly and it will not be possible to turn the load fully "off"; conversely, if the resistor is too large there will be too much "dead space" on the Dim pot and also too much delay when the load power is to be increased from zero.

The correct value of the resistor is that which, when the DC control voltage is at zero, produces Triac switch-on JUST BEFORE the end of each half-cycle. However, the adjustment is not unduly critical, and if operation is satisfactory with the nominal 3.3M resistor there is really no need to worry further.

The purpose of the silicon diode in series with the output of the Darlington transistor pair is to protect the emitter-base junctions of the transistors from breakdown damage which can otherwise occur when the voltage across C1 is low enough to result in the junctions being reverse-biased by the unijunction emitter voltage. The diode is necessary because most NPN silicon planar transistors available have a relatively low emitter-base reverse voltage rating (BVebo).

As with the Vari-watt unit, the Auto-Dim unit tends to radiate electrical interference as a result of the extremely rapid switch-on of the Triac. The suppressor inductor L1 and the three .01uF capacitors bypassing the mains and load wiring help to keep the interference to a minimum. The earthed metal case also plays an important role in this regard.

Although these provisions are normally quite effective, there is a small residual radiation which can sometimes cause trouble where the unit is operated in close proximity to high-gain audio equipment. If such equipment cannot be removed from the area, it may be necessary to fit mains filters and possibly also RF suppressor capacitors at appropriate locations.

As shown, the basic Auto-Dim unit employs a recently released 10 amp G-E Triac,the type SC45D. However, the 6 amp type SC40D unit used in the Vari-watt may be used alternatively if it is anticipated that loads greater than 1,200 watts will never be connected.

No circuit changes are required for this substitution, as the two Triacs have identical triggering requirements. Readers who have already constructed the Vari-watt unit may be assured conversely that the 10-amp Triac is also quite suitable for use in the earlier design, again without modification.

In order to forestall any requests for an Auto-Dim unit of even higher capacity than 2,000 watts–and high though this figure seems, it seems almost inevitable that some will find it insufficient–we publish details of an "add-on" slave circuit capable of providing sychronous control of additional 2,000-watt loads. This is shown in the auxiliary circuit.

As may be seen, it is simply a second power amplifier section, with Darlington pair, unijunction and Triac circuitry as before. The circuitry merely derives mains supply, high- and low-voltage DC pulse supplies and DC control voltages from the main circuit, thereby functioning in synchronism with the latter. The connections to the main circuit are identified by the code letters A, B, C and D.

A single slave circuit will effectively double the power handling capacity of the Auto-Dim; two such circuits will triple the capacity. Further slave circuits may be used if the need arises (!). However if more than two are used it will be necessary to reduce the value of the resistor in the upper arm of the main clipper-regulator, to maintain the 13V supply voltage.

Apart from this the only effect of adding further slave circuits is to reduce the absolute maximum dimming time, by virtue of the shunting effect of the additional Darlington pairs. A single slave will reduce this from 30 minutes to 15; two will reduce it to 10 minutes, and so on. However this will probably be of little concern in high power applications as the dimming times required will normally be from about 10-40 seconds.

Note that the nominal 3.3M resistor in the slave circuits may need to be adjusted slightly in value to synchronise the behaviour of the various Triacs over the lower portion of the range.

In passing it may be worthwhile pointing out that the circuitry shown in the auxiliary diagram is virtually that which would form the basis of a high power-gain amplifier for other applications. Thus by adding a mains isolation transformer and bridge rectifier and regulator-clipper as on the main circuit, the common line identified by letter "D" could be earthed, and DC input applied between this line and point "C".

As mentioned earlier it should also be possible to use the same circuitry as the basis for a high-power regulated DC supply. In this case the Triac would be replaced by two thyristors, an additional secondary being added to the trigger transformer to drive the second unit. The two thyristors would be connected into a full-wave or bridge rectifier circuit, and a reference-comparator circuit added to provide feedback regulation.

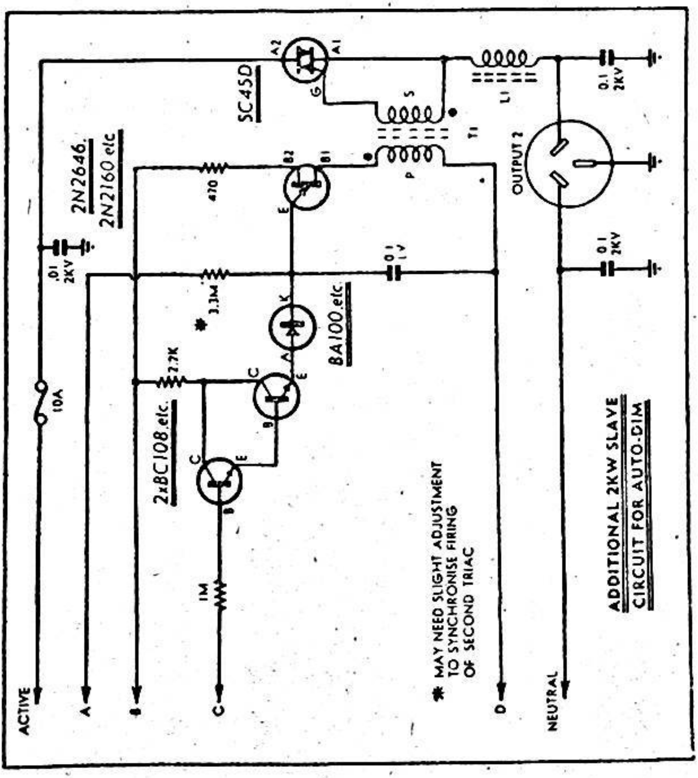
It may in fact be possible for us to give further details along these lines at some time in the future if there seems to be sufficient reader interest. However for the present the foregoing suggestions will have to suffice.

CONSTRUCTION

The construction of the basic Auto-Dim unit will now be described. As may be seen the unit is housed in the same compact 5in x 5in x 5in sloping-panel case used for the earlier Vari-watt and Vari-tach manual units. Despite the larger number of components in the new unit this does not involve undue crowding, and construction should still be a relatively simple job even for those with little previous experience.

The three controls are mounted on the front panel, with the function switch in the upper centre and the Dim and Rate controls at lower left and lower right respectively. At the top of the case is the cartridge fuseholder, while the left and right sides provide for the cord entry and output sockets respectively. Four rubber feet are skrewed to the base to provide a non-scratching but secure support.

Sixteen ¼in diameter holes drilled in the base and a further sixteen holes of the same diameter drilled in the upper rear provide for a small amount of convection cooling of the components. Although the unit remains quite cool in operation, these holes are quite necessary for reliable operation and should not be omitted.



The circuit diagram for "add-on" 2KW slave sections which may be used to extend the capacity of the basic unit.

Inside the case the components are in two groups. The smaller group consists of the interference suppression components, and is positioned in the lower rear of the case proper. From this section only three wires connect to the larger group of components at the rear of the front panel, the second group consisting of the control circuitry proper.

As may be seen a majority of the components in the control circuit are supported on tagstrips screwed to a U-shaped aluminium bracket mounted at the rear of the front panel. The bracket is actually a heat-sink plate for the Triac device, which mounts at its centre. Being connected to the A2 electrode of the Triac the bracket is naturally "alive", and is accordingly fastened to the front panel via 1in fibre insulating pillars.

The bracket is bent up from a 5in x 3½in scrap of 16G aluminium to form a flat "U" 3in x 1in x 3½in. The Triac mounts in the centre via a ¼in diameter hole which should provide a tight fit for its threaded stud, in order to provide efficient thermal contact.

The wiring diagram show the position of the minor components and the wiring; using these as a guide it should thus be easy to duplicate the prototype. Note that the function switch wiring must be completed before the bracket is mounted on its tapped support pillars. Four washers will be required at each support pillar to ensure that there is adequate clearance between the heat-sink bracket and switch lugs.

Trigger transformer T1 and suppressor inductor L1 are both wound on small lengths of 3/8in diameter ferrite rod. That for T1 is 1in long, while for L1 is 2½in long. In both cases plastic insulation tape is used initially to form a base for the windings and finally to provide a protective sheath; additionally in the case of T1 the same tape is used to provide an insulating layer between the primary and secondary.

To obtain the required short lengths of ferrite rod it will usually be necessary to buy a standard length as supplied for broadcast receiver aerials. The rod cannot be sawn satisfactorily; however it can easily be snapped with the fingers if a triangular file is used to make a "nick" or groove at the required spot.

Inductor L1 consists of 50 turns of 18 B & S enamelled copper wire close-wound. Trigger transformer T1 consists of two 100 turn windings of 36-40 B & S enamelled wire, again close-wound. Here the primary should be the inner winding and the starts and ends of both windings should be identified in some way to ensure that they are connected into circuit correctly. Do not forget the tape between windings—this should be of at least two thicknesses to ensure adequate insulation.

Inductor L1 is supported on the termination tagstrip via its relatively heavy connecting leads. However as the leads to T1 are relatively light in guage this unit should be mounted as shown in the photograph. A small spring clip of the type sold as a tool/utensil holder makes a convenient and secure mounting, being itself screwed to the heat-sink bracket.

When wiring up the unit take care that components are not damaged by overheating. This applies particularly to the semiconductor devices—Triac, unijunction, transistors and diodes – but also to the remaining components. A wise precaution is to grip the component leads with a pair of long-nose pliers so that the latter acts as a heat-sink.

It may be noted that the wiring diagram shows a wire link in series with the regulator-clipper diodes. This link is intended as a reminder that an additional diode may be required in order to adjust the maximum output level of the unit. If such a diode is required, it is wired in place of the link.

The panel lettering on the prototype unit was made using rub-on wax transfer type, of which several brands are available. A coat of clear rapid-drying enamel sprayed over the lettering protects it from abrasion.

When the unit is completed, use a multimeter or other continuity tester to check that there is no connection between the heat-sink bracket and the metal case. Also make sure that the case is connected to the earth lead of the input plug, to guard against possible shock.

PARTS LIST

1 Case, 5in x 5in x 5in, with sloping front panel.
1 Rotary switch, 3-pole 3-position single wafer.
1 Cartridge fuseholder, with 10A cartridge.
1 Trigger transformer (see text).
1 Suppressor inductor (see text).
1 SC45D silicon Triac device.
1 2N2646 RS276-2029 unijunction transistor.
2 BC108, 2N3565, RS276-2009 or similar transistor.
1 OAZ213 or similar zener diode.
3 BA100, RS276-1136 or similar silicon diode.
4 OA210, 1N3194, RS276-1138 or similar silicon diode.
1 470 ohm ¼ watt resistor.
1 2.2K ½ watt resistor.
1 3.3K ½ watt resistor.
1 10K 2W wire-wound pot.
1 15K 10W wire-wound resistor.
1 500K linear pot.
1 1M ½ watt resistor.
1 3.3M ½ watt resistor.
3 .01uF 2KV ceramic capacitor.
1 0.1uF LV,930-100V) capacitor.
1 100uF 16VW electrolytic.

MISCELLANEOUS
Mains cord and plug, 3-pin outlet socket, 3 x fibre 1in spacers tapped 1/8in Whit both ends, 2 x 10-lug miniature tagstrips, 1 x 8-lug miniature tag strip, spring tool clip, scrap aluminium, 1 x 7-lug standard tagstrip, 1 x large knob, 2 x small knobs, connecting wire, insulating tape and sleeving, solder, nuts, bolts, washers, self-tapping screws, etc.

A DEMONSTRATION FUEL CELL

Fuel cells, which turn the chemical energy of fuels directly into electrical power without combustion, are growing in importance daily. This article describes how a simple demonstration fuel cell may be constructed in the school science laboratory or home workshop using accessable materials.

WARNING: All the chemicals used in this cell, including the silver nitrate and chloropltinic acid used to prepare the electrodes, are poisonous. However, providing reasonable care is taken to ensure that contact with the chemicals does not occur, the project is quite safe. We strongly recommend that safety goggles be worn to protect your eyes from splashes, etc.

Recently, fuel cells have been finding a use in a number of exotic applications – and are under consideration for many more. Future manned spacecraft sent up from Cape Canaveral, for instance, will have both power and drinking water supplied by hydrogen-oxygen fuel cells.

Already, the U.S. Army Signal Corps is powering its "Silent Sentry" portable battlefield radar systems with small, back-pack IKW fuel cells, while the Allis-Chalmers company demonstrated a fuel-cells-powered tractor more than two years ago.

Experts predict that, if fuel cells develop at the current rate, electric cars and trucks will be a reality in less than 20 years. This is scarcely surprising, as even present-day fuel cells are more than 50 per cent efficient, whereas most engines used in cars and trucks are only about 20 per cent efficient.

Despite the fact that they were virtually unknown 10 years ago, fuel cells are not new. The first crude fuel cell was built in 1839, by the English scientist Sir William Grove, while 50 years later, an improved model was made by Ludwig Mond and Carl Langer–who, incidentally, were the first to use the name "fuel cell."

From their discovery until quite recently, however, fuel cells were regarded as something of a "white elephant." Their extremely high efficiency (theoretically, up to 90 per cent) was acknowledged, but the many technological difficulties which remained to be solved before the cells could be used to generate power in practical quantities kept them as hardly more than an academic curiosity.

In recent years, however, considerable advances have been made in electro-chemical technology. Also, new applications have appeared which require power to be produced from fuel in the most efficient way possible. Research on fuel cells has thus been started on an enormous scale, both by prospective users and by fuel-marketing organisations.

The constructional information presented on these pages, for instance, was adapted from data published by the "Esso" Research and Engineering Company, who are one of the leaders in contemporary fuel cell research.

Although a practical fuel cell, capable of supplying power in quantities sufficient to operate motors, lamps, radio receivers, etc., is rather beyond the home constructor, it is possible to build a demonstration cell quite easily.

The cell which we are about to describe will deliver approximately 0.5 volts at 3-4 milliamps. This order of power is quite trivial, considering the cost of obtaining it, but the description is presented primarily as a practical illustration of basic principles.

As it is, the output from the cell is hardly sufficient to operate anything more than indicating meters. However, it could possibly be used to operate an elementary transistor receiver and it was used for just this purpose in the original Esso demonstration.

Before describing construction of the cell, however, it would be wise to discuss its principles of operation.

The fuel cell which will be described is known as a "Methanol-Oxygen" cell, due to the fact that it consumes as its fuel methyl alcohol (also called methanol) and oxygen. It produces electrical energy by combining the two, without combustion, by electrolytic action in a solution of potassium hydroxide.

Into a container half-filled with a solution of potassium hydroxide, two electrodes are placed. Both electrodes are made of nickel, to withstand corrosion by the caustic potash solution.

One electrode is covered with a thin layer of silver metal. This electrode, which ultimately becomes the POSITIVE electrode of the cell, supplies the gaseous oxygen with four electrons per molecule to reduce it to hydroxyl ions in the following manner:

$$O_2(\text{gas}) + 2H_2O + 4\text{ electrons} \longrightarrow 4\ OH^-$$

(from the air, etc) (from electrode) (hydroxyl ions)

(The silver catalyses the reaction – in other words, it speeds up the reaction greatly, without actually taking part in it chemically.)

The gaseous oxygen required for this reaction may be simply that small amount which dissolves into the solution from the air. However, the output from the cell is poor under such conditions, and it is really necessary to bubble oxygen over the electrode.

If air is blown into the solution around the silver electrode – either from the mouth or from a small pump such as that used for fish-tank aeration – the output will rise considerably. If pure oxygen is obtainable and is used instead, the cell output will increase three of four-fold. The more oxygen presented to the electrode, the greater is the number of oxygen molecules reduced in a given time, and the higher is the current that the cell can deliver.

To help matters the oxygen electrode is given a large area by punching hundreds of tiny holes through it with a small nail and a hammer. This must be done before the nickel is coated with silver, so that the surface of the holes may be covered as well.

The other electrode of the cell is coated with metallic plantinum, in the form of finely divided "platinum black". The platinum catalyses the following reaction, wherein the methyl alcohol is oxidised to formic acid, to produce an excess of four electrons per molecule:

$$CH_3OH + 4OH^- \longrightarrow HCOOH + 3H_2O + 4 \text{ electrons}$$

(methanol) (formic acid)

The formic acid immediately reacts with the potassium hydroxide electrolyte, forming soluble potassium formate, HCOOK. This is part of the function of the potassium hydroxide, to remove the "waste" formic acid from the methanol electrode.

As the equations show, the nett result of the two-electrode reactions is that the oxygen electrode requires four electrons per molecular reaction, while the methanol electrode has an excess of four electrons per molecular reaction. If the two electrodes are connected by an external circuit, a current will thus flow, for the methanol electrode is able to supply the oxygen electrode with its required electrons.

When such a current flows (in the form of electrons from the methanol (platinum) electrode to the oxygen (silver) electrode, or "conventional current flow" from oxygen electrode to methanol electrode), the external circuit receives power. As this power has resulted from an oxidation-reduction reaction between oxygen and methanol, the cell has effectively turned chemical energy into electrical energy.

You may care to visualise this action in another way. For instance, without the external circuit connected, electrons cannot be supplied to the oxygen electrode. Nor can excess electrons be removed from the methanol electrode.

The oxygen electrode thus becomes positively charged, and its reaction ceases due to a scarcity of free electrons required for the reduction of oxygen molecules. Similarly, the methanol electrode becomes negatively charged, having so many excess electrons that there is no inducement for it to accept those produced by the methanol oxidation reaction.

NOT A BATTERY

Without the external circuit connected, the fuel cell action thus quickly ceases, the methanol and oxygen remaining unchanged.

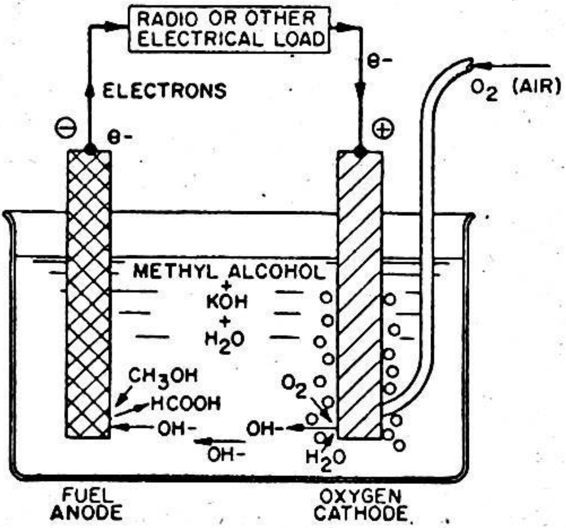
When the external circuit is connected, however, a current can flow which reduces the charge on the electrodes and permits the reaction to proceed. The external circuit thus permits the cell reaction to continue by allowing the cell to sent a current through it! This, of course, is precisely the required effect because, in producing a current, the cell is generating electric power.

As may be seen, the fuel cell is thus more like an engine than a battery—which it would seem to be at first glance. In effect, what it is doing is "burning" methanol, and turning the heat into power—but in a way which, in terms of the fuel, is considerably more efficient than the usual furnace-boiler-turbine-generator system.

The methanol-oxygen cell is not the only type. In fact, most of the fuel cells being used in current projects and applications do not use a liquid fuel such as methanol, but a gas such as hydrogen. Thus the fuel cell is sometimes called a "battery with gas tanks."

At present, fuel cells require fuel in a very pure state, whether it be in gaseous or liquid form. Thus, although they have extremely high efficiencies, they are expensive to run because they use expensive fuels.

SCHEMATIC DRAWING SHOWING OPERATING PRINCIPLES OF METHYL ALCOHOL FUEL CELL



This diagram shows the basic methanol fuel cell, and its various electrode reactions. It should be studied in conjunction with the text, where the operation is discussed in some detail.

This is perhaps the greatest problem faced by would-be users of the fuel cell. Most of the current research is thus being devoted to finding out the exact process whereby impure fuels ruin the cell action. When this problem is solved, it is hoped that fuel cells will be made which will run on natural gas, kerosene, distillates—or even cruder fuels such as sawdust, peanut shells and human wastes!

In passing, the hydrogen-oxygen fuel cells currently being built for space applications are particularly economical, despite the high cost of the pure hydrogen and oxygen gases used as fuels. This is due to the fact that the "waste" of the hydrogen-oxygen cell is ordinary water, pure and drinkable! Thus a space-ship, if it carries its water supply in the form of hydrogen and oxygen, can generate its power "free" with a fuel cell.

For a demonstration fuel cell, we are limited to a methanol type unit. This is because the gaseous-fuel types generally require special apparatus, able to maintain high temperatures and pressures. The methanol cell is simple, operates at room temperatures and pressures, and requires no special apparatus.

To construct the fuel cell, the first things to procure are the nickel electrodes. Ideally, these should be in the form of nickel gauze, or screen, to present the largest area to the electrolyte and fuels.

CONSTRUCTION PROCESSES

For the prototype fuel cell shown, we obtained an ounce of 0.001" nickel foil. The foil measured 6in x 4in and was cut into two sections measuring 6in x 2in.

The oxygen electrode is the one which is especially critical of active area, for at its surface the oxygen, the electrolyte and the catalyst all must come into contact. Thus the more surface there is, the better. To increase the active area of this electrode, we perforated the lower 2½in with as many holes as possible, using a sharp nail and a hammer. The methanol electrode may be left unperforated.

The next step in the construction is to coat the electrodes with their respective catalysts. The oxygen electrode is given a coating of silver, and the methanol electrode a coating of platinum.

To coat the oxygen electrode with silver, it is left for a few hours in a solution of silver nitrate. The solution is prepared by dissolving 5 grammes of silver nitrate in 100 ml (approx. 3.4 fl. oz) of water—distilled water, if it is available. Before being coated in the solution, but after it has been perforated, the nickel should be cleaned in hot water or petrol to remove any grease, etc.

The methanol electrode is coated with platinum black by leaving it for about an hour in a solution of chloroplatinic acid, which is platinum chloride associated with hydrochloric acid. The chloroplatinic acid is prepared by adding 1 gramme of the acid crystals to 100 ml of water—preferably distilled, if available.

(Note: If either the crystals, or the solutions of silver nitrate and chloroplatinic acid are accidentally brought into contact with the skin, wash the affected area immediately and thoroughly with plenty of water. Silver nitrate turns the skin black under the influence of light, in addition to being highly corrosive. Both it and the chloroplatinic acid are poisonous.)

The solutions of silver nitrate and chloroplatinic acid may be kept in bottles after the coating operation and used over again. After coating each electrode, wash it thoroughly in running water, and place it under water in a jar. Neither electrode may be allowed to dry out once it has been coated, for this would ruin the coatings.

CARE NEEDED

With the electrodes prepared, the next step is to prepare the potassium hydroxide electrolyte solution. This is prepared in the 600 ml beaker which is used for the fuel cell.

Into the beaker put 300 ml (approx. 10 fl oz) of water—distilled, if available. Very slowly, add 100 grams of potassium hydroxide pellets. The solution will become hot, and should be stirred as the pellets are added to aid them in dissolving. Leave the solution to cool before assembling the cell.

Note: If potassium hydroxide pellets or solution accidentally touch the skin, IMMEDIATELY wash the affected area in running water, flushing it for approximately 15 minutes. If some vinegar, lemon juice or other mildly acidic solution is available, follow the water with a swabbing of this solution, and then wash in water again. If the eyes are involved, or if the burns are extensive, a physician should be consulted as soon as possible.

To assemble the cell, transfer the electrodes from their water-jar into the potassium hydroxide in the beaker. Place them against the sides of the beaker, on opposite sides, and bend over the top portion of each strip so that it is supported by the top of the beaker.

VOLTAGE RISE

Into the solution, between the two electrodes, place a piece of blotting, filter or asbestos paper cut so that it is as wide as the inside diameter of the beaker. This will prevent the two electrodes from touching accidentally, and will also keep air bubbles away from the methanol electrode when bubbling is used—although this is not particularly important.

If a DC voltmeter is connected across the electrodes (positive terminal to the oxygen-silver electrode), it will register a small voltage—about 0.2 volts —even though no methanol has been added as yet. This voltage is due to the familiar "two dissimilar metals in an electrolyte" action which is used in the dry battery, and is not to be confused with the output of the cell due to its fuel conversion action.

With the voltmeter still connected, add about 35 ml (a little more than 1 fl. oz) of methanol to the electrolyte in the beaker. The output of the cell will rise to approximately 0.7 volts, but will drop slowly to about 0.45 volts.

The drop is due to the gradual usage of all the dissolved oxygen in the electrolyte, which prevents the reaction from proceeding further. If air is now blown into the electrolyte, around the oxygen electrode, the output voltage will again rise to the 0.7 volt level.

For our preliminary tests with the prototype cell, we simply used "breath-power" for the aerating operation, blowing air into the solution with a length of plastic tubing. Experimenters may care to use this simple method too, However, the use of breath-power is undesirable, for two reasons. One is the obvious reason, that one soon becomes extremely tired of blowing slowly and carefully into the tube—or just tired of blowing! The other reason is that there is only a small percentage of oxygen in exhaled air (less than the one-fifth of the total volume), so that it is a very inefficient way of supplying oxygen to the electrode.

SCOPE FOR EXPERIMENT

A better way is to use a small mechanical air pump. As the photographs show, we obtained a small pump of the type used to aerate fish aquaria, which performs the function extremely well. Many readers may have such a pump, or something similar but, in any case, they only cost a few pounds, complete with plastic tubing. We obtained the unit shown at a large city department store.

Naturally enough, the results would be better still if oxygen were bubbled over the electrode. School science laboratories may be able to elaborate the experiment in such a fashion, perhaps generating oxygen by the time-honoured heating of potassium chlorate and manganese dioxide, or by electrolysis. Caution, however, for such methods should not bring a naked flame near the cell! Methanol is quite volatile, and its vapour is highly inflammable.

The end of the aerating tube in all cases should be closed, with a number of tiny holes or slits cut in the side near the end. This will result in the production of many small bubbles rather than a few large bubbles, giving better aeration.

Incidentally, there is plenty of scope for individual efforts in increasing the output of the cell. The main difficulty with the cell is to bring enough oxygen and electrolyte into contact with the surface of the silvered electrode at the same time.

For instance, we would suggest that you try the effect of making the oxygen electrode a disc, perforated as before and placed horizontally near the bottom of the solution. If the air is bubbled in by a tube leading beneath the disc, it would then tend to rise up through the perforations and make a better contact with the electrode. The methanol electrode in such a cell could be a ring suspended near the top of the solution.

Another way of achieving better aeration would be to make the oxygen electrode in the form of a cylinder, feeding the air into it under slight pressure as before. It would thus be forced to make its exit through the performations, giving a good oxygen-electrolyte-electrode contact.

Still another way of improving the cell would be to make screen electrodes, by electroplating ordinary phosphor-bronze or brass filter screen (as fine a mesh as possible) with nickel. The nickel would then be coated with platinum and silver as before. (Phosphor-bronze or brass cannot be used unplated with nickel, for any tiny flaw in the coating would result in the rapid corrosion of the electrode.)

If it is desired to experiment along these lines, the best way of checking the effect of alterations to the cell is to measure its output under load. A simple way of doing this is to meter the current produced in a small 100-ohm resistor connected across the cell electrodes.

We have shown such a resistor and current meter (0-10 mA) in the diagram, to illustrate the way of connecting them to the cell. They are also shown in the photograph.

PRACTICAL TESTS

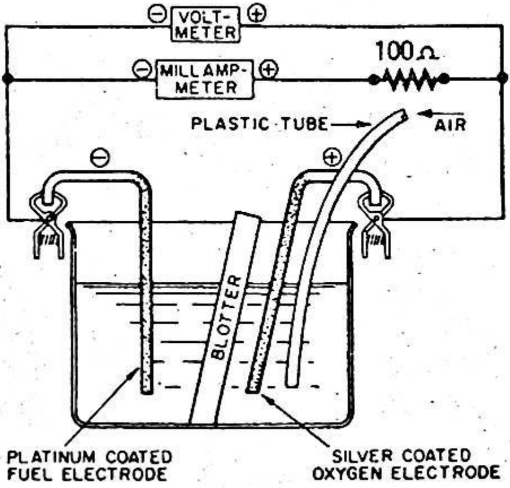
You will find that improvements to the cell will tend to increase its under-load current, rather than its output voltage. However, perhaps the best way of determining whether the cell has been improved by a change is to plot an output voltage-versus-current curve after each change has been made.

To plot such curves, the 100 ohm resistor should be replaced by a series switch and 10,000 ohm rheostat combination. The load may then be varied to provide various values of output current, and the voltage and current readings recorded to enable a curve to be drawn. With the switch open, of course, the voltmeter will register the no-load output voltage of the cell.

This completes the description of the demonstration fuel cell. While it is rather expensive to build from scratch, and delivers only one or two milliwatts, we feel that many of our readers would like to build it in order to familiarise themselves with a device which could well revolutionise the generation of electric power in the near future.

MATERIALS LIST FOR THE FUEL CELL

1 oz Nickel Foil or alternative – see text
1gm Chloroplatinic Acid
5gms Silver Nitrate
100gms Potassium Hydroxide
35ml Methyl Alcohol – Pure
600ml Pyrex Beaker
3ft of plastic or rubber tubing, pair of safety goggles (see text), piece of blotting or asbestos paper, wire, alligator clips, meters, 100 ohm resistor, air pump (if used – see text)



Here are the connections for the meters used to indicate the operation and performance of the fuel cell. Note the polarities, with all positive terminals connecting to the oxygen-electrode side of the circuit.

FIND THE WORD – AN ELECTRONIC BRAIN TEASER

The project is a brain teaser of the best – or worst – kind! The possibility of winning purely by chance is approximately one in three hundred thousand. It is almost impossible to solve by a systematic method.

The puzzle consists of a box approximately 200 x 240 x 65mm. On the top are marked out 25 squares of side length 40mm.

Above these squares is a small toggle switch and an indicator light. Attached to the case by a short lead is a plastic covered piece of metal. Each of the squares is labelled with a letter.

The object of the game is to spell an unknown four letter word, using the plastic covered metal object which, for the sake of convenience, we will call the pointer. When the correct word is spelt, with the letters in the right order, the lamp will light. Hopefully, the player will then know the mystery word.

A "trap" has been included to make it impossible, or very nearly so, to trigger the light by sweeping over all the letters in a random pattern. One of the letters, which does not form part of the word, will interrupt the sequence and take the player back to his starting point, without him knowing.

The game can be made easier by providing a set of clues, if it is found to be too hard. The actuating word can also be changed quite readily, should it become too well known. Some letters appear in the grid twice, so that even if the word is known there may be several ways to spell it.

As our more astute readers may have guessed, the pointer is a small permanent magnet. This is used to trigger reed relays underneath the squares. Since the magnetic field must extend through the top of the box, we must use a non-magnetic material for it.

Referring to the circuit, it can be seen that the puzzle consists basically of five reed relays formed from dry reed inserts and coils. These have been labelled from 1 to 5. R1 to R5 are current limiting resistors, to extend the life of the battery.

Reed/coil combination 1 is the "trap" mechanism. It is arranged so that the coil is connected to the battery at all times. R1 is made adjustable so that the current through the coil, and hence the resulting magnetic field strength, can be altered.

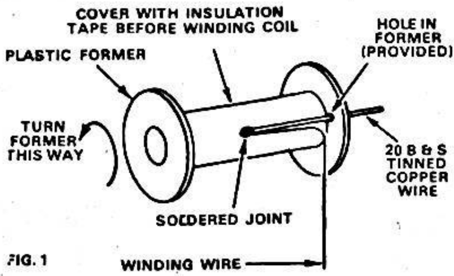


FIG. 1

How to commence the winding. The length of tinned copper wire, held by the insulating tape, takes any strain off the fine wire.

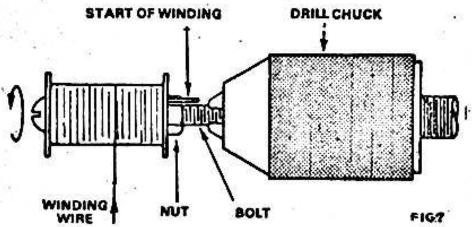


FIG.2

The spool is wound by mounting it in the chuck of a hand drill, and the latter held in a vyce. Wind all spools the same way.

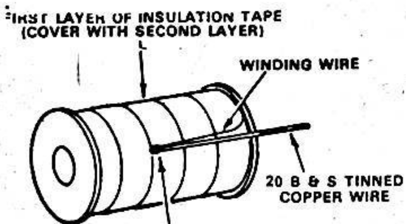


FIG. 3

Terminating the finished winding. The length of tinned copper wire is secured by the insulation tape and protects the fine wire from any strain.

R1 is set so that the associated reed is activated, and its contacts closed. This supplies power to the remainder of the circuit. When a permanent magnet whose field opposes that of the coil is brought close to the reed/coil combination, the reed contacts will open and interrupt the current flowing to the remainder of the circuit.

Once the pointer is removed from the vicinity of R/C1, the reed contacts will close again. Thus, if the pointer is passed over R/C1, the supply to the remainder of the circuit will be momentarily interrupted. As explained below, the remainder of the reeds function in a latching mode, and this short interruption is all that is required to unlatch them.

Reed/coil combinations 2 to 5 are all wired in a similar fashion to each other. The coil of each combination is not energised until the reed contacts close. R2 to R5 are selected so that, if by some means the reed contacts are closed, the resulting field from the coil is sufficient to hold them closed. This is the latching system. The trigger to operate the reed initially is the magnetic pointer.

Thus if the magnet is brought, in turn, close to reed/coil combinations 2 to 5, each one will latch and supply current to the next one. Combination 5 turns on the indicating light L1.

In operation, each reed/coil combination is placed under an appropriate square of the front panel. R/C2 is placed under the first letter of the selected word, R/C3 under the second, R/C4 under the third and R/C5 under the fourth. R/C1 is placed under one of the remaining squares.

The reader may now appreciate how difficult it is to cheat. Not only must one select the letters of the word, one must select them in the correct order. Thus random sweeping up and down or across the board has very little chance of producing the right sequence.

But even if it does, we have the trap circuit to content with. If, in random sweeping, we pass over this position at any time – and this is almost impossible to avoid – any reeds we have already latched up will be immediately unlatched. The odds against picking the right sequence with random sweeping – and avoiding the trap circuit – are almost astronomical.

Having evolved the general design of the puzzle, we were faced with the task of constructing it from readily available materials and components.

For the reed/coil combinations, we used Plessey type ORD 225A dry reed inserts and spool type 6, part no. 801631. These should be available from the usual component suppliers at quite reasonable cost. R2, R3, R4 and R5 are all ¼ watt types, and should present no difficulties. R1 is a 220 ohm trimpot, also a ¼ watt type.

L1 is a 6V 50mA type. It would be possible to substitute a LED and associated resistor, and obtain a smaller current drain, but we felt that this was not desirable, due to possible problems involving polarities.

For power we used four 1.5V "D" cells, wired in series. With a total current drain of less than 150mA, the battery life should be quite long. S1; the on/off switch, can be any suitable type. We used a miniature toggle type.

The magnet is a small cylindrical type. It measures 19mm x 10mm (dia.).

Having chosen the reeds, holders and magnets, we were faced with the problem of mounting the reed/coil combinations so that the system would function correctly. The first requirement concerned the orientation of the combinations with respect to the magnet.

Experiments showed that unambiguous operation was obtained when the axis of the magnet coincided with the axis of the reed, i.e., when the magnet approached the reed end on. With this arrangement, the reed would operate reliably as the magnet approached, and would not open and close during the approach as can occur with other arrangements.

This arrangement was also convenient with regard to mounting the reed/coil combinations behind the front panel. The coil formers could simply be fixed perpendicularly underneath the panel, and the magnet used in a perpendicular manner from above.

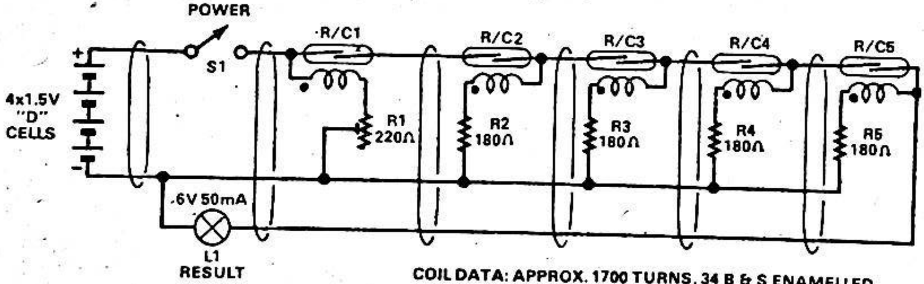
A second requirement concerned the spacing of the combinations. Further experiments showed that if the combinations were spaced 30mm or more apart, then only one combination could be triggered at any one time. To ensure reliable operation, we used a 40mm grid.

Our next problem concerned methods of fixing the combinations underneath the top panel. To make it easy to change the activating word, it was necessary to use only a semipermanent method. Our solution was to use double sided sticky tape, arranged in grid form on the underside of the panel. The reed/coil combinations are then simply stuck to the tape.

Another method would be to glue single sided sticky tape to the panel, with the sticky side up. Alternatively, adhesive vinyl could be glued to the panel. With all these methods, mark the back in some way so that the positions of the reed/coil combinations are known in relation to the squares on the front. They must be in the centre of the squares.

For the puzzle to operate correctly, it is essential to provide the right phasing between the magnetic pointer and the coils. The field from the pointer must oppose the field of coil 1, but reinforce the fields of coils 2, 3, 4 and 5.

This means that the magnet must be applied the same way all the time, with its axis aligned with the axis of the reed. To ensure this, we placed



● DENOTES START OF COIL

MAGNET NOT SHOWN

COIL DATA: APPROX. 1700 TURNS, 34 B & S ENAMELLED COPPER WIRE, DC RESISTANCE APPROX. 50Ω

BRAIN TEASER

The circuit of the puzzle is quite simple. The reed and coil designated R / C1 is the "trap" circuit which will unlatch all the remaining reeds if it is energised during a search for the selected word. Note how its connection differs from the others.

the magnet inside a spare plastic shroud from a standard DIN audio connector. Any similar non-magnetic cover could be used, as long as it ensures that the magnet is always applied to the panel the same way.

We made our own case, using a small piece of masonite and some scraps of timber. Construction is not critical, and we will leave the details to the reader.

The lid of the case is painted with a glossy enamel. We used stick-on letters to makk the squares and a drawing pen to rule the lines. A covering of clear lacquer provides a scratch resistant covering. The arrangement of the letters can be seen from the photograph, but it is not necessary to use this same arrangement.

Construction is best started by winding the coils. Each consists of approximately 1700 turns of 34B&S enamelled copper wire, wound on to the plastic spools.

To make a robust coil, it is necessary to provide a firm termination for the fragile winding wire at both the start and the finish of the winding. This is best done by soldering heavier gauge wire to the winding wire, and making a firm mechanical connection to the former.

Figure 1 shows the method we used for making the initial connection. Wrap the insulation tape firmly over the join, so that the heavy gauge wire is firmly attached to the former. This is necessary to prevent breakage of the winding wire due to movement of the lead-in wire. Clean the enamel from the area of the join before attempting to solder. A razor blade or a sharp knife used as a scraper makes the best tool.

The task of winding is made easier by using a hand drill. Hold the handle of the drill in a vyce, so that the chuck is horizontal. Pass a suitable bolt through the centre of the former, and clamp it tight with a nut. Position the former so that the start of the winding is nearest to the nut. Hold the bolt in the chuck of the drill by the remaining thread.

Use one hand to turn the drill, and the other to guide the wire onto the former. Try to keep the wire in neat layers, and do not allow one section to build up more than another. It will not be necessary to count the number of turns, just wind on as many as will fit. Do not completely fill the former, as allowance has to be made for the end termination.

Regulate the winding so that the wire is at one end of the former when sufficient turns have been added. Cover the winding with insulating tape to hold it in place. Arrange the connection to the 20 gauge wire so that both ends of the coil are at the same end of the former. Firmly tape the outside again to hold the 20 gauge wire in place.

Five coils have to be wound. Ensure that they are all wound in the same direction. This will make it easier to obtain correct operation of the puzzle.

When the coils are finished, the reeds can be inserted in them. Bend one lead of each reed so that it lays back along the reed, and solder a short length of tinned copper wire to it. Insert the reed, lead end first, from the end of the former remote from the coil leads. Push it in only far enough to clear the end of the former, so that it will be as close as possible to the underside of the panel when mounted.

With four of the reed/coil combinations, connect the finish of the coil to one end of the reed. With the remaining one, connect the start of the coil to the reed. Mark this last one R/C1, and connect the 220 ohm preset pot to the finish of the coil. Connect the 180 ohm resistors to the starts of the first four coils, and label them R/C2, R/C3, R/C4 and R/C5.

As shown in the circuit diagram, the wiring forms a "string" with the reed/coil combinations in order along it. This means that it is easy to reprogram the key word very easily. Only three wires connect between each combination, and only two to the batteries.

We held the batteries in place using scrap pieces of aluminium, fastened to the side of the case using self-tapping screws. The batteries are connected in series by soldering directly to their terminals.

Once all the construction has been finished, there only remains the final adjustments. Set R1 to approximately half resistance and turn on the power. At this stage, do not stick the reed/coil combinations to the panel, but leave them loose. Mark one end of the magnet in the same way.

Bring the marked end of the magnet close to the end of R/C2 for a short time. Then bring it close to the end of R/C3, R/C4 and R/C5 in turn. Do not go near to R/C1. If, after approaching R/C5 the light comes on, all is well.

If the light fails to come on, repeat the process but use the unmarked end of the magnet. This should operate the light. If the light still fails to come on, reduce the value of R1 and try again.

Assume that the marked end of the magnet was found to turn on the light. Once the light is turned on bring the marked end of the magnet – i.e., the same end as turned on the light – close to R/C1. The light should immediately go out, and to turn it on again R/C2, R/C3, R/C4 and R/C5 will have to be approached again in sequence.

Once satisfactory operation has been obtained, the reed/coil combinations may be stuck in suitable positions behind the front panel, and operation checked again. R1 may now be adjusted to the largest value of resistance which will still give reliable operation. This must be done by trial and error. R1 controls the sensitivity of R/C1. A large resistance value means that the magnet does not need to be brought very close to R/C1 to trip it.

The magnet can now be placed in its holder, taking care that the correct end is at the bottom so that it can trigger the reed/coil combinations.

To prevent bare leads from the coils from shorting together, we taped them up once all the adjustments had been made, and the puzzle was operating correctly.

Be sure to turn the power switch off when the puzzle is not being used, as power is being consumed all the time, even though the light may not be on.

Parts List

5 Miniature dry reed inserts.
5 Spools to suit.
1 Miniature magnet.
1 Miniature on/off toggle switch.
1 Miniature panel light, 6V 50mA.
4 1.5V "D" cells.
1 220 ohm preset trimpot.
4 180 ohm resistors, ¼ watt.
600m 34B&S or 40SWG gauge enamelled copper wire.
1 Case (see text).

MISCELLANEOUS
Hookup wire, insulating tape, double sided sticky tape, solder, plastic case for magnet, tinned copper wire, scrap aluminium.

BERNARDS & BABANI PRESS RADIO AND ELECTRONICS BOOKS