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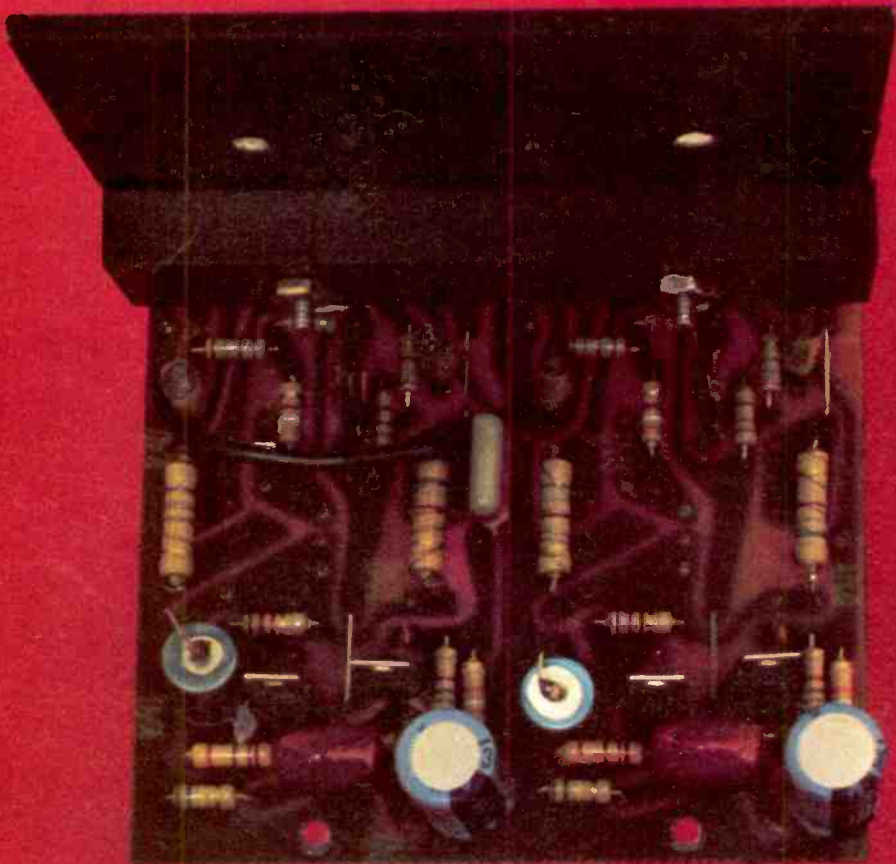

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PROJECTS

FEATURES

NEWS & INFORMATION

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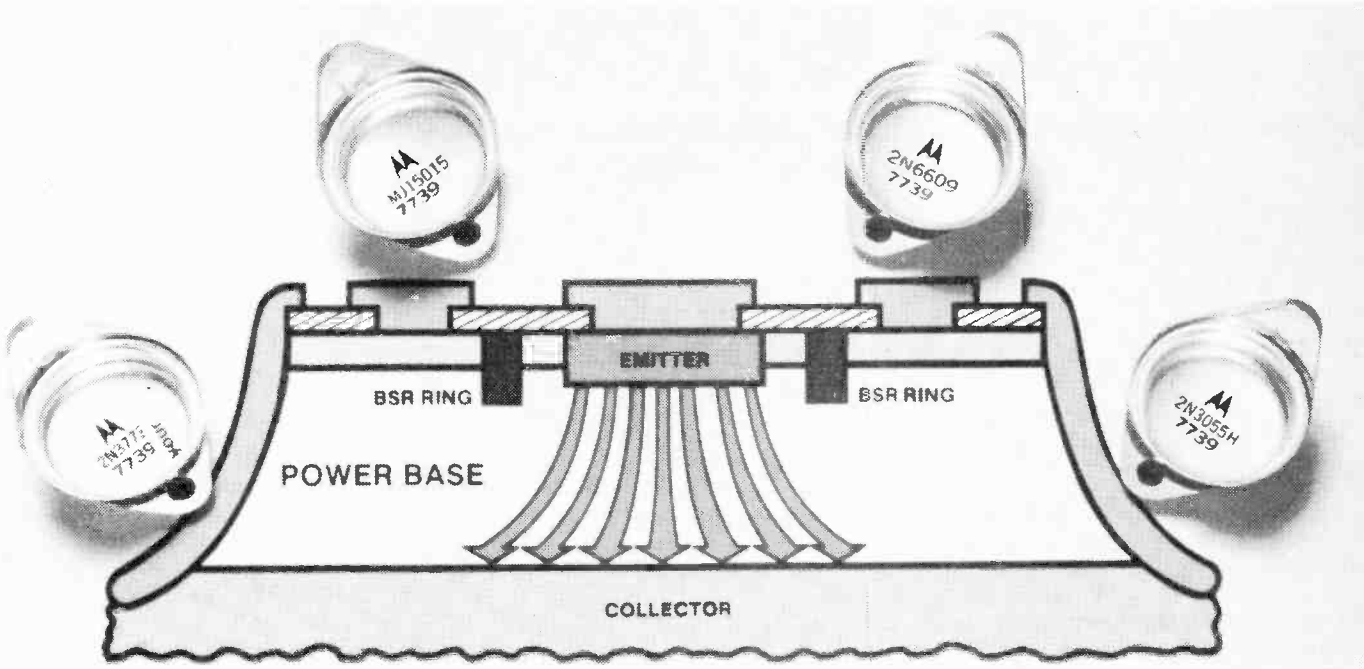
NEWS DIGEST



New Power Transistors

A new breed of power transistors has begun rolling from Motorola's production lines. These new transistors combine the rugged Safe Operating Area (SOA) specified for single-diffused-base types, with the economy and complementary structures of epitaxial-base devices. This unique combination of characteristics is made possible by a new process which reduces crowding of current into destructive "hot spots" by using a patented Base Spreading Resistance Ring to produce more uniform current flow in a relatively thick epitaxial-base region. Newly introduced TO-3 packaged products which benefit from PowerBase include:

2N3055H, a low priced, competitive SOA version of the industry standard.

MJ15015, a new device type whose SOA exceeds that of the 2N3055H, at a competitive price.

2N3773 and 2N6609, a rugged NPN/PNP complementary pair.

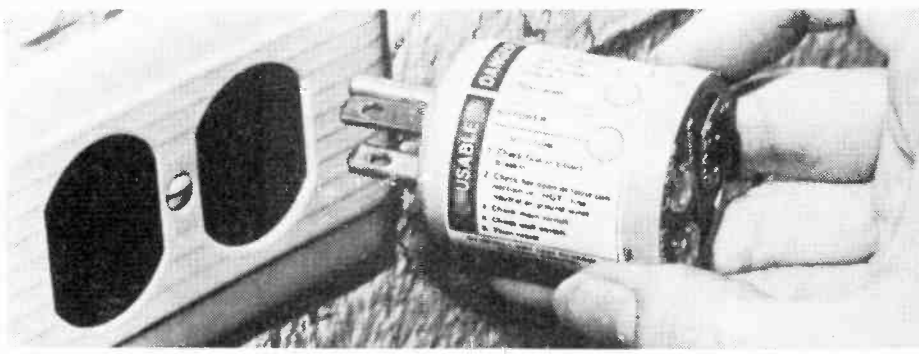
At the moment we have only prices for quantity orders in the US. The 2N3055H, with a SOA of l.95 A, 60 V, is priced at US $0.69 in 1K quantities. The new MJ15015, whose SOA is 3 A, 60 V, with a VCEO of 120 V, is 1K priced at US $0.75. For complementary power designs, types 2N2773 (NPN) and 2N6609 (PNP), both with SOAs of 1.5 A, 100 V, and high voltage VCEO of 140 V, are now available at US $2.07 in 1K lots.

BAND-GAP REFERENCE IC

National Semiconductor's new 2.5 volt band-gap reference IC works like a zener shunt regulator. Regulation is effective over an input current range from 300 uA to 10 mA and breakdown voltage and temperature are adjustable.

ATTENTION FM DEVIATES

Bill Johnson, VE3APZ, has recently brought to our attention a pitfall to avoid for 6 and 2 meter FM enthusiasts. A large number of fully synthesized 2 meter FM rigs employ 7 kHz deviation, but are also capable of operating the entire 2 meter band. It is, however, illegal to exceed 3kHz deviation in the 144-146 MHz region (also 50-52 MHz) — see section 59, subsection 3 of the General Radio Regulations, part II.



A new tester (the GT-20) to check for faulty wiring circuits is available in Canada. No electrical training is necessary to determine ground fault. You simply plug the GT-20 into the outlet and observe the indicator lights on the device. Amber lights will show the presence or absence of power. Reverse polarity, faulty connections or missing grounds are immediately evident when the red light glows, either alone, or in conjunction with the amber lights.

Canadian General Electric Company Limited, Electronic Components, 189 Dufferin Street, Toronto, Ontario, M6K 1Y9.

VFET UPDATE

New data has been received from Siliconix regarding their line of VFETs, discussed in our October and November issues. JEDEC registered numbers have been obtained as follows: VMP1 is now 2N6657, VMP11 now 2N6656, and VMP12 is 2N6658, all TO3 case devices. In addition, three models, VN46AF, VN66AF and VN88AF are available; power VFETs in a TO202 plastic power tab case.
Data sheets from:
Siliconix Incorporated
2201 Laurelwood Road
Santa Clara
California 95054

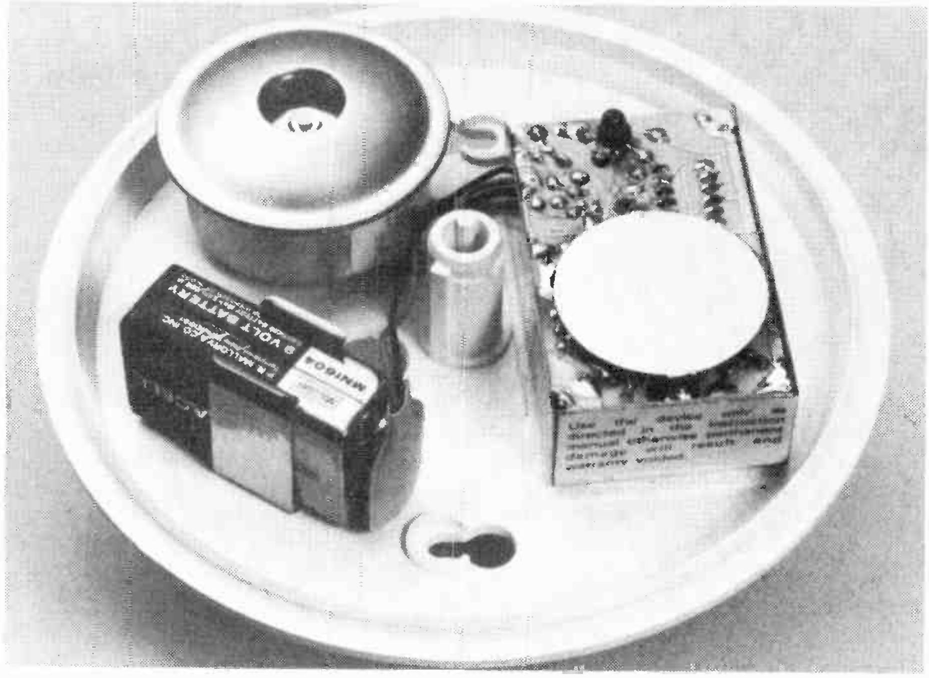
MADE IN SPACE

Two scientists from TRW Inc. have predicted that before the turn of the century there will be commercial manufacturing plants orbiting earth. The weakness of earth's gravity, the availability of solar energy and the endless vacuum source will attract manufacturers of electronic components, medicines, crystals, turbine blades, etc.

OPTICALLY COUPLED TRIAC DRIVER

Motorola's new optical coupler provides 115 VAC full wave switching and isolation equivalent to an electromechanical relay at the command of a low level DC source (such as IC logic). Used alone, the MOC3011 switches power-line loads up to 7.5 watts. Kilowatt loads are switched with a power triac, directly driven by the MOC3011. Bidirectional, triac-like output characteristics of the coupler eliminate the complex interface circuitry previously required for photocouplers having unidirectional transistor or SCR outputs.

The 6-pin DIP MOC3011 encloses a gallium arsenide LED, which is energized by input currents of 10 mA at voltages as low as 2 V. Photons emitted by the LED travel through a clear insulator capable of withstanding 7500 V, to trigger a unique monolithic photosensitive chip in the same DIP, whose output simulates a small bidirectional triac, capable of switching power triac input or small load currents up to 100 mA, and sustaining output voltages up to 250 V in the "off" condition. The MOC3011 is priced at $1.60 in 100-up quantities.



SMOKE SIGNAL

The new 'Centurion Ionization Smoke Detector' is compact and easy to install, and comes equipped with its power source — a 9V battery. The AC powered version of this device has been used in new home construction, and the new model is designed for easy installation in existing properties. It is manufactured for and distributed by *Canadian General Electric, Electronic Components Operator, 189 Dufferin Street, Toronto, Ontario.*

LONGITUDINAL VIDEO

BASF is cooperating with Robert Bosch and Blaupunkt to achieve miniaturization of their longitudinal video recorder — hopefully to be able to present the new product at the Berlin International Radio and Television Exhibition in late 1979. The BASF device was a fixed head to record on an eight millimeter video cassette.

ION DRIVE ENGINES

NASA is going ahead with the development of ion-drive engines for planetary spacecraft. The power source for the long duration flights will be the sun — via large arrays of solar cells.

PASSIVE IR SWITCH

An infrared sensor designed to detect body-heat of people entering rooms will shortly be available from Adcom Systems Corp. of NY, NY. The device can be used to switch on and off room lights, etc., and has a built-in adjustable delay to avoid spurious switching.

WINDMILL INTERFERENCE

Wind turbine blades can cause interference in the UHF TV bands it was reported recently. More research is needed to establish what the specific conditions giving rise to interference are.

ELECTRIC BOAT

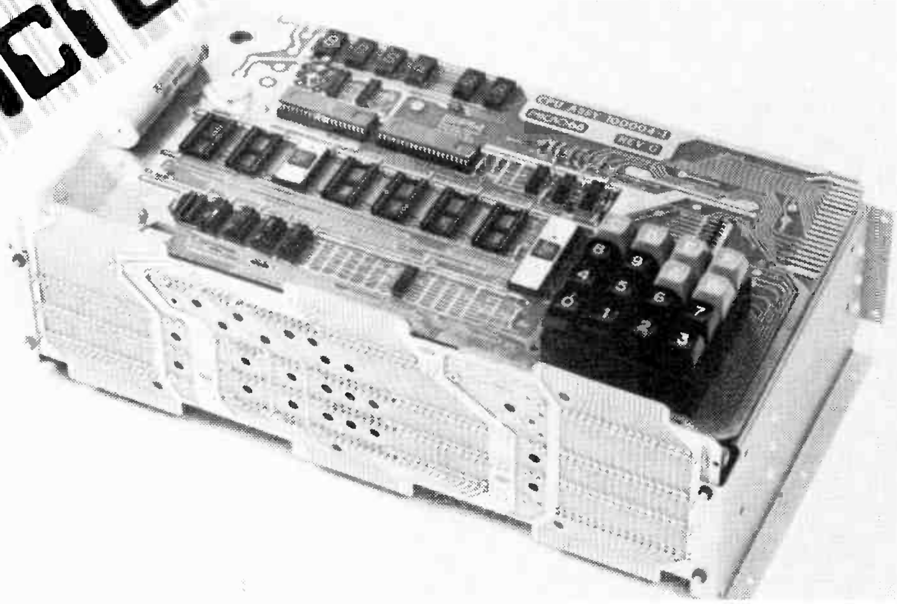
Electricite de France have fitted a 6 kW 72V motor (and a separate 3 kW motor for manoeuvering) to a trimaran. Thirty-six lead acid batteries supply the power, for up to six hours.

PTS go, ATS arrive

As of September 1st, 1977, PTS Electronics Canada Ltd. terminated their business operation in Canada (only). However, ATS Electronics (Alpha Tuner Service) has opened under the same management.

ATS Electronics will honour all PTS warranty tuners, and a complete service on all tuners (VHF, UHF, Combo, and Varactor) will be available. For additional information, contact *Peter Zakarian, ATS Electronics, 8400 St. Lawrence Blvd., Montreal, PQ, H2P 2M4.*

microfile NEWS DIGEST



Electronic Product Associates, (of 1157 Vega St., San Diego, CA 92110) designed this MBC microcomputer system for the OEM. Priced at US $695, the MBC comes complete with hex keyboard, six-digit hex display, monitor program, general purpose board, four-slot mother board and flexible mounting system. The mounting frame, which will accept three peripheral boards (memory, communication board, general purpose board, etc.) is provided with brackets to allow for front, back, side or 19 inch rack panel mounting.

The main computer board will accept up to 768 words of RAM, 2.5K of PROM (with optional PROM adapter) and TTY/CRT/cassette interface.

The on-board monitor program allows inspect and change, load user's program, run user's program and insert break points.

BUBBLE ADVANCE

IBM have come up with an improved bubble memory, enabling ten times the storage density of previous devices. Unlike its predecessors the "lattice file" doesn't rely on the presence or absence of a bubble to store information.

There are slightly different types of magnetic bubble and it is these lesser differences in the magnetic film that are used by the IBM device.

PHOTO DISK

A new method, developed by the Drexler Technology Corporation, improves the photographic disk method of data storage by enabling the data on the disk to be checked and corrected before the disk is developed. Optical disks (another name for this type of disk) are better than the common magnetic disks, provided you want permanent storage, in that they are cheaper, they last longer, and a single 4" disk holds the same data as ten 14" magnetic disks.

These carriers are designed to prevent damage to expensive ICs when they are likely to be frequently plugged in or out of their sockets. For further information contact A C Simmonds and Sons Ltd., 975 Dillingham Rd., Pickering, Ontario, L1W 3B2.

INTEL'S CCD 64K CHIP

Intel are now offering prototypes of the 2464, a 64K charge-coupled memory IC. Production of the 18 pin DIL device is scheduled for early 1978. The 2464 is organized like a stack of 256 RAMs, each of 256-bit capability. Data can be transferred from a page of memory at frequencies as high as 2.5 MHz.

MPU I/O Boards

Tracan Electronics of Toronto inform us that they will be handling a new range of I/O products from Analog Devices. These include data acquisition and analog output boards compatible with microcomputer systems based on hardware from Texas Instruments, Pro-Log, Intel, Motorola, and National Semiconductor. Tracan are at 553 Champagne Drive, Downsview, Toronto, M3J 2T9.

NAKED MINI IN TANDY STORES

Computer Automation's famed 'Naked Mini' computers are being sold in retail stores for the first time through a new computer store operation of Tandy Corp, operators of the Radio Shack chain.

The Naked Mini computers made their public debut in the first Tandy Computer Store, which opened in Ft. Worth in October.

Tandy expects this to be the forerunner of a chain of separate (from Radio Shack) stores it will build to offer a full line of data processing products.

The minicomputers will be sold over the counter in small business-oriented systems packaged by Tandy or as stand-alone units that professionals and sophisticated hobbyists will incorporate into their own systems. The Computer Automation products will also be listed in Tandy's catalogue for the mail-order trade.

Tandy said their emphasis on fully packaged minicomputers and systems aimed at small business and professional users will distinguish their stores from hobbyist shops offering kits and components to home computer buffs. Tandy already sell microcomputers to hobbyists through Radio Shack outlets.

The Naked Mini LSI 4/10 computers to be offered by Tandy are general-purpose, 16-bit minicomputers with 4K, 8K or 12K words of memory, expandable to 64K words.

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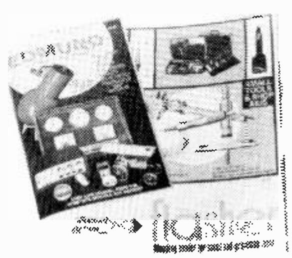

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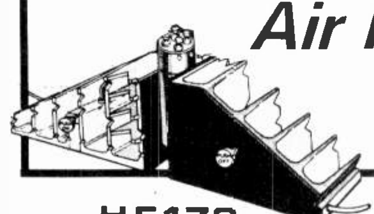

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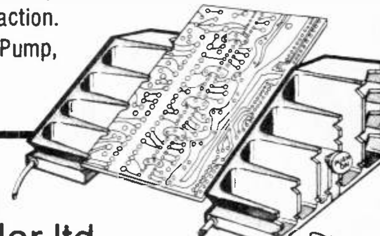

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am stereo

FARCICAL OR FEASIBLE ?

STEREO BROADCASTING is generally associated with FM probably because that's the way it's been transmitted up to now.

But it's perfectly feasible to transmit a stereo programme using modified AM transmitters and receivers. In fact five American-designed systems are being evaluated right now by the USA's National AM Stereo Committee whose subsequent report will be studied by the FCC later this year.

AM stereo broadcasting has the same inherent limitations as AM mono – that is a bandwidth restricted to less than 10kHz. Thus the full audible frequency range can not be transmitted and it is for this, amongst other, reasons that FM transmission is used for high quality stereo broadcasts.

Protagonists of AM stereo accept the limitations inherent in AM broadcasting but point out that the market audience they seek is not the purist FM stereo listener but the 'man-in-the-street'. they say that people are now so aware of stereo that mono reception is anachronistic, and that if AM stereo could be introduced at sufficiently low cost it would be absurd not to do so.

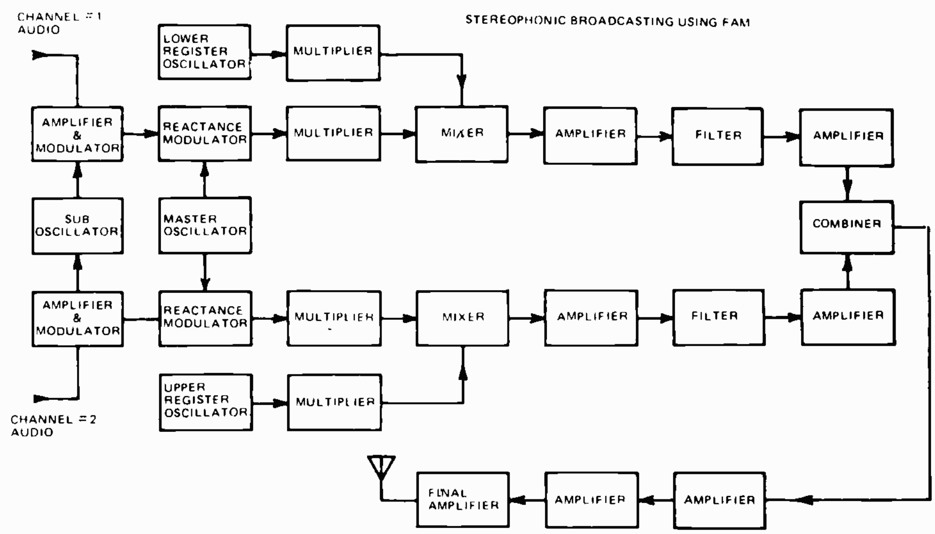


Fig. 1. The Comm Associates transmitter system uses dual RF modulator paths, one for the upper subcarrier and one for the lower. Matrixing of L and R signals is not necessary.

The main attraction of AM stereo *is* low cost. In fact it's possible to modify an existing AM transmitter to stereo operation for well under $15,000. Certainly a low power FM transmitter costs not a great deal more, but it's a different matter for the big 100kW plus systems.

Most broadcasting studio equipment is stereo – certainly all modern recording machinery, cartridge players, record players are so made, as is the majority of programme material.

Stereo AM receiving equipment could be inexpensive. Many potential AM stereo listeners already own a record player which could accept an input from an AM stereo decoder. And even if a complete AM stereo receiver were to be required, such could be built for very little more than the cost of its AM mono equivalent (and would of course offer a whole new market for manufacturers!). Let's consider the five major systems being proposed.

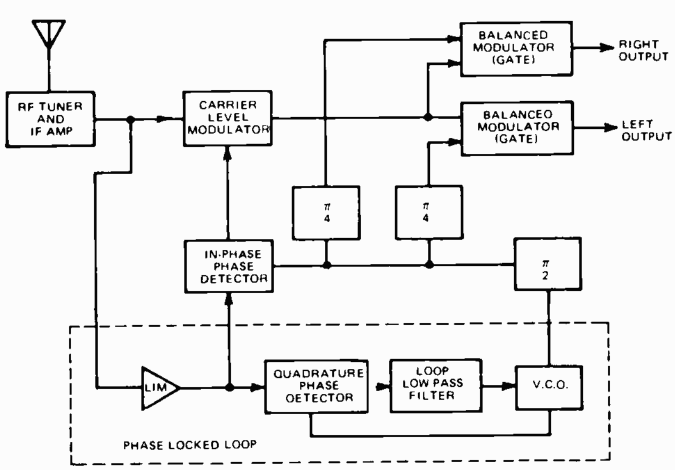


Fig. 2. Motorola's receiver employs both in-phase and quadrature phase detection. In addition, a phase shift system removes cosine modulation inserted at the transmitter.

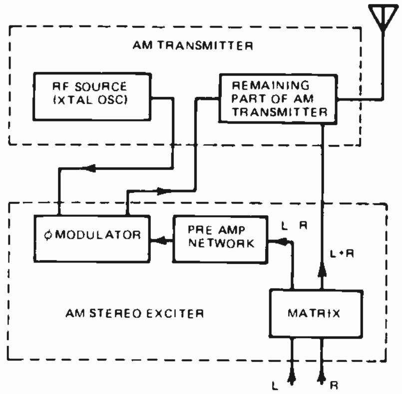


Fig. 3a. The block diagram shows how the L + R and L – R signals are routed through the Belar AM stereo transmitter.

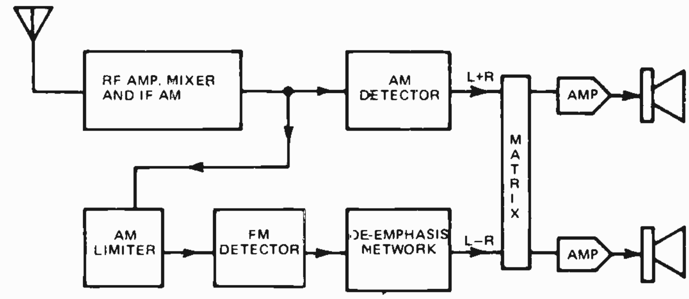


Fig. 3b. The Belar receiver has two IF paths, one to a normal AM detector, and one through limiter stages to an FM detector.

COMM. Associates:

This is probably the simplest proposed system. It is quite different from the other four. The system is called 'Frequency Approach Aperture'; the left channel modulates a carrier just below the main carrier, and the right channel modulates a carrier just above the main carrier. The combined signal goes to a band-pass filter which separates out the upper sideband of the lower carrier plus the lower sideband of the upper carrier (Fig. 1). The output from the bandpass filter is the transmitted signal.

The simplest way to receive the Comm. signal is via two AM receivers — one tuned to the upper sideband, one to the lower sideband! A more elegant way is to use a receiver in which the two signals are separated by filters and then passed on through two separate IF strips and demodulators.

It is important to note that this is not a matrix system. Claimed advantages are good noise characteristics, excellent fidelity and all the well known advantages of supressed carrier single-sideband transmission.

Motorola:

This system uses circuitry vaguely similar to that used in colour TV transmission. The system called 'C-Quan' uses two carriers operating at the same frequency but separated by phase quadrature. Motorola say that a major part of their design is in the elimination of distortion caused when the stereo signal is being received on mono receivers, this distortion apparently caused by some interaction between modulation components. This problem is overcome, claim Motorola, by modulating both the in-phase and the quadrature components by the cosine of the modulation angle.

Motorola's 'C-Quan' receiver is shown in the lower part of Fig. 2. As may be seen, the IF travels along two separate paths, one to an in-phase detector, the other to a quadrature detector. Further elements then remove the cosine term (generated in the transmitter). Finally, the two channels pass through synchronous detectors which recover the left channel and right channel signals.

Belar:

Originally described and demonstrated by RCA, Belar Laboratories propose a matrix system in which an L+R signal amplitude modulates the transmitter just as in mono transmission, while the L–R signal is processed so as to frequency modulate an RF carrier which in turn modulates the transmitted AM signal.

The transmitted carrier thus contains both AM and FM sidebands. The FM sidebands contain the stereo information (i.e. the L–R signal) and the AM contains the L+R signal — the latter of course being totally receivable on any standard unmodified AM mono receiver.

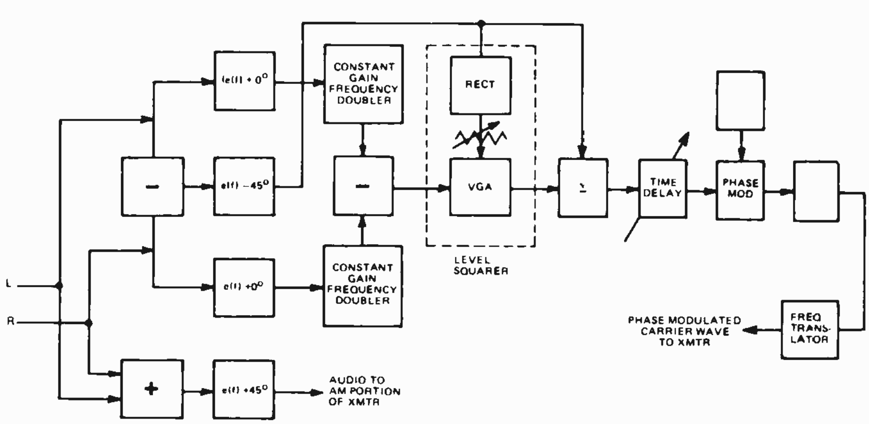
Belar's proposed stereo receiver is shown in Fig. 3a and b.

Kahn:

Although more complex than the Comm Associates proposal Kahn Communications' system is equally as elegant. Here the carrier is phase modulated with the L–R signal and then amplitude modulated with the L+R signal. Some very sophisticated circuitry is used to produce the resultant carrier which has the left channel on one sideband and the right channel on the other.

The transmitted signal can be received in various ways. A normal mono AM receiver tuned right onto the carrier will receive the normal AM envelope (the L+R signal). Stereo reception can be

Fig. 4a. In the Kahn transmitter, the L – R signal phase modulates RF from a crystal oscillator. The L and R signals are carried by separate sidebands, and are picked up on a receiver equipped for phase detection.



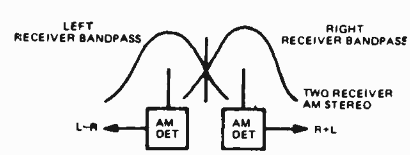


Fig. 4b. The stereo signal from the Kahn transmitter can also be picked up by two mono receivers, one tuned a little high, the other a little low.

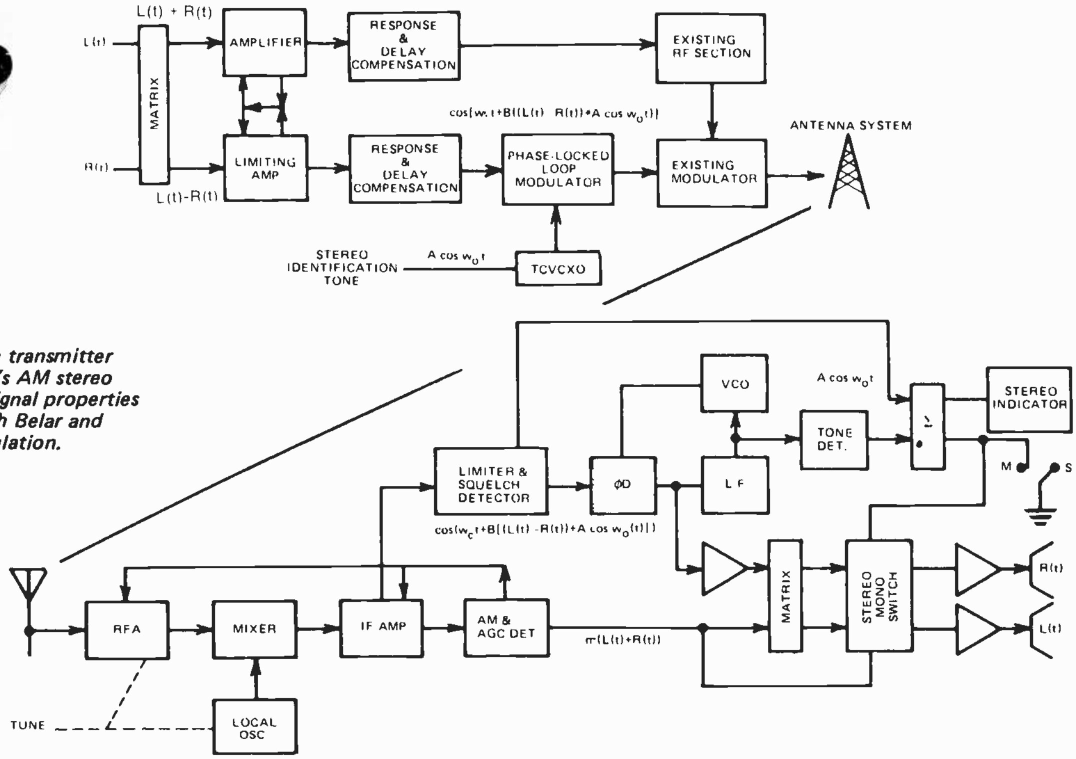


Fig. 5. Block diagram shows both transmitter and receiver stages for Magnavox's AM stereo design. The formulae detail the signal properties at various stages. In common with Belar and Kahn, the system uses dual modulation.

obtained either by using a receiver with phase detection for separating out the L+R and L-R signals — or by using two separate mono receivers (or circuits) one tuned slightly above the carrier, the other slightly below.

The Kahn system has been quite thoroughly tried and proven by stations XETRA (Mexico) and WFBR (Baltimore). Apparently the results were excellent with good freedom from interference, and excellent mono and stereo reception. Over 15 dB separation was achieved merely by using two mono receivers, and well over 35 dB using the phase detection.

Magnavox:

This system is similar in some ways to those of Kahn and Belar. Magnavox amplitude modulates the L+R signal and phase modulates the L-R signal. A 5 Hz tone frequency modulates the carrier to provide a reference for a wide-band phase-locked loop which generates a phase-modulated signal. This signal is in turn modulated by the L+R signal before transmission.

The receiver consists of a single IF strip the output of which is then split and passed to an envelope detector (for the L+R signal) and to limiters and a phase-locked loop which demodulates the phase-modulated (L-R) signal.

Wait and FCC

At present there is no clear indication from the FCC that AM stereo broadcasting will be introduced at all — let alone any particular system. But the proposals are being taken very seriously by the FCC as well as by the companies involved. And unlike the four channel fiasco in which the manufacturers of four competitive and non-compatible systems fought to establish a hold in a largely disinterested market, AM stereo will, if adopted, be backed by the FCC — who will also determine which system will be used.

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The ETI Guide to Batteries

Wally Parsons shows you what it is like inside the cells, and if you don't want to go with him claim it's not your volt when you are charged!

FROM THE LATE 1960s on, the number and variety of portable battery powered equipment offered to the consumer and built by the hobbyist has multiplied almost beyond counting. In addition, many products which had previously been strictly mechanically powered have been acquiring sophisticated electronics to the point when watches, for example, may have no moving parts. To power such equipment battery manufacturers have provided an equal profusion of batteries and cells, many of which seem so similar or identical, even from the same manufacturer, that the user may be forgiven for being somewhat confused at times.

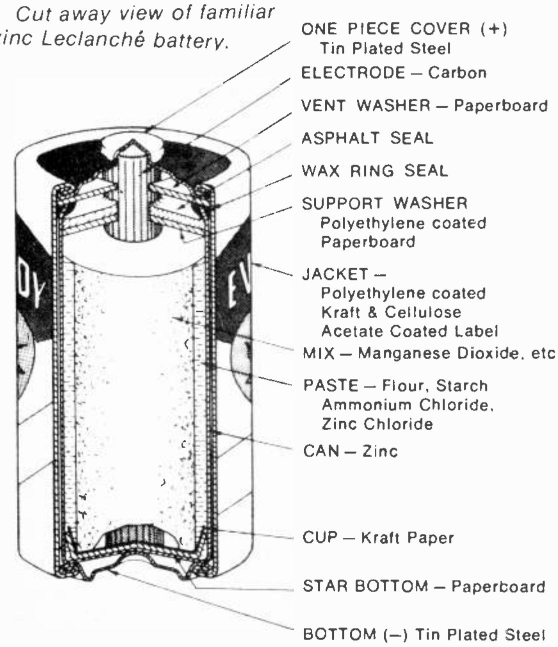
Sales people are of little help; most of them seem to know nothing of the products they sell and care even less. Many are full of misinformation, and have little compunction against passing this misinformation on in the hope that the customer will just go away and quit bothering them.

What is the truth? Are the manufacturers just a bunch of con artists who apply different part numbers to identical products just to gouge more money out of the consumer, or it there any difference? Alkalines are really just souped-up flashlight batteries, aren't they, and besided, you can recharge them too, so those expensive "re-chargeables" must be a put-on, right? Wrong.

Using the right battery for the right application not only will give better, more reliable performance for your equipment, but will even save you money. The right battery may be initially the most expensive, or the cheapest, but it will be the best choice. And battery manufacturers want you to use the best, most economical type. Because they want you to be satisfied with their product, and to continue buying it. They know that this is the most profitable approach in the long run.

Okay, so what is the difference between, say, a type 675 watch battery and a 675 hearing aid battery, or between an Alkaline and an ordinary flashlight battery, and how

Fig. 1. Cut away view of familiar carbon-zinc Leclanché battery.



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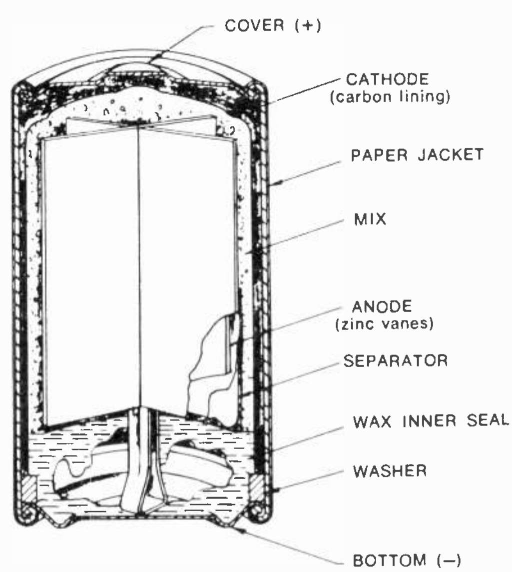


Figure courtesy of Union Carbide

Fig. 2. Internals of zinc chloride battery shows different construction.

The ETI Guide To
Batteries

do you make the choice? And what should you substitute when you can't get the right part? Read on, MacDuff, while we try to sort it all out.

DEFINITIONS

First we'd better define what we're talking about. An electrical power *cell* is a device which stores electrical energy in chemical form, and converts it to electrical energy by chemical action when an external load is connected across it. With some types this is a one way street, while with others you can put electrical energy back into the cell and convert it to chemical energy for later reconversion back to electrical form. A *battery* is any series, parallel, or series-parallel combination of two or more cells, usually in one housing.

Capacity is the total amount of energy available from a cell or battery, usually expressed as the product of current and time, or *ampere-hours*.

Energy is the output capability, ie., capacity times voltage, or *watt-hours*.

Drain is the current flow from a cell or battery into a load. When energy is withdrawn, the cell or battery is being *discharged*. When energy is put back, it is *charged*. Now for a look at cell types.

BASIC BATTERY TYPES

All batteries in general use by the consumer and hobbyist can be broadly divided into two basic types, "primary" and "secondary", and each further subdivided according to chemistry.

A "primary" battery is so called because it converts chemical energy into electrical energy in its primary stage of use, whereas a secondary battery is first charged by putting energy into it, and then discharged. The first involves a non-reversible electro-chemical action, and the second is reversible. This basic difference brings up a fundamental rule which may as well be laid down right now. There is no such thing as a rechargeable primary battery. By defintion, if it is rechargeable, it is not a primary device. This is a matter which we'll look at more closely a little later on, because many readers will have seen battery chargers offered for sale which purport to be useable for recharging ordinary flashlight batteries. Such devices are not only worthless but often dangerous, as we shall see. But for the moment, bear in mind the difference between the two basic types: primaries are put into service, and discarded when exhausted. A common example is the ordinary flashlight battery. Secondaries are recharged after full or partial exhaustion, and reused many times. The automobile battery is an example.

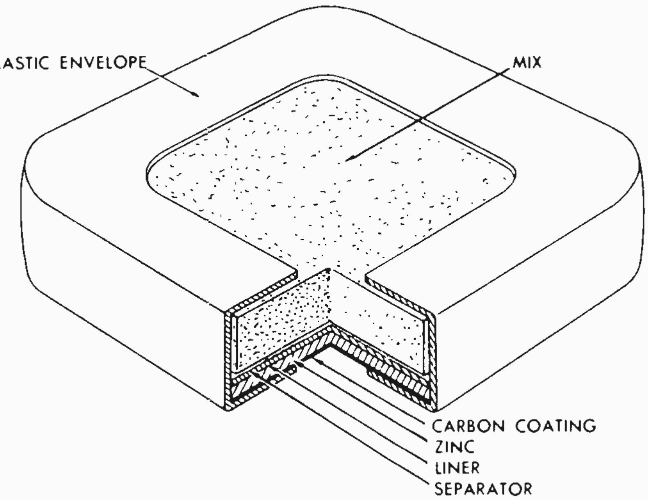


Fig. 3. Construction of flat cell.

Figure courtesy of Union Carbide

PRIMARY TYPES

Disregarding some exotic types found only in the laboratory or in space satellites, there are four basic primary batteries in common use, Leclanche (Carbon-Zinc), Mercury, Silver Oxide, and primary Alkaline-Maganese-Dioxide.

LECLANCHE

This is the familiar Carbon-Zinc battery so dear to the hearts of High School physics teachers. It is the oldest type of dry portable power still in use, low in cost, and available in the widest range of voltage, current capacity, and terminal arrangements. It can be found in flashlights, portable radios, electronic flash, toy automobiles (not counting the Detroit and Japanese variety), and even the Bionic Man can probably use it from time to time. Stock voltages ranges from 1.5V to 510V, from 60 uA to 2A. Because it is the most familiar, we will examine it in detail, and use it as a reference to which other types will be compared.

Structure

The Leclanche battery (Fig. 1) is a chemical system consisting of a zinc anode (usually the case) and a centre rod which may be of carbon separated by an electrolyte, typically ammonium chloride and zinc chloride dissolved in water, as well as a depolarizing mix which may include large amounts of carbon to lower internal resistance. In operation, an electrolytic action occurs. The total chemical action is rather complex, but basically material is reduced from the zinc anode by the action of the electrolyte and deposited on the carbon cathode. This process occurs at a rate determined by the total resistance between the two electrodes, including any external circuit. Since it is an electrolytic process, the zinc atoms are dismantled and ions produced, allowing current to flow. Since the chemicals in the electrolyte and the water enter into the reaction, the process ceases when they are used up. The exact compound depends on the precise formulation used in the particular cell, and the formulation determines the electrical characteristics. Hence the wide variety available. Nevertheless, all Leclanche batteries operate this way.

The physical construction of the cell also contributes to its electrical characteristics. For example, the "inside-out" structure (Fig. 2) provides for high efficiency by exposing a large area of carbon and zinc to the electrolyte. This allows higher current and longer life with no increase in size. The flat cell uses carbon coated on zinc to form a duplex electrode: the carbon of one cell and the zinc of the adjacent one. The amount of depolarizing mix can be increased producing greater energy per unit of volume. (Fig. 3).

Performance

The open circuit voltage of a Leclanche cell is 1.6V and under optimum load conditions drops to

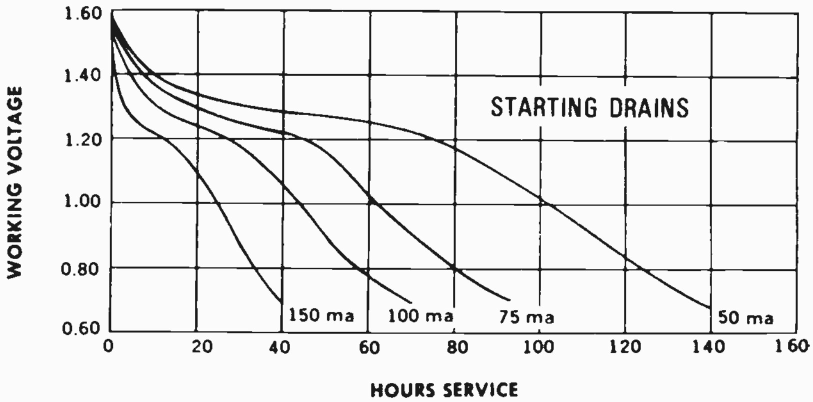


Fig. 4. The life story of a Leclanché battery.

1.5V for a fresh cell at 70°F. As it is discharged the voltage drops gradually to about 1.2V and then falls more rapidly as it is further discharged. It is considered to be discharged when it output voltage drops below the value acceptable for the application. Thus, a lower voltage may be acceptable for flashlight use where some dimming of the light may not render it unuseable, while in a portable cassette recorder tape speed may drop off if voltage is much below 1.2V. It also means that a cell which is no longer useable in one application may be put into service elsewhere, either because a lower voltage is acceptable, or because current drain is lower. An example of this would be the transferance from recorder use to a low current portable radio, or even a electronic photo-flash unit.

The total service capacity of a Leclanche cell is not a fixed number of ampere-hours, and for this reason this specification is not normally published. At light loads the electro-chemical efficiency is higher than at heavy drains, so the useful life varies by more than inverse proportion to its normal capacity, and is an economical choice in high current applications despite increased initial cost. Thus, a heavy duty "D" cell may give twice the useful life a standard type even with only 50% greated rated ampere-hours capacity. (Fig. 4).

Another characteristic of a Leclanche cell is its ability to recover a portion of its serviceability when allowed to rest. Thus, operation for short periods of time will extend the practical usefulness of the cell. Flashlights, toys, cassette dictation machines, electronic flash units, simple continuity testers are examples of the kind of applications in which this characteristic is used to advantage.

Storage, and Temperature

Leclanche cells self-discharge at a relatively high rate. Therefore, if maximum service is desired they should be purchased as fresh as possible and used as soon as possible. This is the reason for better service from cells purchased from industrial wholesale suppliers, and other dealers with a rapid turn-over in stock; they haven't been sitting on the shelf discharging themselves for most of the year. This also means that the average user gains no cost advantage by purchasing carton quantities at discount prices. However, improved shelf life can be obtained by storage at low temperatures because of the reduced chemical activity of the cell. Storage at 40°F is easily possible by storing in the egg or butter compartment of a domestic refrigerator (right beside your colour film), and the only precaution needed is to allow the cell to come to room temperature before use so as to avoid moisture condensation. Even freezing does no harm provided the cell is not repeatedly subjected to temperature cycling.

Unfortunately, the opposite occurs with high temperature. Chemical activity increases, reducing shelf life, even causing disintegration if exposed for prolonged periods to temperatures above 125°F. Where are these temperatures encountered? How about the glove compartment of an automobile in the summer. Or the outer housing of a furnace. It is common practice to have a flashlight at these locations for emergency use. It is common to find the batteries dead when the emergency arises. This is obviously not a good application for a Leclanche cell.

Now, the same relationship between temperature and chemical activity also affects service. Thus, at low temperatures, activity is reduced, and cell serviceability goes down. At 0°F capacity may be as little as 25% of its room temperature value. Photographers who do a lot of outdoor work in the winter may experience difficulties with automatic cameras, or with flash units. Also, if you leave a flashlight in the car for emergencies, you may find yourself not only unable to start the car on a cold winter night, but unable to use the flashlight, for the same reason. In any case, with all these applications, shelf life frequently makes these cells less than optimum for any kind of stand-by application. This includes service as a voltage source in ohmmeters. One can see such cells discharged to the point where almost any load will cause virtually complete voltage loss, and yet the cell is still capable of swinging the meter full scale. But with calibration 1000% off, who needs it.

As a general rule, a Leclanche cell, or for that matter, any cell should be used in the kind of service recommended by the manufacturer. Basic specifications between two types may seem identical, but this does not mean that they will give the same service in a given application. For example, an Eveready type 850 cell may appear to have greater current capacity than an ordinary "D" size flashlight cell. However, the 850 is especially formulated for photoflash use; it delivers very high current for a very brief period of time; moreover, and of even greater importance, it reaches full current very quickly. Flash synchronization is measured in small fractions of a second. We don't want the shutter to open and close while the battery is still thinking about firing the bulb. In this case, the current is used to heat up a small filament which in turn fires a combustible material, usually magnesium, inside the bulb. The camera synch is set to fire the bulb a specified time before the shutter opens to allow the bulb to reach maximum brightness at the instant of exposure.

Batteries designated for transistor use generally operate at light current drains for continuous periods. Who wants to turn the radio off while a flashlight battery recovers?

We have seen that the familiar Leclanche battery is a versatile, inexpensive source of electrical power suited to a wide variety of applicaltions, but it does have its limitations which become quite apparent in many specialized applications, especially in modern electronics. To overcome some of these limitations, other types have been developed.

The ETI Guide To
Batteries

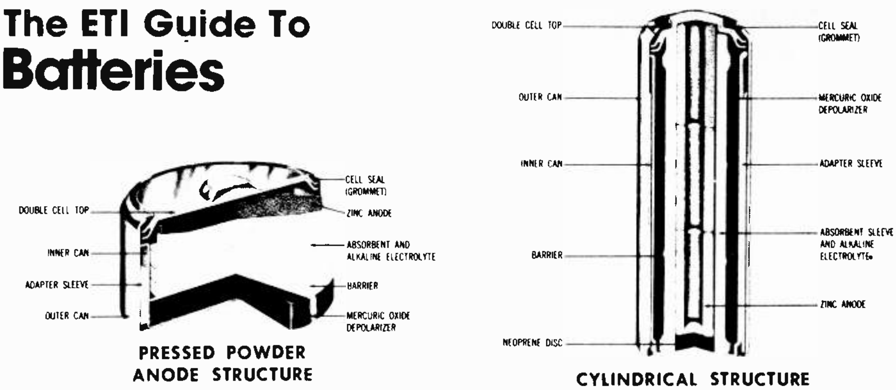


Figure courtesy of Union Carbide

Fig. 5. Flat and cylindrical mercuric oxide cells.

MERCURIC OXIDE

This was one of the first batteries to find specific application in consumer electronic devices, and in fact really made the transistor hearing aid practical, especially those tiny affairs hidden in the ear, under the hair, or in the eyeglasses. Because of their high efficiencies mercuric-oxide batteries can be made which combine very small size with high capacity, and range from the 1.35V tiny button jobs used in watches and hearing aids up to 97.2V high current batteries suitable for radio transmitters. Although moderately expensive, they offer one of the most cost-effective portable primary power sources available for electronic applications.

The mercuric-oxide cell consists of a depolarizing cathode of either pure mercuric-oxide, or of a mixture of mercuric-oxide and maganese-dioxide, an anode of pure amalgamated zinc, and a concentrated aqueous electrolyte of potassium hydroxide. (Fig. 5). Since hydrogen gas is formed in use, they are normally manufactured so as to provide automatic venting, and means of relieving excessive pressure which may develop under short-circuit conditions. Long service life results from the utilization of over 90% of all active materials, unlike the Leclanche type in which the depolarizer may be dried out long before the theoretical maximum energy has been drawn from the cell.

Performance

Nominal voltage is 1.35V with the mercuric oxide cathode, or 1.4V when mercuric-oxide and manganese-dioxide is used. Although this is a little lower than the Leclanche rating, it is obtainable throughout the life of the cell. Among the most outstanding characteristics are the following:

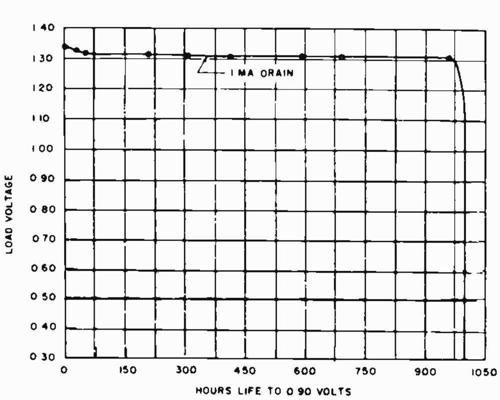
— Highest capacity to volume ratio of any cell other than silver-oxide. This results in highest output for a given physical size.
— Flat discharge characteristic. Within the recommended range, the output voltage is constant regardless of load. Moreover, this characteristic holds throughout the life of the cell.
— Fairly constant ampere-hour capacity. There is no need to use a higher capacity than required for a heavy load.
— Low and constant internal impedance. This insures good energy transfer and excellent regulation.
— No recuperation required. No need to shut down equipment while the battery recovers. This makes it an excellent choice for extended or continuous use.
— Long shelf life. This improves the prospect of obtaining maximum service by removing the need for maximum freshness.
— Good high temperature characteristics.

The flat discharge characteristic is especially attractive in electronic applications. In hearing aid use, the instrument retains its characteristics and the user obtains specified hearing correction throughout the battery life. This is especially important to persons with severe hearing loss whose instruments must deliver high power levels to be useful. A drop in output may result in hearing difficulties, or severe discomfort resulting from distortion. In tape recording applications, one is assured of correct tape speed over long periods of use, and since there is no recuperation required, the machine can be run continuously for the entire length of battery life. The low internal impedance is also useful in photoflash applications since it allows high discharge to commence quickly, ensuring good flash synchronization.

In fact, the only real disadvantage which results from the flat discharge characteristic is that the cell will give normal service and then quit suddenly and with little warning as it reaches the end of its useful life. And because its life expectancy is high it is easy to forget how long it's been in the equipment. However, at least if used in an instrument such as an ohmmeter, there will be no loss of calibration; the meter will either work or it won't. The solution is to carry a spare. (Fig. 6)

Temperature

Mercuric-Oxide cells are unaffected by temperatures of up to 130°F and may even be operated at 200°F for a few hours. Remember the car's glove compartment in the summer?



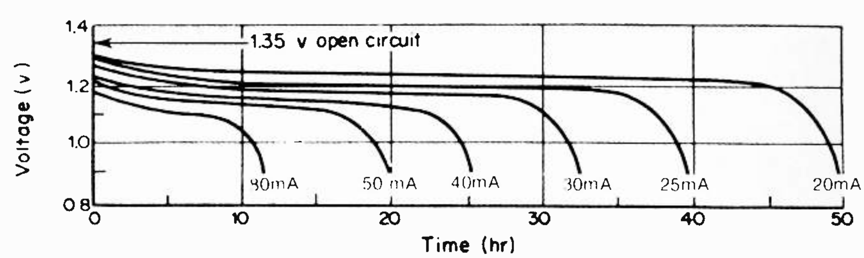


Fig. 6. Mercury battery discharge.

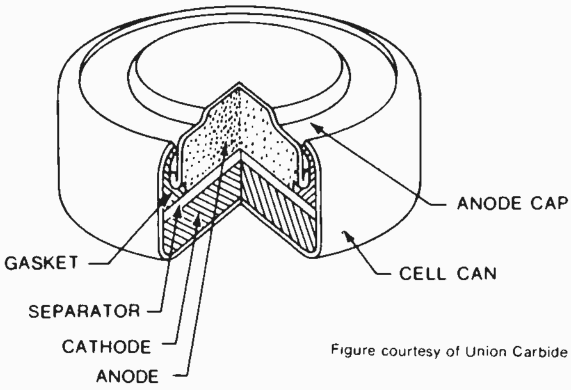


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Fig. 7. Slice into a silver oxide cell.

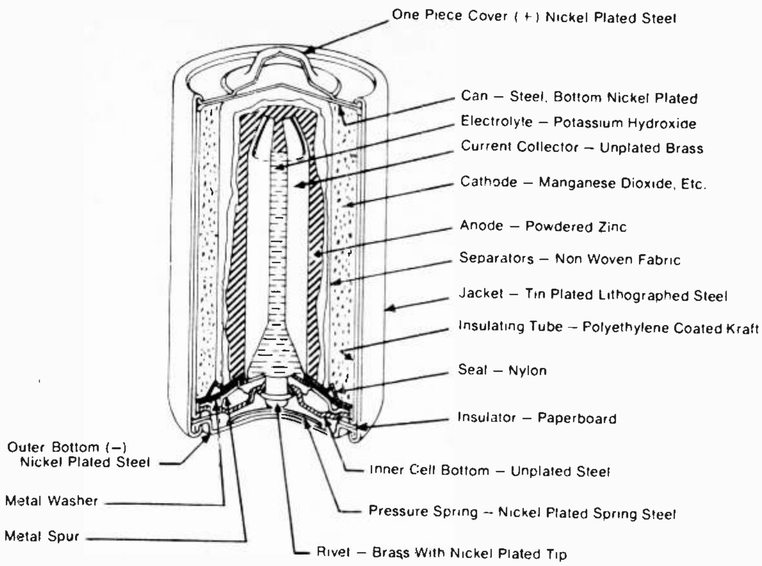

Fig. 8. Primary alkaline cutaway.

But we can't usually have it both ways, and mercuric-oxide cells generally suffer in performance at temperatures below 40°F, although some types have been developed for use at low temperatures. But when the temperature gets down to the freezing point the cell is almost useless except at very light drains. This could present problems with some automatic cameras, except some of the newer ones using I²L logic, but watches and hearing aids usually benefit from body heat. However after a long day on the ski slopes, or climbing Mount Everest some difficulty might be experienced, but these are exceptional conditions which may be satisfied by Silver Oxide or Alkaline types.

SILVER OXIDE

Physically, at least in the smaller sizes, these resemble mercuric-oxide types, and are similar in performance. The silver oxide cell consists of a depolarizing silver oxide cathode, a large surface area zinc anode, and a highly alkaline electrolyte, which may be potassium hydroxide to obtain high current density at hearing aid drains, or sodium hydroxide for long term reliability in watch batteries, or mixtures of silver oxide and manganese dioxide to maximize other characteristics. (Fig. 7)

Performance

Silver Oxide batteries offer similar performance to Mercuric Oxide, with the exception of a higher voltage, (1.5V) better low temperature characteristics, and an even higher capacity per unit volume. The main advantage of this higher capacity lies not so much in the ability to pack more power into a given space, but rather to manufacture a cell of extremely small size without loss of capacity. Consequently, the voltage and current ranges available are somewhat limited, covering a range of about 100uA to 10mA. This is not a reflection of the capabilities of the system but rather reflects the areas of application in which the silver oxide chemistry can be used to greatest advantage. Modern hearing aids, cameras, electret microphones and other transducers, watches and any application involving small size, high reliability, voltage accuracy, constant discharge characteristics, or any combination of these including reasonable cost, are all applications in which silver oxide cells can be used to advantage. Many applications in which mercuric oxide would normally be used could benefit from the use of silver oxide.

PRIMARY ALKALINE-MANGANESE DIOXIDE-ZINC ("Alkaline")

This system dates back to the middle 1950 s and was developed in answer to a growing need for a high rate source of electrical energy to replace Leclanche types.

The electrochemical system consists of a zinc anode of large surface area, a manganese-dioxide cathode, and an electrolyte of potassium-hydroxide. The main difference from Leclanche cells lies in the highly alkaline nature of the electrolyte, and in the construction. The combination results in a cell which delivers energy at a high rate. (Fig. 8)

Performance

Alkaline batteries show a discharge curve similar to that of Leclanche types (Fig. 9). The principal difference lies in the total service capacity, which is also relatively independent of the discharge schedule. Thus it can be used to advantage in applications requiring heavy drains. The inherent energy capability is not significantly greater than that of Leclanche's, but a much higher percentage is available for useful work. Alkaline cells will generally outperform Leclanche cells in most applications by a factor of 2 to 10 times. However, under very light loads there is little advantage gained. This is due to the fact that under light loads Leclanches do not exhibit a need for recovery time, and give their maximum ampere-hour service. However, under heavy loads, the alkaline really delivers spectacular service. Heavy-duty flashlight service, photoflash, battery powered toys including radio-controlled models, electronic photoflash (recycling times are shorter because the cell can sustain the heavy load imposed by the invertor circuit), tape recorders, all these and more are excellent applications for Alkaline cells.

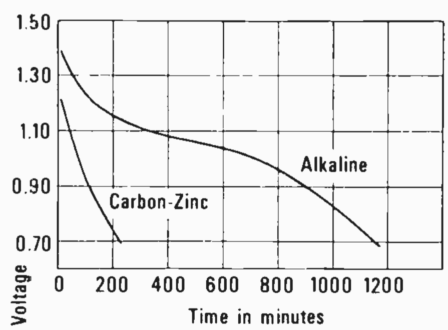

Fig. 9. Comparison of alkaline and Leclanché battery lives.

The ETI Guide To
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Remember our old friend, the flashlight stored in the glove compartment for emergency use? Well, this is the battery to use. It will deliver even under cold winter conditions, and yet its long shelf life is not impaired by high interior temperatures under direct sunshine. It may not be as cost-effective due to the occasional duty cycle, but it will give power when you really need it. And that's what counts.

LITHIUM

Although current prices place this type outside the realm of batteries you're likely to buy at the local Jug milk store, this is a type which is likely to see more and more service in years to come. Developed by Mallory (who seem to be developing all kinds of goodies these days) in answer to a need for an even higher density energy medium at reasonable cost, it offers gravimetric energy densities of up to 150 watt-hours per pound, almost three times that of mercury and four times that of alkaline. They promise to reduce the size and weight of existing products, and offer exceptional shelf life.

Construction

A Lithium foil anode, a separator, and a carbonaceous cathode are wound together spirally, in a manner similar to tubular capacitors. It's a simple structure, and mounts in a steel case with welded leads brought out to external terminals. It uses a non-aqueous electrolyte, thus no hydrogen evolves during discharge. Venting is used to prevent pressure buildup due to internal heating which may result from improper use or disposal.

Characteristics

Nominal voltage is 2.95 Volts, and is extremely stable during discharge. One interesting characteristic is the slightly depressed voltage developed after extended storage. Unlike other systems, the voltage actually *rises* after use, although the time involved is in the order of minutes.

Low temperature characteristics are better than any other types and will operate from -40° to 70°C. Fig. 10 shows cell structure and Fig. 11 shows discharge characteristic in comparison with other types.

SECONDARY, OR RECHARGEABLE CELLS

So far we have dealt with throwaway cells. Once the energy is used up you throw them away, you cannot put it back. But with secondary types the energy removed can be replaced, often over several hundred cycles. Although the initial cost, including charger is several times that of primary types, this cost is amortized over several recharges, and if one uses a great deal of battery-stored energy, considerable savings may be realized. For example, a single Leclanche "D" cell may cost around 50¢, as against perhaps $5 for a NiCad. If a charger costs $10, for a total outlay of $15, it has paid for itself after 30 cycles. If a total of 150 cycles is obtained, the effective cost reduces to 10 cents per cycle, plus the cost of electricity. Of course, if it takes 10 years to go through this many cycles, it may not be worthwhile, but it still might beat inflation.

Three basic types of secondary cells are in common use, Secondary Alkaline, Nickel-Cadmium, and Lead–Acid.

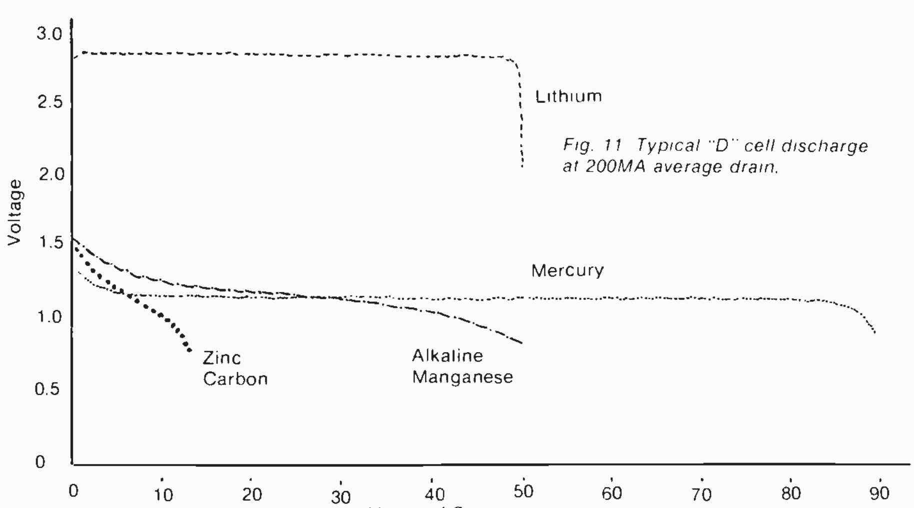
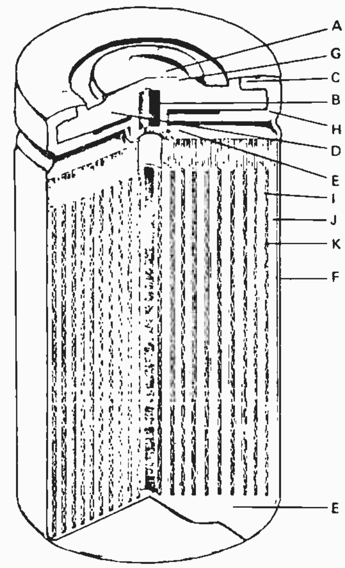


Fig. 11 Typical "D" cell discharge at 200MA average drain.

Lithium Cell Structure



KEY
A Solder Tab **B** Septum **C** Epoxy **D** Top **E** Insulator **F** Cell Case **G** Venting **H** Grommet **I** Separator **J** Lithium Anode **K** Cathode.

Fig. 10. Lithium cell cutaway.

SECONDARY ALKALINE-MANGANESE-ZINC

This is a relative new type developed from the original primary Alkaline cell, using basically the same chemistry, and showing the same electrical characteristics as its primary brother, at least on the first discharge cycle. Further cycles show a gradual lessening of capacity, but even so one may expect from 20 to 40 charge-discharge cycles before the cell must be discarded. (Fig. 12).

It is vitally important that a secondary Alkaline cell be discharged to its rated capacity when first placed in service, before any attempt is made to recharge it. Otherwise, should it be inadvertently over-charged, damage to or even destruction of the cell will occur. Therefore, decreasing either the discharge current, or the total ampere-hour withdrawal, or both, will increase the cycle life of the cell. However, exceeding the rated capacity will reduce the cycle life. This is not a cell for casual use. It is at its best in applications where the user can keep track of the rate of discharge.

Recharging is accomplished by connecting a current supply, positive to positive, and negative to negative of the cell. The charger should be regulated in such a way that the charging current tapers off as the degree of charge increases, and the charging voltage limited to the end-of-charge voltage of the cell. Charging at a constant current rate requires

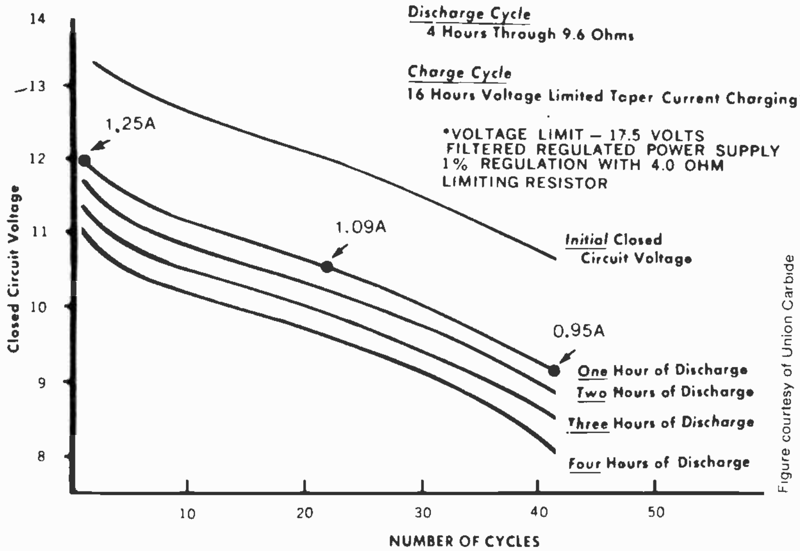


Fig. 12. Typical voltage performance of #561 battery.

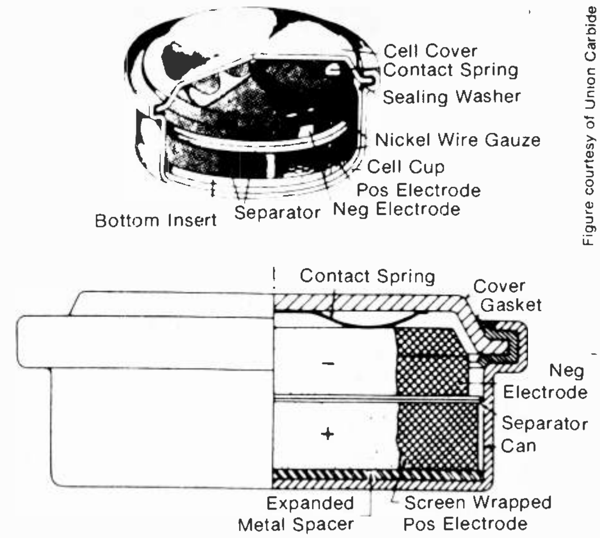


Fig. 13. Standard button cell.

close control of the charge time to avoid over-charging. This is like trying to boil an egg by placing it in cold water and timing it from the moment the water starts to boil. Somehow it always starts to boil just after you go to answer the phone and find a salesman at the other end. But we'll talk about chargers a little later.

Secondary alkaline cells offer a means of reusing the power source at a small fraction of the cost of other secondary types, although they do not give the same service. One thing to watch out for is the polarity reversal; an "inside-out" construction is used in which the case becomes the positive terminal and the centre rivet is negative, exactly opposite from Leclanches. If used as substitutes for Leclanches be sure either that they be inserted "backwards", or that polarity is unimportant. A cassette trying to run backwards can produce a beautiful snarl. Not to mention damage to electronic components.

Most manufacturers have discontinued manufacture of this type of cell: better types are now available at reasonable costs, and do not require the fuss needed to get satisfactory performance from secondary alkalines. However, if anyone still has some, a little care may get maximim use from them.

NICKEL CADMIUM CELLS

Truly one of the very best portable power devices in commercial use, this type of cell may be charged and discharged many, many times, and still show a constant potential, almost as constant as mercuric-oxide. It will stand more abuse than any system, including excessive discharge, long periods of overcharge, and still deliver top performance. In terms of cost per hour of use it is by far the most economical system available today. It requires absolutely no routine maintenance, and very few precautions in use. Long term reliability is so high that it can be permanently hard-wired into equipment, and can even be purchased with built-in charging facilities.

Like all secondary cells, it is a combination of active materials which can be electrolytically oxidized and reduced repeatedly. Oxidation of the negative electrode and reduction of the positive simultaneously generates electrical power. In a secondary cell this process is reversible, and current input in the proper direction will drive the primary reaction backward and restore the condition which existed prior to discharge. An uncharged NiCd cell contains a positive electrode of nickelous hydroxide and a negative electrode of cadmium hydroxide. During the charge process the cadmium hydroxide is reduced to pure cadmium and the nicklelous hydroxide becomes nickelic hydroxide. The electrolyte is potassium hydroxide. Towards the end of a charge cycle, (and during overcharge) oxygen is generated at the positive electrode and hydrogen at the negative electrode. Without adequate precautions the resulting pressure would cause cell rupture. Modern NiCd designs provide means for venting and/or inhibiting the evolution of hydrogen and providing for the reaction of oxygen within the cell, thus minimizing problems due to overcharging. (Fig. 13, 14, 15, 16).

This does not mean that overcharging is beneficial or even harmless. On the contrary, correct charging is essential to obtaining optimum performance for these devices. NiCd cells should always be constant current charged at no more than the 10 hour rate, unless the manufacturer specifically recommends otherwise, as with fast-charge cells. In practice we might have to restore about 120% of the energy withdrawn, therefore 12 hours recharging would be called for.

Trickle charging at the 30 to 50 hour rate is also possible for cells which are to be kept on standby, or may be subjected to variable and intermittent drains, yet are to be kept fully charged. Constant voltage and

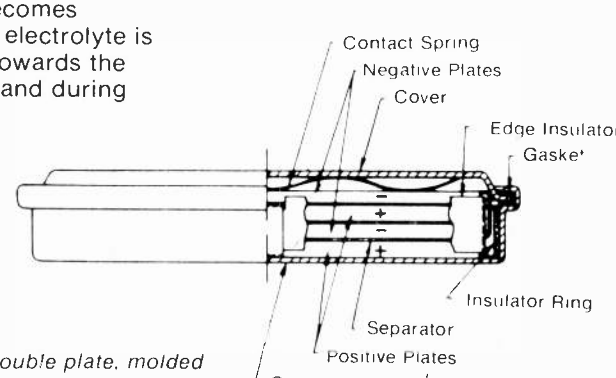


Fig. 14. Section of double plate, molded electrode, high rate button cell.

The ETI Guide To
Batteries

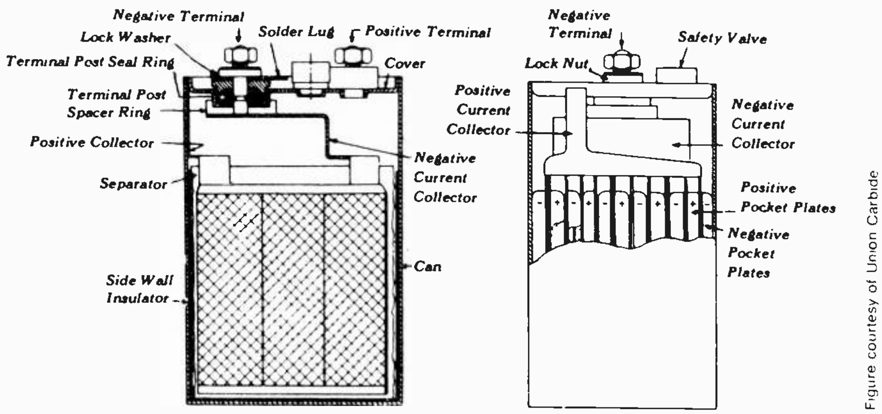


Fig. 15. Standard rate pocket plate rectangular cell.

float charging, in which the charging voltage is constant and current varies according to state of charge, should be avoided unless effective precautions are taken to prevent overheating and ultimate destruction of the cell. Similarly, multiple cells should not be charged in parallel unless each cell has its own series resistor; differences in internal resistance between different cells might otherwise result in different cells charging at different rates, with some even overcharging. More on charging later, but this also brings us to one final point with regard to NiCds.

Cell Reversal

In this imperfect of worlds we do not expect perfection. We specifiy resistors and capacitors in percentage tolerances, we sometimes select transistors on a matching (and sometimes a specified mismatching) basis. No two samples of the same product are exactly alike. So it is with NiCd and other cells. Now, suppose we have three cells in series under load. Over a period of time they gradually lose charge. However, suppose the middle cell becomes completely discharged before the other two of the series. When this happens oxygen will be evolved at the cadmium electrode and hydrogen at the nickel. Gas pressure may eventually cause rupture, unless adequate venting is provided. Many manufacturers now sell NiCds in matched sets to avoid this problem, but it can still occur if cells are improperly charged, and then deep discharged, because the differences between cells is then magnified. The solution is a simple one: use a properly designed charger, and don't discharge to the point where the cell is useless. After a reasonable amount of use get it on the charger. This isn't a Leclanche where you want to get the most for your money and then throw it away. While the equipment is sitting idle, you might as well charge the battery pack. This way you also don't have to resort to fast charging systems to get it back into service when you need it.

Discharge characteristics are similar to mercuric-oxide, although not quite so flat. Aside from the obvious advantage of rechargeability, they offer the additional advantage of low internal resistance, as well as serviceability over a wide temperature range, much like alkalines. The shelf life of a charged NiCd is not as good, however, so if they are to be stored, recharging may be necessary from time to time. However, they lend themselves readily to such practices as rotation, in which a set is kept in a charged state and exchanged for a partially exhausted set which is then placed on charge.

All kinds of portable equipment now uses NiCds in this way. Pocket calculators, electronic flash units, walkie-talkies, recorders, electric shavers, toothbrushes, massagers, soldering irons (a "must" for anyone working with MOS devices) portable TV, film cameras, power tools, the list keeps growing.

Meanwhile, back at the lab, some changes have been made to the earliest of rechargeable power sources.

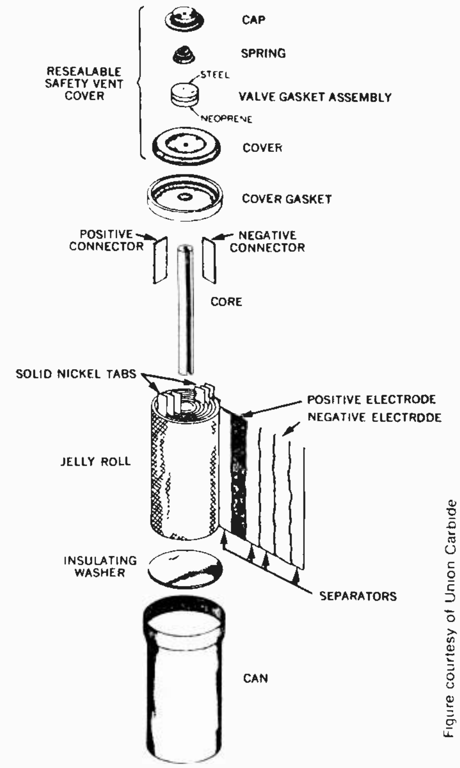


Fig. 16. High rate cylindrical cell.

THE LEAD-ACID BATTERY

Developed by Gaston Plante in 1859, it has been the workhorse of rechargeable portable power packs. Without it we might still be starting our cars with hand-cranks. It has the highest voltage-per-cell of any system and the lowest cost per watt. It also happens to be heavy, and contains corrosive sulphuric acid, two factors which have limited its use outside the automotive and stationary applications. But it can withstand very high rates of discharge and charge. For example, a high-compression V-8 engine may require as much as 500 amps initial cranking current through its starter, and yet this can be supplied by a battery with only 80 A/H capacity. 30 minutes on a 50 A charger and a discharged battery will go back into automotive service. This may reduce its charge-discharge cycle capability somewhat if one makes this a regular practice.

Everybody knows the basics of lead-acid batteries (except, it seems, some service station attendants). Negative plates are formed of porous lead applied to a lead alloy grid. Positive plates of lead dioxide are also supported by a lead alloy grid. Acid resistant plate separators, and an electrolyte solution of sulphuric acid, are housed in and supported by a suitable acid resistant container.

Electrical energy in an external circuit is produced by the electron displacement of the chemical oxidation-reduction reaction occurring in the cell. Application of an external supply will drive this reaction in the reverse direction thus recharging the battery. Hydrogen gas is produced at the negative electrode and must be properly vented. It also results in loss of electrolyte and requires topping up from time to time with distilled water (NOT tap water). Crystalline sulphate also forms over a period of time, gradually reducing the usefulness of the unit, if it is allowed to stand in a discharged state for a long period of time. They must be kept in an upright position to avoid loss of electrolyte.

This is not what we usually think of as portable, but there are newer types available which eliminate most of the drawbacks. The Globe Gel/Cell, for example, eliminates the danger of corrosive sulphuric acid spills by using a gelled electrolyte. This has the advantage of allowing operation in any position, makes possible a sealed unit, and eliminates the danger of acid spills even if the case is broken.

All lead-acid batteries should be charged at a constant voltage, or a voltage-limited taper current rate. Under these conditions the current will self-adjust according to the requirements of the battery under charge, and will automatically terminate charge when the battery has reached its specified end of charge voltage. For stand-by use, a float charge (NOT trickle charge) is recommended, with the voltage slightly below the end of charge voltage of the battery. The use of constant current and/or trickle charging may result in overheating and damage. This also means that the same charger is not useable for both NiCd and lead-acid batteries, even if the voltage can be adjusted. Also, lead-acid batteries should be charged either singly or in parallel; if several units are charged in series, differences in one unit may result in some batteries being overcharged, and other undercharged. This is why one bad cell in a car battery usually requires scrapping the whole unit.

Typical applications include portable TV sets, lighting systems, camping equipment, power tools, garden tools, radio transmitters, and others requiring high current and long life.

Incidentally, an interesting characteristic of batteries of the Globe Gel/Cel variety is the *increase* in capacity after about 20 charge-discharge cycles. Also, there is no permanent cell-reversal after deep discharge, and, unlike NiCds, if used well under their rated capacity, there is no "memory" phenomenom in which the capacity is temporarily reduced until the unit has undergone several high-rate cycles.

A standard cell voltage is 2.1V open circuit, and although others are available, most common types are batteries of 6 V and up. Varieties of packaging are considerable, and may range from the familiar car battery shape, through cubic package similar to the old Leclanche "B" pack, and even small types resembling large flashlight cells, in which the plates are flexible and separated by an absorbent electrolyte carrier, and the whole thing rolled up like a jelly roll.

MORE ABOUT RECHARGING

General Principles

All batteries contain potential energy in chemical form and have the ability to convert this into electrical energy by electro-chemical action.

Secondary batteries use electro-chemical systems which are reversible converting electrical energy to chemical energy by electro-chemical action.

The basic requirement for battery charging is a source of direct current of a voltage higher than that of the fully charged battery. The positive terminal of the charger is connected to the positive terminal of the battery, and the charger's negative terminal connected to the battery's negative terminal, so that current is forced through the battery in the reverse direction, as illustrated. Refering to figure 17, we see that there are two variables to be adjusted, current supplied to the battery, I, and voltage across it E. Intimately related to these factors are the cell internal resistance and cell voltage. Just as the different cell characteristics vary over the discharge cycle, so do they when recharging, and thus for example, the increasing cell voltage during recharge will possibly affect the current through the battery. For example. NiCd voltage increases rapidly with time during the early stage of charging, but less rapidly as full charge is approached. This is the reason for not using a constant source of voltage for charging purposes.

Alkaline-manganese cell, on the other hand, show a more gradual rise with time, as do lead-acid.

Thus, the charging circuit must be designed in accordance with battery characteristics and usuage. The important considerations are: Battery internal resistance (usually fractions of an ohm), initial and final charging currents, voltage change during charge, charge time, and desired end of charge voltage. In addition, consideration should be given to such variables, as temperature variations, line voltage variations, and, where multiple useages are contemplated, variations in charge load.

Charge Rates

It is standard practice to specify charge and discharge rates in terms of the ampere-hour capacity of the battery. This rate is obtained by dividing the capacity in ampere-hours by the current in amperes. Thus, the 10 hour rate for 1 A-H battery is 1/10 or 0.1 amperes, and the time factor is 1/0.1 or 10 hours.

In general, the charge rate is chosen to replace 140% of the energy expected to be taken from the battery. Excessive charge rates, or extended charge times will reduce the battery life and should be avoided. A proper choice is a balance between these extremes, and manufacturers recommend a rate of between 10 and 14 hours depending on the battery design for full charging, and from 30 to 50 hour rate to replace charge lost through internal self-discharge. In all cases the engineering department of the manufacturer of the battery to be used, no matter which company, will be glad to advise the user should problems be encountered. As mentioned earlier, they want you to get the best possible service from their products, they like satisfied customers, and this is the best way to ensure satisfaction and minimize complaints.

CHARGING METHODS

There are numerous possible basic approaches to battery charging, each suitable for different applications.

Constant Voltage

A fixed voltage is supplied to the battery, hence the current will be given by

$$I = \frac{E - Ec}{Ri}$$

In other words the current is limited by the internal resistance. Since this is typically only a fraction of an ohm, E must be only a small amount greater than Ec to obtain a reasonable current. In addition, a small change in cell voltage causes a large change in current. If E was set to the final cell voltage then charge current will start at some large value, and decrease to zero.

A complex and expensive regulator is required to carefully set E, making this charge method impractical.

Constant Current

This is the simplest and cheapest method to do approximately. As figure 18 shows, it is accomplished using a voltage source much greater than cell voltage, with a resistor R_s big enough that the charge due to increasing cell voltage is insignificant. Similarly R_s is much greater than R_i and hence internal resistance changes are also negligible. In practice, variations on this theme range from very careful current regulation with transistors etc, to loose regulation where the voltage source is merely rectified AC. A typical NiCd powered calculator comes with this last type of charger — adapter, in fact with the adapter in use the batteries are both being charged and acting as smoothing capacitors.

Constant current charging is recommended for NiCds, secondary alkaline, and also lead-acid if the user can control the charge time. Simple application of Ohm's Law establishes the resistor and voltage values.

TAPER CURRENT

This system provides a fairly high initial charging current which tapers off to a lower value at the end of charge. The taper results from the battery voltage rise during charge, and therefore tends to be closely matched to the requirements of the battery. Design methods and circuits may control the shape of the taper, but battery voltage still controls actual current. By incorporating a voltage limiting circuit set for desired end of charge voltage,charge can be terminated when complete, and left on to provide a trickle charge.

TRICKLE CHARGE

By holding the charge voltage to a value slightly above the battery voltage a small trickle current will be supplied to counteract the self-discharge characteristic of the battery. At the same time, should current be taken from the battery, it will then be replaced by the charger.

CHARGING PRIMARY BATTERIES

The best method of recharging primary batteries can be summed up in one word: DON'T.

Many charger units are available to the consumer which purport to recharge any kind of battery in use today including primaries. These are generally cheap units sold at cheap prices and of very simple design. In the author's opinion they are of little or no use, and can be very dangerous. Even when used with secondary cells, there is no way that for under $10.00 a unit can be built which will handle the variety of charging characteristics required. Like most "something for nothing" schemes what you really get is nothing for something.

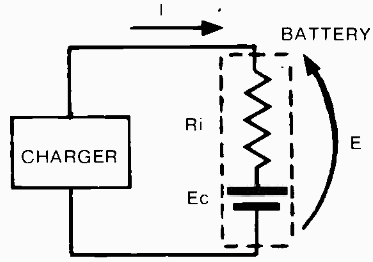
Why Not?

Theoretically, and under certain strictly controlled conditions Leclanche cells can be rejuvenated (a more accurate description than "recharged"). These conditions are:

1. The operating voltage on discharge must be *at least* 1 Volt per cell.
2. Rejuvenating must commence as soon as possible after removal from service.
3. Recharge should be at 120-180% of the ampere-hour discharge.
4. Charging must occur over a long period of time — at least 12 to 16 hours.
5. Cells should be placed in service as soon as possible.

With Leclanche cells zinc is removed from the anode, unlike NiCds, for example, where the nickel and cadmium compounds are altered during discharge, and reversed during recharge. Thus, to restore useability to a Leclanche cell we must replate the zinc which was removed during discharge, and we must do it evenly. To do this requires that most of the original zinc remain intact. But this is more easily said than done, as anyone involved in electroplating will tell you. Because of the near-impossibility of depositing zinc evenly, dendrites, or tree-like growths of zinc develop and eventually touch the cathode, internally shorting the cell. The same unevenness also results in some areas of the zinc case becoming thinner than others and eventually holes develop and the cell leaks.

Deep discharge uses material unevenly, thus aggravating the above problems. Thus suitable candidates



R_i – internal battery resistance
Ec – cell voltage

Fig. 17. Battery charging.

for rejuvenating are those which have seen light service. It's somewhat like a heart transplant; The guy who needs one usually has other complicating conditions which result in an inability to survive the operation, while the ideal candidate is unlikely to need a transplant. Similarly, the best cells for rejuvenation are fresh cells.

Attempting to recharge any sealed cell can be dangerous. Excessive gassing which may result from excessive charge rate may result in cell rupture, and personal injury or damage to equipment. This is especially true of tightly sealed primary alkaline, mercury, or silver oxide cells. If you ignite gunpowder or other similar substances in a tightly sealed enclosure, when it finally ruptures the energy released is quite intense. A weapon operating on the same principle is the grenade. And that is precisely what you have when one of these batteries goes off.

As to any economic advantage gained, what advantage? NiCds are far less expensive in the long run than even "successfully" rejuvenated Leclanches, and mercuries are selected for their specific characteristics rather than re-useability. The author feels that in no way is attempted rejuvenation of primary cells a good idea, and that the sale of rechargers for this purpose should be restricted by law.

INADVERTENT "RECHARGING"

Which brings us to the matter of equipment designed for use with batteries or external supplies. All too often such equipment is poorly designed in that when the external supply is connected it places a voltage across the battery terminals. With such an arrangement we may have a constant voltage source, which is undesirable for use with NiCds, and a dangerous condition with primary batteries. The user should satisfy himself before purchasing such equipment that the connector has an interlock system

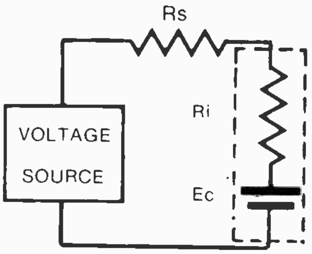


Fig. 18. "Constant" current source battery charger.

which removes the battery from the circuit when the external supply is connected, or else a switch to select the power source. Cheap pocket calculators and cassette recorders seem to be particularly likely to have this problem, and a sure indication of it is the instruction to remove the battery when using the external supply. This is downright inconvenient, and completely unnecessary. But it is something to watch out for and you're probably better off passing over such equipment.

And there's not much point in trying to take advantage of this design by using a NiCd because you would then have a constant voltage charging system, which, we have seen, is undesirable, and would most likely lead to overcharging.

CHOOSING THE RIGHT BATTERY/SYSTEM

Selecting the right cell or battery is really a simple operation provided it's approached systematically. In general, the following criteria should be considered:

1. Nominal Voltage
2. Current Drain
3. Anticipated operating schedule
4. Desired service life
5. Service temperature
6. Size and weight.

Usually one or two criteria will be dominant and the others traded off as necessary.

Thus, if the equipment will not operate below a specific voltage, this may shorten the effective service life. Thus, for a cassette recorder a flashlight cell is unsuitable since its voltage will drop to an unsatisfactory level too quickly. A mercury cell will start off slightly on the low side and may cause a slight loss of speed, but would last for quite some time. One of the problems here is the conflict between the requirements for the transport and the electronics. Mercuries would be great for the electronics and give long life, but the transport requires a heavy current drain, which dictates a very expensive battery. The obvious choice is either a primary alkaline, or NiCd and charger. The user can make this choice if he is building the equipment, and also when using commercial products designed for standard flashlight size or 9V transistor size batteries.

TABLE ONE

BATTERY TYPE	FEATURES	APPLICATIONS
Leclanché	Low initial cost, easy availability	Radios, toys, novelties, flashguns, slide viewers.
Alkaline	Wide temperature range, gradual voltage drop, good shelf life, high capacity, low resistance.	Radios, Electronic flash, Flashlights, tape recorders, R/C Models
Mercury	Excellent high-temperature performance, flat discharge, low noise.	Hearing aids, electret microphones, preamplifiers, secondary voltage standards, watches, cameras, test instruments, some calculators.
Silver Oxide	Flat characteristic, good low temperature performance	Watches, hearing aids, cameras, light meters, instruments
Nickel Cadmium	Rechargeable, good temperature range, high capacity, high cost, but most economical.	Shavers, soldering irons, toothbrushes, electronic flash, recorders, radios, calculators
Lead Acid	High capacity, rechargeable, high cycle life, economical	TV, lights, power tools, transmitters, garden tools, film cameras, recorders, fire and burglar alarms

Where his choice is more limited is with things like electret microphones, cameras, hearing aids, and the like where only one specific type is useable. Even here there is often some choice. In general, the best battery is the one specified by the manufacturer. But such statements as "Uses 4-D cells", or "1-9V transistor battery" is not a specification, it's a size, and any idiot can figure out the size just by looking at the battery compartment. But if the specification says "Use Mallory RM 675 or equivalent", then use an RM 675, or an Eveready E675, or some other manufacturer's equivalent part number, but DON'T use, say, an EPX675 even though it's the same size and seems to have similar specifications. The latter is a very low drain cell intended for use in cameras. Under very light drain mercury cells will exhibit a migration of mercury within the cell which causes premature shorting. The low current variety has barriers built in to prevent this and so give longer life. These barriers, however, reduce the total capacity making it unsuitable for higher current applications where it will give shorter life than the correct type.

With this in mind, plus the applications guide in Table 1 you should now be able to ignore the sales clerk who wants to sell you transistor batteries for your flashlight, flashlight batteries for your recorder, and hearing aid batteries for your camera.

ACKNOWLEDGEMENTS

Our thanks to Union Carbide, Burgess-Gould, ESB (Ray-O-Vac) and General Electric for their assistance in the preparation of this article. Many of the figures were taken from "Eveready Battery Applications and Engineering Data" copyright 1971 by Union Carbide Corporation.

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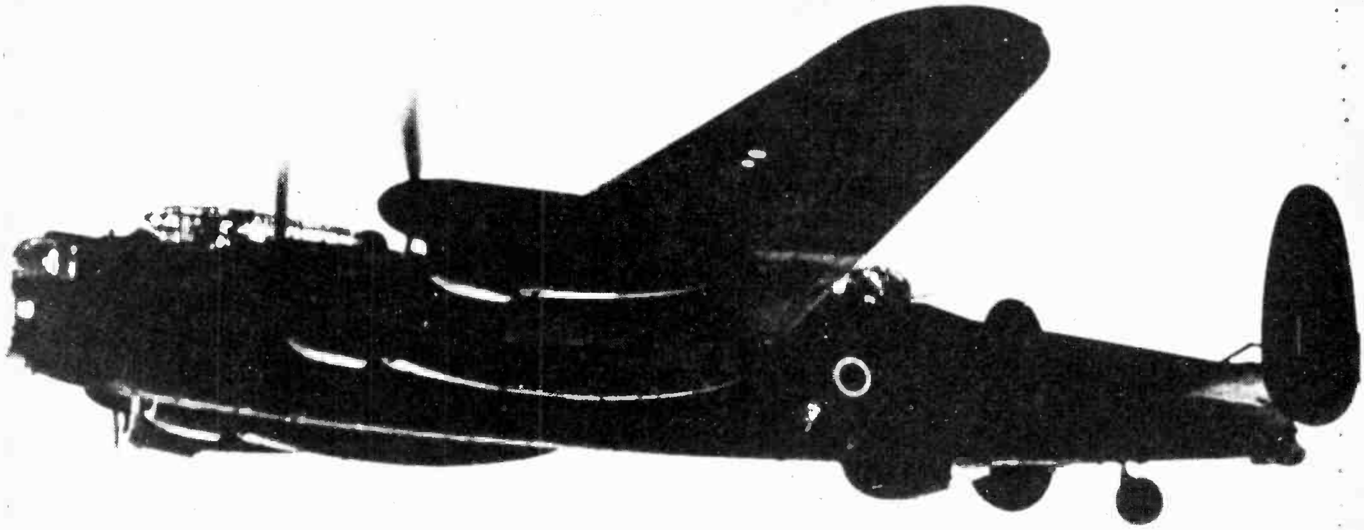
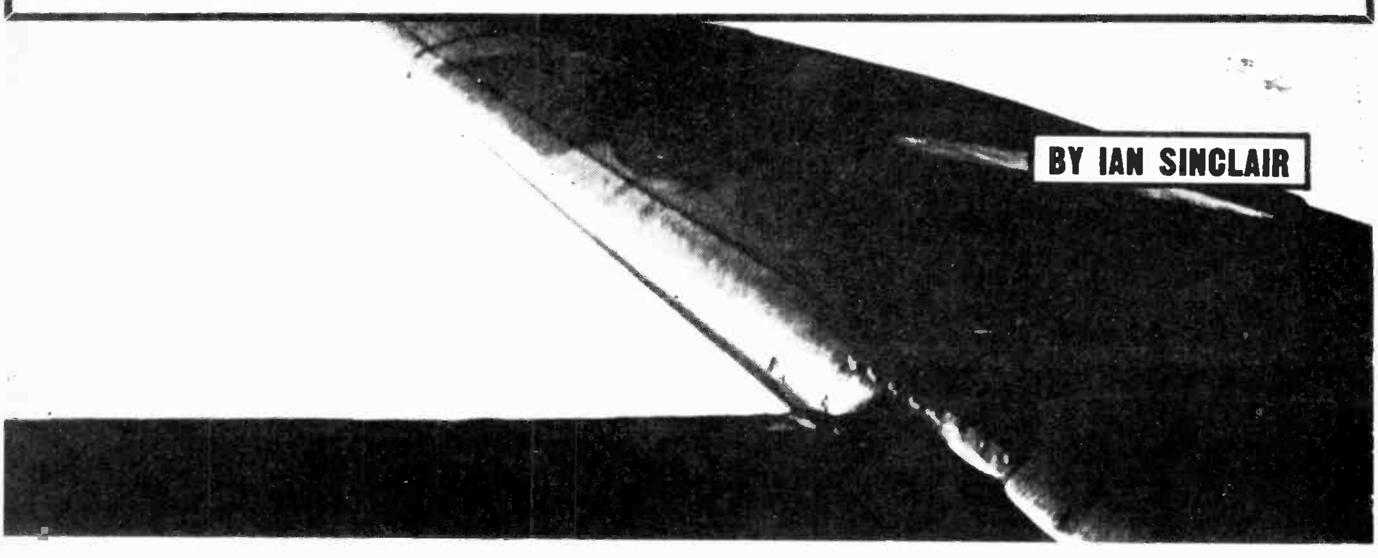
THE USE OF RADAR BY BOTH SIDES IN WORLD WAR II WAS OF CONSIDERABLE STRATEGIC IMPORTANCE, WITH THE ADVANTAGE SHIFTING FROM ONE SIDE TO THE OTHER WITH EACH NEW DEVELOPMENT. THIS IS THE STORY OF ONE KEY INVENTION WHICH SWUNG THE BALANCE CONSIDERABLY AND WHICH CONTRIBUTED MUCH TO OUR UNDERSTANDING OF ELECTRONICS.



THE TUBES THAT WON THE WAR



BY IAN SINCLAIR

The Tubes That Won The War

THE ESSENCE OF RADAR is that radio signals sent out from a transmitter will reflect from a target which is large compared to the wavelength of the signals, and the reflected signals can be picked up on a receiver.

The time delay between transmission and reception is then a measure of the range of the object which is reflecting the waves. The wavelength which can be used is of considerable importance, since short wavelengths can detect smaller targets and also need smaller antennae. If we want to use reasonably small aerials and to detect objects about the size of an aircraft, then we must use wavelengths of about one metre or less. The methods which we use to generate these wavelengths are therefore of great importance, and the amount of power which can be delivered to the antenna will decide what range is usable, since the received signal can be detected only if it has an amplitude greater than the noise level of the input stage of the receiver.

Thanks to the use of low-noise input stages, pulse gating, and correlation techniques, we can now recover signals which have apparently been lost in noise, but these techniques were not available in the years of the war.

REFLECTIONS AND SHORTENING

Early radar experiments used standard or slightly modified short-wave radio transmitters, with power output stages which were usually large air-cooled triodes with conventional inductor-capacitor tank circuits. In the early experiments, detection was considered more important than range-finding, and the received signal was allowed to beat with a fraction of the transmitted signal to form a slowly changing beat note from a moving target. These arrangements were sufficient to show that the reflected waves could be detected, but the wavelength was too long (frequency too low) and the power too small for radar as we now know it.

What was needed was a generator of waves of much higher frequency and much greater power. In addition, if such a generator could be made small enough to be carried in an aircraft, a substantial advantage in night bombing would be obtained.

Using conventional triodes, this was impossible. The stray capacitances of a large triode are so large that even the inductance of a short piece of straight wire gives a tuned circuit whose frequency is too low (assuming that oscillation takes place). The power output of such a tube at extremes of frequency is too low in my case.

Fortunately, as so often happens, the foundations for a new type of construction were already laid. These foundations were the magnetron effect on electron beams, and the resonant cavity tuning system.

MAGNETIC SPACES

When electron beams travel from a hot cathode to a positively charged anode, the speed of the electrons is decided by the voltage applied between anode and cathode. Equating the potential energy, eV, with the kinetic energy $\frac{1}{2}mv^2$, for each electron we get:

$eV = \frac{1}{2}mv^2$ where e = electron charge
V = accelerating voltage
m = electron mass
v = electron speed.

From this equation, the electron speed, $v = \sqrt{\frac{2eV}{m}}$

Using modern units, the ratio e/m, the specific charge of the electron, is 1.76×10^{11} C kg^{-1}, so that for 5kV accelerating voltage, the speed of the electron is about 4.2×10^7 ms^{-1}, some 42 million metres per second. At this speed, an electron will cover a distance of 1 cm in 0.24 ns, so that we should have no trouble in generating oscillations of a comparable wavetime if we can use such a beam in an oscillating system.

Now if we apply a magnetic field to such a beam, and direct the magnetic field so that it is at right angles to the direction of motion of the electrons as they enter the field, the path of the electrons will be an arc of a circle whose axis is the magnetic field direction. Equating the magnetic force, Bev, on a moving electron with the force needed to move an electron in a circular path, $\frac{mv^2}{r}$ we have: $Bev = \frac{mv^2}{r}$ so that $r = \frac{mv}{Be}$

BEAM BENDING

Using the value of speed given above, to bend the electron beam into a circle of radius 1 cm needs a magnetic field strength of about 2.4×10^{-2} Wb m^{-2}, about one thousand times the magnetic field strength of the Earth. This is not a particularly large field strength, and it was attainable by either permanent or

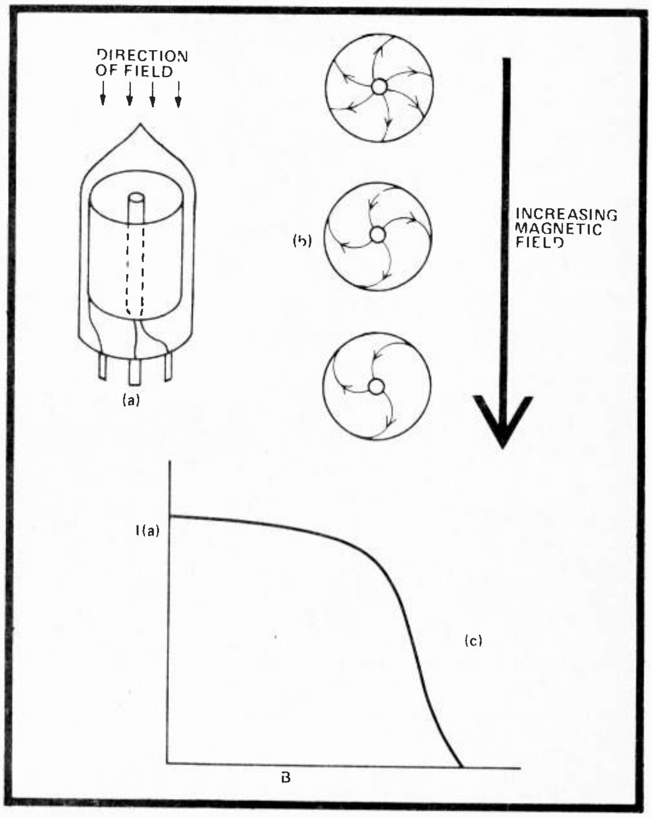


Fig 1. The magnetron effect. (a) Simple magnetron tube. magnet not shown. (b) Paths of electrons as the strength of the magnetic field is progressively increased. (c) Graph of anode current against magnetic field.

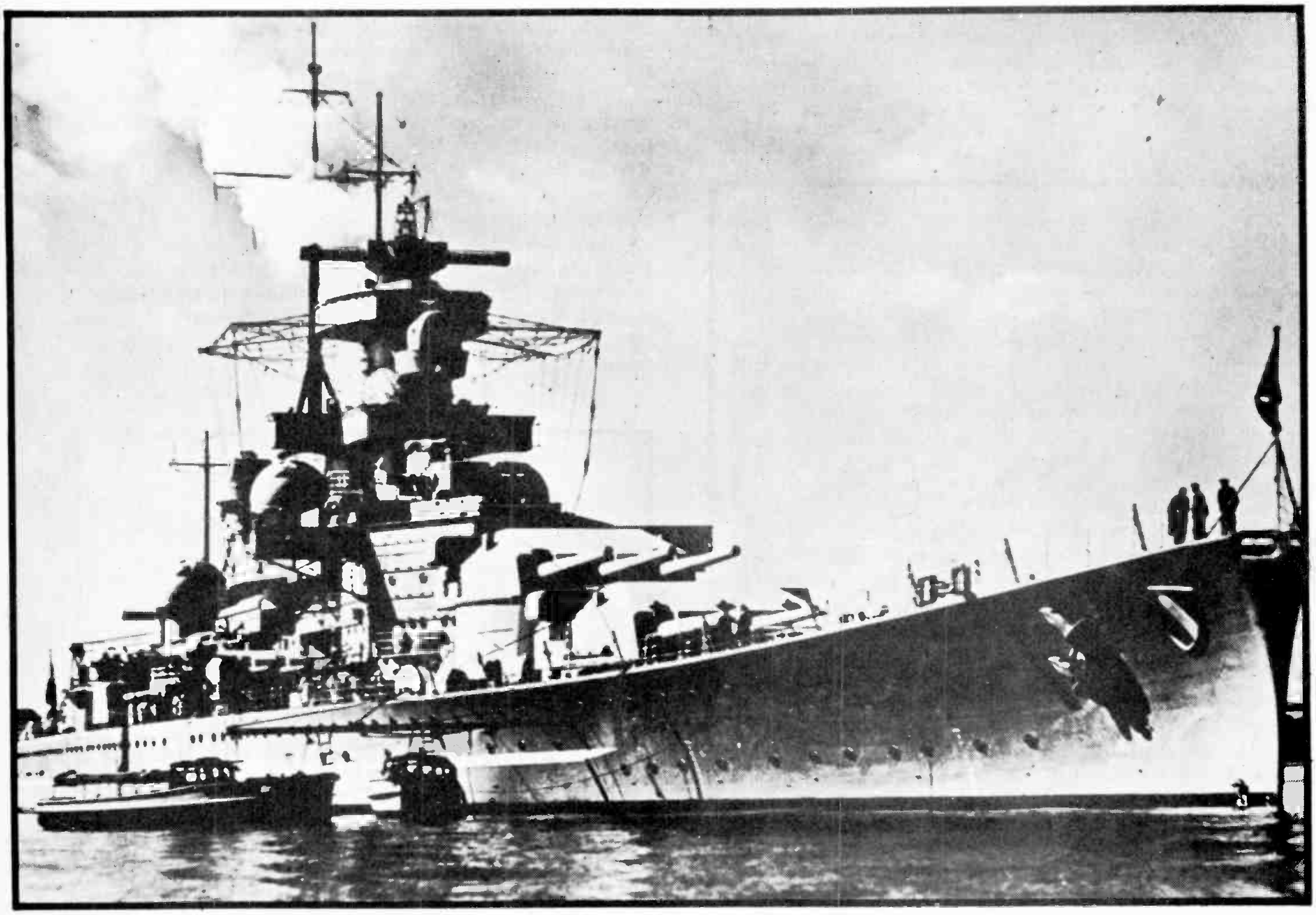
electro magnets. All of this basic theory has been known since early in the century due to the work of J. J. Thomson on the specific charge of the electron.

Later work had made use of the magnetron effect to measure the specific charge of the electron in a different way, as shown in Fig. 1. A tubular cathode emits electrons which are accelerated to a circular anode coaxial with the cathode. When a magnetic field is directed along the axis of the tube, the path of the electrons curves, and becomes more curved as the strength of the magnetic field is increased. If we plot a graph of anode current against magnetic field strength, the graph shows current dropping as fewer electrons reach the anode, and then reaching zero when the magnetic field is strong enough to prevent the fastest electrons from reaching the anode. Using such a "magnetron" tube made to accurately known dimensions, the value of e/m for the electron could be found to very close limits. The great breakthrough in radar was to realise that this tube structure could be combined with resonant cavities to enable us to generate oscillations in the GHz region.

RESONANCE

In the study of sound waves, any space may have resonances, meaning that sound waves of certain wavelengths, related to the dimensions of the space, will be emphasised; these are resonant frequencies, and designers of loudspeakers go to great lengths to get rid of them. A tube is one type of resonant space, and organ pipes and other wind instruments are examples of resonant tubes used to generate sound waves of various frequencies.

A tube which is resonant to one particular frequency will generate this frequency if the air in the tube is set into oscillation by any disturbance. An example of particular interest in this case is the flute. In this instrument, the player blows air across a small hole in a resonant tube. Air striking the edge of the hole (controlled by the players mouth-shape) builds up a pressure wave which sets the air in the tube into oscillation at its resonant frequency, and the resonant waves in the tube then make the air passing across the hole flutter, keeping up the oscillation. What we have here, translating into familiar electronic terms, is a d.c.



The mighty Scharnhorst. One of Germanys new generation of capital ships. As modern as anything then afloat, fast enough to outrun anything which could outgun her, and armed sufficiently to sink anything fast enough to catch her. Yet the Scharnhorst fell victim to the Magnetron!

The battle of North Cape was the battle which proved the importance of radar in surface engagements. Leaving Norway to attack convoy JW 55B the Scharnhorst was dogged by a series of disasters and unfortunate decisions by High Command which led her, on December 26th 1943 in appalling weather to face the British cruisers Belfast, Norfolk and Sheffield — all radar equipped and using it! Scharnhorst herself had radar equipment, but standing orders prevented its use (as a measure against breaking radio silence!) In the engagement which followed the British ship directed their fire with radar, and by chance destroyed the Scharnhorst radar!

They followed her on radar until the battleship Duke of York came up to engage, also using radar, with her superior armament.

Scharnhorst was sunk. Her superior speed and firepower were of no avail.

On New Year's Day 1944 Admiral Dönitz reported to Hitler "Without serviceable radar equipment it is no longer possible for surface forces to fight the enemy."

supply (the player's breath), a resonant tuned circuit (the tube of the instrument), and postive feedback (the effect of the resonant waves on the breath stream.

A similar effect can be expected using a beam of electrons. A circular cavity cut into a block of metal will act as a tuned circuit, using the inductance of the conducting material and the stray capacitance between sections at (momentarily) different potentials. This is a resonant cavity, and the wavelength of resonance is related to the size of the cavity. When such a cavity oscillates, both electric and magnetic fields will exist, and these will be rapidly alternating fields, going through a cycle of building up in one direction, dying away, reversing, building up in the reverse direction, dying away and so repeating millions of times per second.

Can we carry the similarity a little further, and imagine a small slot in the cavity? At such a slot, alternating electric and magnetic fields will exist, and these will alternately repel and attract an electron beam which is just skimming past the slot like the breath of the flautist. Would such an arrangement give enough positive feedback to keep a resonant cavity oscillating? At the beginning of the war, only experiment could decide, and it fell to Randall and Boot, working in England, to perform the crucial experiment, so creating the first cavity magnetron oscillator. This tube was capable of supplying U.H.F. oscillations at power levels greatly in excess of any previously obtained at such frequencies, the perfect answer to the demands of the radar system.

Fig 3. A coastal defence tower. Standing some 360 ft high, the apparatus was used to detect low flying intruding aircraft which were flying too low for normal stations to detect them. Lone raiders often adopted this tactic to reach specified targets, or to make photographic records.

CAVITY MAGNETRON

The cavity magnetron combines the principles of the resonant cavity with the earlier magnetron tube. The cathode is a tube coated with electron emitting material, and with a heater winding inside for starting the electron emission. The anode is metal block, finely machined to a circular profile with a set of resonant cavities breaking into the inner surface of the block. The whole tube is evacuated and sealed, and then mounted between the poles of a strong permanent magnet. Since it would be inconvenient to run the cathode at ground potential and have the metal anode and its cooling fins positive, the anode is grounded (and connected to waveguide through a thin "window") and the cathode run at a negative voltage.

When an accelerating voltage exists between the anode and the cathode, the electrons are accelerated from the cathode, and the magnet shapes the beam so that its shape is circular, brushing past the ends of the cavities as it tries to reach the anode. For a given strength of magnet, the voltage between anode and cathode would have to be the correct value for the beam to take the correct path, but this value is fortunately not too critical. The movement of the beam excites the cavities into oscillation, and the oscillating cavities in turn will alternately repel and attract the beam.

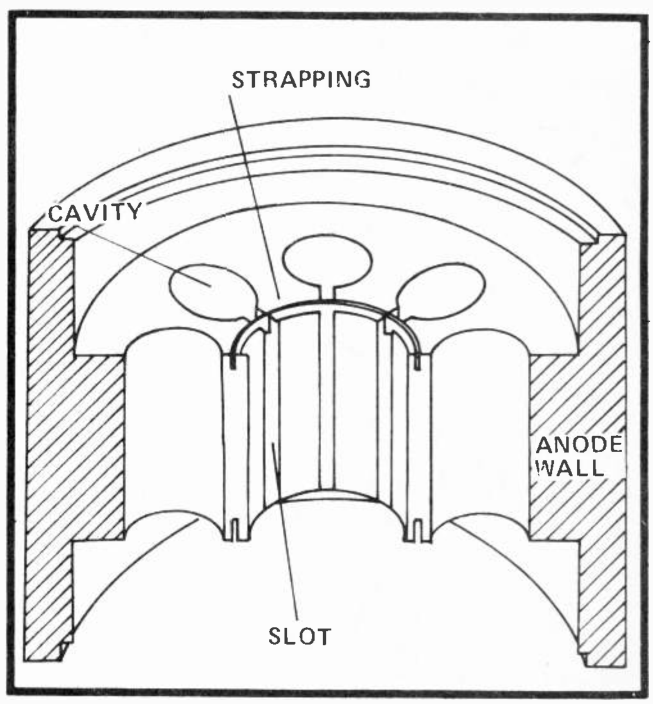
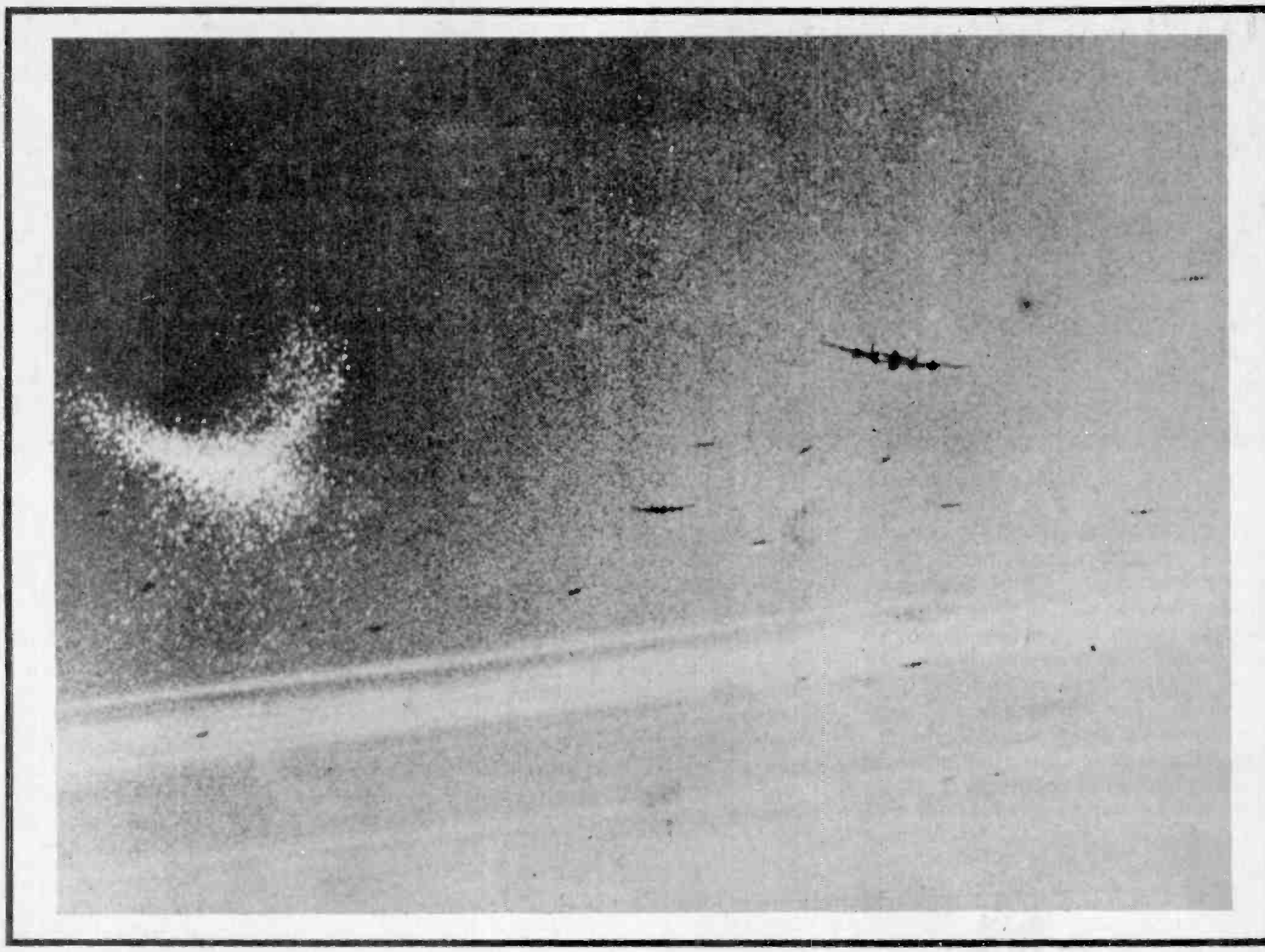


Fig 4. Cross-section of a cavity magnetron, which in this case uses cavities of cylindrical shape, linked to the anode by slots. The strapping links can also be seen. Other cavity shapes are also used.



PHOTOGRAPHS BY COURTESY OF IMPERIAL WAR MUSEUM.

The photograph shows a Lancaster bomber dropping 'window.' This was shredded aluminium foil, dropped to confuse German ground radar. The beams were scattered by the foil, giving totally erroneous readings upon re-receipt. In the background can be seen some of the other aircraft in the raid, in this case a 1,000 bomber attack on Essen.

The foil is the silvery shimmer to the left of the photograph, scattering as it falls.

COMBINATION LOCK

The combination of these effects causes the beam alternatively to strike and then be repelled from the anode, so that the oscillations in the cavities can have very large voltage amplitude, of the order of the applied voltage. Similarly, by using a large cathode, high beam currents are possible so that the peak power developed in one cycle of oscillation can be very large. At the same time, the size of the magnetron is modest, since the radius of curvature of the electron beam is small, and the power dissipated would melt the anode if the beam were applied continuously. The answer here was to pulse the beam by applying a short (1 µs or less) negative pulse of several kV amplitude to the cathode at a repetition rate of 1 000 pulses per second or so. By using this technique, the power developed during a pulse, which could be of thousands of cycles of the microwave frequency, could be many kilowatts, giving excellent range, yet the average power, and hence the heat dissipation, would be only a thousandth of this value, since the valve would be on (in this example) for only one microsecond in each millisecond.

DEVELOPMENTS

Inevitably some development was needed. The early cavity magnetrons were unstable, changing frequency for no apparent reason. This is a problem which also afflicts those learning to play wind instruments, because all resonant cavities will resonate to harmonics (multiples of frequency) of the lowest note which is possible (the fundamental). The resonant cavities of the magnetron have the further complication that two sets of oscillations are taking place in them, oscillations of magnetic field and oscillations of electric field. The cure was to shape each cavity to make one mode of oscillation dominant, and to use cavities which were interconnected, with alternate cavities "strapped" so as to reinforce the desired frequency of oscillation.

In addition, the tendency of magnetrons to burn out their cathodes too quickly was found to be due to the extra heating caused by the beam current. This could be counteracted by using the heater only for starting the tube, switching it off whenever the magnetron started to oscillate so that the beam current could then provide the heating.

FROM THE NORTH CAPE TO OVENS

Nowadays, the magnetron is still the high power, high frequency microwave signal source, used in radar, in microwave ovens, and in materials research. The advantage which the cavity magnetron gave during the war was of major importance, and the advantage, unlike so many others before and since, was never quite lost.

50 D 50 Stereo

This design uses Darlington transistors to make a high

PAY ATTENTION READERS, time to dust off your soldering irons, here's an amp project that's different because *you're* going to built it. Fifty watts per channel stereo on a single board, 3½ by 4 inches! Just the item to boost your tuner, preamp, tape or ? signals. High power but low distortion are complemented by simplicity of construction. This is all made possible by the use of darlington transistors. They look like transistors, they act like transistors but they're actually two transistors in one, thus providing much higher gain. This means only five transistor packages for each channel.

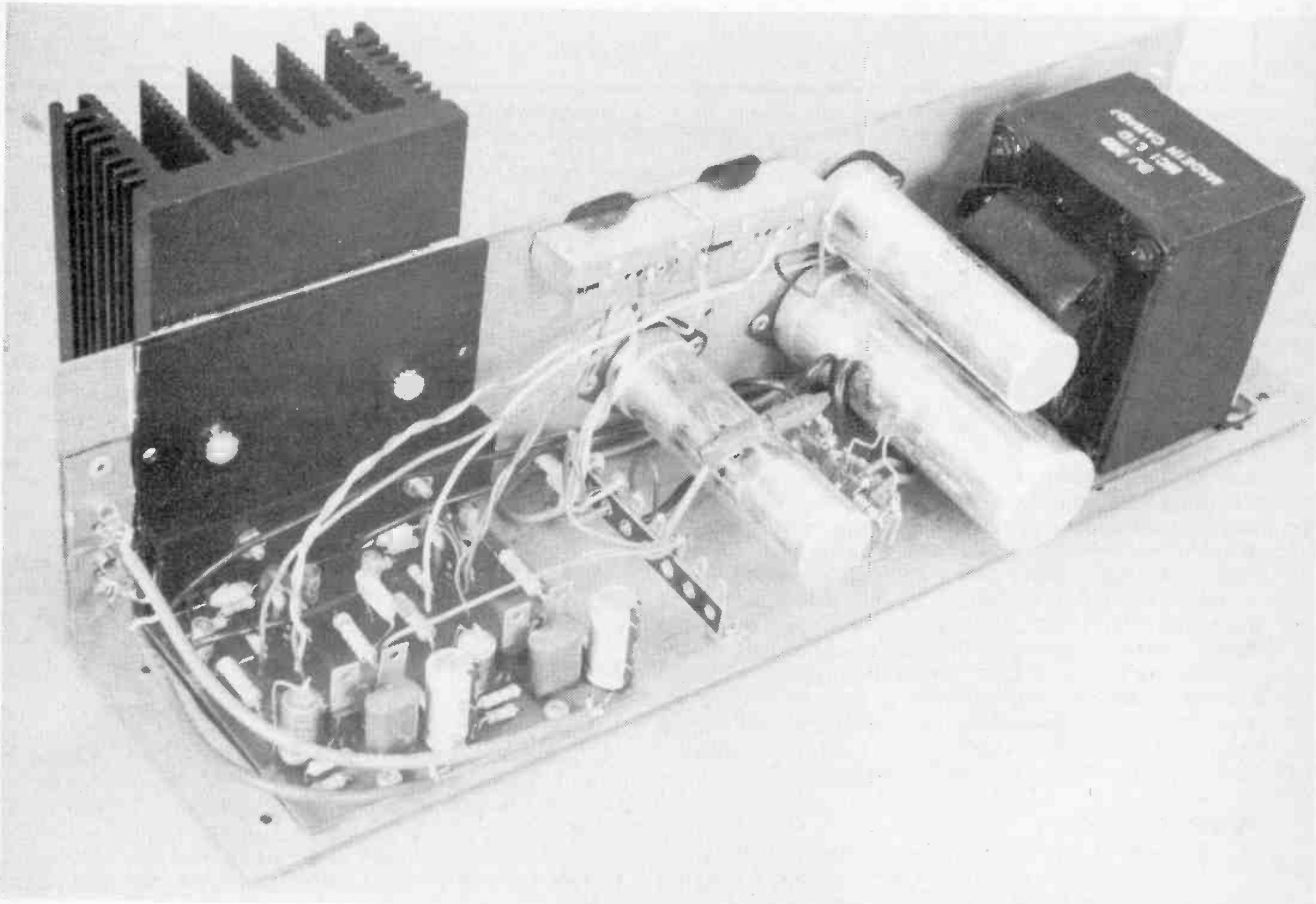
Further simplification comes from the use of a one-sided power supply, but it is a compromise resulting in the need for output coupling capacitors. This means the amp does not respond down to DC, but who can hear DC?

We feel that this proven circuit is an example of elegant design.

CONSTRUCTION

We could tell you to mount the components on the pc board, solder them all in etc, but since this *is* the amp you are going to build, let's take a different view.

The first step for your own personal project engineering department is a little planning. By this we mean a look at your mechanical requirements, what's your finished project going to



Power Amplifier

quality, easy to construct power amplifier at low cost.

look like? What connectors are you going to use for input and output? Style of indicator lights and power switch, length of line cord etc. These are all things not on the circuit diagram, but which are best sorted out first.

Next stage—purchasing. Perhaps you will have decided to buy the kit (advertised elsewhere in the magazine) or you may enjoy the challenge of doing it all yourself, you like making pc boards, you probably have many of the parts already. By sorting out the left over details you can now go and buy or order all the bits you don't have in one swoop, instead of holding up a half completed project waiting for a couple of sockets. This is a doubly good idea since you will then have all the parts before construction starts, to assess exactly how the bits will fit.

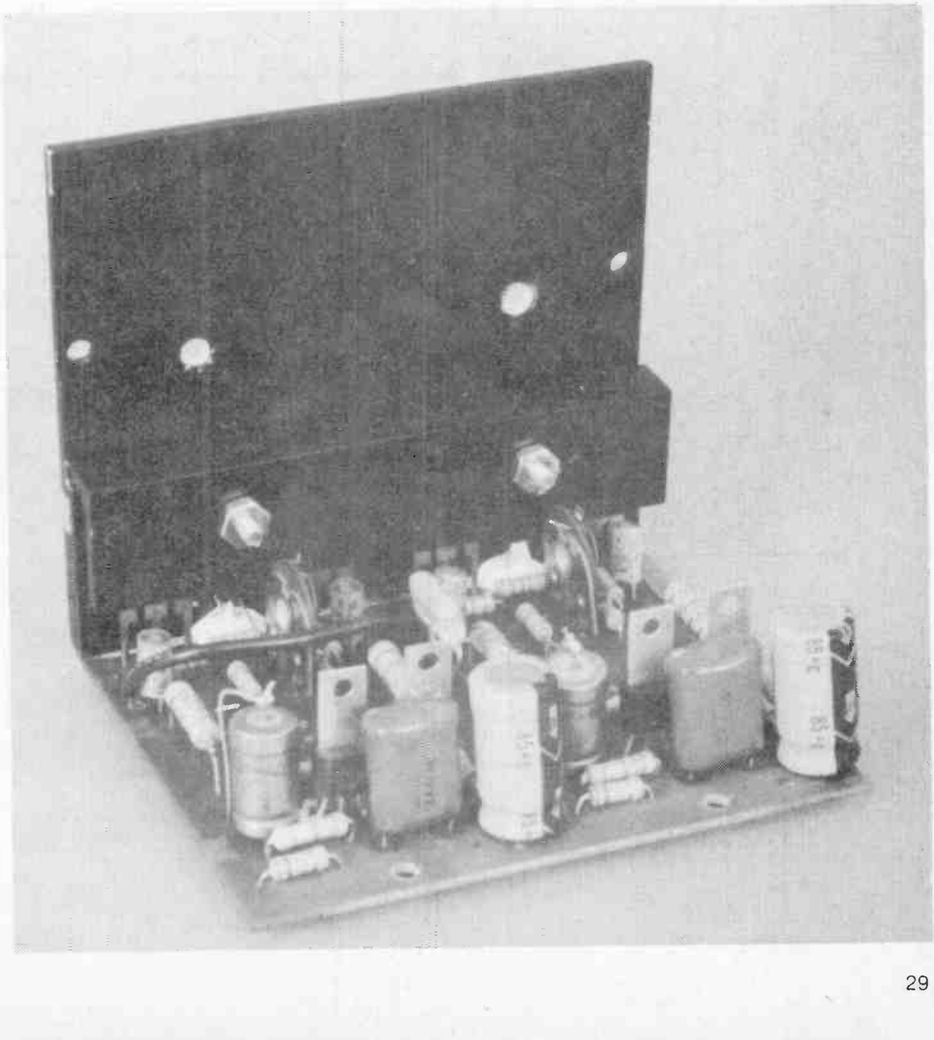
Actual assembly should start with the mechanical side again. Cut, drill, bend, screw all chassis and cabinetry pieces, before doing any soldering. This will allow mounting of switches, circuit breakers, sockets and off-board components all at once, whereupon they can be wired in smooth sequence and won't be damaged so easily.

In our model the heat sink involved three pieces, see figure 3, two of which may be seen here. The transistors are trapped between the small L shaped piece, and the larger plate, which in turn is bolted through the chassis to the large heat sink visible in the lead photograph. Heat sink compound is used at all joints, the overall effect being to maximize heat transfer away from the transistors. If a substitute heat sink is used it should have a thermal resistance of less than one degree centigrade per watt. Q3 provides temperature compensation and is held at the temperature of the output transistors by placing it in contact with the heat sink with thermal compound.

The power supply circuit should be the first to be completed; then check wiring carefully making sure that all "hot" points are insulated or well away from the metal chassis. Test the power supply output voltage with a DC voltmeter. The transformer is 65V r.m.s. centre tapped which will result in a "no load" DC voltage of 1.4 times that, or about 90V. Once confidence has been obtained in that section it's time to build up the pc board. A good trick to use here is not to insert the components for both amplifier channels at the same time. Mount them at different times then check to see if both halves of the board look the same. If so, you probably did it right. Look at the pictures before mounting the power transistors.

After this comes the final wiring of the chassis mounted bits and pieces to the board, and attachment of board to chassis and heat sink.

The power transistors should be insulated from the heat sink.



ETI 50D50 AMPLIFIER

ADJUSTMENT

The trimmer pots adjust the bias on the output transistors, which sets the quiescent, or "no input signal" current, and minimizes crossover distortion. BEFORE switching on, set these pots to approximately the middle of their range. They may be finely adjusted by one of these methods.

(1) Short the inputs to ground (this represents zerò input voltage). Then with a milliammeter in the power supply line to *one* channel adjust its pot so that 15 mA are drawn. (No, you can't do both channels at once!)

(2) Feed in a 1kHz sine or triangle wave signal (start off small, increase to suit) while observing output on oscilloscope. Adjust trimmers to minimize distortion (figure 4).

(3) With speakers attached feed in a (small, increase as needed) 1kHz sine wave. You can hear the best sine wave as the resistor is adjusted, but this takes a little experience or experimenter spirit. What is happening is that crossover distortion is a collection of harmonics, which can be minimized by ear.

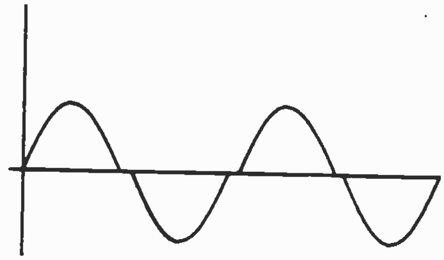
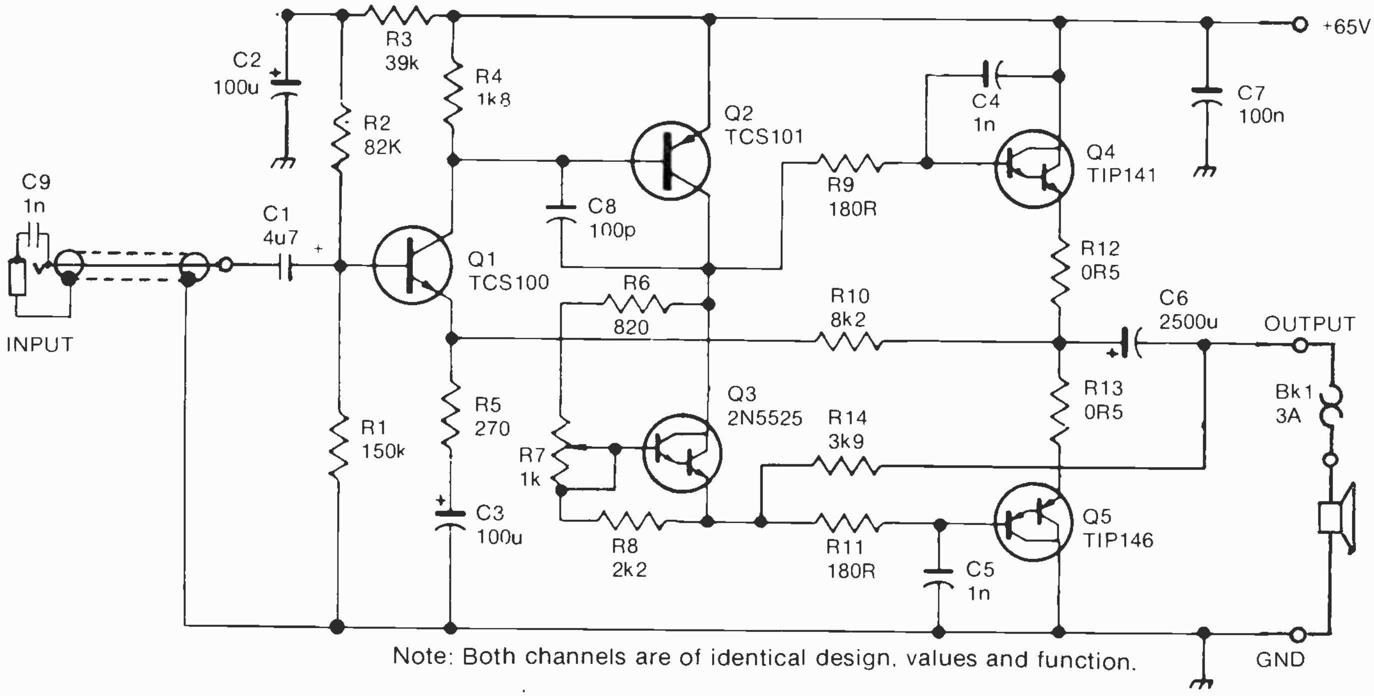
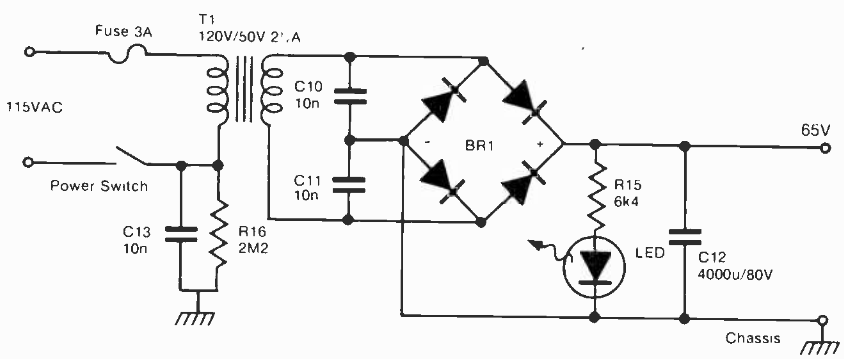
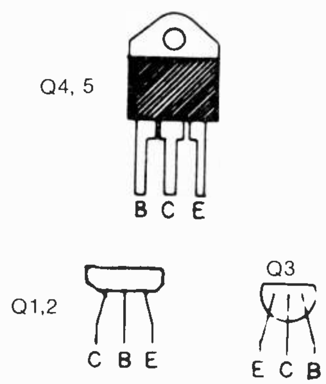


Fig. 4. Example of "crossover distortion". Flat portion is due to both output transistors being off at once with small input signal and insufficient bias current.

Fig. 1. Circuit diagram of one channel of amplifier, and power supply capable of handling two channels.







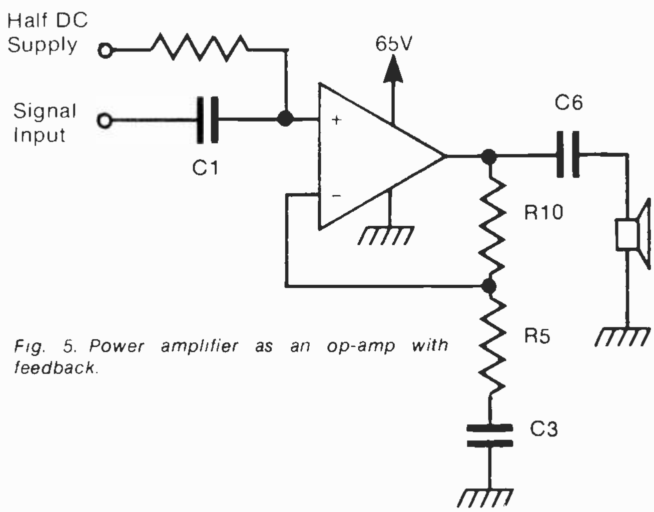


Fig. 5. Power amplifier as an op-amp with feedback.

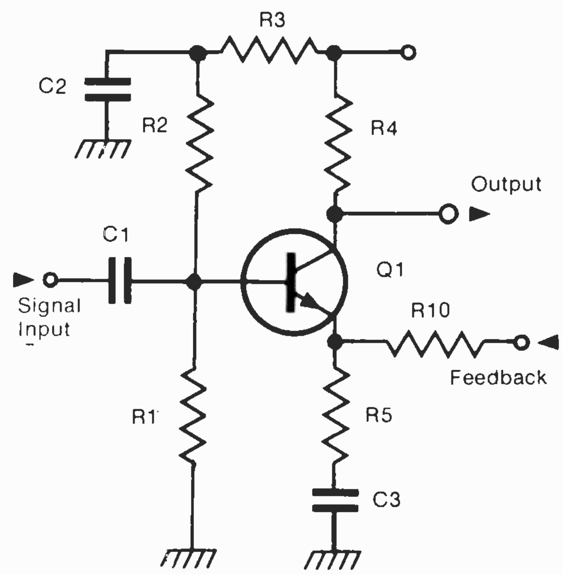


Fig. 6. Amplifier input stage showing positive and negative inputs.

Drawn as figure 5, the amplifier looks much simpler. What we have is a "power op amp" in a familiar configuration. Note that close to DC frequency, the capacitors have little effect, hence Vi+ will be the voltage supplied by the R1, R2, R3 voltage divider, while DC feedback comes straight through R10. This is a gain of one, and the DC input is set to make the output voltage in the middle of the power supply range, thus allowing for greatest possible output swing. The DC component of the output is blocked by C6.

Comparing figure 5 with 6 which shows the amplifier input stage both Vi+ and Vi- are coupled via Q1 to succeeding stages with gain of equal magnitude. However, Vi- is only about one thirtieth of the output voltage, making the amplifier voltage gain about 30.

The input impedance is the parallel combination of R1, R2 and that impedance seen through the base of Q1. The latter is R5 times the hfe of the transistor or a minimum of 13k. The overall resulting input impedance is at least 10k, quite adequate for most applications.

Q2 generates the signal necessary for driving output transistor Q4, while Q3, follows this voltage a fixed amount lower (about 3V less) to drive Q5. Adjustment of R7 varies the difference between base voltages on Q4 and Q5, which ensures there is enough bias that both don't turn off together as the (AC) voltage approaches zero. C8 provides negative feedback around Q2 to reduce gain at ultrasonic frequencies.

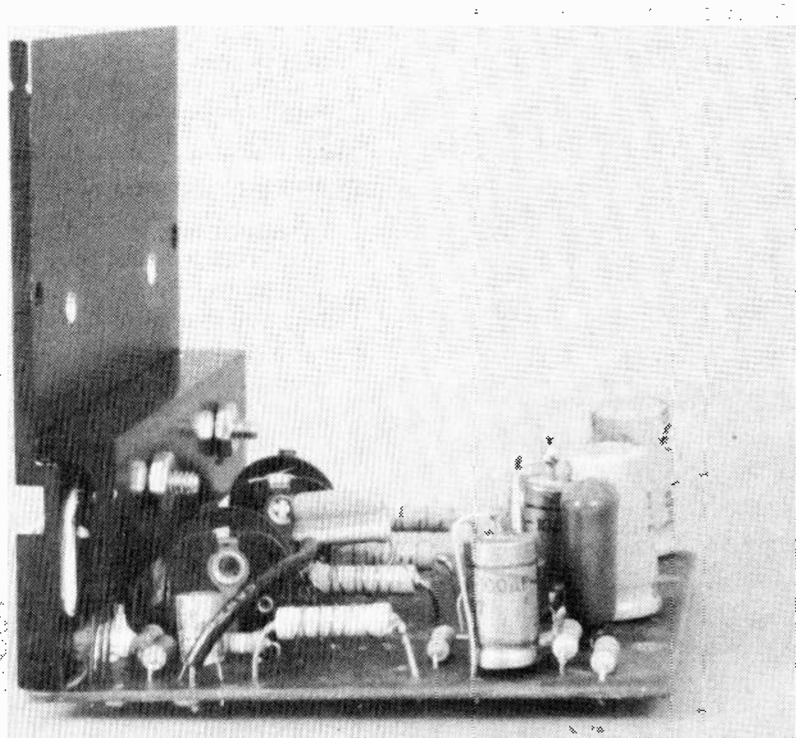


Fig. 3. Side view of amplifier board showing heatsink mounting details. Note also the "wirewound" half ohm emitter output resistors made with a measured length of resistance wire, wound on a large value composition resistor as a form. A standard resistor may be used but may be hard to find or expensive in your area.

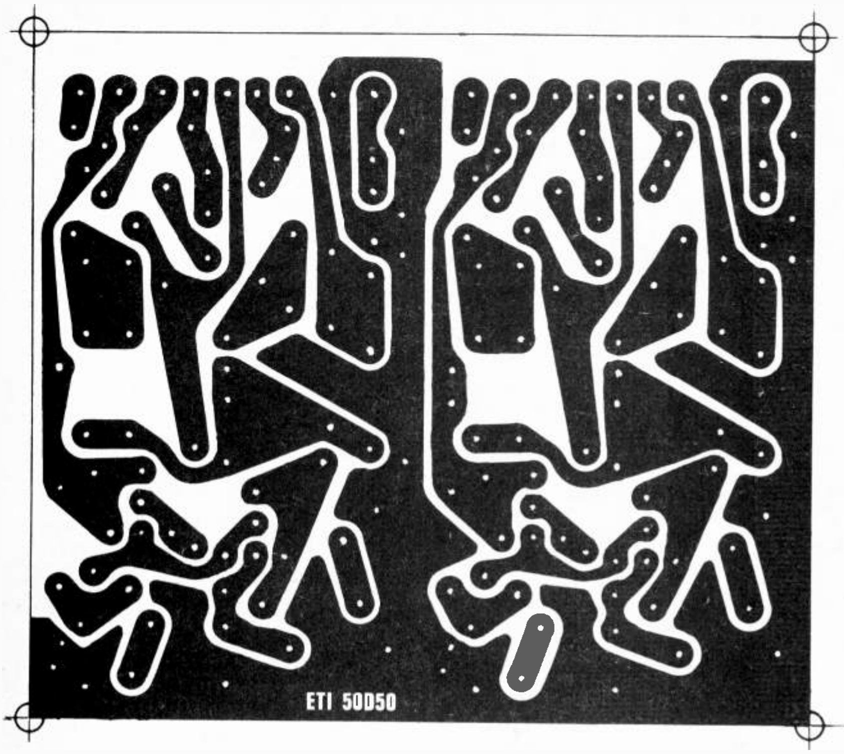
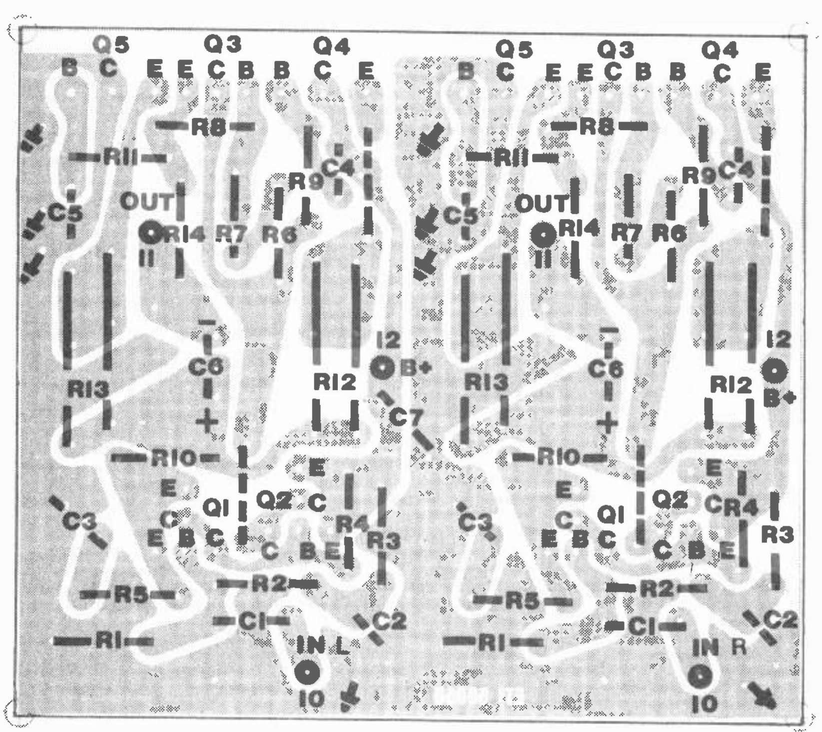


Fig. 2a. Printed circuit layout for two channels, shown full size, 3.5 by 4 inches.

Fig. 2b. Top view of pcb showing component layout and off board connections.



Parts List

PARTS FOR ONE CHANNEL, TWO REQUIRED FOR STEREO

RESISTORS all ½ Watt 5% unless noted.

R1	150k
R2	82k
R3	39k
R4	1k8
R5	270R
R6	820R
R7	1k Trimpot
R8	2k2
R9	180R
R10	8k2
R11	180R
R12	OR5/5W
R13	OR5/5W
R14	3k9

CAPACITORS

C1	4.7u 65V Electrolytic
C2	100 u 63 Volt electrolytic
C3	100 u 63 Volt Electrolytic
C4	1n Ceramic
C5	1n Ceramic
C6	2500 u 60 Volt 2 Amp. Ripple Rating
C7	100 n Polyester
C8	100 p Ceramic
C9	1n Ceramic

TRANSISTORS

Q1	TCS 100 (TI) or MPSA06
Q2	TCS 101 or 103 or MPSA56
Q3	2N5525
Q4	TIP 141
Q5	TIP 146

CIRCUIT BREAKER Reset type 3A

HEATSINK see text
Mounting plate, angle, main radiator. Red-point 5k or equivalent. 1 degree centigrade per watt.

POWER SUPPLY

TRANSFORMER
T1 50V/2½A or better

BRIDGE RECTIFIER
BR1 100 PIV/3A or better

CAPACITORS

C10,11	10n/500V
C12	4000u/80V electrolytic
C13	10n/300V

RESISTORS

R15	6k4
R16	2M2
LED	red, 10mA
FUSE	3A Fast Blow

PROJECT MISCELLANEOUS
Speaker connectors, input sockets, line cord and strain relief, shielded and unshielded insulating kits.

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JANUARY ISSUE:

COMPANDER PROJECT. THE PROBLEM WITH NOISE REDUCTION SYSTEMS IS THAT THEY ARE COMPLICATED — TOO COMPLICATED FOR THE HOME CONSTRUCTOR. BUT NOT THIS DESIGN BY THE ETI PROJECT TEAM — OUR COMPRESSOR-EXPANDER USES A SINGLE IC TO DO ALL THE WORK.

NOISE REDUCTION SYSTEMS. WE COMPARE THE DIFFERENT SYSTEMS AND EXPLAIN HOW THEY WORK.

PLUS the usual complement of features, projects, Tech-tips, data sheet, micro-biography, bits, bytes & bauds, and so on.

CANADA'S OWN ELECTRONICS MAGAZINE
There's always something in it for you!

The articles mentioned here are in an advanced state of preparation, but in order to keep you up to date with the fast moving world of electronics, we might have to change our plans before we publish next month's issue.

ETI INDEX VOLUME ONE - 1977

PULL OUT FOR QUICK REFERENCE

AUDIO AND TELEVISION

COMPONENTS & TECHNOLOGY

COMPUTING AND MICROPROCESSING

MISCELLANEOUS FEATURES

PROJECTS: AUDIO

PROJECTS: TEST BENCH EQUIPMENT

LOOK WHAT YOU'VE BEEN MISSING

Since we started publishing ETI in Canada the circulation growth has been dramatic. That means that there's thousands of our readers who have missed some terrific issues earlier this year. But we knew it would happen and we printed extra issues so now that the volume one comes to a close there won't be any excuse for gaps in your collection. The only issue we can't supply is April — we didn't realise how fast we were catching on and our extra copies were all sold straight away.

The chart shows just the main features and projects in the various issues we have available, but for some months we are selling out fast so you'd better hurry and get your copies now. Just send us $2 (not cash) for each issue you require, to ETI BACK-NUMBERS, Unit 6, 25 Overlea Blvd., Toronto, Ontario M4H 1B1.

DIRECT FROM OUR FOREIGN OFFICE IN THE U.K.. SOMETHING FOR THE BRITISH NATIONAL SPORT.

SPIRIT LEVEL

IN ORDER TO DRIVE a car safely your mind must be clear, and your reaction to situations as sharp as possible. Drink not only dulls the brain, but slows reaction time as well. Unfortunately it also seems to make most drivers over-confident of their ability to drive correctly, usually with the result that they get 'bugged' by the police — and rightly so!

What we are offering here is a simple method of proving to someone, especially yourself, that those 24 pints HAVE had some effect after all! Although the device operates by demonstrating an increase in the time taken to react to a given stimulus, it is *not* meant as an accurate 'reaction timer'. and should not be treated as such.

U.K. staff field testing the design. In the background we have the pub's landlady, to her left Gary Evans - Editorial Assistant, Ron Harris - Assistant Editor, and holding the machine Diego Ricon - Art Director. Following a thorough test, staff reportedly returned to work.

Down In Nine

To use the Spirit Level, switch on and press the reset button. After what seems like an hour (actually about 8 seconds) the light will begin to 'move' rapidly up the column of LEDs as the circuit cycles through. When it reaches the top, it will stop there. Your task is to prevent it reaching '9'. Pushing the 'Stop' button holds the LED on whatever number it was passing through at that instant.

So the more you drink, the slower you will be able to react, and the higher up the column will rise the glow (if you can't stop it at all before it reaches the top — put a pillow on the floor quick, you're about to pass out!). With component values as we have them, it takes about 0.4 seconds to cycle from 0 to 9.

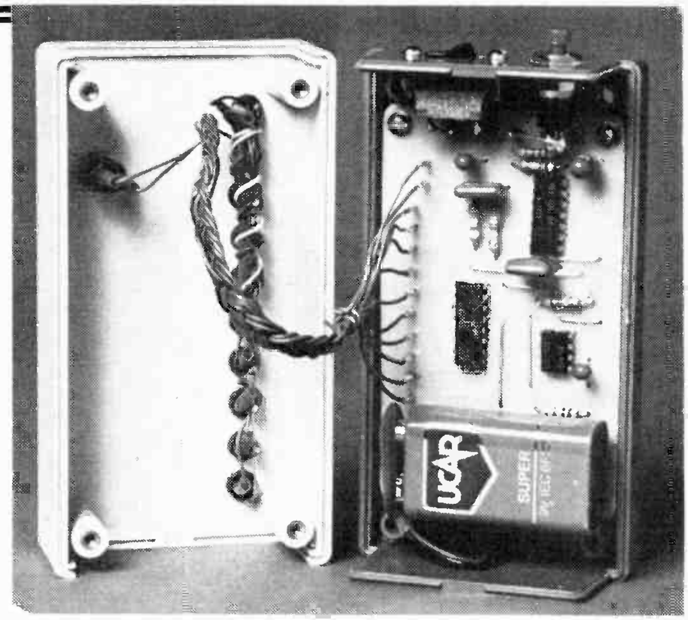
Originally we had a shorter 'wait' period before the oscillator was switched on, but this was too easy to anticipate — any longer and it becomes boring. Slower cycle times are not a good idea, since there will then have to be a greater effect to make any difference to the score. Make it quicker by all means — see 'How it Works' for the relevant details if you intend to meddle!

Half And Half Pint

Take a reading before you touch the ale. We found the average to be 3 or 4 (in a sober condition!). As the evening progresses and the number of pints rises, so will your score. Even one pint, if given time to be ingested, can take away that 'edge', and add one to your score. If you were averaging 3 half an hour ago, and now can't do any better

Left: Our most unusual subject! Long John here insisted (by flapping his wings and squawking at 100dB) upon his turn. He failed. Maybe he couldn't find the button, the smell of alcohol was too much for him.

Right: Internals and all that. Layout within a box of this restricted dimensions is somewhat critical! Our PCB and a 9V battery will live in harmony within the Verobox specified. The six links on the board can be clearly seen here — make sure you don't miss any of them out when wiring up



than 6 you're only half the driver you were!

Now before our readers condemn us as converts to Alcoholics Anonymous, let us add this was conceived as a 'fun' project and remains so. Drinking and driving is never a good idea, and you'll get much more fun out of the game if you *don't* have to play it in earnest to avoid being breathalized.

Construction Points

The only problem to be faced in construction of our Spirit Level is that of keeping the size down sufficiently to make it portable. Why oh why does *nobody* produce a decent small box to fit a 9V battery and a PCB?? The Vero box we employed is *nearly* ideal, but a few millimetres more would allow the battery to slot in sideways, and make the box much more versatile. Anyway, gripe over.... back to work. Build up

HOW IT WORKS

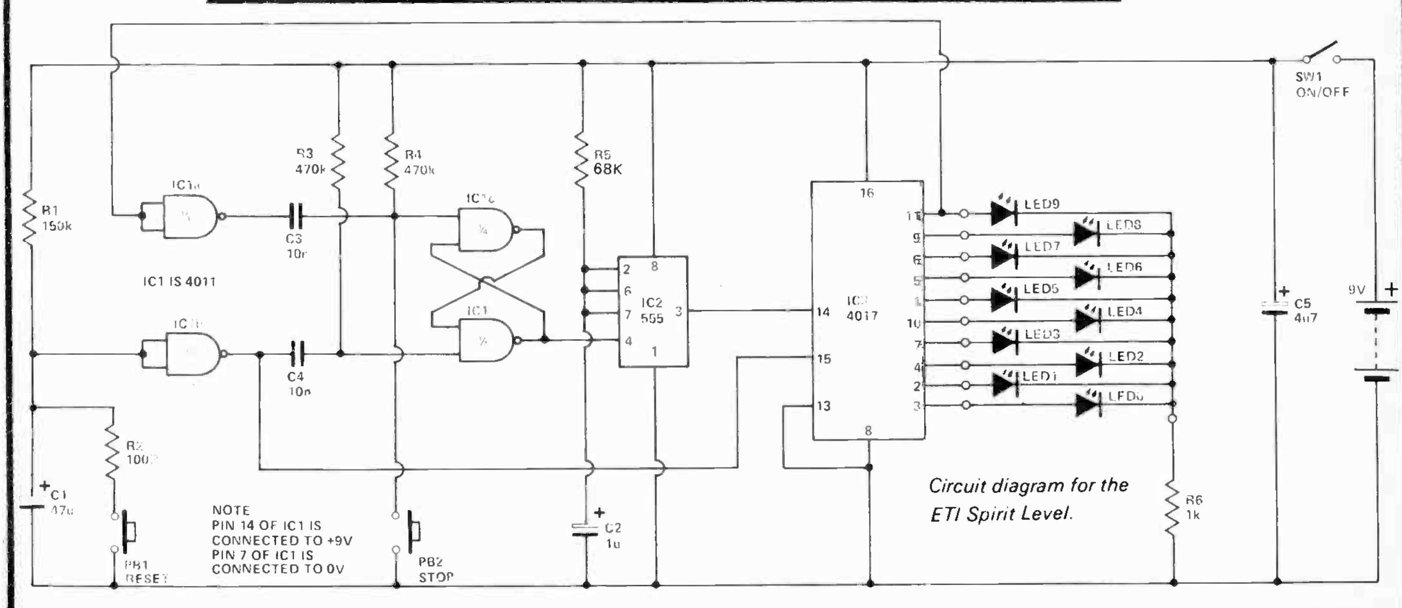
The LED display column is driven from the output of a 4017 CMOS decoder. This counts and outputs, in decimal form, the input pulses presented to pin 14.

These are produced by IC2 a 555 wired as an astable. Timing period for this is determined by R5 and C2 according to the formula t=1.4RC.

IC1c and IC1d are wired as a toggle circuit,normally holding the reset pin low so that operation is inhibited. Upon switching on C1, starts to charge through R1 giving the time delay to avoid anticipation on the part of the player. After about 8 seconds IC1b's input goes high, the output goes low and the toggle action takes the 555 reset, pin 4, high so that the oscillator will run.

IC3, the 4017, will count the pulses until output 'a' is enabled. Normally the chip would recycle to nought and start again. However the connection to the inverter, IC1a will reset the toggle and stop the astable by forcing the reset pin low.

Pressing the reset button PB1 takes IC3 reset to zero and sets the toggle back to inhibit. The 'Stop' facility is provided by PB2 and R4 which reset the toggle by halting IC2.



Circuit diagram for the ETI Spirit Level.

This is what our box looked like when we'd finished it. It might be advantageous if the "o" LED was spaced away from the remaining column, so that it indicates a "waiting" mode rather than anything else.

the board as per the overlay, keeping components as close to the PCB as possible. Leave the ICs until last or, better still, use holders, low profile versions of which should just go in. As the chips are CMOS — watch it when handling them.

Keep all wires to the LEDs as short as you reasonably can so that when the box is closed up too much strain is not placed on the components inside due to overcrowding. Refer to the internal photograph to see how our workshop layed theirs out if you are in any doubt or trouble.

Before switching on, check the polarity of the LED column, and the orientation of the chips, it can be an expensive 'short cut' not to bother!

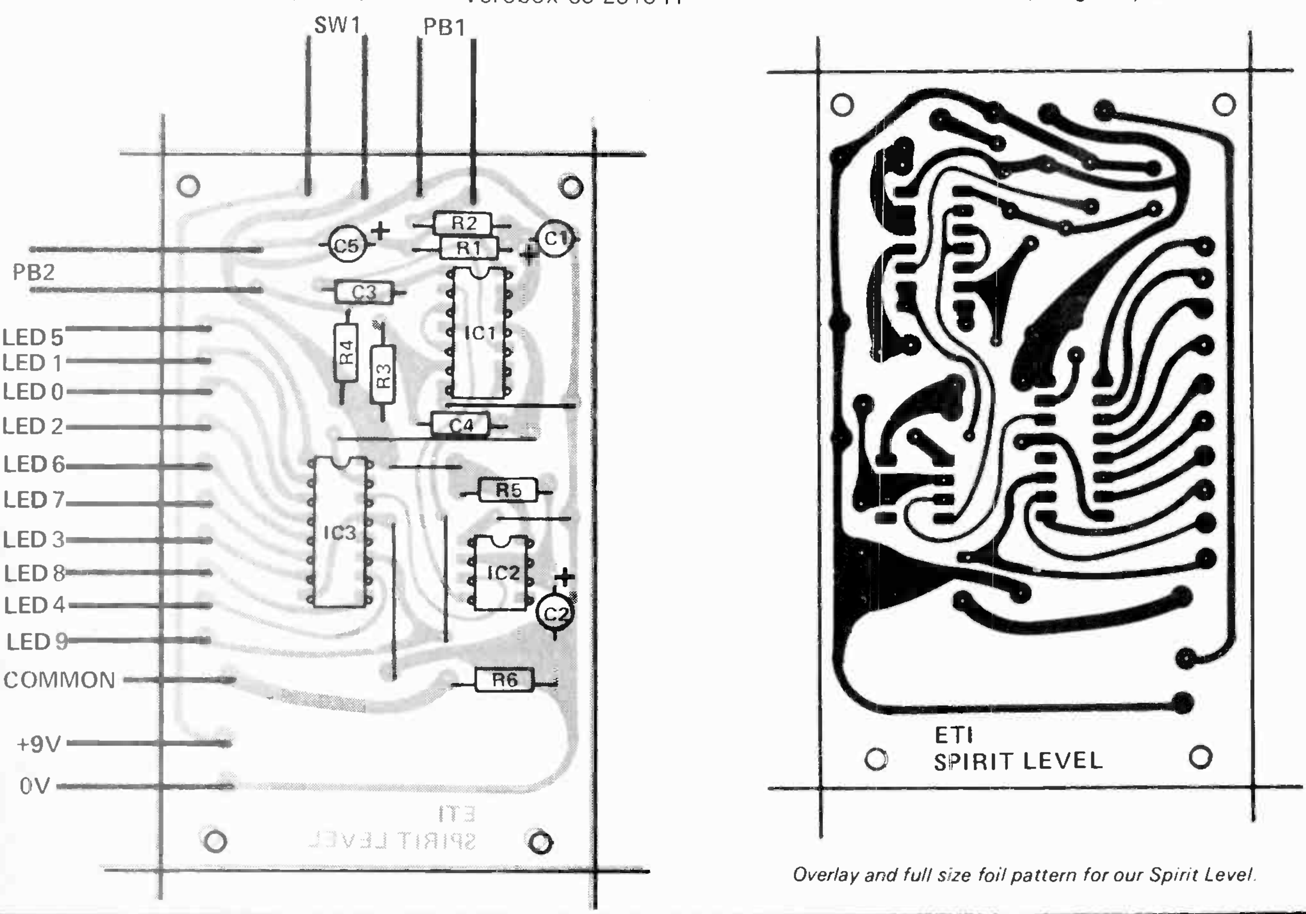
Getting The Bird

People's reactions to the Spirit Level can be quite hilarious, especially after a few 'jars'. We found disbelief and accusations of cheating to be the most common. For some reason our prototype possessed the property of attracting the pub parrot who insisted on his turn! He failed miserably so if you're driving home tonight and see a car driven by a parrot heading for you — not only are you sloshed, so is he! ●

> This story shot on location at ETI-UK's local, The Black Horse in Rathbone Place, London.

PARTS LIST

RESISTORS		C2	1u 16V	SWITCHES	
R1	150k	C3,4	10n polyester	PB1,2	push to make single pole.
R2	100R	C5	4u7 16V		
R3,4	470k	SEMICONDUCTORS		SW1	rocker action single pole
R5	68k	IC1	4011		
R6	1k	IC2	555	TEST GEAR	
		IC3	4017	1 barrel IPA draught bitter	
		LED1-9	TIL209 or similar.	2k5 bottles high stability Scotch	
				5 litres Vodka (high tolerance)	
CAPACITORS		CASE		1 Parrot (optional)	
C1	47u 16V	Verobox 65 2518 H		1 Drunk (obligatory).	



Overlay and full size foil pattern for our Spirit Level.

BINDERS

In response to many requests from our readers we have arranged for binders to be made so that you can keep ETI's first Canadian volume together and protected from damage. The binders are covered in attractive leather-look black plastic and are designed to hold twelve issues. The ETI design is printed in gold letters on the spine.

The binders cost $5.00 each, which includes postage and packaging. Do not send cash — you can pay by cheque, Mastercharge or Chargex. Credit card orders must include your account number, the expiry date, and your signature. In all cases allow six weeks for delivery. Send your order to ETI Binders, Unit 6, 25 Overlea Blvd., Toronto, Ontario M4H 4B1. Don't forget to include your name and address. Ontario residents add 7% PST.

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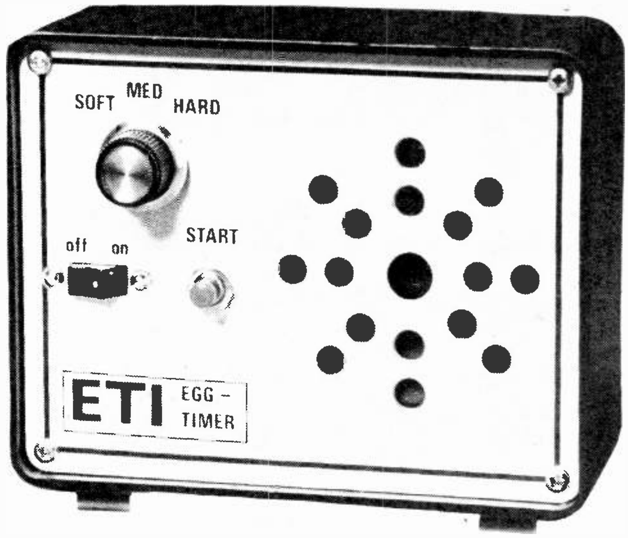
Get cracking on our

EGG TIMER



This design uses two integrated circuit chips to provide a versatile and accurate timer for your kitchen

THE ANALOGUE MINERAL egg timer that has been used in the kitchen until now has a number of serious drawbacks. The main one being that when it has finished "doing its thing" it does nothing to draw attention to the fact. Instead it sits quietly on your shelf while your attention is elsewhere and your egg is becoming decidedly hardboiled.

Our egg timer gets over this problem by giving you a shout when it feels that your breakfast is ready.

Getting it together

Construction is made easier if our PCB layout is used, pay particular attention to the orientation of the integrated circuits and electrolytic capacitors during assembly. When the board is finished, make a quick check of the soldered joints, also check that there are no solder bridges.

Our pictures show how we mounted the PCB board and the layout of our front panel.

As you like it

The preset resistors, RV1, 2, 3, can be adjusted to provide the following range of times depending on the position of SW2:

Soft
Medium
Hard

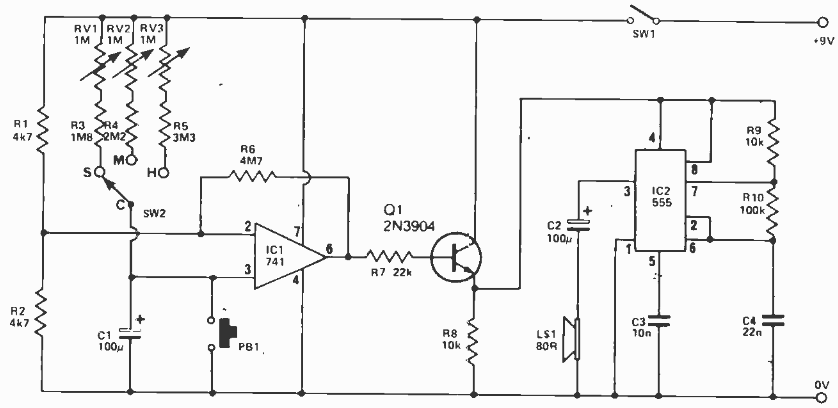


Fig. 1. Circuit diagram of egg timer.

To use the timer, switch on SW1 and press PB1. The timer will operate after the period selected by SW2 has elapsed.

The unit uses very little current in its timing mode but a lot more when it is producing the tone. So, for long battery life, do not leave the unit switched on and producing a noise for too long.

How it works

The timer is based on the 741 op amp, IC1. R1 and R2 hold the inverting input at half supply voltage. Pin 3, the non-inverting input, is connected to the junction of C1, PB1 and SW2.

SW2 selects one of three resistor and potentiometer combinations, the value of this combination determines the timing period.

Upon operating PB1, to discharge C1, the voltage on C1 will increase towards the supply rail at a rate determined by the resistors selected by SW2.

When the voltage on C1 reaches half supply voltage the output of the 741 will swing from nearly 0 V to near to positive supply rail.

The time taken for the 741 to change O/P state is approximately 0.7 CR seconds where C is in farads and R in ohms.

The second IC is a 555 connected as an astable oscillator with a frequency of about 800 Hz.

When the O/P of the 741 is near 0 V the transistor Q1 is biased off and the 555 has no power applied to it. When the 741 changes state, Q1 turns on, allowing the 555 to oscillate and the tone is produced.

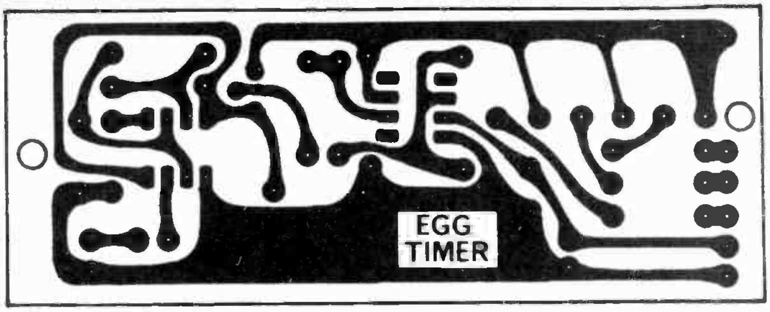


Fig. 2. Foil pattern of egg timer shown full size (100mm x 40mm).

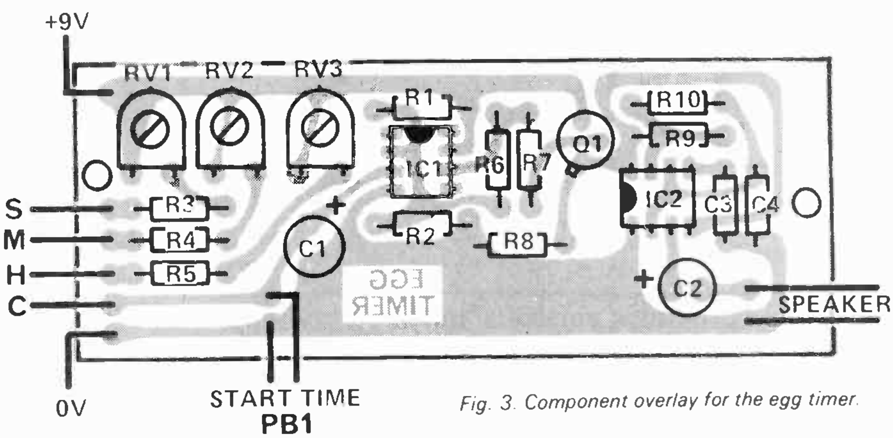


Fig. 3. Component overlay for the egg timer.

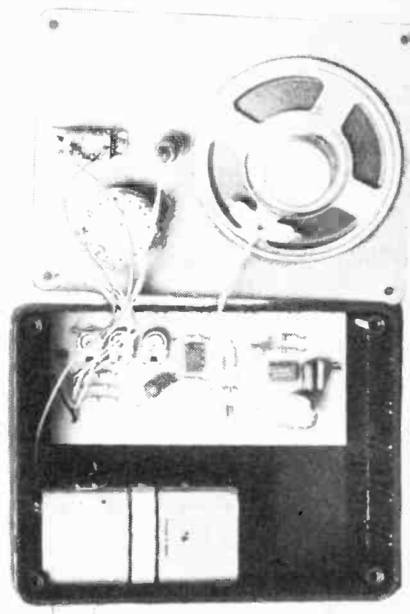


Fig. 4. View of the interior of the egg timer showing the location of the major components.

Parts List

RESISTORS (¼ W 5%)

R1,2	4 k 7
R3	1 M 8
R4	2 M 2
R5	3 M 3
R6	4 M 7
R7	22 k
R8,9	10 k
R10	100 k

CAPACITORS

C1	100 u 10 V tantalum electrolytic
C2	100 u 16 V electrolytic
C3	10 n polyester
C4	22 n polyester

POTENTIOMETERS

RV1-3 1 M min. hor. trim type

SEMICONDUCTORS

Q1	2N3904
IC1	741
IC2	555

SWITCHES

PB 1	push to test type
SW1	off-on rocker or slide
SW2	1 pole 3 way rotary

LOUDSPEAKER

High Impedance type - 50 to 100R.

MISCELLANEOUS

pcb as pattern, 9V battery and clip, case, knob, rubber feet, wire, etc.

ETI DATA SHEET

NSL 4944 UNIVERSAL LED — NATIONAL

THE NSL4944 IS A simple two-lead device normally used as an AC or DC indicator whch can also be used as a rectifier and constant current source at the same time in associated circuitry. Further, most of the regulating circuitry is not in series with the LED. This allows the complete regulated LED to operate at only about 300 mV more than a standard red LED. Thus the NSL4944 operates on half the voltage needed by previously available regulated or resistor LEDs. The device is rated for a maximum of 18 V forward and reverse.

These characteristics provide several advantages. Unloaded TTL gates provide enough voltage, in either high or low states, to directly drive the universal indicator. Size and weight can be saved in instruments with a number of indicator lights by reducing the size of filter capacitors or voltage regulators. The NSL4944 can operate on unfiltered DC or at somewhat reduced intensity on 3 to 12 VAC. Since the IC within the regulated LED blocks reverse voltage, the device can be used as a low voltage rectifier or polarity indicator.

Equivalent Circuit

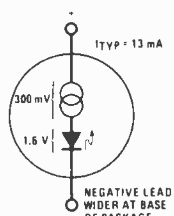


FIGURE 1. Equivalent Circuit

The LED and its current source, as illustrated in Fig. 1, both fit within a standard LED package. The typical operating voltages shown allow the device to operate with lower supplies and take up less room than an LED and resistor.

Schematic

Figure 2 shows how some of the operating features of the device are achieved. The rectifying characteristic occurs because the only input to the device passes through the IC's PNP emitters. These have a high reverse voltage in standard linear processing. The voltage reference and compari-

Features

- Supply range 2 V to 18 V
- Reverse polarity protection
- Constant light output over 3 V
- No larger than normal LED
- 12mA to 14 mA current
- 300 mW dissipation

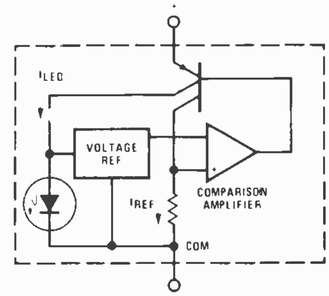


FIGURE 2 Schematic Diagram.

son amplifier operate from the same low voltage that the LED does. The big PNP transistor which passes both I_{LED} and I_{REF} can be operated almost in saturation since the comparison amplifier can pull the PNP base down to only one volt from common.

Unfiltered AC

Power and parts count is minimized by powering the indicator from a low voltage transformer winding as shown in Fig. 3. This method, however, provides only half intensity light, but the apparent visual decrease is not as great. Some flicker occurs if the observer moves his head rapidly. The supply of Fig. 4 will provide up to 87% of maximum light output. The bulk of a filter capacitor is still not needed, and at 12 VAC in, flicker will be almost imperceptible since the LED "off" periods will be less than a

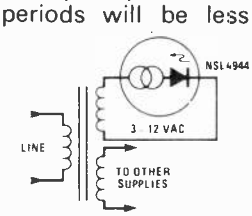


FIGURE 3. AC Power

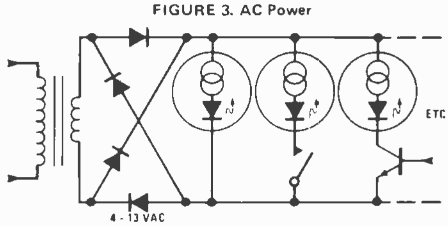


FIGURE 4. Unfiltered DC Power

millisecond. In both situations, the indicator may be switched a number of ways, including bipolar transistors, since only DC can pass through the indicator.

Full Intensity

As shown in Fig. 5, full intensity and zero possible flicker are achieved by minimal DC filtering. The small capacitor shown operates with 10 V p-p ripple and only about 8 V average DC, while the constant current drain characteristics of the NSL 4944 allow

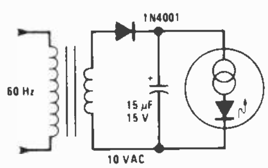


FIGURE 5. Minimizing DC Filtering

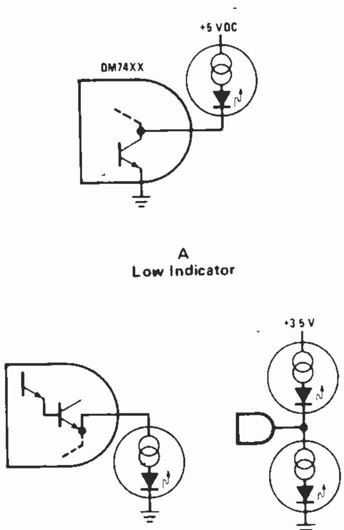
only a few percent change in light intensity. If a system or instrument with a regulated supply has a number of LED indicators, regulator size and dissipation can be minimized by powering the regulated LEDs from the unregulated voltage.

Reduced Intensity

The low operating voltage and constant current characteristics make the regulated LED an ideal status indicator for digital circuitry. An interesting fact to keep in mind is that full regulator current is not needed to light the LED. If, for example, only 8 mA is available (from a voltage of 1.6 to 1.9 V) the LED will light at a somewhat reduced intensity. The regulator will be switched full on instead of current limiting . . . but in such a situation it doesn't matter.

TTL Drive

Any circuit capable of supplying 10 to 20 mA and a voltage swing of at least 1 V can switch the NSL4944 from an off to an on state Fig 6a, b. Within 25°C of room temperature, an input voltage of 1.3V will produce little or no light, and 2.3 V will produce 70% to 90% of full output. However, with a small signal change, the pre-existing biases must be correct. The output swing of a TTL stage goes much closer to ground than to the 5 V supply.



A
Low Indicator

B
High Indicator

C
Combination

FIGURE 6. TTL Indicators

Therefore, Fig. 6-C requires a 3.5 V supply for the indicators to have complete off-on switching.

Replacing FETs

In many circuits or small instruments the need for a constant current source or current limiter arises. FETs can generally only be used as low current sources, so for 10mA or more one must resort to other parts. If an indicator or pilot light is also needed, the regulated LED may be a very economical source of the needed constant current.

The examples below illustrate all three characteristics of the NSL4944. It is a combined rectifier, constant current source, and pilot light.

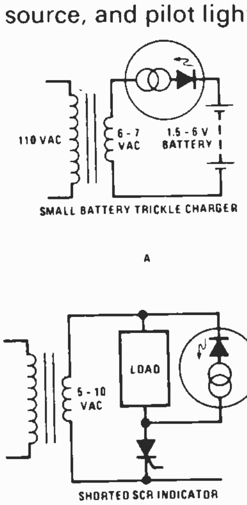


FIGURE 7.

Shortproof Circuit

A current source can also be a current limiter. Fig. 8 shows an NSL4944 put in the collector of an emitter follower such as might be used in a pre-amp or mike mixer cable driver.

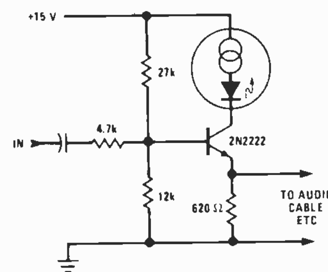


FIGURE 8. Current Limiting and Short Protection

Normally voltage across the LED is only 2 V, allowing almost full supply-to-supply swing of the emitter follower output. In comparison a limiting resistor would either greatly increase output impedance, or severely limit output swing. However, if the output cable is accidentally shorted, only a little more than the rated current of the LED will flow. Output transistor dissipation actually decreases under emitter short conditions.

Delay Tactics

Logically, a constant current source is helpful in designing time delay circuits. If the circuit of Fig. 9 were built with a resistor, the timing period would only be half the amount shown, and timing would vary over 50% with the supply variations shown.

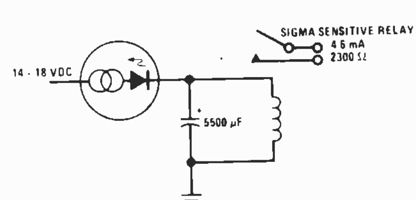


FIGURE 9. Six Second Time Delay

Instead, the current regulated LED is still drawing within 10% of full current when the relay reaches its 11 V pull-in voltage. The 14 to 18 V supply variation will produce only about a 3% timing variation, a considerable improvement. Variations due to temperature and electrolytic capacitor tolerances will remain however.

A number of LEDs can "share" a single constant current LED. Further, any of the ordinary LEDs can be turned on and off by a shunting switch without affecting operation of any of the others.

Active Loads

The lamp-driver Schmitt of Fig 10 illustrates a still further use of the NSL4944's constant current source. Substituting a current source for the collector resistor increases the useful voltage gain of Q_1. Further, almost full base current remains available to Q_2, even when supplying 12 V output, which would not be possible using a resistor. When the lamp and Q_2 are off, most of the LED current flows in

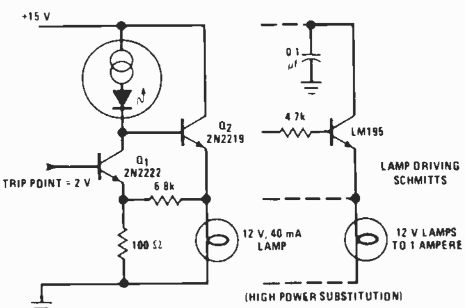


FIGURE 10. Use as Active Load

the 100 R resistor, thus determining the circuit's switching or trip point of 2 V.

With Q_1 saturated, Q_2 still provides a volt to the bulb, contributing some preheating and reducing the bulb's starting current surge. On, Q_2 provides the bulb with 12 V due to the minimum voltage drop in the constant current LED. The 6k8 feedback resistor sets hysteresis at a measured 50 mV at the input. This can be varied without having to change the rest of the circuit. 10k provides almost "0" hysteresis (undesirable and unstable) while 2k sets a hysteresis of 0.5 V.

The NSL4944 is available from National Distributors, price about $1.

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THIS ARTICLE LOOKS at some of the uses of these new Microprocessor (MPU) integrated circuits and associated components. "In one short article?", you may ask, but we don't mean to go into great programming details, etc, all we intend to do is to show how you could use an MPU in your next project.

ONE ARMED BANDIT RIDES AGAIN!

JOHN MILLER-KIRKPATRICK

Minicomputer or Box of Tricks?

The main function of a microprocessor chip is to replace a whole boxful of TTL and LSI logic gates, not just components for a specific job but a whole range of devices. One of the most logical uses for an MPU chip is in a minicomputer system especially as the cost of such a system is now within the reach of a larger number of hobbyists. The minicomputer system is usually seen as a unit for home information retrieval and/or a controller for complex household lighting, heating or cooking. The system could be programmed to keep recipes, play TV games, help with homework, do the household accounts, etc. Any job or function which is boring, repetitive or requires complex calculations and record keeping can now be done with an MPU. Yes it could do the washing-up but the I/O interface would be too complicated, using a simple keyboard and perhaps your TV as a VDU most of the jobs mentioned above would be quite feasible. As ETI is presenting System 68 for just that purpose this article is not intending to look at the minicomputer type of use for an MPU chip.

"Sort out that box of Rubbish"

How many times has your wife/husband/? complained about your "general purpose electronic component storage system" otherwise known to the family as The Junk Box? To help to keep the peace it is necessary to attempt to sort out all of your resistors, capacitors and ICs about 3 or 4 times per year. These sessions can sometimes be very productive for the home constructor as you can find all sorts of 'lost' goodies which you no longer have a planned use for. When you have finished this massive re-organisation of your supplies you may find that you have an organised storage system for your TTL or other logic ICs, in other words you may now have a boxful of logic to cover most applications in most projects.

Now that peace reigns in the household for a time you may be able to build that project, basically the same as the magazine project but with a few changes dependant both on your preferences and your stock of ICs. Do you find that some times you build exactly as per the magazine article, sometimes you use some of the article and sometimes you have a brainwave?

Everybody Redesigns

Either accidentally or on purpose nearly every electronics constructor redesigns a circuit when he comes to building it. That is exactly what the main intention of this article is — were you beginning to wonder? In order to show how to use an MPU in an otherwise TTL/CMOS project I have used as an example the Electronic One-Armed Bandit project which is now in ETI Top Projects Book 4 and intend to discuss how this could have been built with an MPU. As this project contained about $20 worth of ICs while an MPU design would cost a lot more, a one-armed bandit with an MPU is not an economically feasible proposal. One could argue that MPU chips are going to get cheaper or that you could add enough features to the basic bandit to make it worth the extra money, but for the present let's ignore the cost and talk about the principles involved.

The block diagram of the original bandit is shown as Fig 1, physically it was presented as four units —case, power supply, main logic PCB and display PCB. The display PCB contains a 3 digit counter, 3 decoders and 3 seven segment displays, it also has 12 LED lamps which are used as "spinning wheel' indicators. The lamps flash apparently randomly and then stop and indicate 3 sections of the 12 lamps, some of the combinations of the 3 lamps selected are winners and others are losers.

By referring to the block diagram you can see that three oscillators cause the 3 sets of 4 lamps to flash at different rates, this gives an extra feeling of randomness so that you do not feel too cheated when it has all of your money! Pulling the handle feeds the oscillator outputs to the 3 divide-by-ten counters. When the handle is released the oscillators and counters stop. The states of the stopped counters are now gated into a decoder which produces a set of outputs corresponding to first prize, second, third, fourth or hard-luck! The first four of these outputs cause a number to be loaded into a pre-settable counter which then proceeds to count down to zero whilst at the same time incrementing the payout counter. The payout counter is decremented at each pull of the handle and thus the final unit is a good representation of the real thing, even if it does not have random Hold and Double or Quits features.

Leave that and that but rip the rest out

Any builders of the original unit might be interested enough to do just that and so lets have a look at what we still need in the MPU version. The case would need little or no modification, any mods being the addition of more buttons, lamps, bells and whistles to extend the features of the basic unit. The power supply would need to be changed to give +5V and −12V and or −20V depending on the devices used. MPUs do not require fancy power supplies with millivolt regulation, the 7805 5V regulator and a couple of zeners will suffice.

For the present we will leave the display PCB with its associated counters but it is not indispensable! We are thus left only with the main logic PCB which is exactly where our MPU wants to go.

A microprocessor chip can be thought of as several separate units in one chip. The first unit is a decoder similar to a BCD to seven segment or decimal decoder, the data fed to the decoder is an instruction. Thus an instruction might be decoded so as to cause a clear or an increment of a counter, alternatively it might gate a flip-flop and thus cause an output to change state. Simple MPUs such as SC/MP have about 50 different instructions, the 6800 has about 80, while a Z80 has 130. The range of instructions covers logical operations such as AND, OR and EXCLUSIVE-OR, counter incrementing/decrementing/loading/dumping, or the transfer of data from one part of the chip to another in parallel or serial form. If you wanted to build an MPU you would need shift-registers, counters, decoders, latches and a decoder (ROM), all of these to be interconnected so that each can control/be controlled by any other.

The instructions which we feed into our decoder could be decoded as a transfer of data from a register to a latch which is in turn connected to the outside world. It is convenient to have only one set of information connections to the outside world and thus these connections have to serve as instruction input and as counter input/outputs, this set of lines to the outside is called a bi-directional data bus.

As we need to use this data bus for both instructions and data we need to store each separately internally, thus are born the expressions Instruction Register and Accumulator Register, really just a couple of 8 bit latches. SC/MP has an extension to the Accumulator and naturally enough this is called the Extension Register, it can swap its data with that in the Accumulator and has the additional function of being a shift-register with its serial input and output connected to the outside world. Thus our first instruction could cause the data on the data bus to be latched into the Accumulator, the second instruction swaps data with the Extension and the third and subsequent instructions clock the data in the Extension out to the MPU output pin at the same time as clocking the data on the serial input into the Extension. To build such a device with TTL would require about a dozen packages, with SC/MP it becomes a set of bit patterns input to the decoder.

The 8 bit wide instructions mentioned above have to be presented at the data bus in sequence and as they are required. If they were hard-wired in a very small

Fig. 1. Block diagram of "One Arm Bandit" using conventional TTL/CMOS logic.

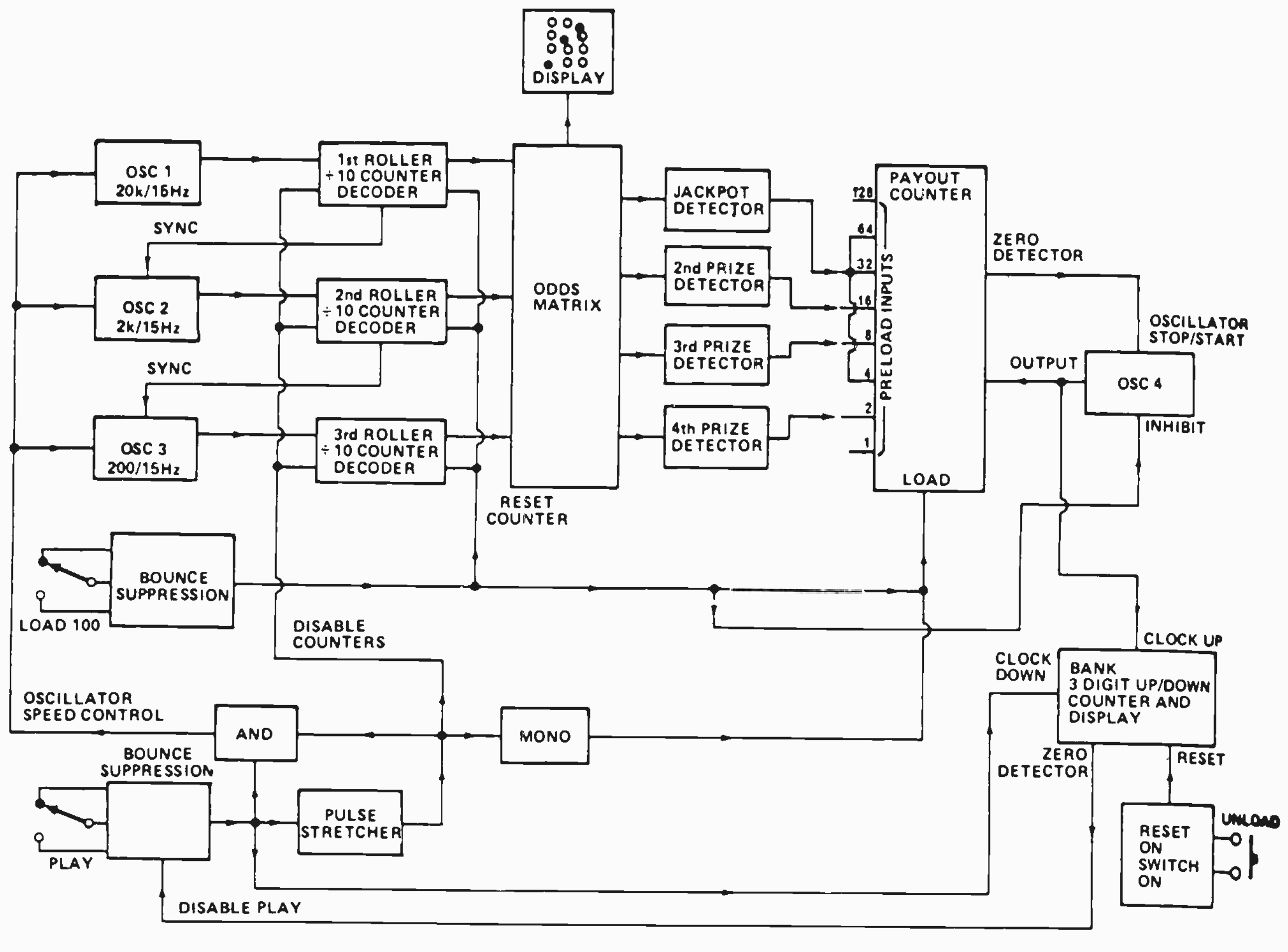
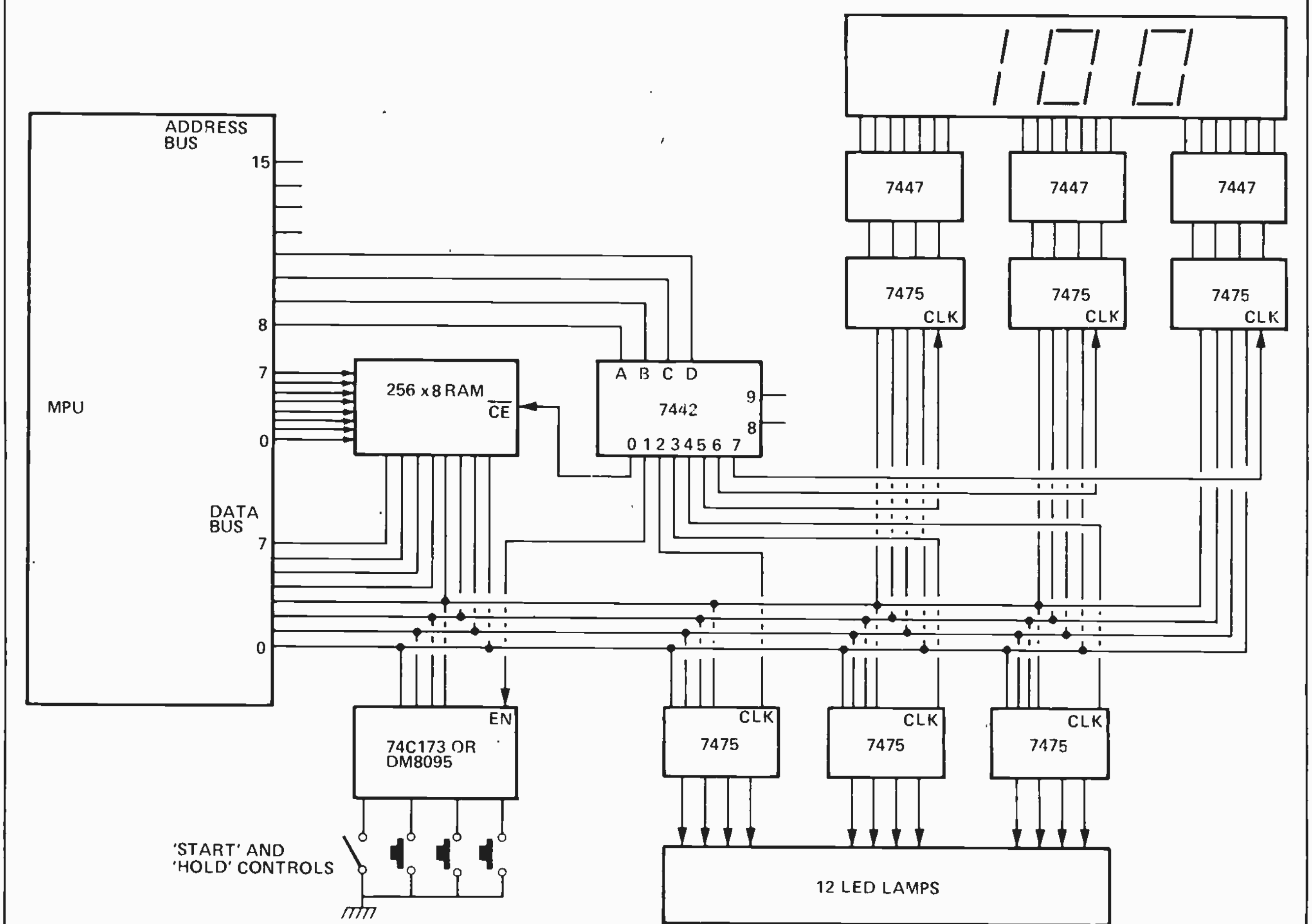


Fig. 2. Block diagram showing "Bandit" based around an MPU chip.



system a 7442 type of decoder could be used to enable each set of bits at a time. The 7442 would need to know the address of the next data unit as this information is supplied by the Address Bus which is normally 16 bits wide thus giving access to 65,536 sets of data in place of the 7442's ten. The Address bus is held internally as a 16 bit parallel access counter which can exchange data with the Accumulator, Extension or Pointer Register. Thus, if we can change the value of the Address bus counter we can point the MPU back to a previous instruction address and thus cause it to enter a loop. The Address register is known as a Pointer register, in SC/MP, for example, there are 4 such registers, PR-O is used for the next instruction address and the other 3 are used to access other addresses for data I/O. By loading a Pointer Register in a manner similar to that of loading the Extension we can either access any of our 65,536 addressable slots or we can cause the MPU to get its next instruction from any of the slots.

Accumulating data

The Accumulator is used for input/output and also for the results of logical ANDs, OR, and EX-ORs, it can also be used as the result and one of the operands in an ADD instruction.

Data input/output can be accomplished through the serial I/O pins connected to the Extension or via the main data bus. It is usual to have some area of RAM connected to the data bus for storage of intermediate results, a couple of MM 2112 chips gives 256 Pigeon Holes each with 8 bits of data storage. The RAM is accessed by a Pointer Register which selects a) the RAM physical devices and then b) one of the 256 locations within that RAM. The 16 bit pattern for location zero (the first) in a RAM based as hex location 0F00 would be 0000 1111 0000 0000, it is easy to see how this bit pattern could be decoded with AND and NAND gates to give a single enable line signal (one 7420 and two 7421s?). Similarly, if we had a couple of 7475 latches we could decode a particular address (eg 0E00) and use the enable to clock the latches and thus store the data which had been output on the data bus at the same time. These 7475s are to be used for driving the LED lamps in our Bandit so that we need two sets of latches (0E00 and 0E01) to give us a maximum of 16 LED lamps (we need 12). We can use a similar latch but with WIRE-OR or TRI-STATE outputs (74173) to latch data into the MPU from a set of switches such as the start handle or possibly HOLD switches.

Simulation is the Answer

If you had lots of sheets of paper you could pretend to be an MPU pretending to be our bandit. Get someone else to operate you by pulling your left arm as the Start handle and then start counting very fast until they release your arm, if you can manage it count three totals at a time and thus when your arm is released you can write down these three numbers on a scrap of paper. The MPU would do the same thing by sensing the changes in the data from our switch latch, adding to pseudo-counters in RAM locations (scraps of paper) and then stopping when the switch latch changes state again.

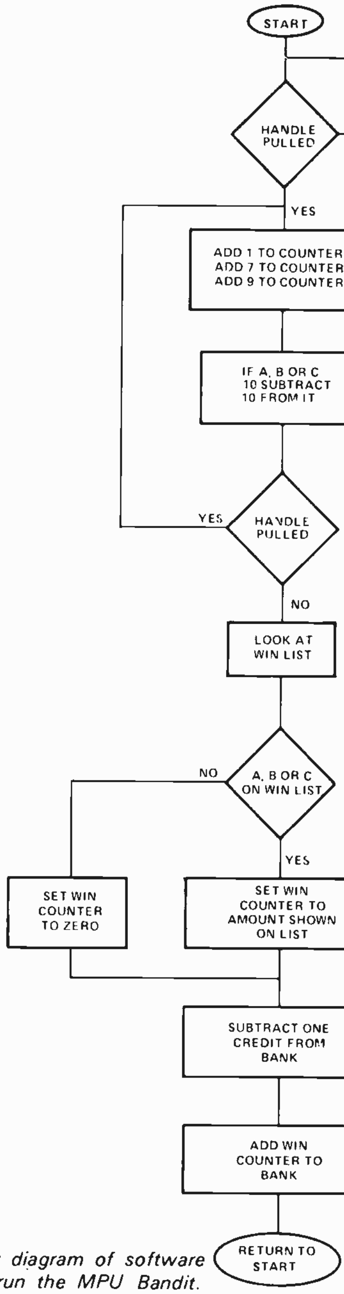


Fig. 3. Flow diagram of software required to run the MPU Bandit.

Now you look at your scraps of paper and decide whether the numbers correspond to any on a list of winning combinations which you have previously compiled. If the combination is a winning one then your list will have a 'Win amount' figure next to the winning combination, this figure is now credited to the players bank. If the player did not win then one unit is taken from his bank. You are now ready to have your arm pulled again.

If we use the existing display PCB we have to add or subtract from the bank by pulsing the bank counters on that PCB. We could keep these counters internally and latch out the BCD data in a similar way to that with the LED lamps, via a couple of latches. These latches would then feed into the BCD to seven segment decoders and on to the displays. There is no reason at all why the BCD to seven segment conversion could not be done within the MPU and seven segment data output to the latches and then directly to the displays.

Hardware and Software

A simple definition used to be that Hardware hurts your foot if you kick it and you cannot kick software. Now that computers are not the giant metal monsters that they used to be this definition is no longer true but hardware is still the physical devices and software the program.

For our application we obviously need an MPU chip and as our application is very simple let's use a SC/MP MPU. We need somewhere to store our program and our pseudo-counters, for this we could use a 256 x 8 bit RAM (2 MM2112s), for a more permanent unit we would have to additionally use a PROM but we can use RAM in this example. We have to enter our program of sequence of bit patterns into the RAM starting at address location 0001 as this is where SC/MP goes to find its first instruction after the reset button is pressed. A simple development system will allow programming of the RAM with simple toggle switches and the program can be checked out at a very slow speed or as single steps.

We also need a four bit input latch (74173) connected to the handle and HOLD switches and 3 four bit latches (74173 or 7475) for the LED lamp drivers. If you intend to replace the BANK counters with software pseudo-counters then another 3 four bit latches will be needed to latch out the BCD data for each digit. To make accessing of these latches easy we can ignore the top four bits of the address bus and use the next four bits as inputs to a 7442 1 of 10 decoder. This will now break up the addresses into 256 byte lumps, any access to 0000-00FF will enable the RAM, 0100-01FF the switch latch, 0200-02FF and LED latch, etc. A block diagram of this is shown as Fig 2, as you can see the outputs from the 7442 are used as follows.—Output 0 address locations 0000-00FF used for main RAM (program & Data)
Output 1 address location 0010 used for switch latch,
Outputs 2, 3, 4 address locations 0200, 0300, 0400 used as LED lamp drivers.
Outputs 5, 6, 7 address locations 0500, 0600, 0700 used as BCD output latches. With the exception of the RAM all of the other devices hung onto the data bus only use bits 0-3 of the data bus, the other bits being ignored.

Conclusions

The system designed here is hopefully one of the simplest MPU circuits you have ever seen. Once you have grasped the idea of using one 8 bit data bus for most of your input/output you are well on the way to understanding MPUs. The very nice thing about MPUs is that for any given hardware configuration there are lots of software possibilities, for instance we have to have a four bit latch for the start switch so why not hang 3 HOLD buttons on it as well? By latching out seven segment data instead of BCD you could use **any** combination of the seven segments plus decimal point to display letters or patterns, by moving up to a 5 x 7 matrix display you could output even more patterns/-letters. At an approximate guess the hardware shown in fig 2 would cost about $50 compared to the $20 for the original (displays not included) but for the extra money you have a much more flexible system. MPUs are not cheap but for what they can do for you they are a bargain!

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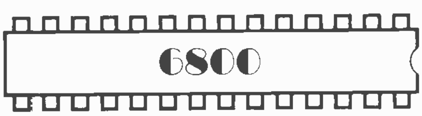
This month a look at the "other" mpu, the Motorola 6800, and the closely related 6500 series from MOS Technology.

IN THE FIRST two parts of this series we have covered the 8000 series mpus and their assorted support chips. This month we move on to the "other" processor which is very popular in the hobbyist field, the Motorola 6800, and its close relatives in MOS Technology's 6500 series.

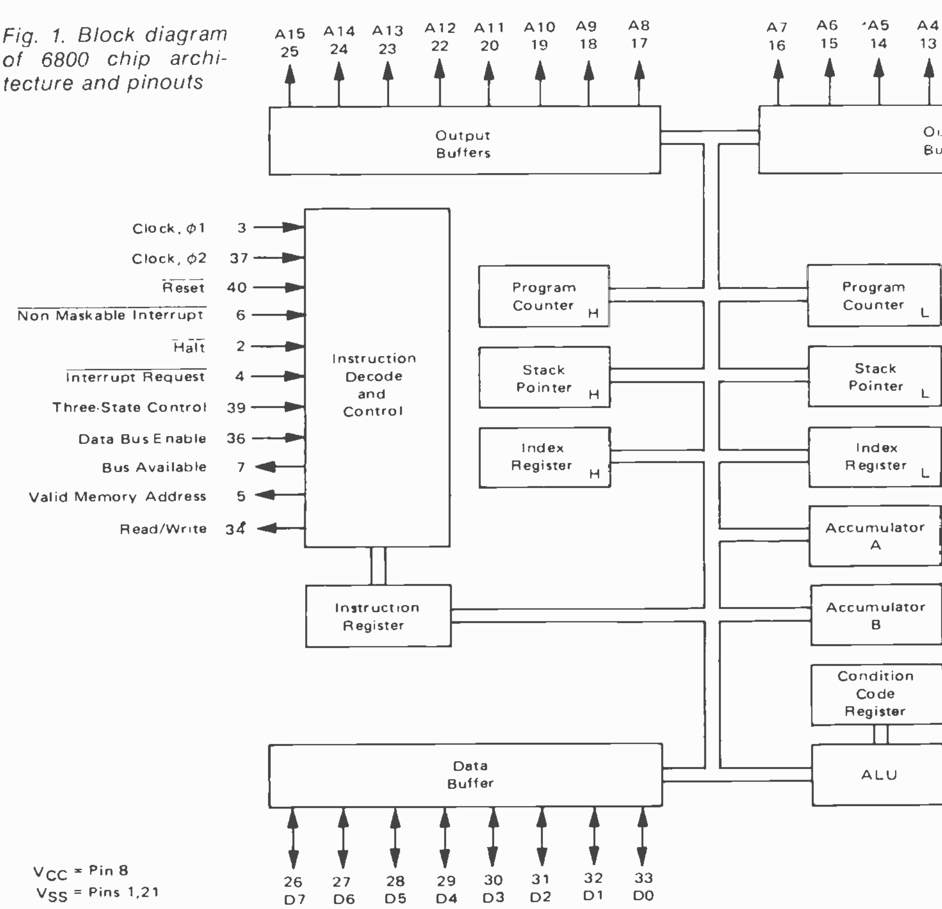


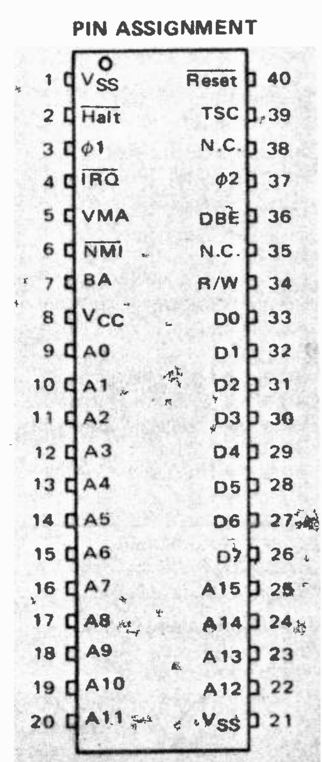
6800 HARDWARE

The 6800 hardware is very straightforward, at least in block diagram form, figure 1. There are a number of registers shown attached to the internal bus, each with a specific function in mind, in contrast with the 8080, which includes several general purpose registers. Some of 6800 registers can however be used as general storage if not otherwise in use. To summarize: the two byte (16 bit) program counter of course keeps track of the current or next location in the program, and may be incremented, or otherwise altered in case of branches or subroutines. The stack pointer (16 bits) is used to record the next available space in the "stack", an area in memory used for saving processor contents while performing subroutines etc. The contents of the index register (16 bits) may be used to "offset" the address of the operand in index mode instructions (see below).

Two accumulators are included, these are the registers upon which the arithmetic and logical functions operate. The instruction register is

Fig. 1. Block diagram of 6800 chip architecture and pinouts





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used to hold the instruction while the instruction dècoder is deciding what to do about it. Finally, the arithmetic logic unit (ALU) is the device which performs the arithmetic and logic functions. Associated with the ALU is the condition code register, whose individual bits indicate such conditions as zero, negative, carry, half-carry and interrupt. These conditions may be tested for conditional branches.

Interface to the rest of the microprocessor system is quite simple also. Sixteen bits of buffered address (1 TTL load, 130pF) and 8 bits of bidirectional data bus (same capability) are all present, plus an assortment of control inputs and outputs. A non-overlapping two phase clock with fairly strict requirements is used, for which purpose the MPQ6842 clock buffer is available. The other lines are as follows:

Three-State Control and Data Bus Enable: Inputs which control whether the address and data bus drivers are enabled. These allow possible external control of the buses by turning off the processor outputs (example — Direct Memory Access). They are rarely used for this purpose since almost all systems large enough to warrant this employ external buffers on the data and address buses, which are themselves controllable.

Reset: Initializes processor registers.

Interrupt Inputs: see below.

Halt: Causes processor to stop after current instruction completed, and all bus drivers turn off. May be used with some logic to achieve single instruction operation.

Bus Available: Indicates that the address bus is indeed available.

Valid Memory Address: Due to the internal workings of the mpu, miscellaneous signals may appear on the address outputs. To avoid inadvertantly activating some unsuspecting device, VMA is used to tell every chip on the bus when to pay attention to the address, and when to ignore it.

Read/Write: Tells all devices whether to input or output to microprocessor. Power supply requirements are just 5V, and the original 1MHz model has been joined by 1.5 and 2 MHz chips, with instructions taking 2 to 12 cycles.

SOFTWARE

The instruction set for 6800 is shown in figure 2 For instructions involving an accumulator, either may be used. Seven addressing modes are available in various combinations.

Accumulator: One byte instructions operating on the accumulator.

Immediate: The second (or second and third for LDS and LDX) byte, following the op code, contains the operand.

Direct: The second byte of the instruction contains the address in zero page (lowest 256 bytes) of memory of the operand.

Extended: Second and third bytes contain the operand's address.

Fig. 2. The instruction set of the 6800 mpu.

ABA	Add Accumulators
ADC	Add with Carry
ADD	Add
AND	Logical And
ASL	Arithmetic Shift Left
ASR	Arithmetic Shift Right
BCC	Branch if Carry Clear
BCS	Branch if Carry Set
BEQ	Branch if Equal to Zero
BGE	Branch if Greater or Equal Zero
BGT	Branch if Greater than Zero
BHI	Branch if Higher
BIT	Bit Test
BLE	Branch if Less or Equal
BLS	Branch if Lower or Same
BLT	Branch if Less than Zero
BMI	Branch if Minus
BNE	Branch if Not Equal to Zero
BPL	Branch if Plus
BRA	Branch Always
BSR	Branch to Subroutine
BVC	Branch if Overflow Clear
BVS	Branch if Overflow Set
CBA	Compare Accumulators
CLC	Clear Carry
CLI	Clear Interrupt Mask
CLR	Clear
CLV	Clear Overflow
CMP	Compare
COM	Complement
CPX	Compare Index Register
DAA	Decimal Adjust
DEC	Decrement
DES	Decrement Stack Pointer
DEX	Decrement Index Register
EOR	Exclusive OR
INC	Increment
INS	Increment Stack Pointer
INX	Increment Index Register
JMP	Jump
JSR	Jump to Subroutine
LDA	Load Accumulator
LDS	Load Stack Pointer
LDX	Load Index Register
LSR	Logical Shift Right
NEG	Negate
NOP	No Operation
ORA	Inclusive OR Accumulator
PSH	Push Data
PUL	Pull Data
ROL	Rotate Left
ROR	Rotate Right
RTI	Return from Interrupt
RTS	Return from Subroutine
SBA	Subtract Accumulators
SBC	Subtract with Carry
SEC	Set Carry
SEI	Set Interrupt Mask
SEV	Set Overflow
STA	Store Accumulator
STS	Store Stack Register
STX	Store Index Register
SUB	Subtract
SWI	Software Interrupt
TAB	Transfer Accumulators
TAP	Transfer Accumulators to Condition Code Reg.
TBA	Transfer Accumulators
TPA	Transfer Condition Code Reg. to Accumulator.
TST	Test
TSX	Transfer Stack Pointer to Index Register
TXS	Transfer Index Register to Stack Pointer
WAI	Wait for Interrupt

Indexed: The second byte is added to the index register, the result (held in a temporary register so as not to affect the index register) is used as the address of the operand. This mode is particularly useful for accessing tables etc.

Implied: The instruction (one byte) applies to a particular internal register.

Relative Addressing: The second byte is used to branch forward or backwards from the current location up to +129 or -125.

The instruction set itself contains quite a comprehensive list of arithmetic and logic functions, branches with tests for all conditions, branch and jump to subroutine, plus manipulation of condition code bits. Versatility of the index register(s) and stack pointer is increased by several instructions.

INTERRUPTS

In the 6800, four interrupt-like modes are possible. The first is RST which initializes the machine, and which causes a read from (hex) addresses FFFE, FFFF.

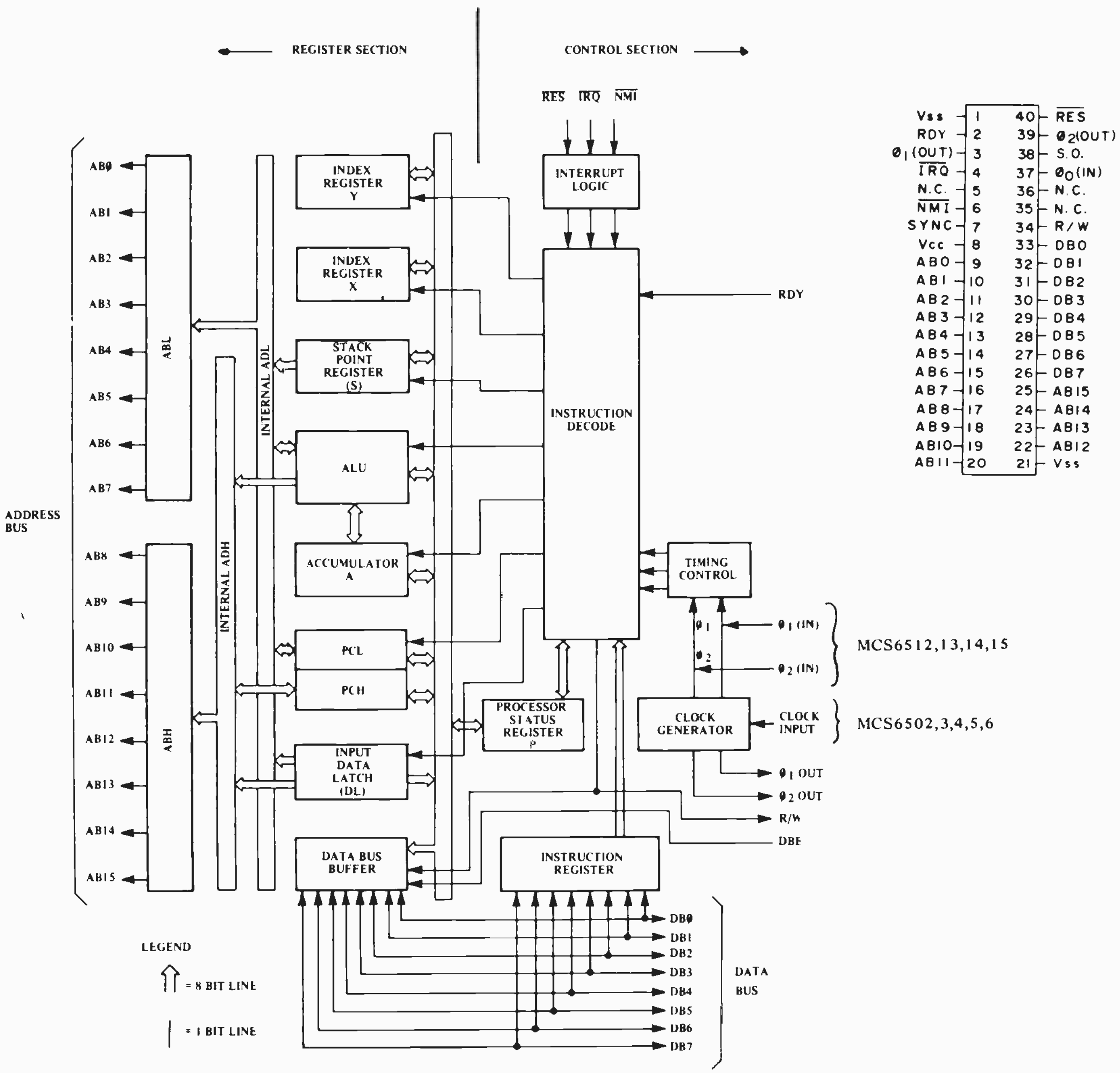
At these locations the processor fetches the address of the first routine to execute, presumably an initialization routine.

During normal operation, a signal on the Non-Maskable Interrupt line will cause execution to stop after the current instruction, the next address is saved on the stack, and the address of the interrupt service routine is fetched from FFFC,D.

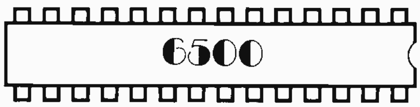
Operation of the Interrupt Request line is similar, except that by setting the interrupt mask bit in the condition code register, the mpu will ignore an IRQ signal. The IRQ address is FFF8,9. Finally there is an instruction, software interrupt (SWI) which causes an interrupt type action to take place, using addresses FFFA,B.

The 6800 interrupt mechanism means that interrupt servicing will generally be by "polling". That is to

Fig. 3. Block diagram of 6500 series chips. The pinout is for a 6502 mpu.



say, if several chips are all attached to an interrupt line, then the service routine "asks" each one in turn (by reading the device's status register) who interrupted. The order of asking determines the priority of each device. This is cheap but slow. Vectored interrupt capability is possible with complex, non standard hardware.



The 6500 series of processors are in many respects very similar to the 6800, but incorporate what MOS Technology feel are numerous improvements. The series is not as widely known as the 6800, its main exposure being through the KIM and PET.

The biggest and "best" of the line is the 6502, and to encourage the use of this mpu the 6501 was introduced. The 6501 is hardware compatible with the 6800, ie a plug in replacement, but incorporates the instruction set of the 6502 which is significantly different. The user is thus provided with a means to sample the 6500 series instructions (not compatible) without needing a complete system.

6501

As stated the 6501 is externally very similar to the 6800, the main difference being that VMA is not needed, since all addresses from the 6501 are valid.

The internal block diagram for the 6500 series processors is shown in figure 3 In contrast with the 6800, the 6501 contains only one 8 bit accumulator, two 8 bit index registers, a 16 bit program counter and 8 bit stack pointer. The status (condition code) register is again similar to the 6800 with the addition of one bit to set "decimal mode" of operation (BCD arithmetic) and one bit associated with software interrupts.

The switch from two to one accumulator might hamper some, but the change from one 16 bit index register to two eight bit ones is often advantageous. Index registers are generally used for table operations, where the base of the table is given with the op code, and the index register is added and incremented for each table access. Few tables are longer than 256 entries; but two tables might easily be used.

6500 SOFTWARE

A complete listing of instructions is given in figure 4 most of which are self explanatory. What is most interesting is the multitude of addressing modes. There are two major categories of addressing modes. The first of these, "direct" covers all the same address modes as those in the 6800. One small difference to the programmer does occur however. Where two bytes of

Fig. 4. The instruction set of the 6500 series mpus.

ADC	Add Memory to Accumulator with Carry
AND	"AND" Memory with Accumulator
ASL	Shift Left One Bit (Memory or Accumulator)
BCC	Branch on Carry Clear
BCS	Branch on Carry Set
BEQ	Branch on Result Zero
BIT	Test Bits in Memory with Accumulator
BMI	Branch on Result Minus
BNE	Branch on Result not Zero
BPL	Branch on Result Plus
BRK	Force Break
BVC	Branch on Overflow Clear
BVS	Branch on Overflow Set
CLC	Clear Carry Flag
CLD	Clear Decimal Mode
CLI	Clear Interrupt Disable Bit
CLV	Clear Overflow Flag
CMP	Compare Memory and Accumulator
CPX	Compare Memory and Index X
CPY	Compare Memory and Index Y
DEC	Decrement Memory by One
DEX	Decrement Index X by One
DEY	Decrement Index Y by One
EOR	"Exclusive-Or" Memory with Accumulator
INC	Increment Memory by One
INX	Increment Index X by One
INY	Increment Index Y by One
JMP	Jump to New Location
JSR	Jump to New Location Saving Return Address
LDA	Load Accumulator with Memory
LDX	Load Index X with Memory
LDY	Load Index Y with Memory
LSR	Shift Right One Bit (Memory or Accumulator)
NOP	No Operation
ORA	"OR" Memory with Accumulator
PHA	Push Accumulator on Stack
PHP	Push Processor Status on Stack
PLA	Pull Accumulator from Stack
PLP	Pull Processor Status from Stack
ROL	Rotate One Bit Left (Memory or Accumulator)
ROR	Rotate One Bit Right (Memory or Accumulator)
RTI	Return from Interrupt
RTS	Return from Subroutine
SBC	Subtract Memory from Accumulator with Borrow
SEC	Set Carry Flag
SED	Set Decimal Mode
SEI	Set Interrupt Disable Status
STA	Store Accumulator in Memory
STX	Store Index X in Memory
STY	Store Index Y in Memory
TAX	Transfer Accumulator to Index X
TAY	Transfer Accumulator to Index Y
TSX	Transfer Stack Pointer to Index X
TXA	Transfer Index X to Accumulator
TXS	Transfer Index X to Stack Pointer
TYA	Transfer Index Y to Accumulator

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address information follow the op code, in the 6800 system one writes them high order then low order. For the 6500 processors they are placed low order byte first, which at first looks odd but there is a good reason. Example: in a normal instruction execution, the address of the op-code is placed on the bus, and the op-code input to the instruction register. In the second cycle the op-code is being interpreted, while the next byte is loaded into an internal low order address register. Now if the interpretation of the op-code shows that it was a one byte instruction, the second byte was not necessary and is ignored. If a zero page instruction then the byte is already in the low address register, and if an absolute (two byte address needed) instruction another byte will be needed but at least the first one (low order) is already in the correct register. In the 6800 the op code must be interpreted before the second byte can be put in the high or low register. This points out an important feature of the 6500 series, that every cycle is used for mpu input whether needed or not, (which is why no VMA is needed) but which often saves time.

The second category of addressing modes is the indirect category wherein the 6500s really shine.

This mode is a little complicated, so keep in mind that the objective is to get the operand. In plain indirect addressing the location following the op-code contains the address (in zero page) where two consecutive locations contain the address of the operand. Figure 5 shows the relationship. It is generally used where the final address (CB) is to be calculated at a later date, but the place to find that calculated address (A) can be established. To further beautify (complicate) matters, we can add indexing to either the second address (indirect indexing) or first address (indexed indirect). In the first case we may be accessing a table at a remote location, in the second perhaps accessing a table of remote locations, either way the final address is in some way to be left open for the program to calculate and insert. These modes are also most useful in subroutines.

Program Location	Program Contents	Location	Contents	Location	Contents
X	Op-code	00,A	B	C,B	Data (operand)
X+1	A	00,A+1	C		

Fig. 5. Indirect addressing on the 6500 series mpus.

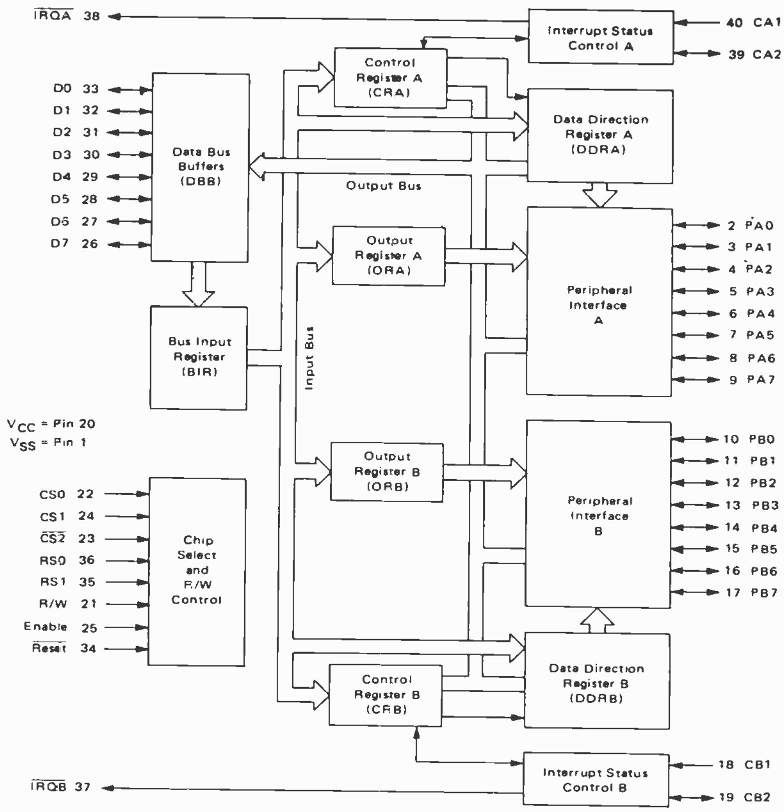
6502

The 6502 includes a number of features over the 6501, and of course the same software features.

HARDWARE

The block diagram figure 3 again applies, and the pinouts are shown in figure 3. The improvements are

Fig. 6. The Peripheral Interface Adapter provides two 8-bit bidirectional ports.



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significant. A simple crystal or RC TTL single phase clock input is all that is required, the chip provides phase one and two outputs. A very important feature to hobbyists and prototype builders is the function of the RDY line. Similar to the HALT of the 6800, the difference is that the 6502 will stop with the addresses available on the bus, rather than in high impedance state. The advantage is that in debugging and single stepping it is very simple to stop and see where you are, and what data is at the location in memory. To do the same thing with a 6800 needs extra logic and latches.

Others in the 6500 series:

In addition several other processors are available, all "subsets" of the 6502. The 6503, 4, 5, 6 are 28 pin versions, with reduced addressing, control and interrupt combinations, on chip clock, and reduced cost. The 6512 is a 40 pin model with two phase clock but otherwise like the 6502. The 6513, 14, 15 are similar to the 6512 and again are 28 pin versions. 1MHz and 2MHz versions are available of each one.

SUPPORT CHIPS

Since the buses for the two families are so similar, support ICs for one will generally work for the other.

The popular system staples are:

6810: 128 x 8 static RAM

6820: Peripheral Interface Adapter: provides two 8 bit parallel I/O ports, each bit programmable as in or out plus "handshaking". The two ports provide different input and drive capabilities, giving TTL and CMOS compatbility.

6830: 1024 x 8 ROM

6850: Asynchronous Communications Interface Adapter: Provides buffering and control for reception and transmission of serial data, eight and nine bit, with various code options.

6852: Synchronous Serial Data Adapter.

6860: Digital Modem for use with the ACIA, this unit provides the modulator, demodulator, and control signals for telephone communication.

6520: Peripheral Interface Device: similar to 6820.

6530: Peripheral Interface/Memory Device: includes 1k ROM, 64 bytes RAM plus two 8 bit bidirectional ports, and programmable interval timer with interrupt.

6522: Similar to 6520, plus timers, serial-parallel, parallel serial shift register, and input data latching, plus expanded handshaking.

6532: Includes 128 byte RAM, two 8 bit bidirectional ports and timer.

Just introduced or in the near future are:

6802: Microprocessor + RAM + Clock

6801 and 6809: Microprocessors for 1978.

6821: Peripheral Interface Adapters

6840: Programmable Timer

Plus an assortment of special purpose interface adapters and memory items.

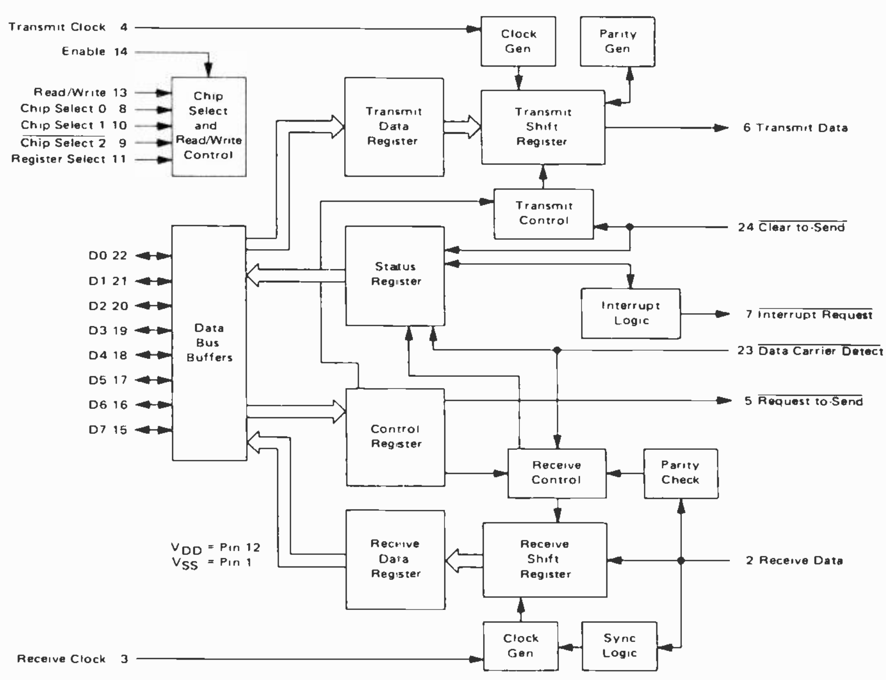
The Motorola 6800 is second sourced by AMI, Fairchild and Hitachi, while Rockwell is on the 6502 team.

Information from:
Motorola Semiconductor Products
Canada
490 Norfinch Drive
Downsview M3N 1Y4

Commodore/MOS Technology:
Commodore Business Machines Ltd.,
3370 Pharmacy Ave.,
Agincourt, Ontario, Canada.

Next month Microbiography takes a look at the RCA 1802.

Fig. 7. Block diagram of Asynchronous Communications Interface Adapter.



MICROPROCESSING AND THE RADIO AMATEUR

BITS, BYTES and BAUDS

by Bill Johnson VE3APZ

Last month reference was made to such terms as memory address, peripheral address, etc. We saw how an address can be represented as various combinations of bits, and how a 16-bit address has become a popular standard for both mini- and micro-computers, giving 65,536 available addresses, or 64K. ('K' is generally assumed to represent 1024 when talking in terms of memory size.)

The Pigeon-Hole

It is sometimes difficult for the layman to understand the concept of memory addresses, and how the computer generates and the memory decodes them. The easiest way to visualise them is to think of a pigeon-hole system as would be used in a hotel for keeping messages for guests. Each box has a number assigned to it. When the desk clerk wants to leave a message for a guest, he simply puts in into a hole with the guest's room number marked beside the hole. Now let us assume that the pigeon-holes have only enough room for one message — i.e. when the clerk puts a second message into the hole, the first one falls behind the board and is lost. If he wants to read something from the last message for a guest, he simply goes to the location (room number) associated with that guest and retrieves the message. Naturally, if he wants to read the third last message that was put into the pigeon-hole he can't, because it has been lost.

An Electronic Pigeon-Hole

A memory system has the same kind of philosophy. You can store only one message (in a computer's case, a fixed number of bits) in any location. If you put another byte into that location, you will destroy the first. You can read it any number of times, however, because each time that you read it, it automatically gets put back into the same memory location for future use, until somebody writes a new byte into that location.

SIGNALS USED	ENGLISH EQUIVALENT	BUS OPERATION
CONTROL	HEY!	CLOCK ALERTS ALL PERIPHERALS (INCLUDING MEMORY) TO LOOK FOR THEIR ADDRESS
ADDRESS	YOU!	ADDRESS LINES GIVE OUT A SPECIFIC ADDRESS
CONTROL & DATA	DO THIS!	DATA ARE EITHER TAKEN FROM OR PUT ONTO THE BUS LINES, DEPENDING ON THE STATUS OF READ/WRITE LINES

Fig. 1 - Bus dialogue

Now let's look at what hardware our system needs. The average MPU can address 65,536 bytes of memory, so it must have 16 lines coming from it, each being a 1 or 0, to indicate which of the 64K addresses it wants to use. Using a typical MPU chip, such as the 6800, we will need eight data bits to pass the data over from the MPU to the peripheral or vice versa.

We will also need some control signals to tell the peripherals (including memory) to look for their address, and what to do if they find it. Such signals are called "clock", "read", and "write".

Memory Addressing

As a general convention, the address lines can be called A0 to A15, and the data lines will be called D0 to D7.

It is not necessary for every chip in a memory system to decode each one of the 16 address lines. What generally happens is that chips are arranged in convenient blocks, such as may be convenient to fill a particular size of memory board. In this case, logic circuitry on the board looks at all 16 bits (less the number required to address the individual locations on the board) and inhibits all chips on the board when the address signalled by the MPU is outside the range of that board.

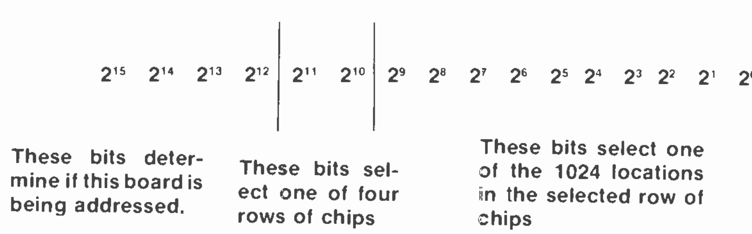


Fig. 2a. Use of bus address bits

BITS, BYTES, and BAUDS

A block of memory is assigned a starting address (the bus address of the lowest byte on that block) when the system is built. This is usually done with jumpers soldered to the board, or with DIP switches. In figure 2A, address bits A12 through A15 are assigned to determine the board number. As you can see, there are four bits, giving 16 combinations. Each one of these combinations can have 4K addresses, which gives us our 64K (65,536) maximum addresses.

Let's assume that the memory has A12 to A15 set to all zeroes. Since we have specified that this board will be the lowest in memory, then it will respond. However, the chips on the board respond to 1024 addresses. If we just address this board and let the chips decode their 1024 addresses, we will get four chips all thinking that they are being addressed. To prevent this, we take the leftover bits A10 and A11 and use the four combinations of these two bits to select one of four groups of eight chips. Each chip is connected to one data line, the eight chips operating in parallel thus hold the eight bits of each byte.

Reading and Writing

We now see how the MPU can select a group of eight chips of the many on the bus. These selected chips will respond by either putting the eight bits that are stored in their addressed locations onto the bus, or by taking what is on the bus and storing it.

This can be controlled in many ways. Some systems have two separate signals, READ and WRITE. READ, when present, indicates to the peripheral that the MPU wants to input data, so it will put them onto the bus when selected. WRITE, when present, indicates to the peripheral that it should take the information from the bus and store it in its addressed location.

Which Way is Up

At this point a word of warning about READ and WRITE, INPUT and OUTPUT. To avoid the confusion that may arise because the MPU INPUTS while the peripheral is OUTPUTTING, a general convention exists which says that the words INPUT (or READ) and OUTPUT (or WRITE) are always used with respect to the MPU. In other words, OUTPUT data always flow from the MPU to a peripheral, during a WRITE operation, whereas INPUT data always flow from a peripheral to the MPU, during a READ operation. There is one exception to this rule, during NON-PROCESSOR TRANSFERS, which will be dealt with in the next article in this series.

Fast Memory, Slow Memory, and Timing

There are two basic schools of thought on how a peripheral device such as memory should respond to a computer. One way is called a SYNCHRONOUS bus, the other is called ASYNCHRONOUS. Both have their advantages and disadvantages. A SYNCHRONOUS bus is one, such as is used in the 6800 MPU, in which a peripheral is given a precise amount of time to respond to a request from I/O. This time is fixed by the system clock. If the peripheral fails to respond properly during this time, the MPU carries on regardless, not knowing that its commands have not been carried out. Failure of a peripheral to do its job within the allocated time can result in totally unpredictable errors. For this reason, if a SYNCHRONOUS system has various memories attached to it, some very fast to respond, and some comparatively slow, the whole system will have to be slowed down so that the slowest device can operate reliably. The main advantage of this type of system is that it is far cheaper than the ASYNCHRONOUS bus. In the latter, a system is designed with various devices that are called MASTERS* and others that are called SLAVES. (For our present purposes, the MPU is the MASTER and the memory is the SLAVE). This system works in a HANDSHAKE fashion, i.e. one in which the MASTER, who controls the bus, sends out an address, a command, and a MASTER SYNC pulse. The MASTER SYNC pulse is similar to the clock pulse on a SYNCHRONOUS bus, except that as soon as MASTER SYNC is sent, the MASTER turns off its own internal clock. Thus, no more MASTER SYNC pulses are sent, and the bus sits in a state of limbo. When the peripheral is ready, it puts its information on the data bus (or takes information put there by the MASTER) and sends a signal called SLAVE SYNC. Upon receipt of SLAVE SYNC, the MASTER then carries on its work, normally issuing another MASTER SYNC to another address and so on. In this way, slow memories can take a long time to respond, while advantage can be taken of the extra speed of fast memories.

**MASTER, SLAVE, MASTER SYNC, AND SLAVE SYNC are terms and signals used on the DEC UNIBUS. They are used here as representative terms only.*

I/O to Slover Peripherals

So far, the only peripherals that have been mentioned are the various memory banks. Memory is fine, but it is so expensive (relatively) that it is only economically feasible to use it for data and programs that are currently being used, and to which access is very quickly needed (in the order of 1-2 uS). To store programs and data, we use such peripheral devices as tape drives (cassettes, 9-tracks, formatted etc.) discs (floppy, cartridge, multi-platter), paper tape, etc. For data that are not needed as quickly (in the order of 200-300 mS) such offline storage is useful because, even though it is extremely slow to get data from, it allows storage

ADDRESS RANGE	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
$0000 — 03FF	2102	2102	2102	2102	2102	2102	2102	2102	ROW 0
$0400 — 07FF	2102	2102	2102	2102	2102	2102	2102	2102	ROW 1
$0800 — 0BFF	2102	2102	2102	2102	2102	2102	2102	2102	ROW 2
$0C00 — 0FFF	2102	2102	2102	2102	2102	2102	2102	2102	ROW 3

Fig 2. Memory block addressing for a typical 4K x 8 board using 2102 (1K x 1) static RAMs. Board is set up as lowest of 16 possible places in a 64K system.

of from 200k bytes to many megabytes which would be prohibitively expensive using core or solid-state memory.

As an example of an I/O transfer, let's use a paper-tape punch on a model 33 teleprinter (TTY). That's about the slowest peripheral that you can get. I mentioned above that, in the case of an ASYNCHRONOUS bus, the MASTER can be made to wait while a SLAVE goes through its cycle. This is fine if the SLAVE delays the MASTER for a few hundred nanoseconds, or even a few microseconds, but the difference between that and the nine milliseconds required to send one byte to a TTY machine makes it very clumsy to hold up the bus for that long. Also, if the bus in question were to be SYNCHRONOUS, it means that the computer would have to be slowed down to fractions of a thousandth times its normal speed — a ludicrous proposition.

What actually happens is that the data for punching are sent to a DATA REGISTER, which appears as a single memory address on the bus. Associated with each DATA REGISTER will be a STATUS REGISTER at another (usually the next sequential) memory address. The purpose of the STATUS REGISTER is to allow the MPU to monitor the progress of the data transfer to the slow device. Let's assume that bit 0 of the STATUS REGISTER indicates that the device which sends to the TTY is sitting idle. We can test for this condition in our program by doing a READ at the STATUS REGISTER address and seeing if this bit is set. We can then do a write of the data that we wish to send to the TTY at the DATA REGISTER address. The logic in the TTY interface will then clear bit 0 of the STATUS REGISTER and start sending the data, bit-by-bit, to the TTY. While this is happening, the MPU is free to address memory and other peripherals, and carry on executing a program. The program, for example, could be calculating an employee's paycheque, while the printer is printing that of the last employee to be processed. Such a program is called a FOREGROUND program. Every once in a while, the program can switch over to another program, called a BACKGROUND program, which checks to see if the PRINTER READY bit (bit 0) is set in the printer interface STATUS REGISTER, and if it is, sends the next data byte to the interface and switches the computer back into FOREGROUND mode. This can go on until the processor runs out of data to process, in which case it just keeps waiting for the printer interface to become idle before it can send another byte.

Why Just Sit There?

As you can see, the above way of doing things gives us the use of the processor while waiting for the periperhals, but we still have to waste time occasionally checking to see if the printer interface is ready. Wouldn't it be nice if the printer interface had some way of telling us when it's ready, so we don't have to keep checking? Well, such a system exists. This is called an INTERRUPT PROCESS, and together with DIRECT MEMORY ACCESS and the use of the console TTY, forms the content of the next article in this series.

NOTES FOR READERS OF "TOP PROJECTS" AND "CIRCUITS"

For readers of our special publications "Top Projects" and "Circuits" we present here some useful conversions. We will in future be including this information with the books.

DIODES

OA91 Germanium	1N34
OA95 Geramium	1N38
OA200 Silicon	1N4148
BA100 Silicon	1N4148

GERMANIUM TRANSISTORS

AC127	2N2430
AC128	2N2706
AC132	2N2706
AC176	2N2430
AC187	2N2430
AC188	2N2706
ACY22	2N1188
AD161	2N4077
AD162	2N2835
OC72	2N2706

SILICON TRANSISTORS

BC107	2N3904
BC108	2N3904
BC109	MPS6514; MPS6515
BC109C	TIS97; MPSA18
BC148	2N3904
BC153	2N3904
BC158	2N3905
BC169C	MPSA18*
BC177	2N3905
BC178	2N3905
BC179	2N3905
BC182L	2N3904*
BC184	MPS6515*
BC209	MPS6515
BC212	2N3905
BC214	MPS6523
BC258	2N3905
BC327	2N5819
BC328	2N5819
BC337	2N5818; 2N2222A
BC441	TIP31A*
BC461	TIP32A*
BC548	2N3904
BC549	MPS6515
BC558	2N3905
BCX 31	2N5858
BCX 35	2N5857
BCY54	2N3905
BCY71	2N3905
BD135	TIP29A
BD136	TIP30A
BD137	TIP29B
BD138	TIP30B
BD139	TIP29C
BD140	TIP30C
BD266	TIP145
BD267	TIP140
BDY20	2N3055
BF224	2N3904*
BFR40	TIP31A
BFR80	TIP32A
BFX30	2N2905A
BFX84	2N2297
BFX85	2N4001
BFX88	2N2905A
BFY50	2N2297; 2N2222A
BFY51	2N2297; 2N2222A
BSS15	2N5320
ZTX300	2N2222A
ZTX500	2N2907A

*These transistors may have different lead configurations. Check carefully before use.

ORP12: This light dependent resistor has a dark resistance of 10M, which decreases to 300R in bright sunlight.

PP3 battery: This is our 9V "transistor" battery.

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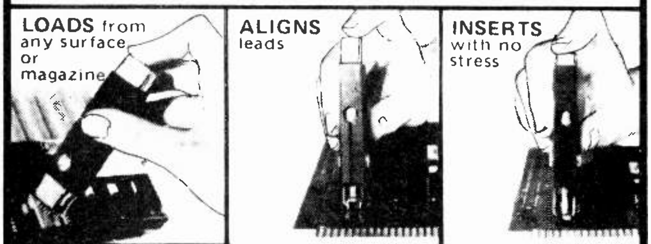

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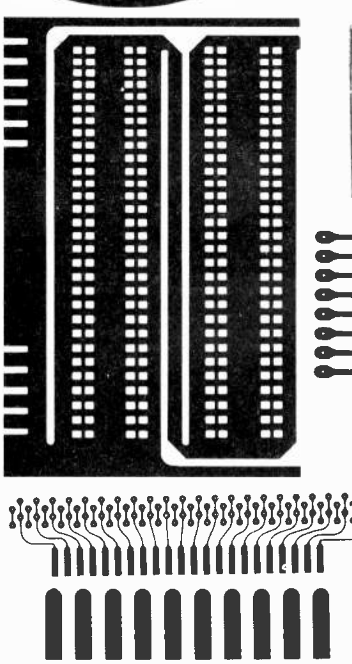

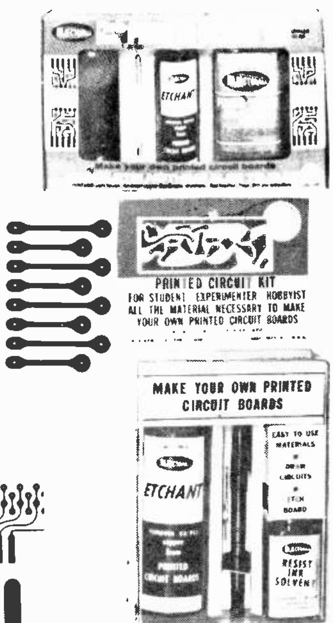

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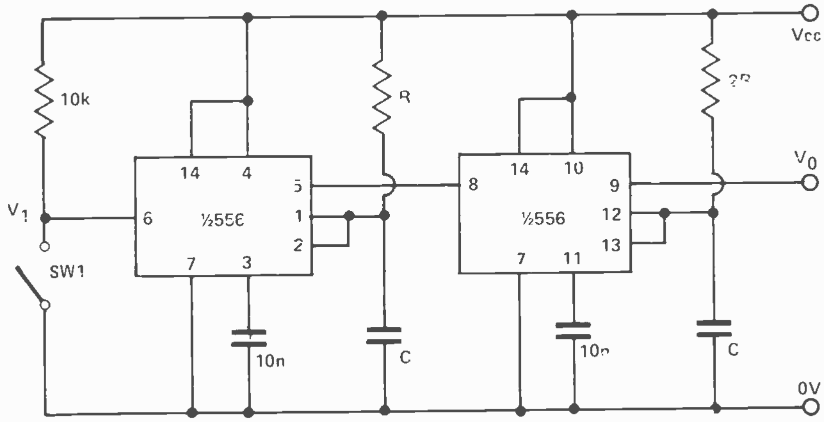
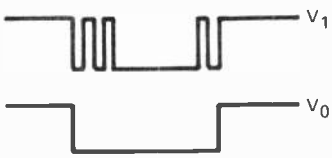
Contact Debounce

A. V. Bates.





The circuit described below can be used to provide contact debounce, or can be used as a dual retriggerable monostable.

With SW1 in the off position, pin 5 is low, and holds pin 9 high – the same as the input. When the switch closes, pin 6 goes low causing the monostable to start timing. Pin 5 goes high allowing pin 9 to go low. As the monostable is retriggerable, any contact bounce only extends the timing period.

When the timing period is complete, pin 5 remains high, due to pin 6 being held low by the switch. Releasing the switch allows pin 5 to go low which triggers the second monostable. Pin 9 now goes high and remains high after the timing period as pin 8 is being held low. Any bounces during this period merely retriggers the first monostable. For this reason, to ensure correct operation, the period of the second monostable must be twice that of the first.

The period of the bounce suppression is the timing period of the first monostable, and is given by:
T (seconds) = 0.693 x R x C.

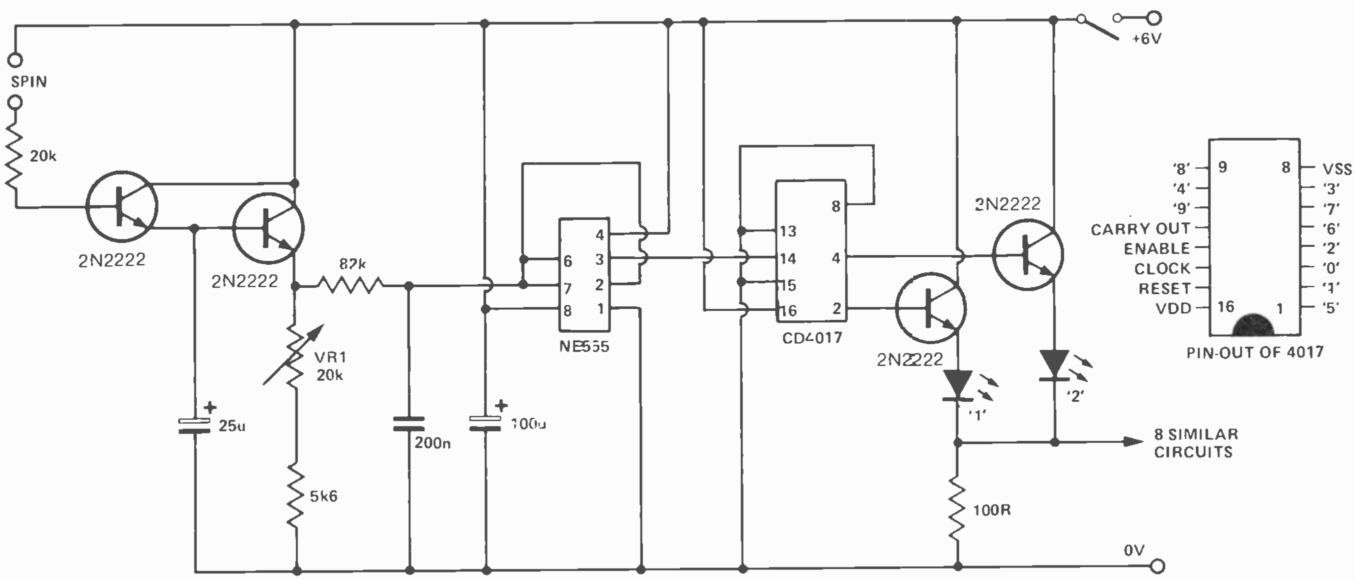
Touch-Spin Mini Roulette

David Ian

Ten LEDs arranged in a circle form the 'wheel' for this miniature roulette.

A finger held on the 'SPIN' contacts will cause the LEDs to flash in order round the circle, the speed slowly increasing. When the finger is removed the flashing will slow and one LED will remain lit.

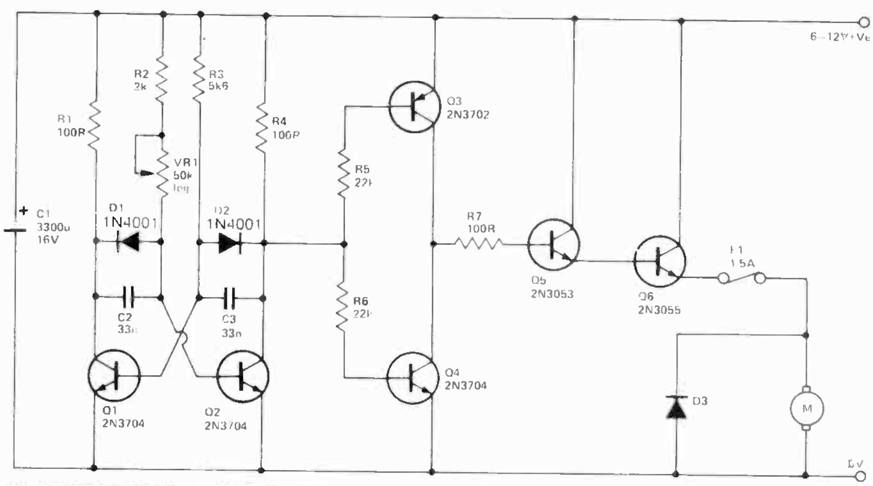
The LEDs are mounted behind a red translucent perspex panel with the numbers 0 to 9 marked on a clear sheet of celluloid mounted between the LEDs and the perspex. With a current of 20 to 30mA through the LED the winning number is clearly illuminated. VR1 can be adjusted to change the time taken for the 'spinning' to stop.



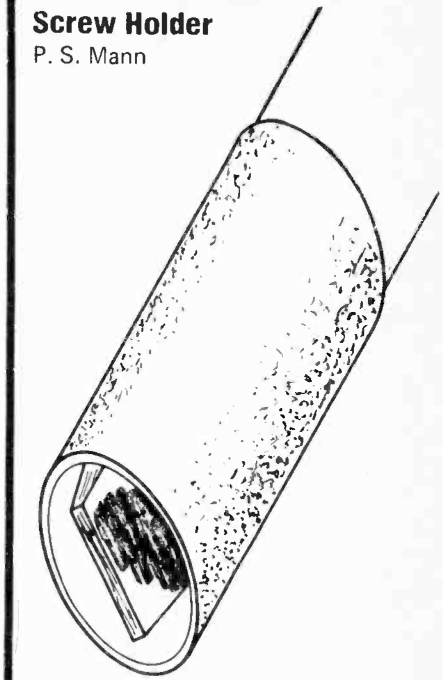
DC Motor Speed Controller
D. Strange

Simple controllers for DC motors as previously published have been found to be limited in their application. This new design is capable of controlling a wide range of DC motors enabling high torque to be available at low speed.

In the circuit, Q1 and Q2 form a multivibrator operating at about 7kHz. VR1 is used to alter the mark/space ratio of the square wave which is fed via R5 and R6 to the bases of complementary transistors Q3 and Q4. The joined collectors of Q3 and Q4 are switched hard between positive rail and zero volts, turning on and off completely the output transistors Q5 and Q6. Consequently the dissi--pation of the output transistors is very low. D3, a power germanium diode, is inserted across the motor to suppress transients which were found to reduce torque by approximately 30% in the prototype. A silicon power diode with a germanium diode such as 1N107 in parallel is equally efficient at transient suppression.



Screw Holder
P. S. Mann

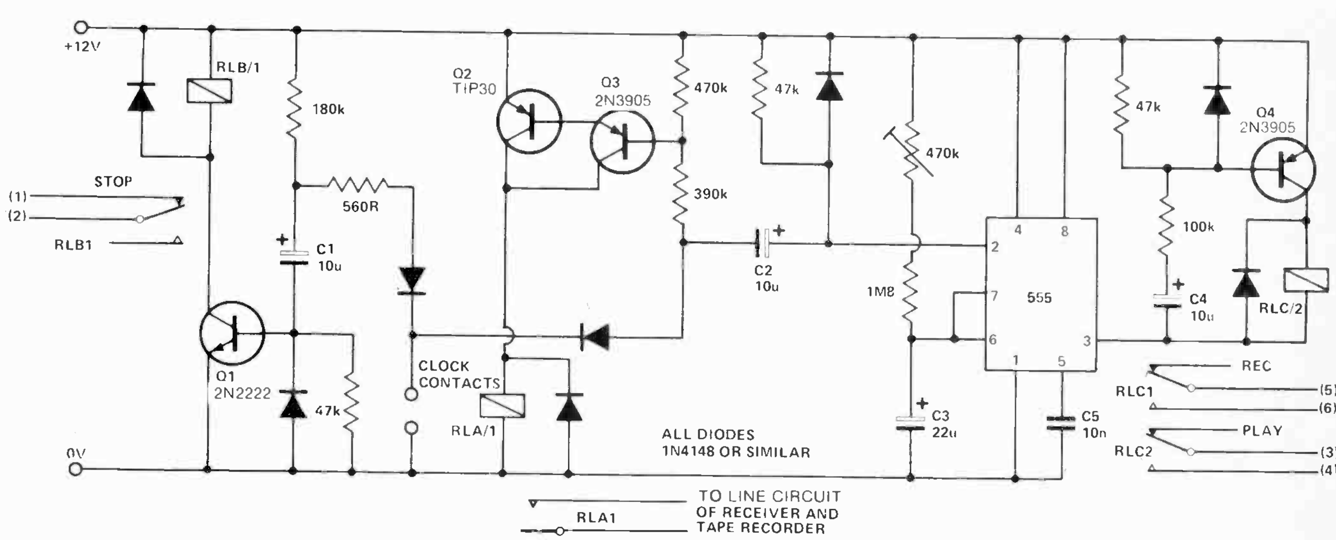


This simple but ingenious idea should help relieve the frustration of trying to fit tiny screws into awkward places.

A short length of insulation is put over the end of a small screwdriver until flush with the end.

The screw can then be slipped into the insulation until it engages with the screwdriver, where it will be held in place by the insulation.

Tape Recorder Controller
D. H. E. King

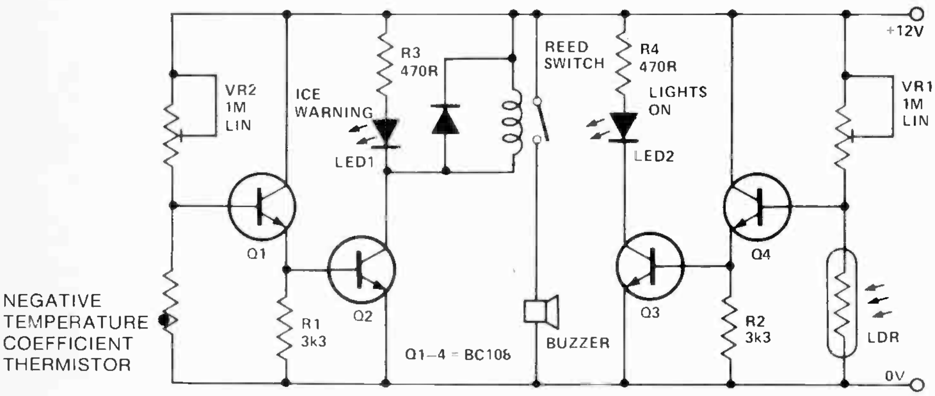


Ice Warning and Lights Reminder

D. Chivers

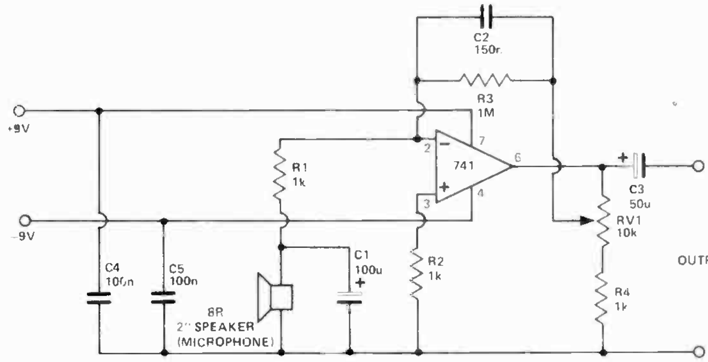
This simple device will tell a driver if his lights should be on and will warn him if the outside temperature is nearing zero, by lighting a LED and sounding a buzzer.

The units action is self explanatory; VR1 adjusts sensitivity for temperature, VR2 for light. Both thermister and LDR should be well protected. Most high gain NPN transistors will work and the experimenters junk box will almost certainly hold some.



Heartbeat Preamplifier

P. J. Tyrrell



This simple circuit, when connected to an audio amplifier, allows one to listen to heartbeats. The low frequency gain is set by R1 and R3, in conjunction with VR1 and R4. VR1 permits the gain to be varied over the range 60-80 dB.

C1 and C2 introduce some low frequency cut, reducing 60Hz pickup whilst C4 and C5 help prevent instability caused by the high gain of the circuit.

The output should be connected to the magnetic cartridge input of the audio amplifier, with the bass turned up high.

The circuit shown enables a solenoid operated tape recorder to be left to record a program unattended. It was originally designed to be used on a Revox A77, in conjunction with a digital clock based on the Caltex CT7001, but could be adapted for other recorders, clocks, or mechanical time switches. The clock is set to switch on one minute before the program starts, and switch off as it finishes.

When the clock contacts close, RLA is operated via Q2 and Q3, applying power to the receiver and recorder. At the same time C1 is discharged, and C2 applies a negative pulse to pin 2 of the timer, which triggers, discharging C4. The output of the timer goes high for one minute, allowing time for the recorder and receiver to warm up. As the timer output goes low, C4 charges through Q4 momentarily, operating RLC which starts the recorder.

At the end of the preset time the clock contacts open, discharging C2 through Q2 and Q3 which delays RLA from dropping out by approximately 5 seconds. As the clock contacts re-open C1 charges through Q1, operating RLB opening the normally closed stop contacts for a short period, stopping the recorder. After the 5 second delay has elapsed, RLA opens, removing power from the equipment.

RLB and RLC may have light contacts, but RLA must be a heavy duty line rated type. Ideally the digital clock should be crystal controlled, to eliminate short term line frequency fluctuations. The numbers shown in brackets are the appropriate pin connections on the 10 way remote control plug of a Revox A77.

Battery Tester

R. N. Soar.

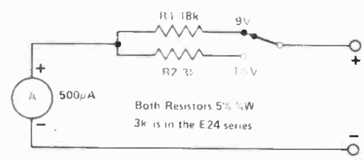
This circuit was designed as a simple tester for 1.5 and 9 volt batteries.

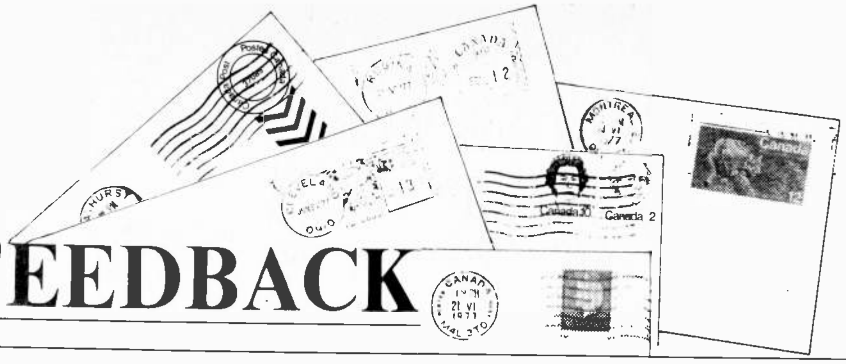
It uses a cheap 500μA recording level meter of the kind used in cassette recorders, costing around $1.00

The scale is as indicated in the diagram and can be interpreted as follows—

BLACK—Replace battery
RED—Weak battery
GREEN—Good battery

A new battery should give a full scale deflection.





FEEDBACK

ETI KITS

I have an interest in the ETI 427 Graphic Equalizer advertised in your October 1977 magazine.

Will you please send me further information on how I could obtain the complete parts to build a stereo version of the equalizer.

I would like to know the cost of the parts including the case and other miscellaneous. Please send me this information as soon as possible.

May I hear from you soon.

M.F., Edmonton, Alberta

We know of no company in Canada supplying a complete set of parts for our Graphic Equalizer project (but in other countries where we have published this design there are suppliers). Hopefully soon someone will realise the business potential and bring out a kit. We will be happy to grant permission to any company interested, provided they can provide a good service for our readers.

In the meantime all we can do is tell you where you can buy the PCB, the other components are available from various suppliers. Magnum Electronics and B&R (see advertisements in this issue) supply the boards.

UNANSWERED LETTER

I wrote to you with a technical query two months ago and have not yet had a reply. Here again . . .

C.T., Ottawa

We reply to all letters (admittedly it might be a few weeks before we get around to it in some cases) that are accompanied with a stamped self-addressed envelope; the need for the SSAE is clearly spelt out on the 'Information' page of ETI. In your case we had no SSAE which explains why you didn't get a reply.

ETI BURGULAR ALARM

I would like to have more information on your Burgular Alarm published in the May issue (p. 14). From your explanation it seems that the alarm sounds only if LED 1 is on after the 30 seconds delay. Does that mean that a burglar can open a door and then close it in less than 30 seconds (reestablishing the circuit) without switching the alarm on?

Is it possible to add an "immediate" switch for night protection (alarm sounds as soon as the circuit is modified).

Are you going to publish a pushbutton code electronic lock in the future issues? I would like to have a way to switch the alarm on or off from the different doors of the house.

Thank you very much for your help.

P.D., Boucherville P.Q.

The 30 second delay built-in to our Burglar Alarm takes effect when the project is switched on by the houseowner. Thirty seconds later, when he has left the building, the alarm is ready to sound immediately the sensing circuits are activated. There is no delay between the time when the burglar sets off the sensing circuit and the sounding of audible alarm. The delay occurs only as the householder leaves his property.

We do not have a push-button code lock project scheduled for the near future, but we are considering your suggestion.

MAIL STRIKE

As a subscriber to ETI magazine I am worried about what will happen to my copy if there is a mail strike.

F.T, Calgary

There is little we can do under these circumstances. We will keep your copy (or copies) until the Post Office will deliver it. It might mean that you get two copies at one time when the strike is over. Hopefully the situation will not arise.

It says, "Put all the parts together until you get something that looks like the picture on the box".

PUBLICATIONS FROM ETI

CIRCUITS No. 1:

A brand new concept from the house of ETI more than 100 pages packed with a wide range of experimenters circuits. Based on the 'Tech Tips' section carried in the overseas editions of ETI, Circuits 1 is the first of a series of specials - produced for the enthusiasts who know what they want, but not where to get it! Circuits 1 will also act as a catalyst for further development of ideas, ideal for the experimenter. The collection of more than 200 circuits is complemented by a comprehensive index, making searches for a particular circuit quick and simple. Also, similar circuits can be compared easily, due to the logical layout and grouping used throughout. Last and by no means least, Circuits 1 has no distracting advertisements in the main section!

TOP PROJECTS

TOP PROJECTS No. 3
Now available in Canada, this book contains 27 projects reprinted from the UK edition of ETI. Look at the cover picture for an idea of the contents. $2.50

TOP PROJECTS No. 4
Twenty-eight projects from the UK edition of ETI; as you can see by those mentioned on the cover there's at least half-a-dozen you have been waiting for. $2.50

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Volumes 1 and two of the best introductory series to electronics ever published in a magazine. Volume three, completing the series, will be available in a few months.

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Please specify which publications you require, and print your name and address clearly.

INFORMATION

COMPONENT NOTATIONS AND UNITS

We normally specify components using the recently agreed International Standard. Many readers will be unfamiliar with this but it's simple, less likely to lead to error and will be used by everyone sooner or later. ETI has opted for sooner!

Firstly decimal points are dropped and substituted with the multiplier, thus 4.7uF is written 4u7. Capacitors also use the multiplier nano (one nanofarad is 1000pF). Thus 0.1uF is 100n, 5600pF is 5n6. Other examples are 5.6pF = 5p6, 0.5pF = 0p5.

Resistors are treated similarly: 1.8Mohms is 1M8, 56kohms is 56k, 4.7kohms is 4k7, 100ohms is 100R, 5.6ohms is 5R6.

BACK NUMBERS

Previous issues of ETI-Canada are available direct from our office for $2.00 each. Please specify issue by the month, not by the features you require.

EDITORIAL QUERIES

Written queries can only be answered when accompanied by a self-addressed, stamped envelope, and the reply can take up to three weeks. These must relate to recent articles and not involve ETI staff in any research. Mark your letter ETI Query.

NON-FUNCTIONING PROJECTS

We cannot solve the problems faced by individual readers building our projects unless they are concerning interpretation of our articles. When we know of any error we shall print a correction as soon as possible at the end of News Digest. Any useful addenda to a project will be similarly dealt with. We cannot advise readers on modifications to our projects.

COMPONENT STORES

ETI is available for resale by component stores. We can offer a good discount and quite a big bonus, the chances are customers buying the magazine will come back to you to buy their components.

PRICES

All prices quoted in the editorial of ETI are in Canadian dollars, except where stated. Advertisers in U.S. may give U.S. dollar prices. Where we only know an overseas price, e.g. in U.K. pounds, we convert approximately to Canadian dollars, erring on the conservative side, where possible.

COMPONENT SUPPLY

We do not supply components for our projects and are unable to supply advanced information on components used in any projects. However to enable readers to obtain printed circuit boards without undue delay we will be supplying retailers and manufacturers with certain p.c. board designs. Any company interested in receiving such designs should write to us on their headed note paper requesting details.

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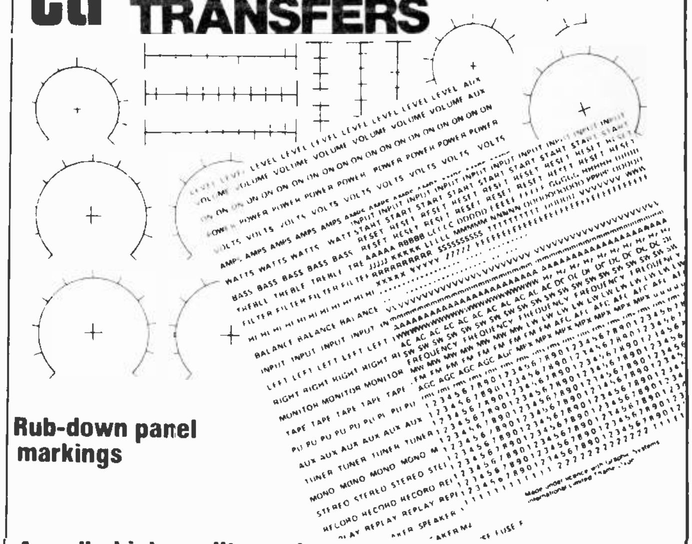

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