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No. 84

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ELECTRONICS

The Maplin Magazine

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DECEMBER 1994 · £2.10

Printed in the United Kingdom

Lots of Super Projects For You to Build!

Christmas Tree Light Sequencer

Electronic Quiz Game Scorer

Valve Voltage Regulator

High Power SMPS for In-Car Amplification

Programmable Day/Night Thermostat

Model Railway Circuits

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ISSN 0957-5456

DECEMBER 1994
VOL 14. No. 84

IN THIS ISSUE...

PROJECTS *FOR YOU TO BUILD!*

FEATURES *ESSENTIAL READING!*

REGULARS *NOT TO BE MISSED!*

ABOUT THIS ISSUE . . .

Hello and welcome to this festive Christmas issue of *Electronics!*
Ready and waiting to be 'unwrapped' this month are a whole host of projects:

To really get you into the Christmas mood there's a brilliant three-channel light sequencer that makes use of digital phase-angle control, which means that instead of the usual boring flashing patterns, this unit is able to control lamp brightness, and thus produce fade in and fade out patterns as well as flashing patterns. Groups of patterns are stored on a preprogrammed EPROM, with four banks of sequences, the first three cater for one, two or three channels and the fourth is a group of test patterns for use when building and testing the unit. We've called the unit a Christmas Tree Light Sequencer, but the unit can also be used to control disco lighting, etc. As the unit stands it can control 100W per channel, but by uprating the triacs, up to 400W per channel can be controlled.

Last Christmas we published a Priority Quiz Buzzer project, and to complement it this year, there's a Quiz Game Scorer project. The unit counts from 0 to 999, with up/down buttons to increment/decrement the display in units, tens or hundreds (naturally full carry forward and borrowing is implemented). There is, of course, the obligatory reset button. The unit is provided with a liquid crystal display, but provision is made on-board for LED display driver ICs as well, so that large off-board displays can be driven too. Multiple units can be cascaded, if required, to give larger counts, and of course the unit can be used for plenty of other counting applications other than quiz game scoring.

The Maplin Digital Train Control System has proved to be an extremely popular project, in this issue are three mini projects that can be used on a layout controlled by this system. The projects are head and tail lights (with automatic direction sensing), train location detection (for use with a mimic panel) and automatic loop control (allowing inclusion of a loop that connects back onto itself without the need for manual switching of the supply to the rails).

For valve fans, there are a couple of valve-based voltage regulator circuits, these are ideal for use with valve-based audio circuits that require a regulated noise free HT supply. If you didn't already know, in next month's issue of *Electronics* we will be publishing a Hi-Fi valve-preamplifier project designed to complement the popular Millennium 4-20 valve power amplifier.

Following on from last month's stereo power amplifier project, in this issue there's a purpose designed switched mode power supply to power the in-car amplifier – it'll blow your socks off!

To help keep control of your heating bills, there's a Day/Night Thermostat project that allows different temperature settings to be programmed at different times of the day (and night!), the unit includes a low temperature warning output that can be used to indicate heating system failure, or as a frost-stat.

Plus, there are plenty of fascinating features, series and regulars to read and enjoy; so until next month, from everyone here at *Electronics*, enjoy this issue and have a Merry Christmas!

R D Ball

Exclusive Subscribers' Club Special Offer

On offer this month, to subscribers only, is a 17-piece Universal Driver Set pictured above – it is available for just £4.79, normal price £5.99, a saving of over 20%! Also on offer is a Versatile Intruder Alarm, as reviewed in the October 1994 issue of *Electronics* – it is available for just £16.99, normal price £19.99, a saving of 15%. If you are a subscriber, full details of how to order the Universal Driver Set and the Versatile Intruder Alarm are included on the special offer leaflet in this issue – if the leaflet is missing contact Customer Services on (01702) 552911. If you are not a subscriber and would like take advantage of future special offers and other benefits of subscribing, turn to page 37 of this issue to find out more.

ABC CONSUMER PRESS

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Published by Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Tel: (01702) 554155. Fax: (01702) 553935.
Lithographic Reproduction by Planagraphic Studios, 18 Sirdar Road, Brook Road Ind. Estate, Rayleigh, Essex SS6 7UY.
Printed in the United Kingdom by St Ives (Caerphilly) Ltd., Caerphilly, Mid-Glamorgan, CF8 3SU.

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UK NEWSTRADE DISTRIBUTION
United Magazine Distribution Ltd., 16-28 Tabernacle Street, London EC2A 4BN. Tel: (0171) 638 4666. Fax: (0171) 638 4665

Project Ratings

Projects presented in this issue are rated on a 1 to 5 for ease or difficulty of construction to help you decide whether it is within your construction capabilities before you undertake the project. The ratings are as follows:

1 Simple to build and understand and suitable for absolute beginners. Basic of tools required (e.g., soldering iron, side cutters, pliers, wire strippers and screwdriver). Test gear not required and no setting-up needed.

2 Easy to build, but not suitable for absolute beginners. Some test gear (e.g., multimeter) may be required, and may also need setting-up or testing.

3 Average. Some skill in construction or more extensive setting-up required.

4 Advanced. Fairly high level of skill in construction, specialised test gear or setting-up may be required.

5 Complex. High level of skill in construction, specialised test gear may be required. Construction may involve complex wiring. Recommended for skilled constructors only.

Ordering Information

Kits, components and products stocked by Maplin can be easily obtained in a number of ways:

Visit your local Maplin store, where you will find a wide range of electronic products.

If you do not know where your nearest store is, Tel: (01702) 552911. To avoid disappointment when intending to purchase products from a Maplin store, customers are advised to check availability before travelling any distance.

Write your order on the form printed in this issue and send it to Maplin Electronics, P.O. Box 3, Rayleigh, Essex, SS6 8LR. Payment can be made using Cheque, Postal Order, or Credit Card.

Telephone your order, call the Maplin Electronics Credit Card Hotline on (01702) 554161.

If you have a personal computer equipped with a MODEM, dial up Maplin's 24-hour on-line database and ordering service, CashTel. CashTel supports 300-, 1200- and 2400-baud MODEMs using CCITT tones. The format is 8 data bits, 1 stop bit, no parity, full duplex with Xon/Xoff handshaking. All existing customers with a Maplin customer number can access the system by simply dialling (01702) 552941. If you do not have a customer number Tel: (01702) 552911 and we will happily issue you with one. Payment can be made by credit card.

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Prices of products and services available from Maplin, shown in this issue, include VAT at 17.5% (except items marked NV which are rated at 0%) and are valid between 4th November 1994 and 28th February 1995 errors and omissions excluded. Prices shown do not include mail order postage and handling charges, which are levied at the current rates indicated on the Order Coupon in this issue.

Technical Enquiries

If you have a technical enquiry relating to Maplin projects, components and products featured in Electronics, the Customer Technical Services Department may be able to help. You can obtain help in several ways; over the phone, Tel: (01702) 556001 between 9.00am and 5.30pm Monday to Friday, except public holidays; by sending a facsimile, Fax: (01702) 553935; or by writing to: Customer Technical Services, Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Don't forget to include a stamped self-addressed envelope if you want a written reply! Customer Technical Services are unable to answer enquiries relating to third-party products or components which are not stocked by Maplin.

'Get You Working' Service

If you get completely stuck with your project and you are unable to get it working, take advantage of the Maplin 'Get You Working' Service. This service is available for all Maplin kits and projects with the exception of: 'Data Files'; projects not built on Maplin ready etched PCBs; projects built with the majority of components not supplied by Maplin; Circuit Maker ideas; Mini Circuits or other similar 'building block' and 'application' circuits. To take advantage of the service, return the complete kit to: Returns Department, Maplin Electronics plc., P.O. Box 3, Rayleigh, Essex, SS6 8LR. Enclose a cheque or Postal Order based on the price of the kit as shown in the table below (minimum £17). If the fault is due to any error on our part, the project will be repaired free of charge. If the fault is due any error on your part, you will be charged the standard servicing cost plus parts.

Kit Retail Price	Standard Servicing Cost
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£40.00 to £59.99	£30.00
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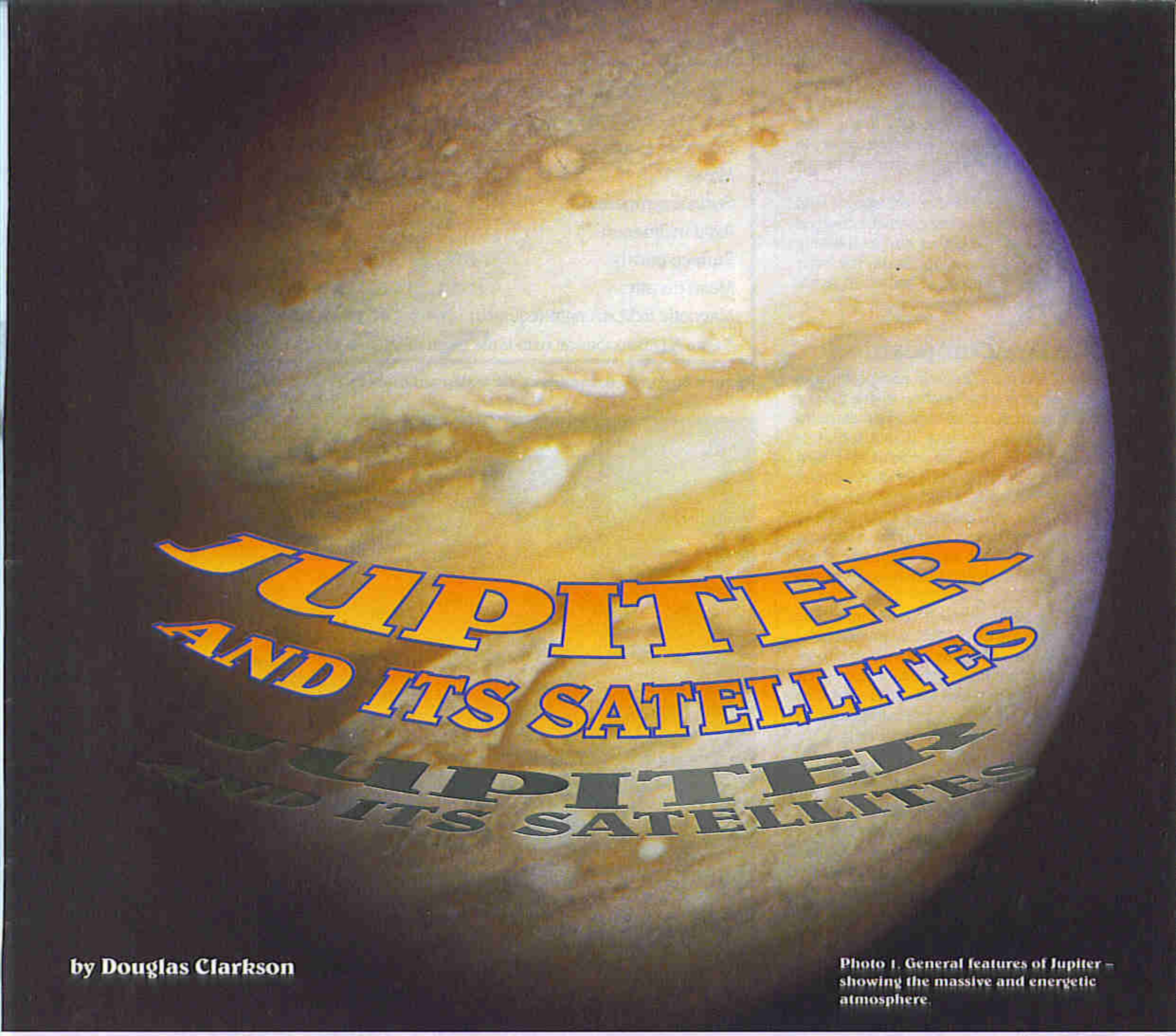
Over £150.00	£60.00 minimum

Readers Letters

We very much regret that the editorial team are unable to answer technical queries of any kind, however, we are very pleased to receive your comments about Electronics and suggestions for projects, features, series, etc. Due to he sheer volume of letters received, we are unfortunately unable to reply to every letter, however, every letter is read — your time and opinion is greatly appreciated. Letters of particular interest and significance may be published at the Editors discretion. Any correspondence not intended for publication must be clearly marked as such.

Write to: The Editor, Electronics – The Maplin Magazine, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Jupiter and its Satellites



by Douglas Clarkson

Photo 1. General features of Jupiter – showing the massive and energetic atmosphere.

Jupiter: The Giant Planet

As additional information is gathered about the planets within our own solar system, it becomes increasingly clear that very diverse environments exist upon them. In the case of Jupiter, however, not only is the main planet itself of interest, but its attendant set of moons – sixteen in all – hold many surprises. With Ganymede, one of the moons, being larger in size than Mercury, the moons of Jupiter give additional insights into how different planets/moons establish their own finely balanced environments.

Jupiter more than dwarfs the other planets within the solar system. It has, for example, more than twice the mass of all the other planets put together.

The scientific significance of Jupiter has grown considerably in relation to understanding the physical evolution of planets within the solar system and, perhaps more importantly, obtaining clues about the evolution of life on Earth. It is thought, for example, that the present-day atmosphere of Jupiter closely resembles the early atmosphere of Earth.

One of the great mysteries of Jupiter (apart from its Giant Red Spot) is the fact that it radiates more heat energy than it receives from the sun. Some unknown mechanism of internal heat generation is thought to be at work. Theories of release of heat due to shrinkage of the diameter of the planet are passing out of favour. Also, newer theories linked to the behaviour of hydrogen at high pressures, and involving aspects of 'cold fusion', are receiving some consideration.

The mysterious features of its energetic atmosphere are shown in Photo 1 – one of the many series of superb photographs taken by the Voyager spacecrafts.

Jupiter has no solid surface, and thus no form of manned landing can ever be attempted. Its consort of moons straddle the planet in an inner group of eight, and an outer group of eight. It is thought that the outer group have, probably through time, been captured by the strong gravity of Jupiter and that the inner group relate to the phase of initial formation of the major planets.

Intense ionising radiation fields, however, bombard most of the inner family of moons – Io, Europa and Ganymede. Only cold, barren Callisto is relatively free of the lethal radiation.

Jupiter and its attendant moons, however, provide a very rich scientific hunting ground – which is the reason for the current NASA Galileo mission.

Jupiter: Human History

In 1610, Galileo was one of the first to study Jupiter with a telescope. The relative motions of bright points of light about Jupiter were correctly interpreted by Galileo as a sequence of four moons in orbit round the planet. The discovery was an important confirmation of the Copernican theory of planets revolving around the sun – a heresy according to the authorities.

Jupiter: Facts and Figures

Table 1 summarises a few facts and figures about Jupiter. The relatively rapid rotation of the planet on its axis results in a surface velocity of around 45,000km/h. Because the axis of spin of the planet relative to the plane of the solar system is small, there are no specific 'seasons'. Being roughly five times further away from the sun than Earth is, Jupiter receives approximately only 4% of the solar radiation per unit of incident area. Thus, the large set of panels which provide around 2kW of power for the Hubble telescope would only provide 80W at the orbit of Jupiter. The Voyager spacecrafts were, in fact, powered by a series of nuclear power sources.

The relatively large value of magnetic field is responsible for trapping energetic charged particles around the planet, and establishing zones of intense ionising radiation. The inner moon, Io, for example, is bathed in lethal levels of radiation.

The Core Composition

Theories about the internal composition of Jupiter are largely speculative. In one theory, a relatively small silicate core, of a maximum radius of 10% of the total planet radius, is surrounded by a mantle of solid hydrogen up to a radius of around 75% of the planet radius. Beyond this, liquid hydrogen eventually merges with a turbulent atmosphere, including heavier gas elements – methane and ammonia. Such theories, however, are limited by experimental earth-based observations.

The core of the planet is considered to be at a temperature of 25,000K, where the pressures could be as high as 100 million atmospheres. Part of the complication of such models, however, is that helium is soluble in hydrogen at such high pressures, and so multi-component systems could exist.

The Magnetosphere

Jupiter is surrounded by a relatively strong magnetic field. Charged particles tend to spiral within this field – emitting radio waves, and causing accelerated charged particles to be a source of ionising radiation. This active magnetosphere extends out about ten planetary radii – to a distance, approximately, between Europa and Ganymede. The radio emissions from Jupiter were first detected in 1955.

Mean distance from sun:	778·3 million km (5·2 AUs*)
Period of rotation round sun:	11·86 years
Period of rotation on axis (equator):	9 hours 50 minutes
Diameter (equator):	142,000km
Mass:	318 Earth masses
Surface temperature:	−150°C
Axial inclination:	3°
Surface gravity:	2·65 $\times$ Earth's
Mean density:	1·33 g/cm^3 (0·24 Earth's)
Magnetic field strength (equator):	4·3 gauss (13·8 times Earth's)

* One AU (astronomical unit) is the mean distance between Earth and the sun.

Photo 2. Energetic streaming of the Jovian atmosphere.

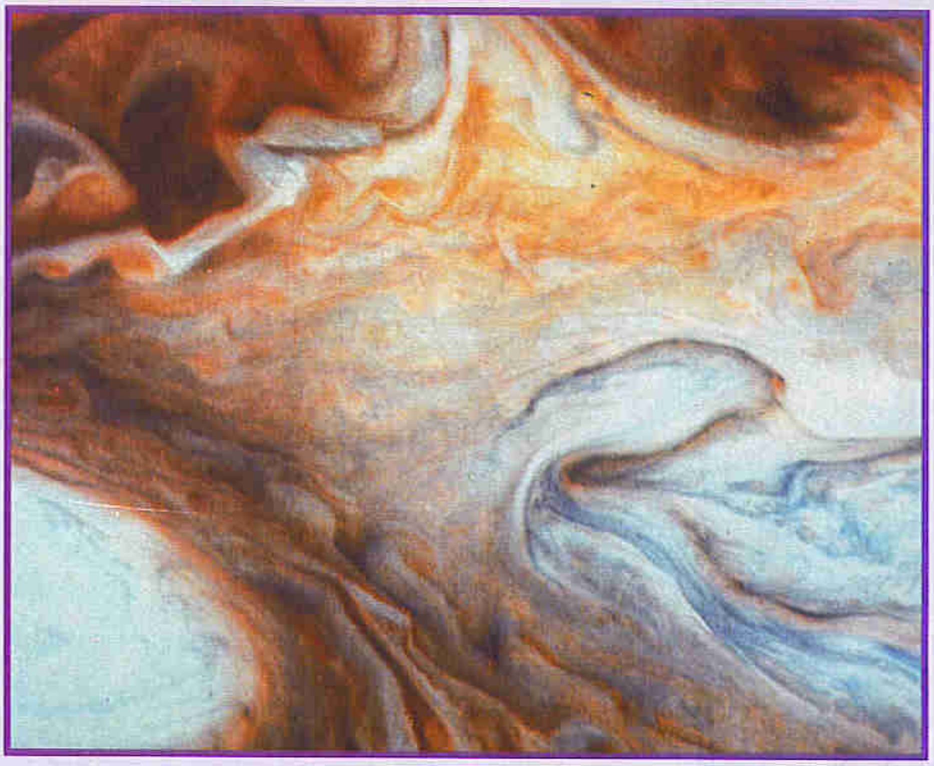


Photo 2. Energetic streaming of the Jovian atmosphere.

Photo 3. Close-up of cloud regions with a dark spot observed by Voyager 2 near closest approach.

Jupiter Probes

Pioneer 10 was launched on 2nd March 1972, and approached Jupiter at a close encounter of 131,000km on 3rd March 1973, sending back a series of 300 pictures. This was followed by Pioneer 11, which was launched on 5th April 1973 – achieving a close encounter at 46,400km on 2nd December 1974. Sampling of the magnetosphere and atmosphere was undertaken. In many ways, the pioneer probes paved the way for the later, highly successful Voyager missions; their work of mapping the radiation fields around the giant planet was an important achievement.

Voyager 1, launched on 5th September 1977, achieved a close encounter distance of 350,000km on 5th March 1979, obtaining good images of Io, Ganymede and Callisto. The companion, Voyager 2, launched on 20th August 1977, achieved its close encounter distance of 714,000km on 9th July 1979. Voyager 1, although launched later than Voyager 2, was sent by a more direct route, and arrived earlier. Voyager 2's path was specifically targeted to cover satellites not well covered by Voyager 1.

One of the more startling discoveries of the Voyager missions was volcanism on Io –

Photo 4. Spectacular close-up of the Giant Red Spot taken by Voyager 1 – showing how the feature persists amid the turbulence and streaming of the Jovian atmosphere.

Photo 5. General features around the region occupied by the Giant Red Spot, taken by Voyager 2.

the Galilean satellite closest to Jupiter. The missions also provided excellent images of Jupiter's atmosphere – including the Giant Red Spot.

The Voyager probes, however, were on a grand tour of the solar system and were not parked in orbit around the planet for longer periods of observation. Both crafts spent nine months traversing the extensive asteroid belt between the orbits of Mars and Jupiter.

Jupiter's Atmosphere

Until a probe can physically descend into the planet's atmosphere, the composition of the atmosphere has to be interpreted from analysis of light reflected from the planet's surface. Molecules have characteristic absorption spectra where photons of specific wavelength are absorbed – leaving dark bands in reflected spectra. Some gases, however, are difficult to detect using spectroscopy absorption methods. The major components of the atmosphere are considered to be hydrogen and helium, with traces of methane, ammonia, ethane and water.

The active chemical environment, however, with the bombardment of solar ultraviolet radiation, and incidence of lightning discharges, gives rise to a mix of chemical compounds including carbon monoxide, hydrogen cyanide, acetylene and ethane. There is also likely to be vertical mixing in the atmosphere, as compounds formed at depth, and high temperature and pressure, convect upwards into the upper atmosphere. The cocktail of atmospheric components will, probably, be found to be more diverse.

There is considerable interest in finding out more about Jupiter's atmosphere. If the composition of the planet is essentially unchanged since its formation, out of a cloud of interstellar gas and dust, 4·6 billion years ago, then it can provide valuable information about the early state of the universe – providing insight, for example, about theories of its spatial expansion.

There has been speculation that the bulk of the water in Earth's atmosphere resulted from bombardment, over a long period of time, by icy comets. If such a mechanism is valid, then Jupiter should have collected even more water due to its greater gravitational field. There is no evidence, however, of solid deposits of ice at levels within Jupiter.

It is likely, however, that Jupiter's atmosphere contains gases such as neon, which is very difficult to detect from absorption spectra.

Since the present atmosphere of Jupiter would closely resemble that of Earth soon after its formation, there is considerable interest in identifying the range of organic compounds being synthesised in its atmosphere.

The Cloud Systems

The cloud systems of Jupiter have been extensively observed through earth-based telescopes for over 300 years. Clouds appear to rotate in well-defined bands in a westerly to easterly direction. Changes in the patterns can be detected over time-scales of a few hours, indicating that the circulation is highly volatile and dynamic. The highly detailed pictures of the Voyager missions provided additional insight into the nature of the cloud types.

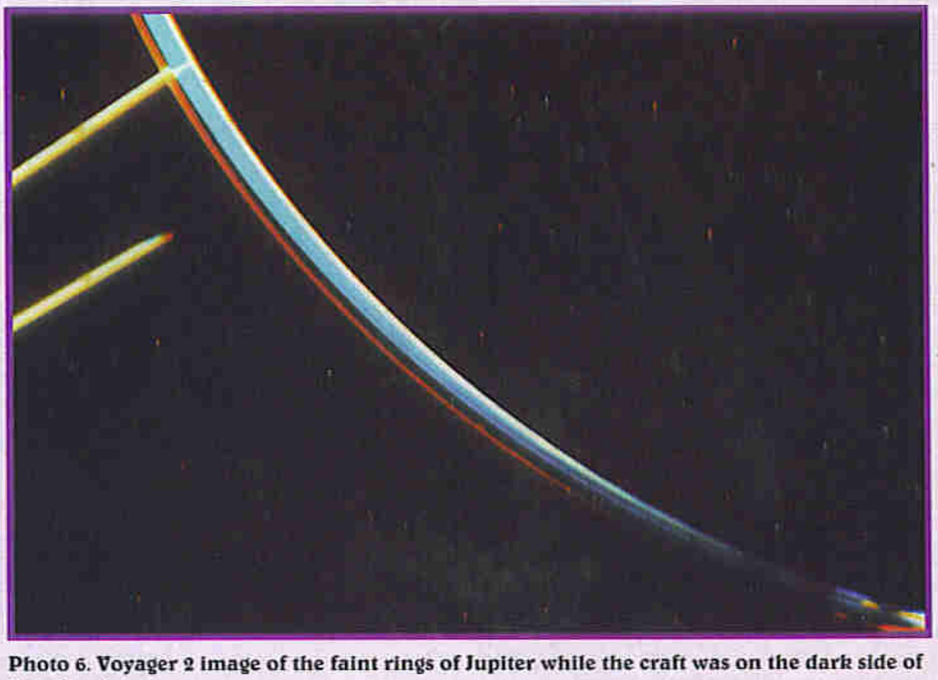


Photo 6. Voyager 2 image of the faint rings of Jupiter while the craft was on the dark side of the planet.

The main cloud layer is tawny coloured. What appears as dark brown clouds are considered to be holes in the main tawny layer – revealing darker elements below. Blue-grey or purple areas are associated with areas of strong thermal emission around the equatorial region. Bright zones, stretching across the northern hemisphere, may consist of frozen ammonia.

The Voyager probes allowed the cloud structures to be studied in considerable detail. Photo 2 shows the general chaotic movement of the atmosphere generally – showing details of features only a few tens of miles across. A region with a dark spot and energetic streaming is shown in Photo 3.

The Giant Red Spot

No account of Jupiter would be complete without some reference to its Giant Red Spot. Even with the close scrutiny of the Voyager probes, however, there is no clear reason for the existence, and apparent stability, of this feature. Could it be the site of a previous impact of the planet with a large comet or a moon that it eventually captured? Is it a site at which significantly more heat energy escapes to the surface from its inner core?

The Giant Red Spot is some 26,000 by 14,000km in size, and has a rotation period of about 12 days. It is clear, however, that it must be driven by a large energy source from within the planet, otherwise it would have, sooner or later, been absorbed into the surface atmospheric chaos. An orbiter craft, with sensitive instruments to detect minute gravitational field perturbations, could probably test some of these theories.

Associated with the main feature is a series of three unique white oval patches.

Photo 7. Voyager 1 image of Io and Europa, apparently dwarfed by the giant planet.

Photo 4 shows a superb close-up of the Giant Red Spot, showing how its features persist as a distinct entity amidst violent streaming of atmosphere around it. Photo 5 shows more general features of the Jovian atmosphere around the region of the Giant Red Spot.

The Ring of Jupiter

The existence of a ring of material round Jupiter was first suspected when Pioneer 11 detected a reduction of charged particles at a radius of around 1·7 times the radius of the planet. The ring is considered to consist of very small dust particles, probably emanating from a small moon within the satellite system. It has been suggested that either Metis or Thebe could be the source of the fine particles.

The ring of Jupiter is a very faint structure. Photo 6 shows the image taken by Voyager 2 as it captured the light from the faint rings while on the dark side of the planet. The apparent double image is caused by the long exposure. Part of the ring is cut off by Jupiter's shadow.

Name	Mean distance from Jupiter (km)	Year of discovery	Radius (km)
Metis	128,000	1979	20
Adrastea	129,000	1979	12·5 × 10 × 7·5
Amalthea	181,000	1892	135 × 83 × 75
Thebe	222,000	1979	55 × 45
Io	422,000	1610	1815
Europa	671,000	1610	1569
Ganymede	1,070,000	1610	2631
Callisto	1,883,000	1610	2400

Table 2. Summary of inner satellites of Jupiter.

Satellite Families

Table 2 summarises the inner set of satellites of Jupiter. It is customary to separate them into two groups – an inner group which includes those up to the orbit of Callisto, and an outer group beyond this. It is assumed that the outer group have probably been captured in fairly recent times by Jupiter's gravity, but that the inner group have evolved with Jupiter itself.

Jupiter, however, more than dominates the view for all of the Galilean satellites, as the image of Photo 7 shows. In the foreground, the moons of Io and Europa appear to be totally dwarfed by the giant planet. The picture was taken from a distance of about 12 million miles.

Photo 8. Active volcano on Io's horizon. Material is being ejected some 100 miles above the moon's surface.

Photo 9. False colour mosaic of Io – showing the zones of current volcanism on this surprising moon.

Photo 10. View of flat, featureless surface of Europa.

Io

Io is slightly larger than our own moon and, being the densest, was expected to be the most cratered. The observations of Io, however, produced some of the greatest surprises of the Voyager mission. Instead of the expected assortment of impact craters recording innumerable blows from the early days of the birth of the solar system, wide evidence of volcanism was visible. At least ten active volcanoes were observed during the Voyager missions of 1979.

The entire surface of the large moon is undergoing a continual reworking process, so that only traces of relatively recent events are present. The brown, orange and red colourations of Io's surface are probably due to the presence of various forms (allotropes) of sulphur.

While planetary volcanism on the scale of Venus, Earth and Mars can be attributed to the decay of radioactive elements, Io is too small to liberate, through this mechanism, the amount of heat estimated to be driving its volcanic activity. One theory which could account for the creation of additional heat energy is the generation of tides caused by interaction between Io, Jupiter and its attendant moons.

The greatest degree of volcanic activity was detected, initially, at the volcano Pele. Ejected plumes of material some 280km high were observed by Voyager 1. When Voyager 2 took its set of images, however, Pele was inactive.

Photo 8 shows an active volcano on Io's horizon ejecting material 100 miles above the moon's surface. Photo 9 shows a false colour mosaic of features of Io – indicating a very active surface.

One theory of the internal structure of Io is that there is a dense, silica-based core of the moon from which, periodically, lava escapes. Sitting on top of this core is a 4km 'sea' of sulphur and sulphur dioxide, the top 1km of which is solid. When lava breaks out from the core, it generates sulphur volcanism through the top crust. The temperature near some of the active vents on Io's surface has been measured at around 500°C.

While Io is one of the more interesting worlds in the solar system, it is also one of the most deadly – Io sits within the inner radiation belt surrounding the planet. Exposing astronauts to even a few hours of radiation would be fatal without some form of shielding.

Europa

While Io produced a host of surprises, the contrasting details of Europa were just as surprising. Being slightly smaller than Io, Europa was found to very much resemble a white billiard ball – with cracks. Europa is also the brightest of the Galilean moons. The surface is considered to be made up, predominantly, of ice, with almost complete absence of vertical relief. It is considered that, in terms of structure, the surface of Europa may consist of a crust of ice some 100km thick and that, between this and a solid silicate core, there may be an ocean of water or a region of slushy ice. It would be necessary to probe the surface of the moon using seismological techniques in order to determine more precise details of its inner structures.

There would appear, however, to be a process of significant resurfacing taking place, wherein water from lower regions seeps out to melt existing structures. In common with Io, Europa therefore only shows details of a fairly recent past.

Photo 10 shows both the flat featureless appearance of Europa and the distinct lines of fracture of the moon's icy surface.

Ganymede

Ganymede is also considered to have, predominantly, an icy surface, although there is significantly more topography than on Europa. Although Ganymede is one of the largest satellites in the solar system, its relatively low density of around 2 (relative to water) implies that its gravitational fields are too low to hold onto an atmosphere.

Dark regions on Ganymede are considered to be the oldest areas, and show a heavy concentration of craters. Some degree of surface reformation is evident in the lighter areas, where an absence of craters is evident.

The moon was extensively studied by the

Photo 11. Ganymede's topography is more interesting than that of Europa, although it is considered that its surface does undergo some modification due to heat from the inner layers of the moon.

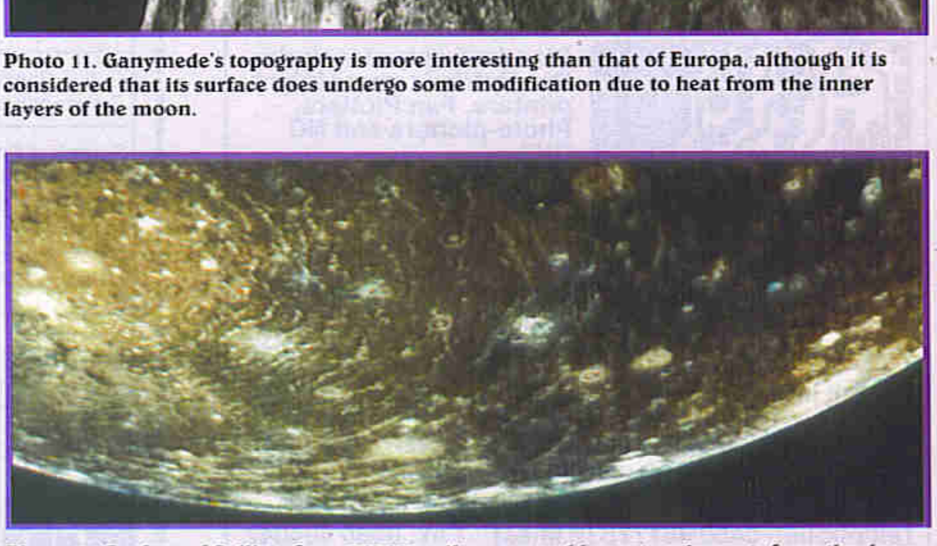


Photo 12. Surface of Callisto from 350,000 miles – scarred by meteor impacts from the dawn of the solar system.

Voyager probes. Voyager 1 took images from a closest distance of 112,030km, and Voyager 2 from only 59,530km. The structure of Ganymede is considered to resemble that of Europa. The crustal layer of ice is probably less than 100km in thickness. While there is evidence of significant earlier surface activity, Ganymede today appears largely inactive.

Photo 11 shows Ganymede's surface from a distance of 151,800 miles, taken by Voyager 2. Features of a size of 1·5 miles can be resolved. Numerous craters with bright ray systems are visible.

Callisto

While the other Galilean moons indicate some degree of present or previous activity, Callisto could be described as the moon where time has stood still since the initial phase of intense bombardment during the first 500 million years of the solar system. The structure of the moon is thought to be a crust of ice, some 200 to 300km thick, with an inner mantle of water or soft ice overlying a silicate core. There is no evidence for reworking of the outer crust of ice, and the level of topography is low.

Some large features, such as a dark region shown in Photo 12, are most likely the result of previous significant asteroid or comet collisions.

Amalthea

In comparison to the Galilean satellites, Amalthea is tiny – only 165 miles long and 102 by 93 miles across. It was discovered by E. E. Barnard in 1892. It was the first Jovian moon to be discovered since the first Galilean satellites were observed in 1610. Both Voyagers succeeded in photographing its bleak details at relatively close range. The surface of Amalthea is quite red, though not as distinctive as Io. It is likely that material ejected from Io has, over time, built up upon Amalthea's surface.

Whether Life?

While the surfaces of Europa, Ganymede and Callisto give the appearance of cold, dead worlds on the surface, the possibility of the existence of layers of water, around a denser silicate core, must give rise to the possibility that some form of low-grade life-form, such as bacteria, could exist there. By analogy, many surprising discoveries have been made on Earth at great depths on the sea floor, where superheated water, rich in mineral nutrients, establishes colonies rich in bacteria. Earth also provides an analogy of the great ice sheets of Antarctica where, on the upper surface of the ice, a barren white desert exists, but, under the ice, the ocean is teeming with life. Perhaps, however, it will never be possible to investigate the inner features of these moons.

Project Galileo

Galileo is a NASA spacecraft mission to Jupiter, designed to send back details of its atmosphere, satellites, and surrounding magnetosphere. Launched aboard the Shuttle Atlantis on 18th October, 1989, it is on track to reach the planet during December 1995. The path of the craft has made use of 'gravity assist' manoeuvres – one with Venus in February 1990, one with Earth during December 1990, and another with Earth during December 1992.

When the craft finally arrives at Jupiter, the atmospheric entry probe will, hopefully, descend through Jupiter's clouds, and send its data to Earth via the orbiter. Following this, the orbiter will proceed to study the giant planet and its attendant moons for a period of two years.

One problem with the craft, however, which has not yet been resolved, is that its main transmitter has not been deployed correctly – a back-up transmitter can only transmit data at a very slow rate of 40Hz. This may greatly impede the usefulness of the entire mission. Hopefully, this can be corrected.

Conclusion

Even though it is some fifteen years since the data of the Voyager missions delighted observers, much of the information that was relayed only served to uncover yet more mysteries. It is unlikely that space flight to other star systems will take place within the next fifty years – perhaps longer if the NASA budget continues to be cut – and it is, therefore, essential that the detail and structure that exists within the solar system should be explored with appropriate diligence.

The rich diversity of the Jovian system provides worlds of great character and uniqueness. Continued scientific study of them is likely to add considerably to our knowledge of the universe as a whole. This will, perhaps, allow us to place more value on our ecosystems, and help us treat them with greater respect. E

3
PROJECT RATING

KIT AVAILABLE (LT69A) PRICE £39.99

Christmas Tree Light Sequencer

Design by Chris Barlow
Text by Chris Barlow and Dean Hodgkins BEng(Hons).

FEATURES

- Three-channel sequential light dimming
- Automatic or manual pattern selection
- Pattern speed and repeat controls
- Opto triac isolated mains control
- 128 stored light patterns
- Filament preheat

Please note that the box shown is not included in the kit and must be purchased separately.

APPLICATIONS

- Christmas tree light controller
- Disco light sequencer
- Show window display lighting

Ever since the introduction of the Christmas tree, people have decorated them with shiny objects, and illuminated them with candles, oil lamps and, more recently, electric filament light bulbs. These long strands of tiny, often highly coloured, lights are woven in and out of the branches of the Christmas tree. It was not too long before electromechanical devices were employed to flash the lights on and off and, with modern electronic circuitry, it is now possible to have a more precise control over the intensity of the light. By using more than one set of Christmas tree lights, interesting combinations and patterns can be formed.

THE unit described in this article, in its standard mode, is capable of driving three separate channels of lights, with up to 100W per channel. This offers the potential to control many sets of Christmas tree lights, arranged in groups of three. When expanded for use with disco lighting, the unit can drive up to 400W per channel.

Circuit Description

In addition to the block diagram detailed in Figure 1, the circuit diagram is shown in Figure 2. This should assist in following the circuit description, or with fault-finding in the completed unit.

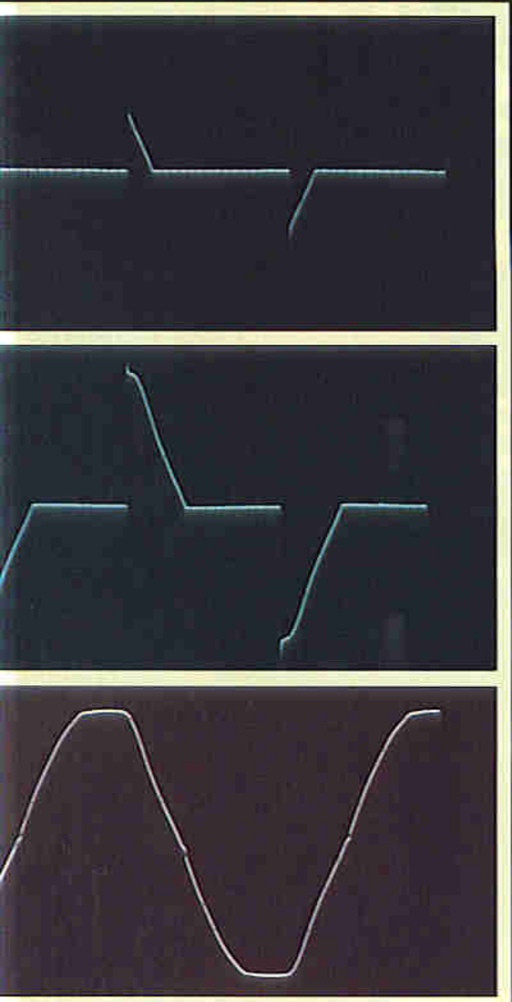
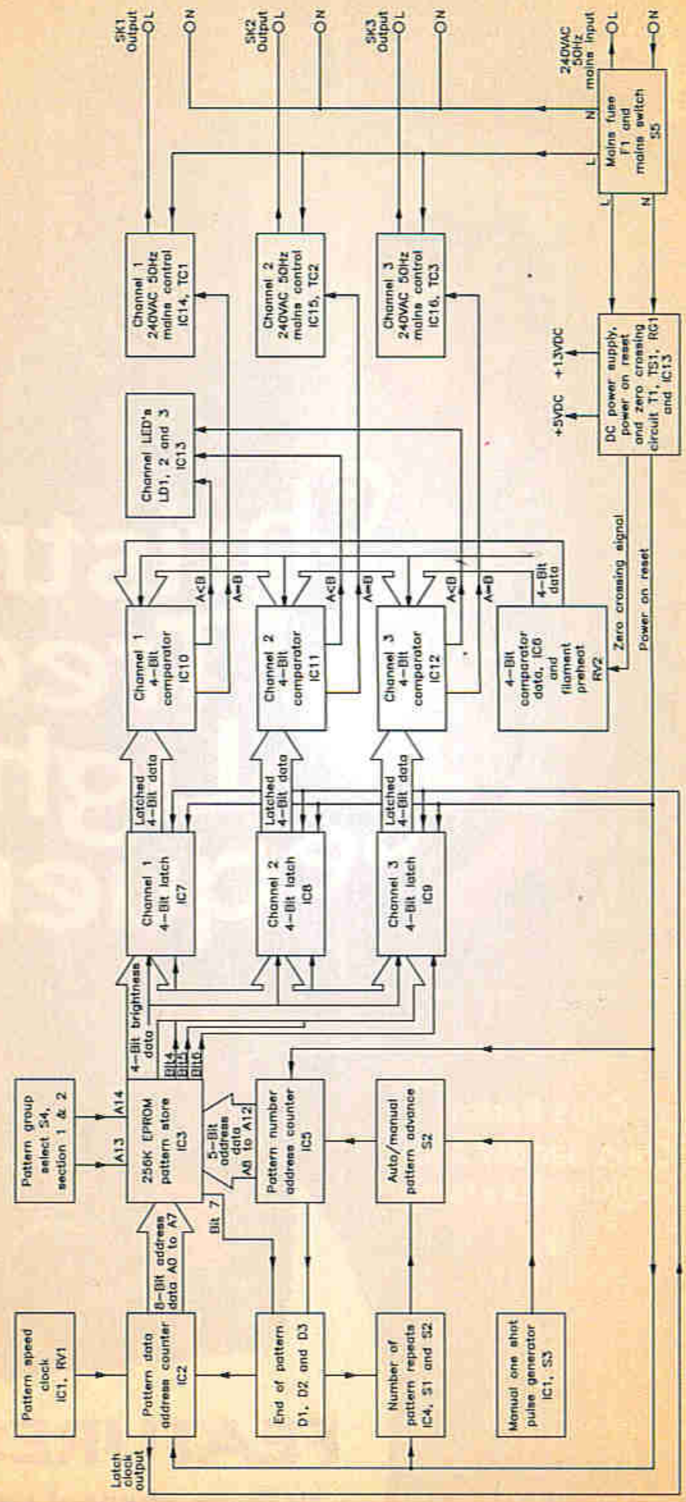


Photo 1. Mains waveforms at different levels of brightness, (top) near minimum (pre-heat); (middle) half; (bottom) maximum.

Figure 1. Block diagram.



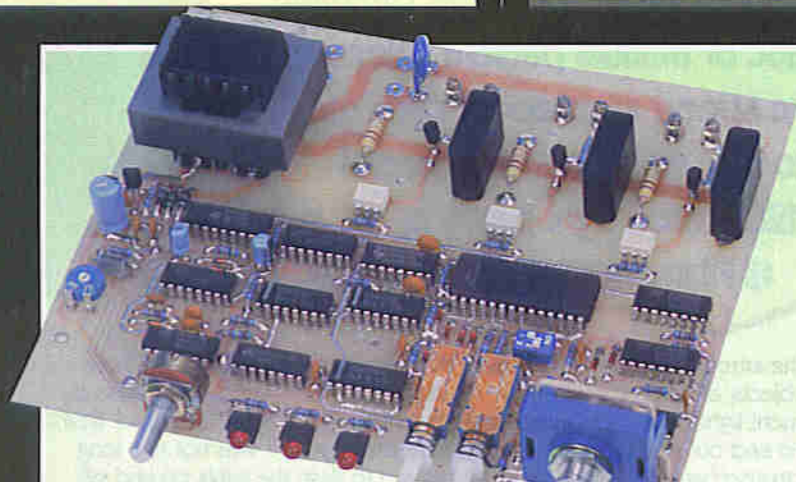


Photo 2. Assembled Prototype PCB: Please note that there are minor differences on the final version due to improvements.

Specification

Supply voltage:	240V AC 50Hz
Supply current:	2A maximum (standard)
	5A maximum (expanded)
Power handling:	100W per channel (standard)
	400W per channel (expanded)
Number of channels:	3
EPROM pattern memory:	256K (32,768 × 8 bit)
Total number of stored patterns:	128
Number of pattern groups:	4
Number of patterns in a group:	32
Number of steps in a pattern:	256
Number of brightness levels:	16
Pattern controls:	Speed
	Auto/Manual pattern selection
	Pattern repeat
PCB dimensions:	170 × 142mm
Case dimensions:	203 × 158 × 65mm

The 240V AC mains input is connected to P1 LIVE and P2 NEUTRAL, with protection of the circuit being afforded by fuse F1, which is fitted in the *Live* side of the mains supply. In its standard (Christmas tree lights) mode, this should be a 2A 20mm quickblow type. However, if you intend using the higher power option, this fuse will have to be increased to a 5A type. The fused protected mains then passes through an illuminated rocker switch, S5, which switches both the Live and Neutral sides of the mains. The switched mains takes two separate paths, one to the triac output circuit, and the other to the primary side of a PCB mounted transformer, T1. This has a transient suppressor, TS1, across it to suppress any high-voltage spikes appearing on the mains

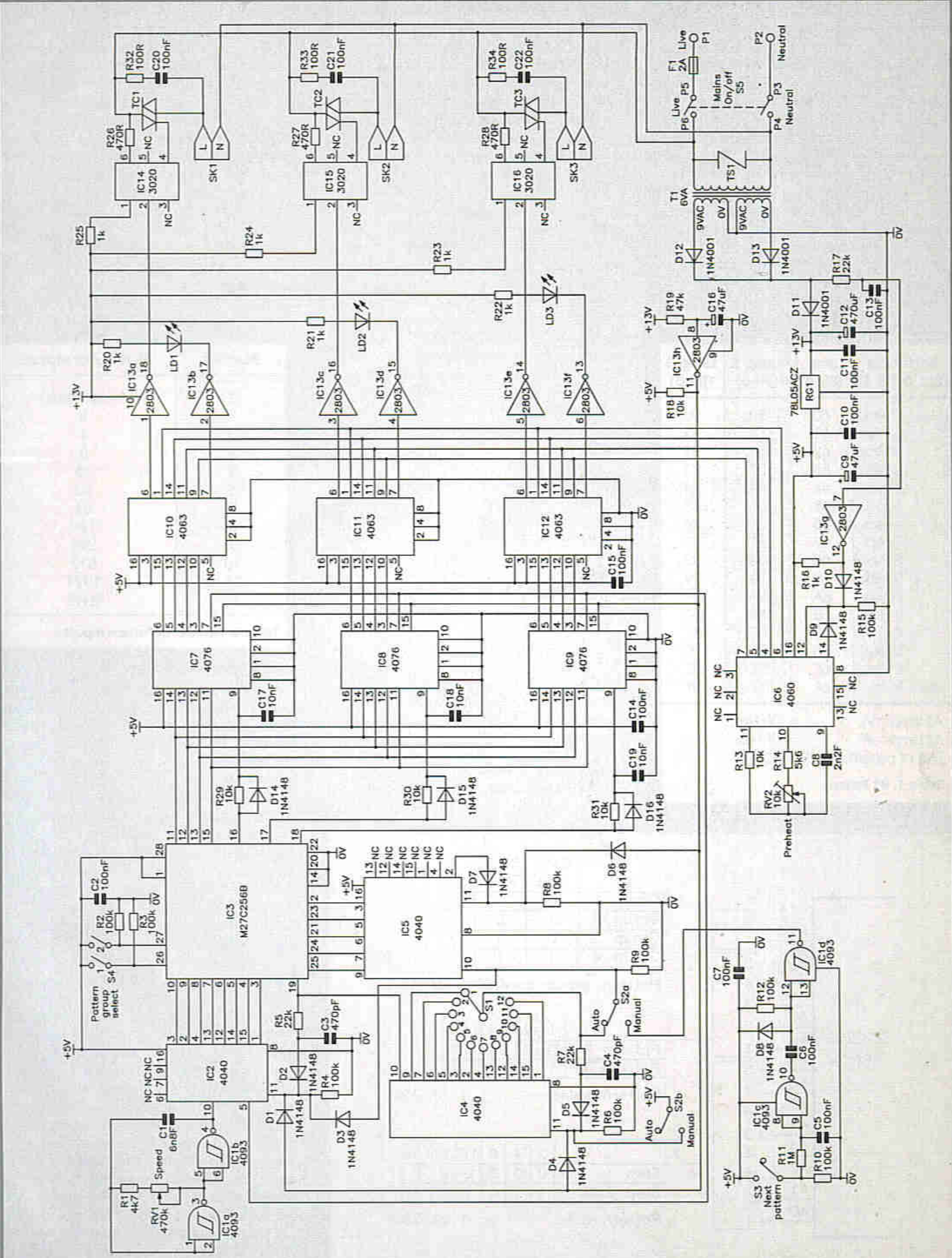


Figure 2. Circuit diagram.

supply. The secondary of T1 provides a low voltage 9-0-9V AC supply, which is full-wave rectified into a DC voltage by diodes D12 and D13. The 100Hz ripple at this point is used to drive the zero crossing circuit via resistor R17 and, to isolate the smoothing effect of the main decoupling capacitor (C12), a diode (D11) is used.

The smoothed, but unregulated, +13V DC supply across C12 is used to drive the channel LEDs (LD1 to 3) and the optoisolator triacs (IC14 to 16). It also feeds the input of voltage regulator RG1 to provide a stable +5V DC supply for the logic circuits. Decoupling capacitors (C9 and C10) serve to remove any noise and interference from the +5V supply.

At switch-on, a reset pulse is generated by R19, C16, and IC13h (pins 8 and 11). This is used to reset all of the ripple counters, and latches, to their initial states.

The 100Hz signal from R17 is applied to the input of IC13g (pin 7), which produces a zero crossing signal at its output (pin 12). This is used to reset IC6 (a 14-stage ripple counter and oscillator) at each half cycle of the mains. The frequency of the oscillator is set by the combined values of R13,14, RV2, and C8. Its frequency range is, approximately, from 9·6kHz to 19·5kHz, measured on pin 11, and has the effect of setting the filament preheat level – filament preheat means that a small current is still flowing through the bulbs, even when they are not illuminated (the filament may have a slight glow, though). This serves to reduce the 'thermal shock' as a bulb is turned hard on, hence reducing the chances of it 'blowing'. Back in the design labs, during testing, not a single Christmas tree bulb blew (and we all know how notorious Christmas tree bulbs can be!).

Brightness (Bits 0 1 2 3)	Lamp 1 (Bit 4)	Lamp 2 (Bit 5)	Lamp 3 (Bit 6)
Max. 0 Hex	60	50	30
1 Hex	61	51	31
2 Hex	62	52	32
3 Hex	63	53	33
4 Hex	64	54	34
5 Hex	65	55	35
6 Hex	66	56	36
7 Hex	67	57	37
8 Hex	68	58	38
9 Hex	69	59	39
A Hex	6A	5A	3A
B Hex	6B	5B	3B
C Hex	6C	5C	3C
D Hex	6D	5D	3D
E Hex	6E	5E	3E
Min. F Hex	6F	5F	3F

All lamps on = 00 Hex
All lamps off = 0F Hex
End of pattern (bit 7) = 80 Hex

Table 1. Bit Pattern.

The 4-bit binary count output, on pins 7, 5, 4 and 6, is fed to one set of inputs of the logic comparator ICs, IC10-12. With this 4-bit code, a hexadecimal number from 0 to F can be represented, and a fifth bit, on pin 14, is used to reset the count. The second set of 4-bit data required by the comparator ICs is stored within a 256K EPROM, IC3, which uses a number of other ICs to access this data.

The data stored inside the EPROM is organised into distinct groups, which must be accessed with the correct memory address. The address is made up from a 15-bit code, A0 to A14 (see Figure 3). The main light pattern group select uses bits A13 and A14, which are manually switched by S4, sections 1 and 2. When both sections are 'off', pattern group 1 is selected. With both sections 'on', group 4 is selected, etc. The five address bits, A8 to A12, are used to select one of the 32 given light patterns within the selected group. The remaining 8 address bits, A0 to A7, are used to access each of the possible 256 individual steps of a given light pattern.

The speed at which the individual steps are accessed is governed by the frequency of the master clock signal, which is generated by IC1a & b. This frequency is set by the value of capacitor C1, and the combined values of the two resistors R1 and RV1. Its frequency range is, approximately, from 160Hz to 12·6kHz, measured on pin 4 of IC1b. It has the effect of setting the overall rate of change of the light pattern.

The output from IC1b drives the clock input (pin 10) of IC2, a 12-stage ripple counter, which is used to generate the 8-bit code required to sequence through a selected light pattern. As IC2 steps through its memory locations, the light pattern is reproduced from the EPROM IC3, see Table 1. The pattern appears as a stream of 8-bit data values on pins 11 to 13, and 15 to 19. The first four bits (0, 1, 2, 3) represent the 16 hexadecimal brightness levels of the light bulb, Photo 1 shows the mains waveform at near minimum, half and maximum brightness. The next three bits (4, 5, 6), when logic low, select which of the three lamp channels are to be set to that brightness level. Finally, bit 7, when logic high, is used to indicate when the end of a pattern is reached; at this stage, the pattern is either repeated, or the next pattern in the sequence is selected.

A second 12-stage ripple counter, IC4, is used to count the number of times a pattern is to be repeated before the next one in the sequence is automatically selected.

Position	Number of repeats
1	1 (no repeat)
2	2
3	4
4	8
5	16
6	32
7	64
8	128
9	256
10	512
11	1024
12	2048

Table 2. Number of Pattern repeats.

The number of repeats is determined by the position of the 12-way rotary switch S1, see Table 2. The output pulse from IC4 drives the clock input (pin 10) of yet another 12-stage ripple counter, IC5, which generates the 5-bit address code for the 32 pattern selections (see Table 3).

If an automatic pattern change is not desired, switch S2 can be activated to select manual pattern advance. A manual one-shot pulse is generated every time S3 is pushed. This is achieved by a simple debounce circuit, comprising IC1c & d, with the output pulse appearing on pin 11.

Each step of the three-channel light control data is held by 4-bit latch ICs (IC7-9). This data is fed to the logic comparator ICs (IC10-12). When the 4-bit brightness data is compared to the 4-bit count from IC6, two of the three outputs from the comparators are utilised. The A < B output on pin 7 is used as a PWM drive to the local LED indicators (LD1-3); the PWM signal makes the LEDs follow the perceived intensity of the mains lights. The A = B output on pin 6 is used to drive the optoisolator triacs (IC14-16). A triac trigger pulse will occur *at a moment in time* which is referenced to the zero crossing point. Depending upon its timing, more or less of the mains waveform will be switched by the triacs (TC1-3). Snubber networks, comprising R32-34 and C20-22, help to prevent mains noise or interference, and protect the triacs from

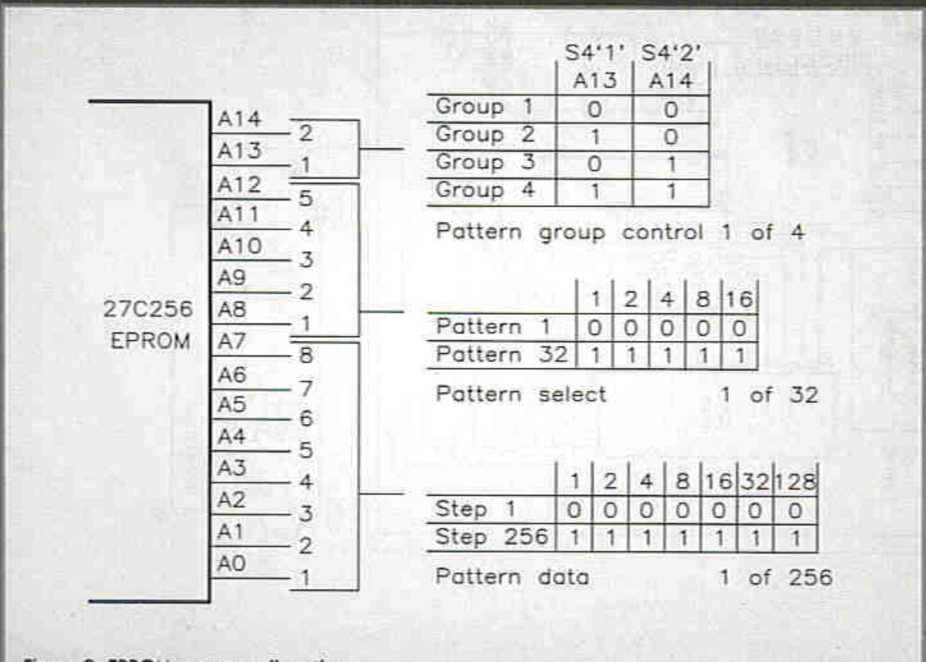


Figure 3. EPROM memory allocations.

switching spikes. The three controlled mains outputs are as follows:

Channel 1 = SK1
Channel 2 = SK2
Channel 3 = SK3

Note that R26 to 28 and R32 to 34 are rated at 2W; this is not due to power dissipation requirements, but simply because 2W resistors have a higher voltage rating than the standard 0·6W metal film resistors, used elsewhere in the unit.

PCB Construction

The assembled PCB is shown in Photo 2. The PCB is a double-sided fibreglass type, chosen for maximum reliability and stability. However, removal of a misplaced component is quite difficult, so double-check each component's type and value (and polarity where appropriate) before soldering! If you require additional information about soldering and assembly techniques, they can be found in the 'Constructors' Guide' (XH79L). The PCB has a printed legend (see Figure 4) to assist you in correctly positioning each item.

The sequence in which the components are placed is not critical, but it is easier to start with the smaller components such as resistors (R1 to R34 and RV2), followed by the ceramic, polyester layer and electrolytic capacitors. The polarity for the electrolytic capacitors is shown by a plus sign (+) on the PCB legend. However, the majority of electrolytic capacitors have the polarity designated by a negative symbol (–), in which case the lead nearest this symbol goes away from the positive sign on the legend.

The transient suppressor, TS1, looks like a large resin-dipped disc ceramic capacitor. *Make certain to correctly identify this component before installing it!*

The diodes (D1 to D13) have a band at one end to identify the cathode (K) lead. The legend shows the diode positions with a symbol like a resistor, but with the prefix 'D'. The symbol also has a bar across one end, this is where the cathode is placed.

Three small CP206D triacs (TC1 to 3) are supplied with the standard kit. However, if you wish to construct the expanded, higher power disco version, then these must be replaced by the larger BTA08-600B triacs, which are mounted on heatsinks. The legend shows both sets of package outlines; make sure that you select the appropriate one!

Next, install the voltage regulator RG1, making sure that its outline corresponds to the package outline on the legend. When fitting the IC sockets, ensure that you match the notch with the block on the board. Note that no 6-pin IC sockets are used in positions IC14 to 16. Install the ICs making certain that all the pins go into the socket, with the pin 1 marker at the notched end. The optoisolator triacs (ICs 14 to 16) are soldered directly into the PCB – try not to keep the soldering iron in contact with the device leads for longer than two seconds. Remember to observe the standard antistatic precautions before you handle the ICs – ensure that you touch an 'earthed' conductor (e.g., domestic water pipes) to remove any static charge which you may have accumulated.

Before fitting the manual pattern advance switch (S3), you must first convert it from

Group 1 (S4: 1 off; 2 off) = lamp 1 only; lamps 2 and 3 are off

Pattern Number	Memory Location	Pattern Description
1	0000-00FF	1 on/off medium speed
2	0100-01FF	1 random levels
3	0200-02FF	1 on/off slow speed
4	0300-03FF	1 up/down
5	0400-04FF	1 positive pulse medium speed
6	0500-05FF	1 up/off and on/down
7	0600-06FF	1 half on/full on fast speed
8	0700-07FF	1 on/off slow, medium and fast speeds
9	0800-08FF	1 random on/off
10	0900-09FF	1 negative pulse fast speed
11	0A00-0AFF	1 up/hold/down
12	0B00-0BFF	1 Morse code message 'MERRY XMAS'
13	0C00-0CFF	1 half on/up/hold/down
14	0D00-0DFF	1 on/off fast speed
15	0E00-0EFF	1 up/off
16	0F00-0FFF	1 half on/random on
17	1000-10FF	1 positive pulse fast speed
18	1100-11FF	1 on/down
19	1200-12FF	1 negative pulse slow speed
20	1300-13FF	1 on/off one short, one long
21	1400-14FF	1 up/hold/up/hold/down/hold/down
22	1500-15FF	1 positive pulse slow speed
23	1600-16FF	1 random up/down
24	1700-17FF	1 up/down/on/off
25	1800-18FF	1 on for long duration/down/up
26	1900-19FF	1 half on random up/down
27	1A00-1AFF	1 on, no pattern
28	1B00-1BFF	1 half on/full on medium speed
29	1C00-1CFF	1 half on/random off
30	1D00-1DFF	1 up/down slow, medium and fast speeds
31	1E00-1EFF	1 negative pulse medium speed
32	1F00-1FFF	1 half on/full on slow speed

Table 3a. Pattern memory locations (Group 1).

Group 2 (S4: 1 on; 2 off) = lamps 1 and 2; lamp 3 is off

Pattern Number	Memory Location	Pattern Description
1	2000-20FF	1 and 2 up/down
2	2100-21FF	1 and 2 on; 1 and 2 down
3	2200-22FF	1 and 2 random levels
4	2300-23FF	1 and 2 on; 2 down/up × 2; 1 down/up × 2
5	2400-24FF	1, 2 up; 2, 1 down
6	2500-25FF	1, 2 negative pulse
7	2600-26FF	1 and 2 on; 2 then 1 down
8	2700-27FF	1 and 2 half on/down/up
9	2800-28FF	2 then 1 up; 1 then 2 down
10	2900-29FF	2 on/off x 2; 1 on/off x 2
11	2A00-2AFF	1 and 2 positive pulse
12	2B00-2BFF	1, 2 on/off; slow/medium/fast
13	2C00-2CFF	1, 2 positive pulse
14	2D00-2DFF	1, 2 up/down overlapping
15	2E00-2EFF	1 and 2 off; 2, 1 up
16	2F00-2FFF	2 up/down x 2; 1 up/down x 2
17	3000-30FF	1, 2 up/down
18	3100-31FF	1, 2 off/half on
19	3200-32FF	1 and 2 up; 1 and 2 off
20	3300-33FF	1, 2 on/off
21	3400-34FF	1 and 2 negative pulse
22	3500-35FF	2, 1 off/on long and short x 2
23	3600-36FF	1 and 2 on; 1 and 2 down
24	3700-37FF	1 and 2 half on; 1, 2 up/down
25	3800-38FF	1 and 2 off; 1, 2 up
26	3900-39FF	1 up/down; 1 up/down overlapping 2 up/down
27	3A00-3AFF	1, 2 on; 1, 2 off
28	3B00-3BFF	1, 2 up/down slow, medium and fast
29	3C00-3CFF	1 and 2 on; 2, 1 down; 1, 2 up
30	3D00-3DFF	1 and 2 half on; 1, 2 up/down slow and fast
31	3E00-3EFF	1, 2 up/down overlapping slow and fast
32	3F00-3FFF	1, 2 on/half on

Table 3b. Pattern memory locations (Group 2).

Group 3 (S4: 1 off; 2 on) = lamps 1, 2 and 3		
Pattern Number	**Memory Location**	**Pattern Description**
1	4000-40FF	1, 2, 3 up/down
2	4100-41FF	1, 2 and 3 random levels
3	4200-42FF	1 and 3, then 2 up/down overlapping
4	4300-43FF	All half on; 1, 2, 3, 2, 1 up/down
5	4400-44FF	3, 2, 1 up/down overlapping
6	4500-45FF	1, 2, 3 on/off
7	4600-46FF	1, 2, 3 up; all off
8	4700-47FF	All up/down
9	4800-48FF	All half on; 3, 2, 1 up
10	4900-49FF	1, 2, 3 up/down overlapping
11	4A00-4AFF	All on; 3, 2, 1 off/on
12	4B00-4BFF	All on; 1, 2, 3 down
13	4C00-4CFF	All off; all up
14	4D00-4DFF	All on; 1, 2, 3 down/up
15	4E00-4EFF	1 and 3, then 2 up/down
16	4F00-4FFF	3, 2, 1 up; 1, 2, 3 down
17	5000-50FF	All on; 1, 2, 3, 2 down/up
18	5100-51FF	All half on; 1, 2, 3 up/down
19	5200-52FF	All half on; 3, 2, 1 up/down
20	5300-53FF	1, 2, 3, 2 up/down
21	5400-54FF	3, 2, 1 up; 3, 2, 1 down
22	5500-55FF	1, 2, 3 up; 3, 2, 1 down
23	5600-56FF	All on; 3, 2, 1 down/up
24	5700-57FF	1, 2, 3 on/off fast
25	5800-58FF	1, 2, 3, 2, 1 up/down overlapping
26	5900-59FF	All half on; 1 and 3, then 2 up/down
27	5A00-5AFF	All half on; 1, 2, 3 up
28	5B00-5BFF	3, 2, 1 on/off fast
29	5C00-5CFF	1, 2, 3 up; 1, 2, 3 down
30	5D00-5DFF	All on; all down
31	5E00-5EFF	All off; 3, 2, 1 up
32	5F00-5FFF	All on; 3, 2, 1 down

Table 3c. Pattern memory locations (Group 3).

Group 4 (S4: 1 on; 2 on) = lamps 1, 2 and 3 test patterns		
Pattern Number	**Memory Location**	**Pattern Description**
1	6000-60FF	Lamps 1, 2 and 3 off (filament preheat)
2	6100-61FF	Lamps 1, 2 and 3 brightness level 1
3	6200-62FF	Lamps 1, 2 and 3 brightness level 2
4	6300-63FF	Lamps 1, 2 and 3 brightness level 3
5	6400-64FF	Lamps 1, 2 and 3 brightness level 4
6	6500-65FF	Lamps 1, 2 and 3 brightness level 5
7	6600-66FF	Lamps 1, 2 and 3 brightness level 6
8	6700-67FF	Lamps 1, 2 and 3 brightness level 7
9	6800-68FF	Lamps 1, 2 and 3 brightness level 8
10	6900-69FF	Lamps 1, 2 and 3 brightness level 9
11	6A00-6AFF	Lamps 1, 2 and 3 brightness level 10
12	6B00-6BFF	Lamps 1, 2 and 3 brightness level 11
13	6C00-6CFF	Lamps 1, 2 and 3 brightness level 12
14	6D00-6DFF	Lamps 1, 2 and 3 brightness level 13
15	6E00-6EFF	Lamps 1, 2 and 3 brightness level 14
16	6F00-6FFF	Lamps 1, 2 and 3 brightness level 15
17	7000-70FF	Lamp 1 on; lamp 2 off; lamp 3 off
18	7100-71FF	Lamp 1 off; lamp 2 on; lamp 3 off
19	7200-72FF	Lamp 1 off; lamp 2 off; lamp 3 on
20	7300-73FF	Lamps 1 and 2 on; lamp 3 off
21	7400-74FF	Lamps 1, 2 and 3 on
22	7500-75FF	Lamp 1 up/down; lamps 2 and 3 off
23	7600-76FF	Lamp 1 off; lamp 2 up/down; lamp 3 off
24	7700-77FF	Lamps 1 and 2 off; lamp 3 up/down
25	7800-78FF	Lamps 1, 2 and 3 up/down
26	7900-79FF	Lamp 1 on/off; lamps 2 and 3 off
27	7A00-7AFF	Lamp 1 off; lamp 2 on/off; lamp 3 off
28	7B00-7BFF	Lamp 1 off; lamp 2 off; lamp 3 on/off
29	7C00-7CFF	Lamps 1, 2 and 3 on/off
30	7D00-7DFF	Lamps 1, 2 and 3 on/off binary count
31	7E00-7EFF	Lamps 1, 2 and 3 random levels
32	7F00-7FFF	Lamps 1, 2 and 3 random on/off

Table 3d. Pattern memory locations (Group 4).

locking to non-locking operation. A special nylon retainer clip is supplied with the switch, which replaces the wire retainer, converting it to momentary non-locking action (see Figure 5). When the retainer clip is removed, the plunger will be forced out by the spring, so ensure that it is held in firmly.

When fitting the PCB mounted switches (S1 to 4), make certain that they are pushed down firmly onto the surface of the board. The 12-way rotary switch, S1, has two mounting pillars, and fixing screws under its body to ensure a rigid support to the PCB (see Figure 6). This switch has a nut and shakeproof washer; if these are removed, a metal ring, which governs the number of positions in which the switch can be set (the stop-ring), is revealed. This ring must be removed and discarded to allow the switch to obtain its maximum of 12 positions. Put the washer and nut back on, and then rotate the switch shaft to its fully anticlockwise position. When fitting the PCB mounted LEDs, and speed control, RV1, again ensure that they are pushed down firmly onto the surface of the PCB (see Photo 3).

Mount the three terminal blocks, SK1 to 3, ensuring that the outputs face towards the outside edge of the board, as shown in Figure 7.

Due to the pattern of terminal pins on transformer T1, it will only fit onto the PCB in one way. However, make certain that it is pushed down firmly onto board's surface.

Next, insert the fuse holder, and fit the appropriate fuse, either 2A or 5A depending upon application. Finally, fit the fuse block cover, as shown in Photo 4.

Finally, set RV2 to its halfway position. This completes the assembly of the PCB. You should now check your work very carefully, making sure that all the solder joints are sound; it is also very important that the solder side of the circuit board does not have any trimmed component leads standing proud by more than 2mm, as this may result in a short circuit. Remove any flux from the PCB by using a suitable solvent.

Box Preparation

The Christmas tree light sequencer PCB assembly is designed to fit into a two-part ABS plastic box (type H2505) (Stock Code BZ76H). Remove the top from the case and set it aside. Next, remove the front and back panels from the base of the box. The self-adhesive labels (see Figures 8 to 10) can be used as a guide for checking the positioning of holes in the front and back panels. The unit can be constructed for use with a simple grommet cable outlet (for Christmas tree lights), or Euro connectors (for disco lighting). Follow the drilling instructions in Figures 11, and 12 or 13. Having drilled the appropriate set of holes, and cleared them of any swarf, clean the panels ready for the self-adhesive labels. Cut out the front panel label by using scissors or a sharp craft knife and the selected rear panel label then remove the protective backing from each. Carefully position the labels, and push down firmly using a dry, clean cloth, until they are securely in place.

The base of the box has several mounting pillars for fixing circuit boards in place. As can be seen from Figure 14, only six of these are required, and the unused pillars should be cut off using a pair of side cutters.

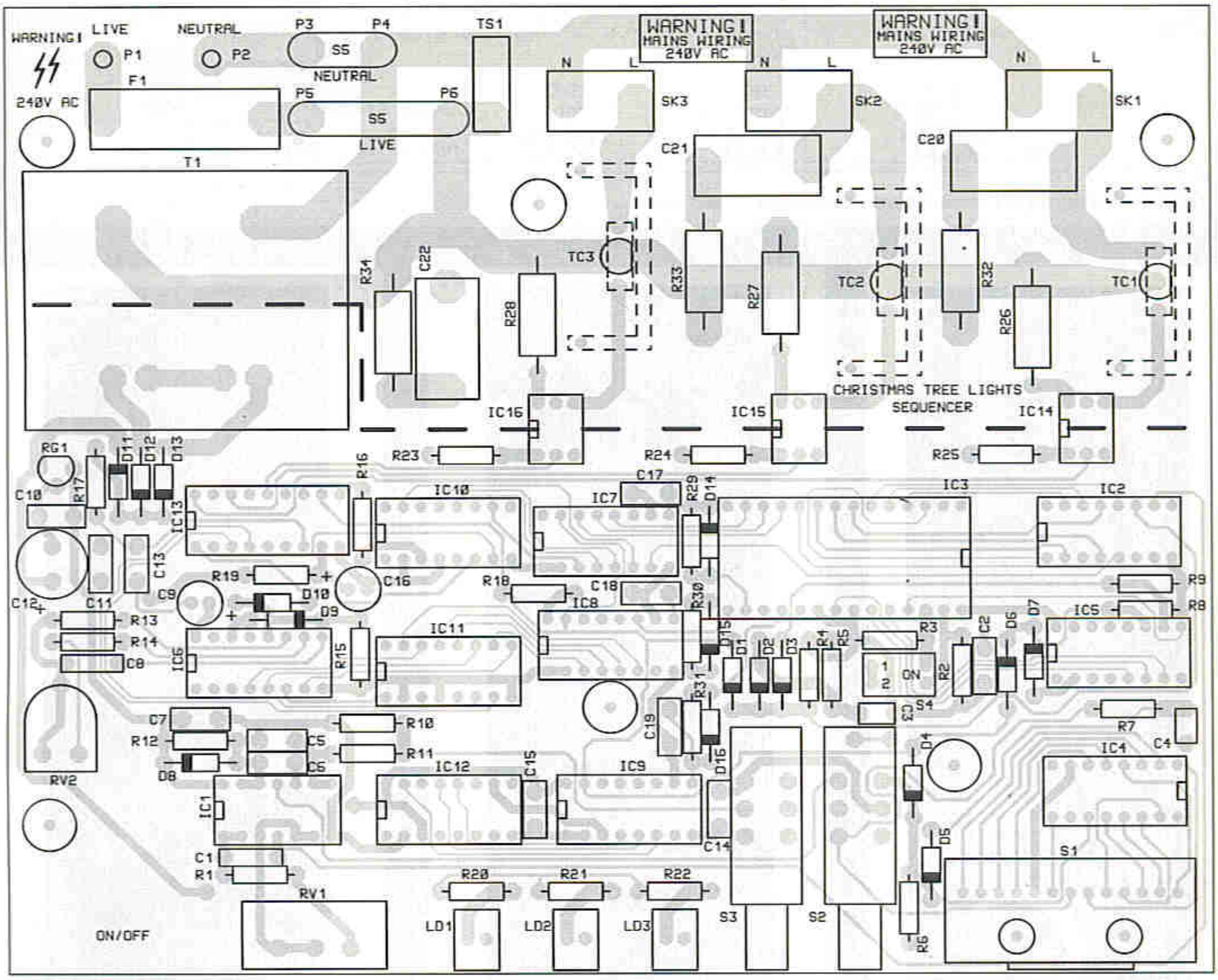


Figure 4. PCB legend and track.

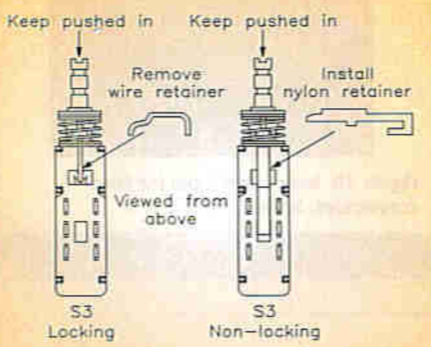


Figure 5. Preparing switch S3 for momentary action.

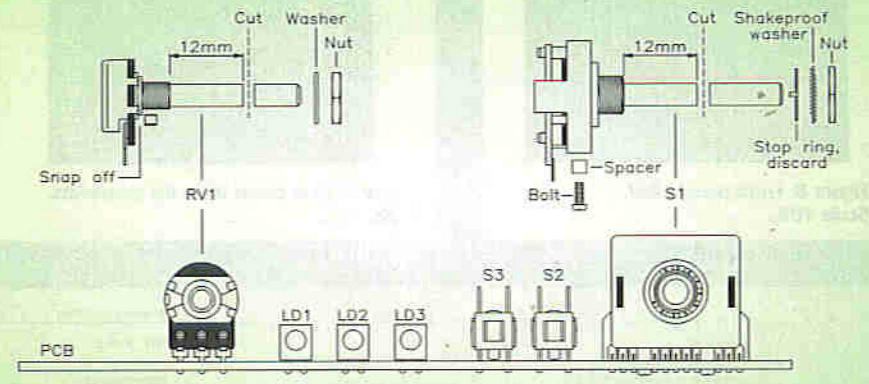


Figure 6. Mounting the PCB switches, LEDs, and RV1.

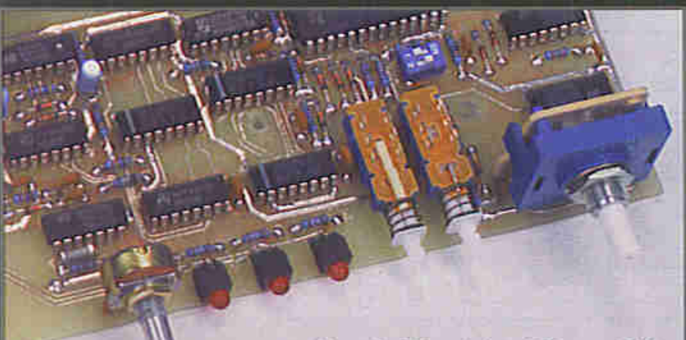


Photo 3. PCB switches, LEDs, and RV1.

Photo 4. Transformer T1, and fuse F1.

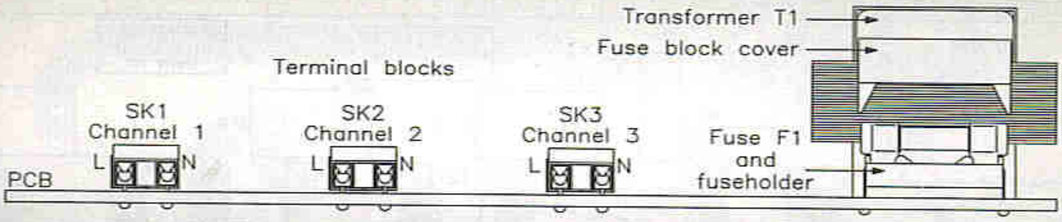


Figure 7. Mounting the PCB terminal blocks, transformer T1, and fuse F1.

Figure 8. Front panel label. Scale 70%.

Figure 9. Rear panel label for grommets. Scale 70%.

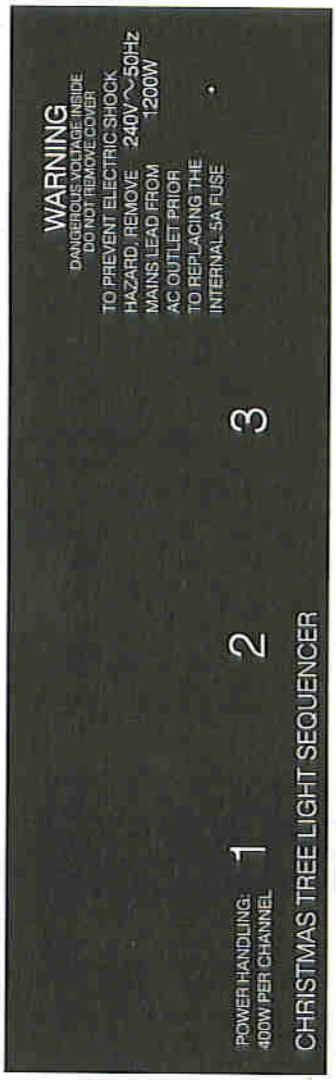


Figure 10. Rear panel label for Euro connectors. Scale 70%.

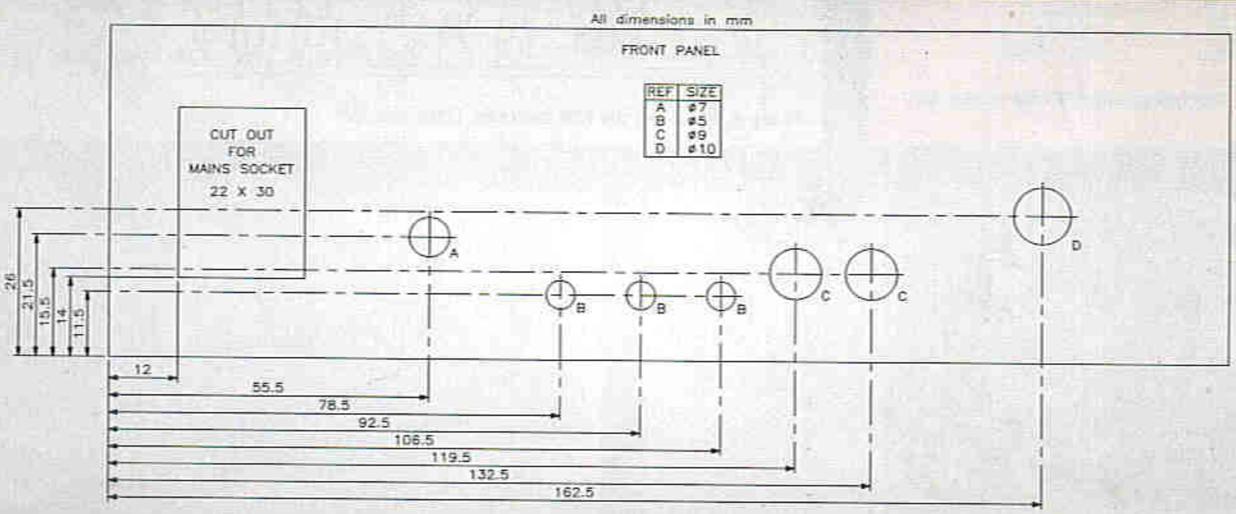


Figure 11. Front panel drilling.

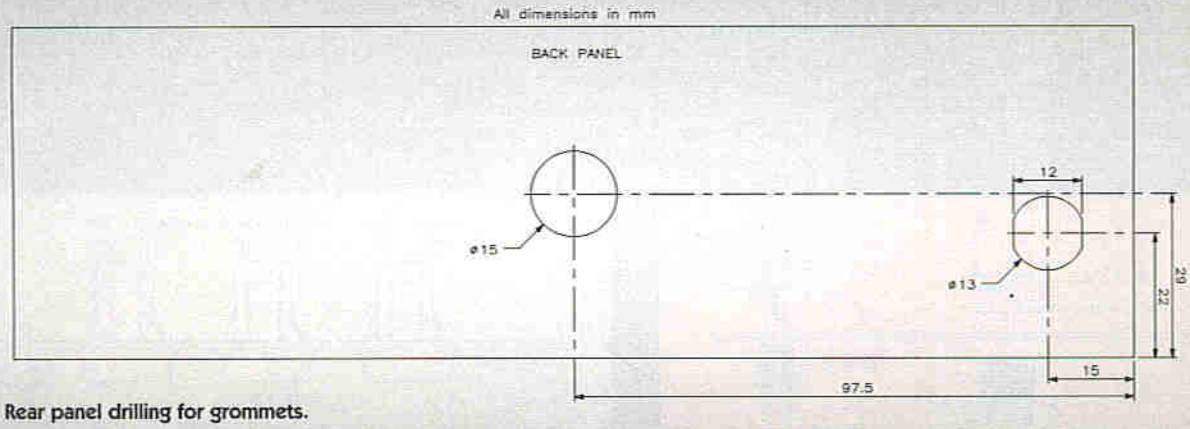


Figure 12. Rear panel drilling for grommets.

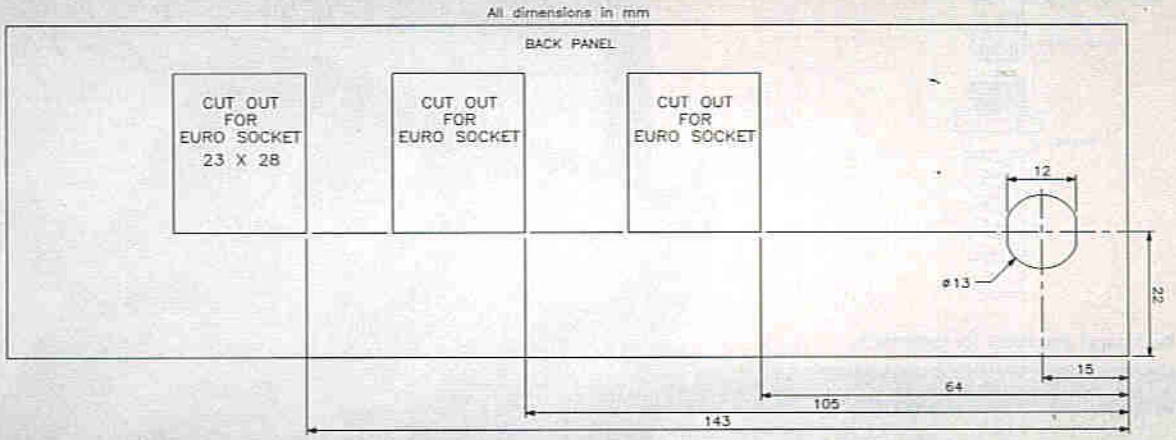


Figure 13. Rear panel drilling for Euro connectors.

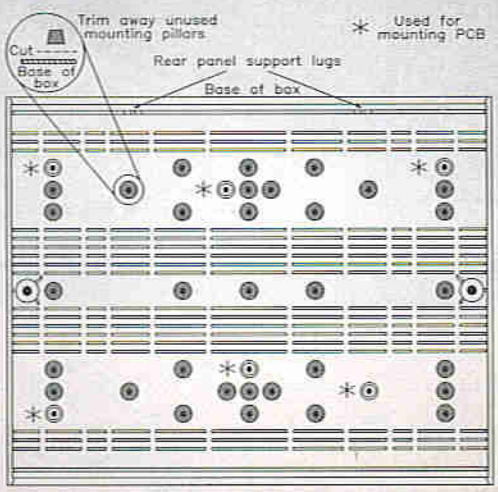


Figure 14. Base mounting pillars.

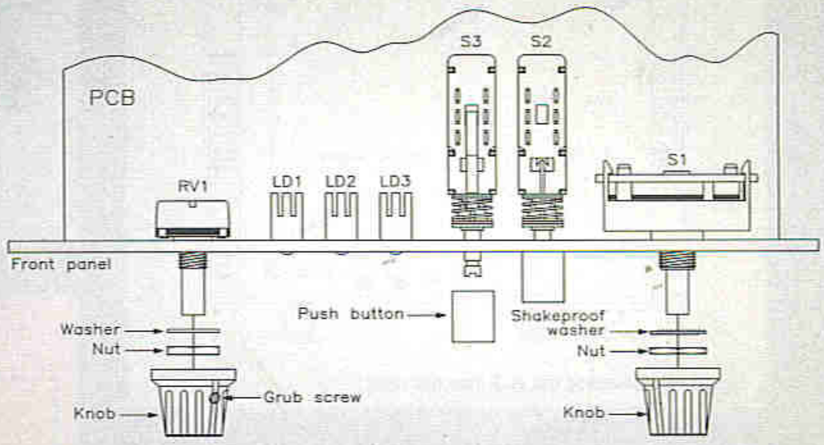


Figure 15. Front panel assembly.

Final Assembly

Before mounting the front panel to the PCB assembly, cut the shafts of RV1 and S1 to a length of 12mm. Ensure that the nut and shakeproof washers are removed from these controls. Next, fit the front panel to the controls using the shakeproof washers and nuts provided (see Figure 15). *Do not* fit the red neon power on/off switch, S5, at this time! Secure the knobs so that their pointers are at the fully anticlockwise position, and check that they travel smoothly round to the fully clockwise position, without scraping on the front panel. Next, fit the two round push-buttons onto the plungers of S2 and S3. Lower the unit into the bottom half of the case, ensuring that the front panel slides smoothly into place, and all the fixing holes in the PCB line up with the mounting points. *Do not* fit the fixing screws at this stage.

The amount of wiring has been kept to a minimum by using PCB mounted switches, indicators and connectors, leaving only off-board mains wiring. Prepare the twin 6A mains cable, and fit it through the strain relief grommet into the appropriate hole in the rear panel. Simply squeeze it closed and snap it in place. Note that this part is common to both rear panel assemblies (see Figures 16 and 17). *Do not* fit the 13A mains plug onto the other end of this cable until it is required during the testing stage. Remove the circuit board, and solder the brown Live wire to P1, and the blue Neutral wire to P2, on the PCB assembly.

Depending upon the application chosen (Christmas tree or disco lights), you should now complete the assembly of the rear panel. For the simple cable exit gland, used for Christmas tree lights, follow the instructions shown in Figure 16. If, however, the disco lights option is required, then the more appropriate Euro connectors must be used, and Figure 17 should be followed. The wiring to the mains power on/off switch, S5, which should now be prepared is common to both. Do *not* fit this switch until it is required.

Refit the circuit board into the bottom half of the case and secure it with six No. 4 × ¼in. self-tapping screws (see Figure 18).

Now, fit the mains power switch, S5, to the front panel, and push on the receptacle connectors, with their covers, as shown in Figure 19 (for grommets) or Figure 20 (for Euro connectors).

The remaining mains wiring for the grommet version are the cables from the Christmas tree lights, which pass through the exit gland to the terminal blocks SK1 to 3, as shown in Figure 19. For the disco version, the remaining mains wiring is between the three Euro connectors and the PCB terminal blocks SK1 to 3 (see Figure 20). Photo 6 shows how the connectors fit neatly between the triac heatsinks.

This completes the assembly and wiring of the unit. You should now check your work very carefully making sure that all the solder joints and terminal block connections are sound. Do not fit the lid of the case until the testing stage has been successfully completed.

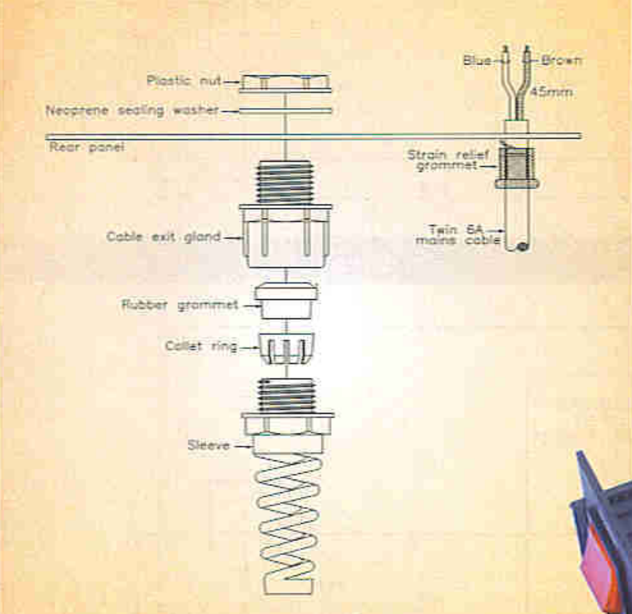


Figure 16. Rear panel assembly for grommets.

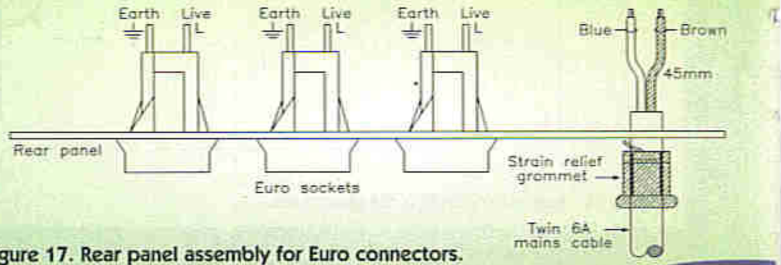


Figure 17. Rear panel assembly for Euro connectors.

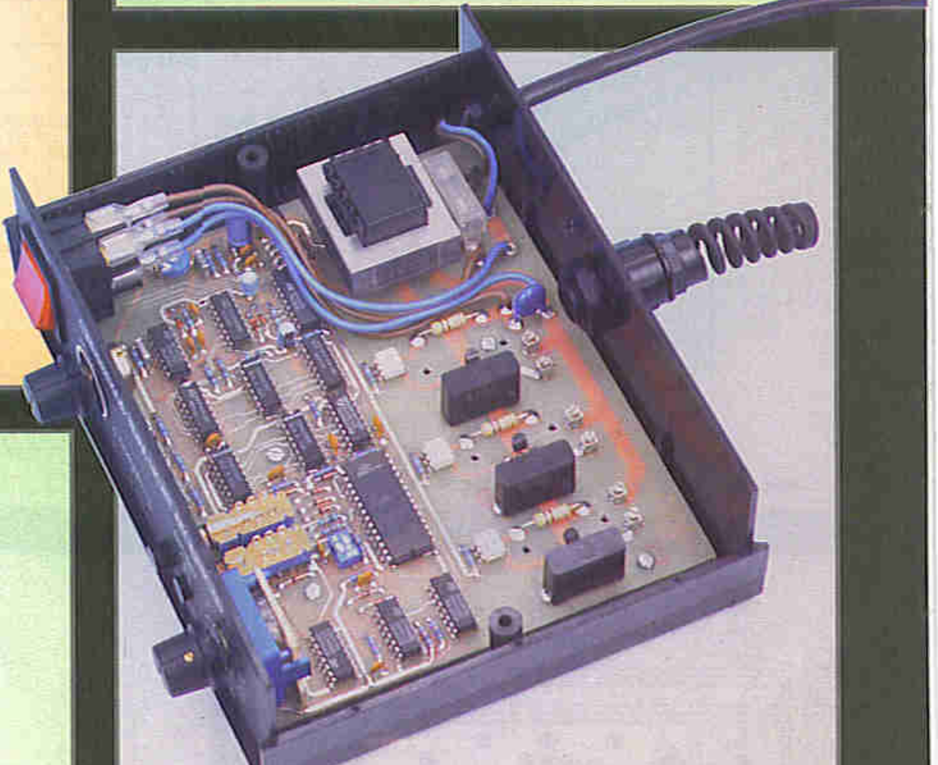


Photo 5. The PCB in its case; grommet option.

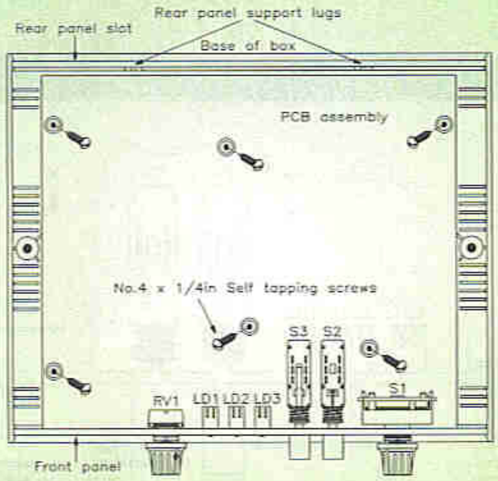
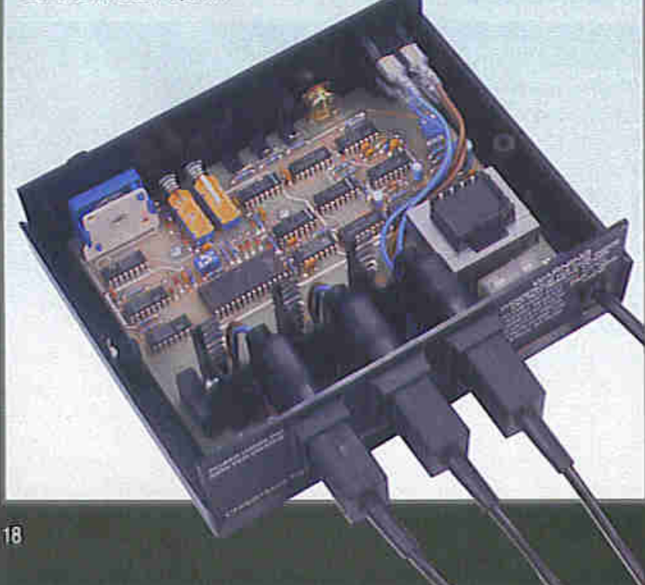


Figure 18. Mounting the PCB into the case.

Photo 6. The PCB in its case; Euro connector option.



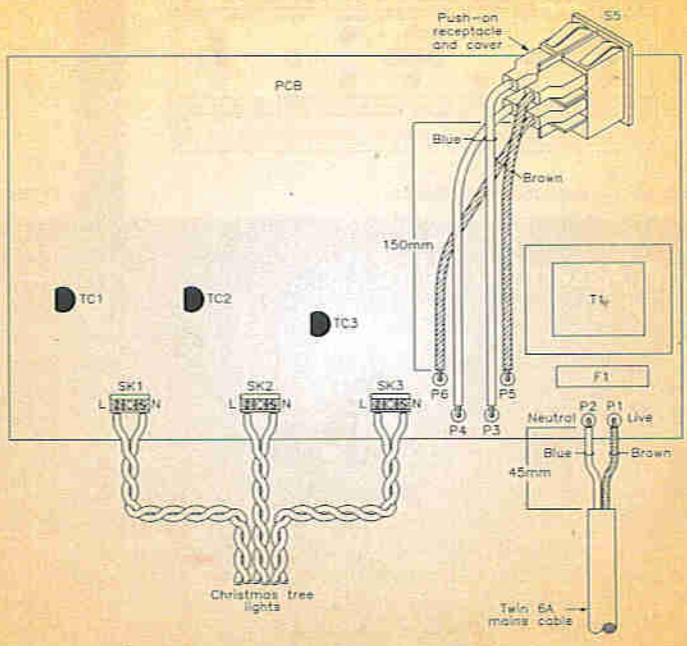


Figure 19. 240V AC mains wiring for grommets.

Important Safety Note:

It is important to note that mains voltage is potentially lethal. Full details of mains wiring connections are shown in this article, and every possible precaution must be taken to avoid the risk of electric shock during maintenance and use of the final unit. Safe construction of the unit is entirely dependent on the skill of the constructor, and adherence to the instructions given in this article. If in any doubt as to the correct way to proceed, seek advice from a qualified engineer.

Testing

All the tests can be made with a minimum of equipment. You will need a multimeter, some Christmas tree or disco lights, and a 240V AC mains supply. All of the following readings were taken from the prototype, using a digital multimeter; some of the readings you obtain may vary slightly, depending upon the type of meter used!

Attach a 13A three-pin mains plug to the 6A power cable, replacing the 13A fuse with a 5A fuse. *Note that the earth pin is NOT used with this unit.* Do not plug the unit into the 240V AC mains supply until you are instructed to do so.

Before testing the unit, set the front panel controls to the following positions:

1) Set the mains power switch, S5, to its OFF position.
2) Set the speed control, RV1, fully anticlockwise – slow speed.
3) Press in the pattern select switch, S2, to select manual mode.
4) Set the pattern repeat switch, S1, fully anticlockwise (no repeats).

Make certain that the PCB controls are set as follows:

1) Set the filament preheat control, RV2, to its halfway position.
2) Set switch S4, sections 1 and 2, both on to select group 4 (the test patterns).

Check that the mains lamps are wired correctly.

The first tests are to ensure that there are no short circuits before you connect the mains power supply. Set your multimeter to read OHMS on its resistance range, and connect the test probes to the Live and Neutral pins of the mains plug. Until the power switch, S5, is switched on, a reading of infinite resistance should be seen. However, when the unit is switched on, a reading of approximately 973Ω should be obtained. Return switch S5 to its off position.

The next tests are performed on the PCB's

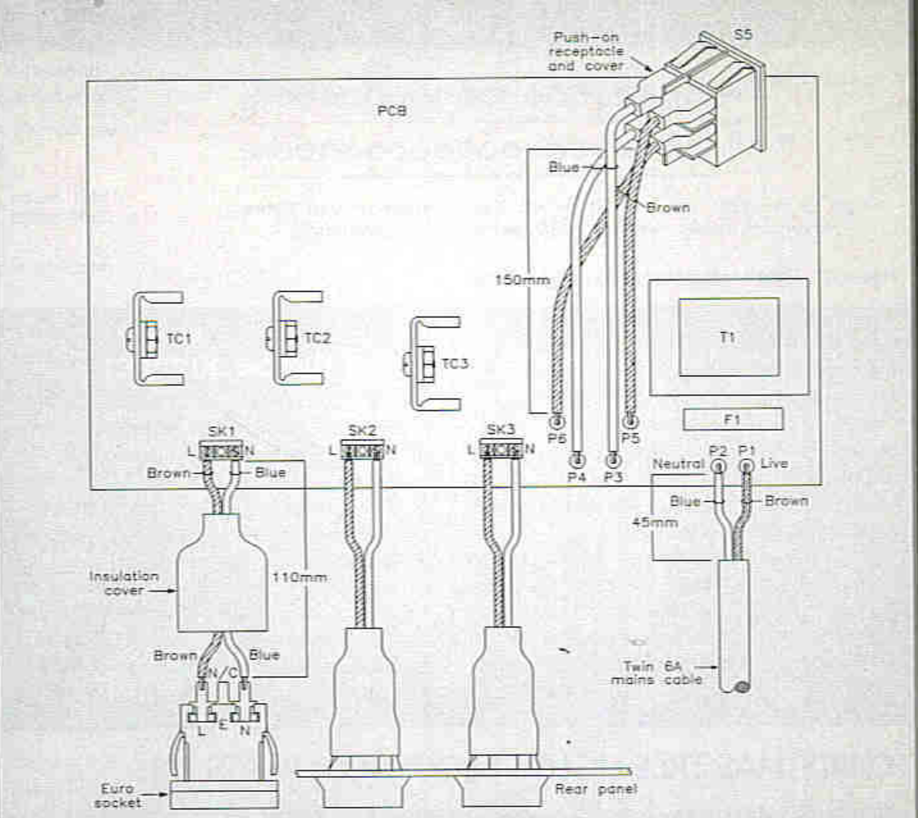


Figure 20. 240V AC mains wiring for Euro connectors.

DC circuitry. Place the test probes (either way round) on pin 8 of IC6, and on the cathode of diode D11; a reading of greater than 30k should be obtained. Next, place the test probes (either way round) on pins 8 and 16 of IC6; a reading of greater than 2k should be recorded.

Remove the test probes, and set your multimeter to read DC voltage. All voltages are positive with respect to ground, so connect the negative test lead to a ground point, i.e. pin 8 of IC6. Plug the unit into the mains supply, and switch on S5. If all is well, then the following three events should occur:

1) The red neon power switch, S5, should illuminate.
2) All of the LEDs and Christmas tree (or disco) lights should illuminate for approximately half a second. This is the power-on reset time.
3) The lights should now stay at pattern 1, group 4, which is the filament preheat level (see Table 3d). At this stage, the lamp filaments could be set at a too high, or too low, preheat level.

The DC voltages present on the PCB assembly should, approximately, match the following readings:

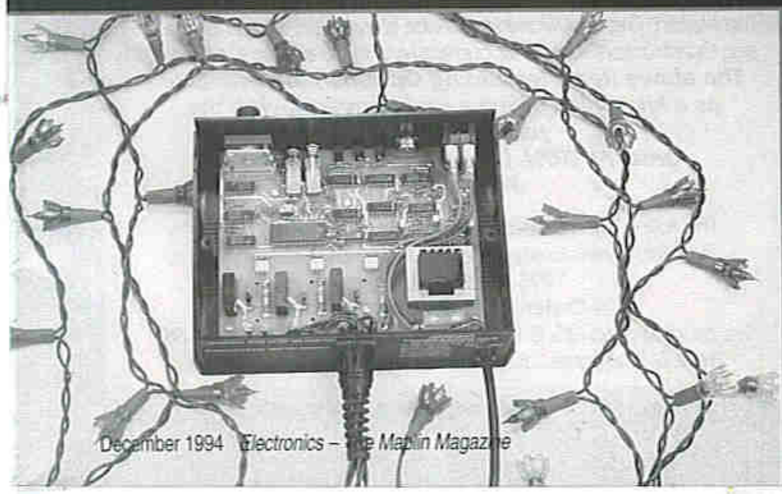
Cathode of D11, and pin 10 of IC13: +13V
Pin 14 of IC1: +5V
Pin 16 of IC2, and ICs 4 to 12: +5V
Pins 1 and 28 of IC3: +5V

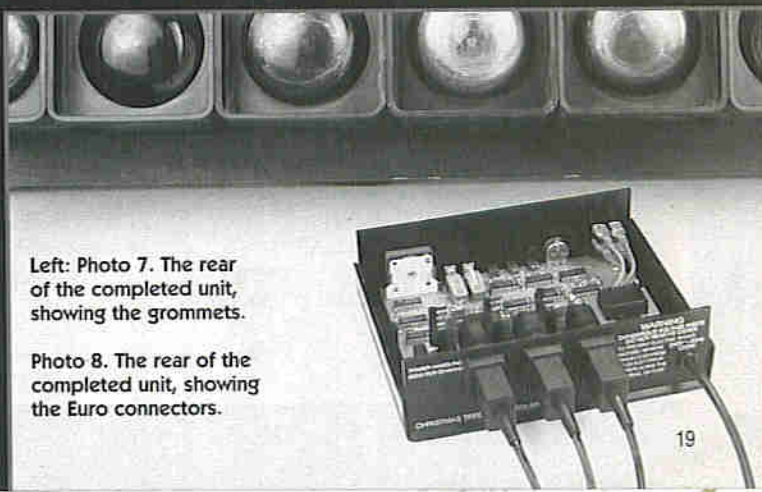
Disconnect the multimeter from the unit, and adjust RV2 to set the filament preheat level. This should be set so the lamps are only just glowing.

The final set of tests are stored inside the EPROM, and are accessed by pressing the manual pattern advance switch, S3. The next 15 patterns correspond to the individual brightness levels of the three lamps. The remaining patterns are different combinations of light sequences, as shown in Table 2. The rate of change of a pattern can be increased by adjusting the speed control, RV1. When the last pattern in the group is reached, control is returned back to the beginning of the group (i.e. the next pattern will be the first in the group).

Switch S4 (sections one and two) can now be set to select whichever group of patterns you require:

Group 1 = channel 1 only, for one set of lights. (Table 3a.)
Group 2 = channels 1 and 2, for two sets of lights. (Table 3b.)
Group 3 = channels 1, 2 and 3, for three sets of lights. (Table 3c.)





Left: Photo 7. The rear of the completed unit, showing the grommets.

Photo 8. The rear of the completed unit, showing the Euro connectors.

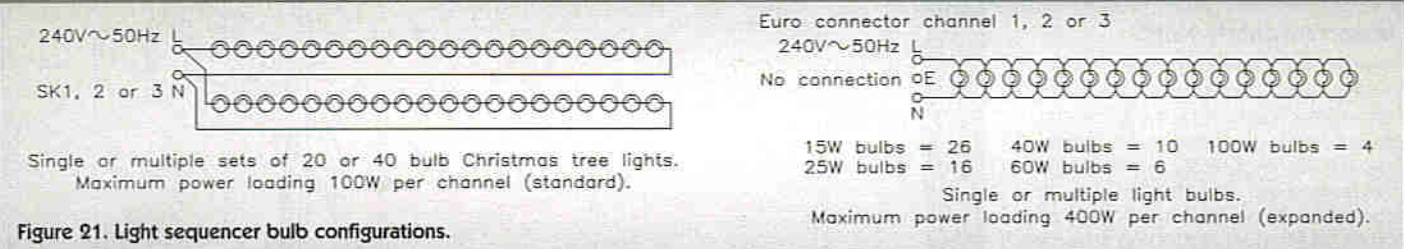


Figure 21. Light sequencer bulb configurations.

To have a more varied selection of patterns, select automatic pattern advance (switch S2 in its out position). With the pattern repeat switch, S1, set to its first position, the pattern will change after each sequence. As the number of repeats is increased, the pattern will be held for a longer time, before advancing to the next in the group.

This completes the testing of the unit, and the case lid may now be fitted, panel support lugs to the front of the unit. The Christmas tree light sequencer is now ready for use.

Using the Sequencer

If your Christmas tree lights have been fitted with 'flasher' bulbs, you must replace them with standard bulbs before using the unit. This is because flasher bulbs will cause a conflict in the control of the light patterns, and the unit will not function correctly.

The standard unit can handle a total power loading of up to 100W per channel. This means that you can use more than just one set of Christmas tree lights per channel; for example, if one set is rated at 25W, then four sets could be used on each channel (see Figure 21).

The expanded unit can handle a total power loading of up to 400W per channel, and this can be made up from a number of different combinations of lamps (see Figure 21). Remember to have some spare fuses and bulbs.

Once set up, the Christmas tree light sequencer should give an added sparkle to your festivities at Christmas time or, indeed, at any party during the year.

HAPPY CHRISTMAS!

CHRISTMAS TREE LIGHTS SEQUENCER PARTS LIST

RESISTORS: All 0·6W Metal Film (Unless specified)			
R1	4k7	1	(M4K7)
R2,3,4,6,8,9, 10,12,15	100k	9	(M100K)
R5,7,17	22k	3	(M22K)
R11	1M	1	(M1M)
R13,18,29-31	10k	5	(M10K)
R14	5k6	1	(M5K6)
R16,20-25	1k	7	(M1K)
R19	47k	1	(M47K)
R26-28	470Ω (2W Metal Film)	3	(D470R)
R32-34	100Ω (2W Metal Film)	3	(D100R)
RV1	470k Miniature Linear Potentiometer	1	(JM75S)
RV2	10k Enclosed Horizontal Preset	1	(UH03D)
CAPACITORS			
C1	6n8F Polylayer	1	(WW27E)
C2,5,6,7,10, 11,13,14,15	100nF 16V Miniature Disc	9	(YR75S)
C3,4	470pF Ceramic	2	(WX64U)
C8	2n2F Polylayer	1	(WW24B)
C9,16	47µF 16V Miniature Electrolytic	2	(YY37S)
C12	470µF 16V PC Electrolytic	1	(FF15R)
C17,18,19	10nF 50V Ceramic Disc	3	(BX00A)
C20-22	100nF 250V PETP	3	(JR34M)
SEMICONDUCTORS			
D1-10,14-16	1N4148	13	(QL80B)
D11-13	1N4001	3	(QL73Q)
LD1-3	PCB Red High-brightness LED	3	(CP53H)
TC1-3	CP206D	3	(UR25C)
IC1	HFC4093BEY	1	(QW53H)
IC2,4,5	HFC4040BEY	3	(QW27E)
IC3	MS05-EPROM M27C256B-12F1	1	(ZC13P)
IC6	HFC4060BEY	1	(QW40T)
IC7-9	HFC4076BEY	3	(QW46A)
IC10-12	HFC4063BEY	3	(QW41U)
IC13	ULN2803A	1	(QY79L)
IC14-16	Triac Isolator MOC3020	3	(QQ10L)
RG1	LM78L05ACZ	1	(QL26D)
MISCELLANEOUS			
S1	12-way PCB R/A Rotary Switch	1	(FT56L)
S2,3	2-pole Latchswitch	2	(FH67X)
S4	Dual SPST DIL Switch	1	(XX26D)
TS1	250V AC Transient Suppressor	1	(HW13P)
T1	9V 6VA PCB Mounting Transformer	1	(YJ53H)
F1	F2A 20mm Fuse	1	(WR05H)
	20mm Fuse Block	1	(DA61R)
	Fuse Block Cover	1	(DA62S)
	14-pin DIL Socket	1	(BL18U)
	16-pin DIL Socket	10	(BL19V)
	18-pin DIL Socket	1	(HQ76H)
	28-pin DIL Socket	1	(BL21X)
SK1,2,3	10mm 2W PC Term 301	3	(JX38R)
	Knob K14B	2	(FK39N)
	Black Small Round Latch Button	2	(KU75S)
	Front & Rear Panel Label	1	(KP74R)
	PCB	1	(GH96E)
	Instruction Leaflet	1	(XU98G)
	Constructors' Guide	1	(XH79L)
OPTIONAL (Not in Kit)			
TC1-3	BTA08-600B Triac	3	(UK54J)
	Vaned Heatsink TO202	3	(FG53H)
F1	F5A 20mm Fuse	1	(WR07H)
S5	Red Dual Rocker Neon Switch	1	(YR70M)
	Push-on Receptacle	1 Pkt	(HF10L)
	Push-on Receptacle Cover	1 Pkt	(FE65V)
	Euro Facility Outlet	3	(HL42V)
	Insulating Cover for HL42V	3	(JK69A)
	Euro Facility Plug	3	(HL43W)
	13A Nylon Plug	1	(RW67X)
	5A Plug Fuse	1	(HQ33L)
	H2505 Small Box	1	(BZ76H)
	SR Grommet 6W2	1	(LR49D)
	Cable Exit Gland	1	(JZ43W)
	6A Black Twin Mains Cable	2m	(CW69A)
	6A Blue Wire	1m	(XR33L)
	6A Brown Wire	1m	(XR34M)
	No. 4 × ¼in. Self-Tapping Screw	1 Pkt	(FE68Y)
	M3 × 10mm Steel Screw	1 Pkt	(JY22Y)
	M3 Isoshake Washer	1 Pkt	(BF44X)
	M3 Steel Nut	1 Pkt	(JD61R)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

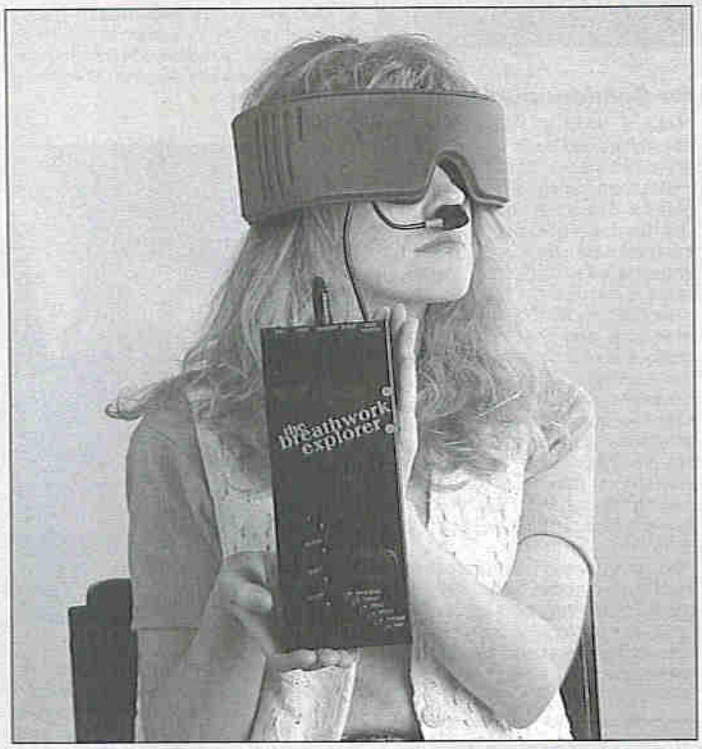
The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.

Order As LT69A (Christmas Light Sequencer) Price £39.99

The following new items (which are included in the kit) are also available separately, but are not shown in the 1995 Maplin Catalogue.

PCB **Order As GH96E Price £14.99**
Pre-programmed MS05 EPROM **Order As ZC13P Price £4.99**
Front & Rear Panel Labels **Order As KP74R Price £2.29**

NEWS Report



Breath Detector

The Breathwork Explorer may be the most powerful meditation tool ever created. It detects your in-breath and out-breath via a nozzle that sits under your nose and, claim its creators, teaches you powerful breathing techniques, and rates your relaxation response.

You put on headphones, and a pair of goggles that incorporate a breath sensor. A separate unit monitors each in-breath and out-breath. It teaches you ancient breathing techniques and reports how well you are doing. It can even tell you how relaxed you are, based on changes in your breathing over a period of time.

You breathe in with the rising tone, hold your breath in the silence, breathe out along the falling tone, and pause in the silence before the next in-breath. After a while you'll find you've entered a very deep, quiet state. At the end of the session the unit will give you a different rating based on how closely your in and out-breaths matched the breath pacing.

The Breathwork Explorer comes with rechargeable batteries, mains charger, instructional tape and user manual – and costs £349 including VAT.

Contact: Life Tools, Tel: (01625) 502602

From Russia with Love

More than 15,000 Personal Systems have been produced since assembly of IBM personal computers began in the Kvant factory of the Nauchny Center in Zelenograd, near Moscow, in October 1993.

The Kvant factory is a unit of the Nauchny Center (an organisation incorporating a number of scientific and technological activities) and produces the personal computers, to IBM's quality standards, under contract to IBM's subsidiary in Russia.

Contact: IBM, Tel: (01705) 561780.

TI Introduce DSP Kit

Texas Instruments has introduced a digital signal processing (DSP) design tool which gives beginners or experienced designers an understanding of DSPs with a very small investment. The TMS320C5x DSP Starter Kit (DSK) is available for a suggested retail price of £81.

The C5x DSK allows designers to experiment with and use a DSP for real-time signal processing. This simple, but useful tool provides the freedom to create software to run on the board as is, or to expand the system by building additional boards.

The kit combines the TMS320C50-based board with an assembler and debugger to provide a development environment for benchmarking and evaluating code in real-time. With the analogue-ready interface, designers can easily benchmark and test applications, such as control systems, audio and speech processing.

Contact: Texas Instruments, Tel: (01234) 223511.

Multiplexed Hall Sensors Communicate Over Two-wire Bus

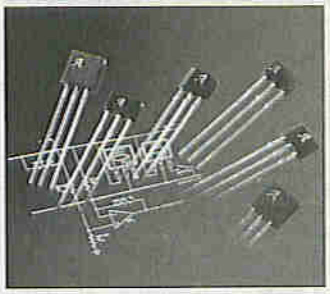
Allegro MicroSystems has developed a new family of multiplexed hall-effect sensor integrated circuits which can sense magnetic fields or switch status and communicate the results over a two-wire power/signal bus.

The new A3054KU and A3054SU ICs are digital magnetic sensing devices, intended for use as multiple sensor systems in automotive, security or building management applications, where it is desirable or essential to minimise the amount of wiring involved.

A sequential addressing scheme is used in which each device has a factory-programmed address. In operation, the IC responds to a signal on the bus and returns its own diagnostic status as well as the status of each monitored external magnetic field. As many as 30 sensors can function on the same two-wire bus.

Each device incorporates a high-resolution bipolar Hall-effect switching circuit whose output drives high density MOS logic stages which decode the address pulse and give a response at the appropriate address. The low-power technology makes the devices ideal for battery-powered and mobile applications.

Contact: Allegro MicroSystems, Tel: (01932) 253355.



Young Amateur 1994

Robert Aley (17), G7SRR, is the 1994 Young Amateur of the Year. He was chosen for this prestigious award by a panel comprising representatives from the Radio Society of Great Britain and the Radiocommunications Agency.

First licensed as 2E1AXZ in 1992, Robert has already become an RSGB Novice Instructor and has recruited other instructors as a result of a talk he gave at the Kings Lynn Amateur Radio Club. He funded his RAE costs by submitting Novice RAE questions to the City and Guilds, 30 of which they accepted and paid for. Robert has already booked his 12WPM Morse test.

His activities include special event stations, and helping the Amiga User Group. He has also written Personal Mailbox System software for packet radio use. Robert has built aerials, an 80m SSB transceiver and test equipment.

Contact: RSGB, Tel: (01707) 659015.

Business Computing

This year's Sunday Times Business Computing Show (Olympia, London, 26 to 29 September) featured technological development across the board, from voice recognition systems to networking products and from Internet services to notebooks.

First time demonstrations included a RISC based PowerPC from Centreprise International, a CD-ROM drive for a local area network and a Network Phone Disc from Technocom. Meanwhile, a number of companies used the show to launch new products, including a 100MHz Pentium from Viglen, and an array of Rank Xerox's latest networked desktop printers.

A highly interesting product from Dragon Systems that caught my eye was Dragon Dictate for Windows – a speech recognition system tailored for the UK market. With over 100,000 words in its vocabulary, the system is set to be of great benefit to computer users with disabilities, such as arthritis or repetitive strain injury.

DSP for Windows

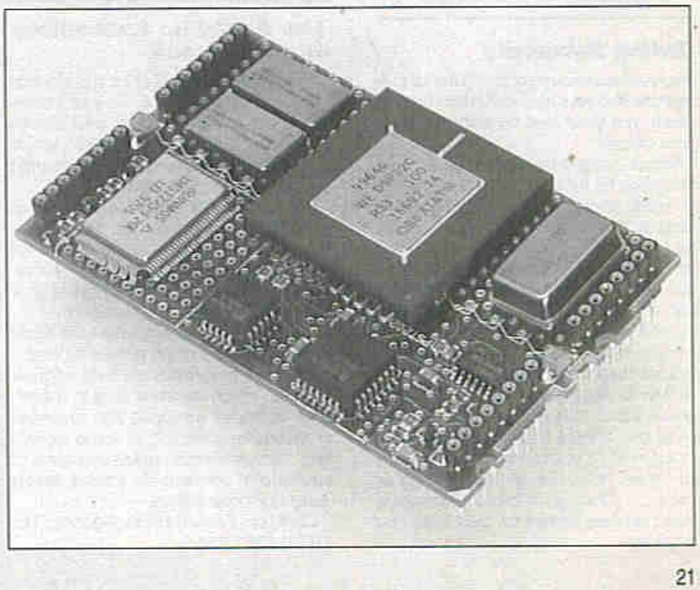
TARDIS is a transputer and real-time incremental system module, designed to run on a PC and provide the performance required to serve either as a stand-alone digital signal processor, or as an element within a larger multiprocessing DSP network.

Originally developed by Ferranti-Thomson Sonar Systems for the real time analysis of acoustic data, the module is ideal for applications requiring additional high performance processing capability from a commercial PC and DOS Windows environment.

TARDIS is installed on standard TRAM motherboards available for PCS, Sun Workstations, BME backplanes and other platforms.

The board features the AT&T DSP 32C hosted by the Inmos T225 transputer providing a high-speed programmable floating-point arithmetic capability with adequate high-speed memory for the DSP; a microprocessor with private memory for general-purpose computing; and hardware and software support for distributed processing and construction of computing networks.

Contact: Ferranti-Thomson, Tel: (0161) 491 4001.



Cellular Digital Goes Nationwide

Cellnet has officially announced its new national digital cellular telephone network.

The Cellnet GSM network is now available nationwide – ten years after the company's London pilot of the UK's first cellular network.

Cellnet's second 'Big Network' today covers 95% of the UK population, and will reach analogue equivalent (98%) by the end of the year.

The new network is costing £300 million and will bring Cellnet's total investment in cellular telephony in the UK to £1 billion.

Cellnet's second 'Big Network' is engineered to ensure users enjoy the service and additional security that the digital specification delivers. GSM technology also brings a new customer benefit; extensive European and International coverage.

Cellnet's GSM customers can make and receive calls on 22 networks in 15 countries. By the end of 1994, this will increase to 30 networks in 22 countries.

With more than one million users already on its analogue network, Cellnet has more than doubled in size in the last two years and expects to double again in the next two. The company now forecasts a total UK market of 10 million cellular telephone subscribers could be reached by the year 2000, at present growth rates.

Cellnet is continuing to invest in its analogue system and today confirmed that a further £25 million is currently being committed to boost capacity for the strong consumer demand expected this year.

Contact: Cellnet, Tel: (01753) 504358.

Dating Dynamite

If you've had enough of doing the rounds trying to find your perfect partner then sit down, put your feet up and reach for your mouse!

Sigma Designs have come up with just the game for those of us who are weary of reality and would prefer to indulge in fantasy. Called 'Man Enough' (a really saucy contribution from Tsunami Media) you can have a go at earning a date with the woman of your dreams, and if that's not enough then there is even 90 minutes of 'live action video'.

If you think this is a game for sad individuals then wait until you play 'Virtual Girlfriend'. Again, with the promise of live action video, this is a programme that gives you access to a real-life girlfriend in your PC. If you're into multiples you can even have two girls on the go at once . . . although if this is your scene then perhaps dames on disk is all you deserve!

Novel Laser Test Technique for Semiconductors

Researchers at AT&T Bell have developed a novel technique for rapidly testing for defects in compound semiconductor materials. The laser technique promises to reduce manufacturing costs, improve quality, and speed up component production to meet the anticipated demand for multimedia and visual communications hardware.

Typically, the semiconductor fabrication process begins by epitaxially growing layers, several molecules thick, of compounds such as gallium arsenide (GaAs), indium phosphide (InP), and their alloys, on a polished InP wafer. For decades microscopes have been used to inspect the surfaces of polished wafers – both before and after epitaxial growth. More recently, mapping systems that detect luminescence have been used to assess wafer quality, with a spatial resolution in the millimeter range. These conventional optical techniques are, however, limited to determining a wafer's suitability in the earliest stages of manufacture. Final product testing generally occurs several weeks later, making wafer-to-chip correlations difficult.

Now a team of AT&T Bell Labs researchers, led by Dr Gary E. Carver, has developed a Spatially Resolved Photoluminescence (SRPL) system that tests for defects at several stages of wafer/device processing, thereby providing valuable information about why a product failed to both production engineers and end users.

The SRPL system uses a one-micron laser spot and scanning mirrors to quickly map a wafer for subtle defects. The resulting signals are digitised, processed, and either displayed on a video monitor or stored on video cassette tapes. An image processing system identifies defects, allowing for the generation of colour-coded wafer maps showing the spatial distribution of defect density. Maps can be generated in 15 to 20 minutes.

Dr Carver's team is currently building a prototype that can be used in factory settings where the manufacture of electronic and photonic products used in video communications can be made more efficient.

Contact: AT&T, Tel: (01734) 324299.

Low-cost PowerBook from Apple

Apple has introduced a cheap addition to its PowerBook family. The PowerBook 150 priced at £999 features a faster processor than its PowerBook 145B predecessor.

Unless you run Apple Machines in your office or at home, and thus want total compatibility, stick with PCs. For a similar spec PC laptop, you'll pay as much as 40% less than Apple are asking for this so-called low-cost machine.

Contact: Apple Computer, Tel: (0800) 127753.

Video Performance

An addition to Texas Instruments' family of video interface palettes (VIP), more commonly known as RAMDACs (Random Access Memory/Digital-to-Analogue Converters) provides the high speeds needed for high resolution graphics applications on PCs and workstations. The highly integrated device eliminates discrete components for frequency synthesizing and phase-lock loop (PLL) capabilities by incorporating these functions on-chip.

Contact: Texas Instruments, Tel: (01234) 223511.

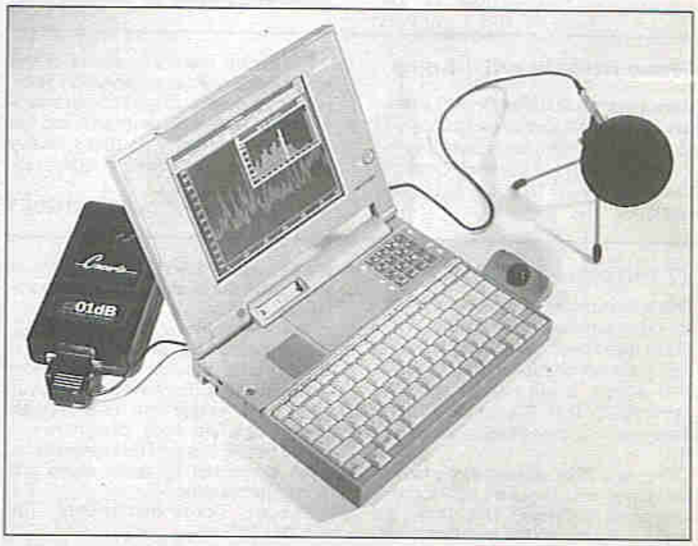
The Acoustic Laboratory in a Notebook

Concerto is the world's first full-function acoustic laboratory that fits into a notebook computer. It was created by the French company O1DB, which specialises in designing measuring applications for portable PCs.

Concerto replaces equipment such as the digital tape recorder, integrating sound level meter and frequency analyser, delivering a level of performance to rival or surpass that of conventional measuring instruments.

The computer consists of a transducer – a microphone or an accelerometer – connected to a miniature data acquisition unit, which transfers data to a notebook computer equipped with a number of extensive sampling of audio signals and simultaneous measurement of equivalent continuous sound levels (Leq) and peak values.

Contact: French Press Agency, Tel: (0171) 235 5330.

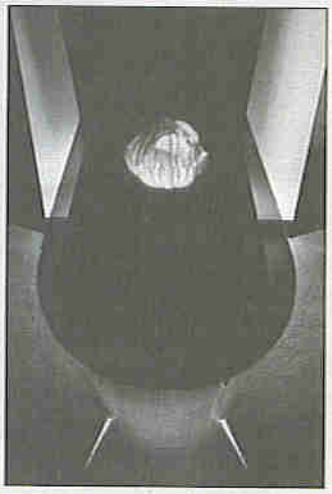


Suspended Image Technology

CRL – once exclusively the R&D arm of THORN EMI – claim to have developed the world's first suspended image technology for the next generation of home entertainment displays.

The Suspended Image System (SIS) is a culmination of five years of research to produce a 'walk through' image suspended in space. Compatible with all existing television and video standards, the SIS produces a glare free image from source material ranging from still pictures to full motion objects and video images, allowing the viewer to experience either full 3D or enhanced depth effects.

The SIS prototype uses a large area planar beamsplitter and other custom optical components to produce the suspended image. Beamsplitters with a uniform layer of metalisation approximately 1/20 micron (or 1/20,000mm) in thickness, ensure the reflection and transmission of approximately equal proportions of incident light.



CRL is currently developing an improved beamsplitter which is polarisation selective. As a consequence, the new beamsplitter will deliver upwards of a 200% increase in the proportion of available light that is directed into the suspended image, resulting in a significant increase in its brightness. The company is also developing a system to allow the user to interact with the suspended image simply by touching it.

The SIS uses relatively inexpensive optical technology, making the display of large images and objects possible. The viewing angle can be adjusted to suit the application, but it is largely determined by the size and projection distance of the suspended image relative to the SIS.

Contact: CRL, Tel: (0171) 388 9988.

TECHNOLOGY WATCH!

with Keith Brindley

A new report on 'teleworking' suggests that companies around the UK are finally taking the plunge and allowing their employees to gain the benefits of working from home. The report, from Spikes Cavell, says that around 13% of companies allow employees to work from home. There are several contributory factors such as: a general rise in self-employment; poor travelling conditions; high rent for offices, but the factor of most interest to this column is the advance which has been made in communications technologies. In truth, of course, there hasn't been so much an advancement in the technologies, instead a more widespread acceptance that the technologies exist. As a 'teleworker' for over ten years, I have to say that communications today are little better than they were ten years ago. Maybe a little more reliable (they *still* have their ups and downs, mind you), and maybe more widespread (I can now choose between electronic file transfer methods, whereas when I first started teleworking there was only one real way to do it), but they have been around for long enough. I mean, after all, there's always been the post – it's only the odd job which requires urgency of electronic file transfer. With a little forethought (for which I appreciate UK companies aren't renowned), there's very little which requires instant communications. Teleworking suits some people but not others, of course. But for those who it *does* suit, employers should seriously consider the benefits. Productivity from an employee actually rises when working from home (despite employers' fears of the opposite), and companies stand to save fortunes in terms of office space. For the employee, things are even better – savings are considerable in terms of transport costs; more time is available for the family and for leisure; and stress is considerably lower.

@Internet

Following on from last month's column and lead feature regarding Internet, some interesting news has come my way about British Telecom's proposed new services. Starting this November its first service comes into operation, providing business users with the facilities whereby they can access a BT point of presence (POP) onto the Internet, including:

- Standard PSTN (public switched telephone system) via a dial-up dedicated port – where users need an ordinary modem;
- ISDN (integrated services digital network) linkup;
- 64K-b/s private circuit (KiloStream);
- an X25 link;

so that access speeds up to 25M-bit/s is catered for.

A friendly front-end is planned, based around Windows software, which each user will be provided with as part of the package. Navigating around the Internet should therefore be as easy as it can be for most business users. Full e-mail service will of course be available, and FTP (file transfer protocol) services will be the norm.

Pricing is unannounced at the time of writing, but is intended to be competitive with existing Internet providers.

Such a service from the likes of an organisation like BT is exciting enough. Many business users might have been holding off on Internet connection, simply waiting for the waves to settle down before dipping their toes into the seemingly cold water. But the new BT business service is really only the tip of the iceberg. Next year should see the launch of a mass-market Internet access service from BT, aimed at residential users, where anyone with suitable computer and modem facilities will be able to hook-up to and surf away to their heart's content on the Internet. (Let's hope that the services aren't like the Titanic and hit the iceberg, sink and take down all of us surfers riding the wave with it.)

It's Good Not to Talk

One of BT's direct competitors, Mercury's *one2one* – the digital mobile 'phone network, looks set to help Internet users with the price of their 'phone bills. If you have an Internet hookup via a local call, BT's rates can seem a daunting hurdle if you intend to spend hours at your computer keyboard, logged onto Internet. We've heard a rumour that a new 'phone handset from *one2one* is going to have a data socket built in, so that mobile computer and fax users can have a direct means of getting on-line (even if this rumour is unfounded it *is* a good idea) so big bosses at Mercury please take note 'cos you'll be onto a winner! Here's why; *one2one*'s off-peak local rate calls for personal users are free. So, if you haven't already worked out, an Internet user could have all off-peak Internet access for free with such a handset if logged onto a local Internet provider. Mind you, *one2one*'s PersonalCall monthly charge is £12.50, so you've got to use the local rate at off-peak times sufficiently to be able to justify the use. But if you've got high BT bills because of your Internet usage, if you have a local Internet provider which doesn't charge for access by the hour, or if you just fancy the convenience of a digital mobile 'phone, you could dispense with BT altogether and go the Mercury digital route. To date, of course, *one2one* has only operated in the London region, but as of this month it's rolling out in the Birmingham and West Midlands area.

And Finally . . .

Just to conclude all this follow-up on Internet, readers might be interested to note that the Internet itself helped last month's feature on the Internet (pages 4 to 7, Issue 83, November 1994) to be completed. The artwork for Figure 1 on page 5, showing international network connectivity was downloaded directly from the Internet via an FTP server in Wisconsin USA. The file (203Kb) took about 18 minutes to download (at 2400 bit/s) and is a colour encapsulated PostScript file. It was used directly, without modifications, to illustrate the feature (i.e. since *Electronics* is produced using computer based Desk Top Publishing, the file was just pasted-in on screen!). The best bit is that, despite being connected to a computer in the USA, the dialled modem connection (to the Internet Point of Presence) was only as far away as a phone call to London – the London to USA connection, and back again, was effectively free. The route to the file was actually printed in the figure's lower left-hand corner for anyone interested in recreating the access.

The opinions expressed by the author are not necessarily those of the publisher or the editor.

2
PROJECT RATING

KIT AVAILABLE
(LT68Y)
Price £24.99

GAME SCORER

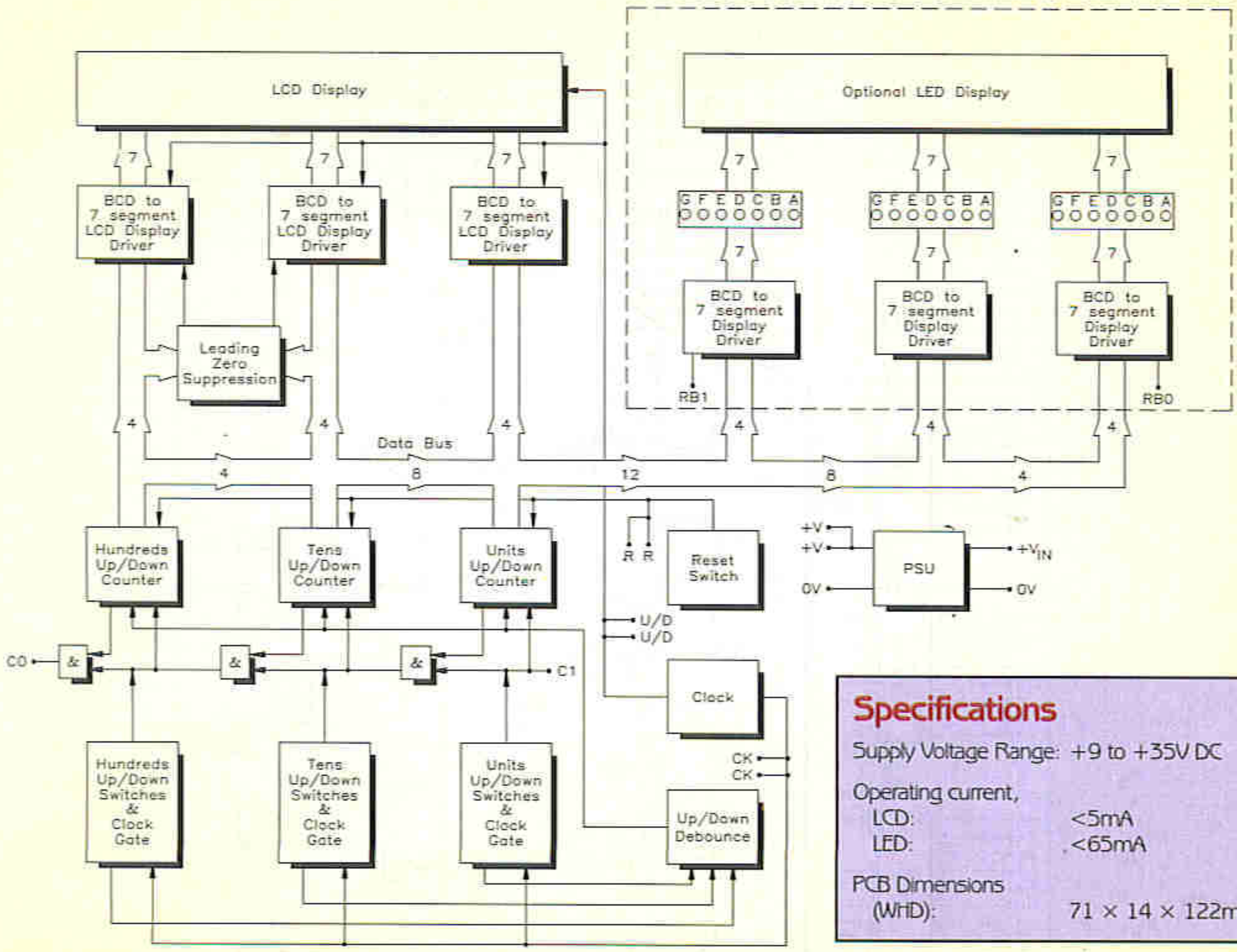
The assembled Game Scorer ready for use. Please note that the box shown is not included in the kit and must be purchased separately.

One of last year's festive projects was a Priority Game Buzzer, similar to those found on many quiz shows; this year's festive project is a 3-digit LCD (or optional LED display) Up/Down Counter that will display the score of the contestant (one required per contestant). The score can be incremented (or decremented) in Units, Tens or Hundreds and can be cleared to 0 with the simple push of a button.

FEATURES

- ★ Liquid crystal display
- ★ Easy up/down counter
- ★ Optional LED display
- ★ Easy to cascade modules

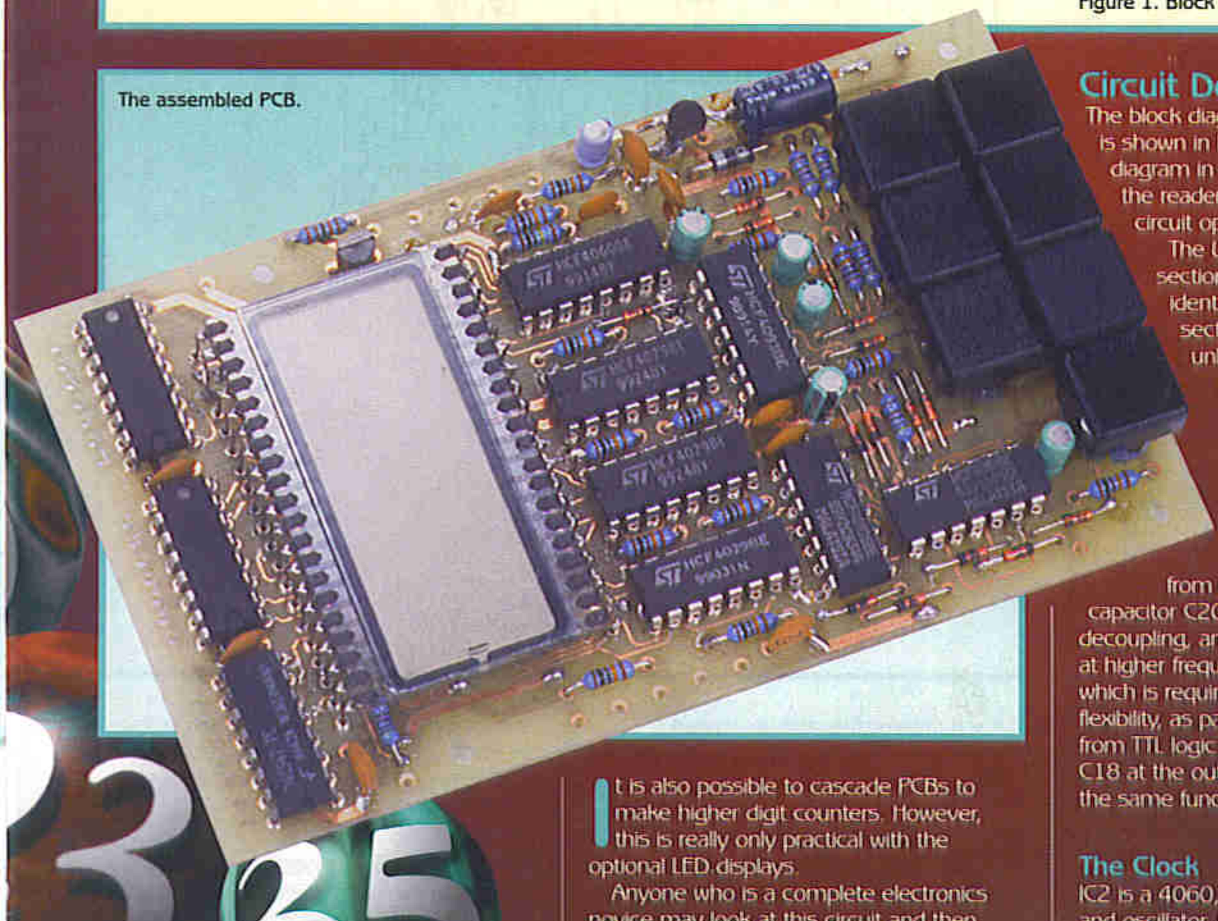
Design by Alan Williamson
Text by Alan Williamson and Robin Hall



Specifications

Supply Voltage Range:	+9 to +35V DC
Operating current,	
LCD:	<5mA
LED:	<65mA
PCB Dimensions (WHD):	71 × 14 × 122mm

Figure 1. Block diagram of the Game Scorer.



The assembled PCB.

It is also possible to cascade PCBs to make higher digit counters. However, this is really only practical with the optional LED displays.

Anyone who is a complete electronics novice may look at this circuit and then quickly turn the page; please don't, as the circuit looks more complicated than it really is. It is nothing more than a ripple clocked up/down counter with a little bit of logic manipulation.

Circuit Description

The block diagram of the Game Scorer is shown in Figure 1, and the circuit diagram in Figure 2; these will assist the reader to understand how the circuit operates.

The Units, Tens and Hundreds sections of the circuit are almost identical, therefore, only the Units section will be described in detail unless otherwise appropriate.

The Power Supply Unit

We may as well start with the power supply unit (PSU). Diode D20 prevents any damage occurring to the circuit from reverse-polarity connections; capacitor C20 provides the main reservoir decoupling, and C19 provides decoupling at higher frequencies. RG1 is a 5V regulator which is required to increase the PSU flexibility, as part of the circuit is constructed from TTL logic devices; capacitors C17 and C18 at the output of the regulator provide the same function as C19 and C20.

The Clock

IC2 is a 4060, a 14-stage ripple counter and oscillator, the frequency of which is determined by R12 and C6. The output of the fifth division stage is used to drive the backplane of the LCD. The output of the ninth division stage is differentiated by C7 and R13 to produce a narrow clock pulse

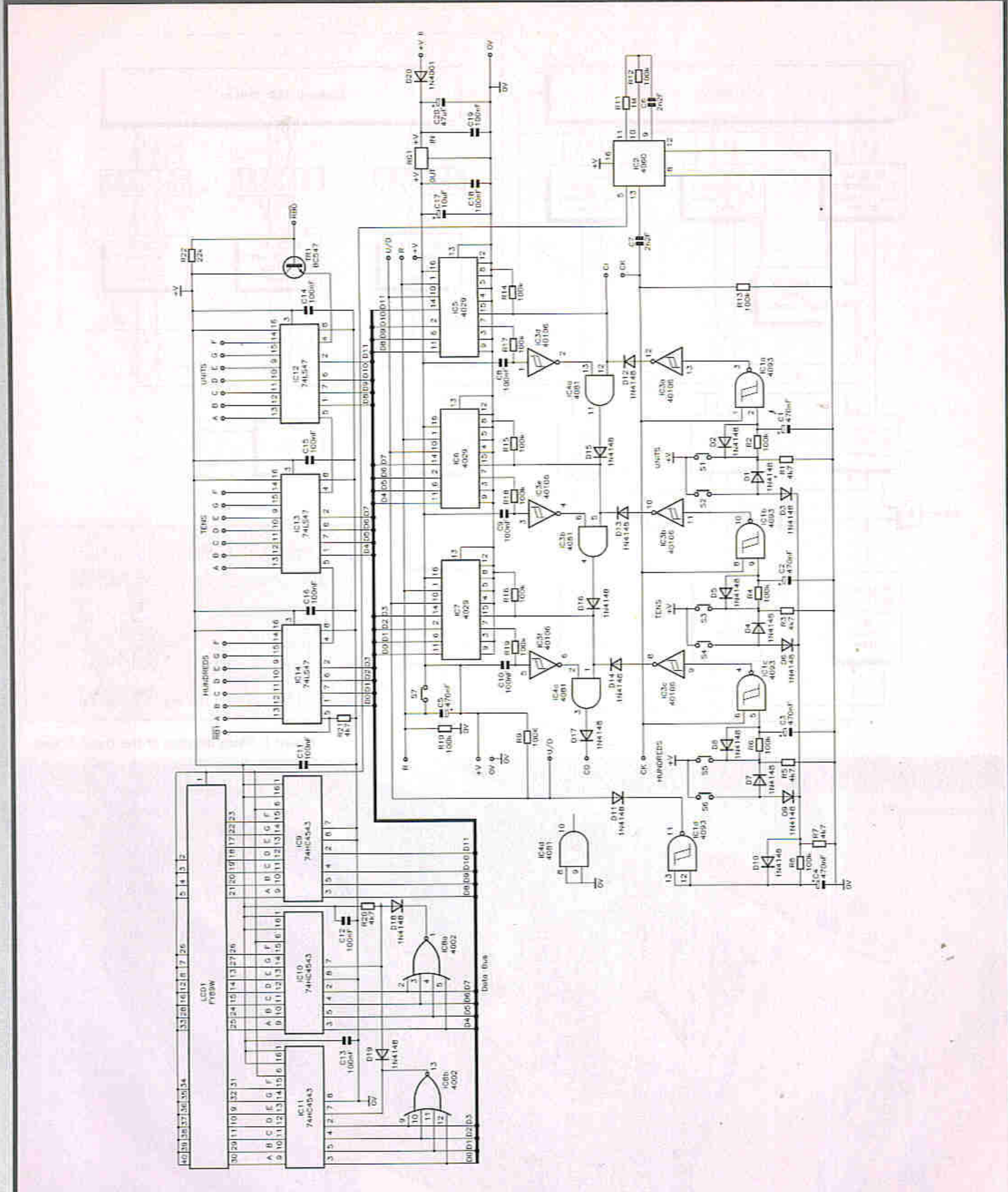


Figure 2. Circuit diagram of the Game Scorer.

rather than a square wave for the common clock line; this is necessary to achieve the correct circuit timing.

Switch Debounce

The 'ODD' numbered switches (S1, 3, 5) are the 'UP' (Units, Tens, Hundreds), and the 'EVEN' numbered switches (S2, 4, 6) are the 'DOWN' (Units, Tens, Hundreds); S7 is the RESET switch.

IC1 is a 4093, a Schmitt-triggered quad 2-input NAND gate package, each has one input commoned to the clock line (CK).

Each of the gates and associated components perform the S1 to S6 switch debounce function.

The UP Switches

Pushing S1 causes C1 to charge slowly via R2; the output of IC1a only changes to logic 0 when the input voltage reaches 60% of the supply voltage *and* when the clock signal is at logic 1.

Releasing the switch discharges C1 quickly via D2 and R1; the output of IC1a then changes to logic 1 when the input voltage drops to 40% of the supply voltage, *or* when the clock signal is at logic 0.

We now effectively have a debounced switched clock signal.

The DOWN Switches

Pushing the switch S2 charges C1 via D1 which has the same effect on IC1a as the switch S1. However, S2 also operates the IC1d debounce up/down circuit via D3. Note, that D10 is fitted the opposite way round to D2, D5 and D8, which gives the up/down debounce circuit a fast charge

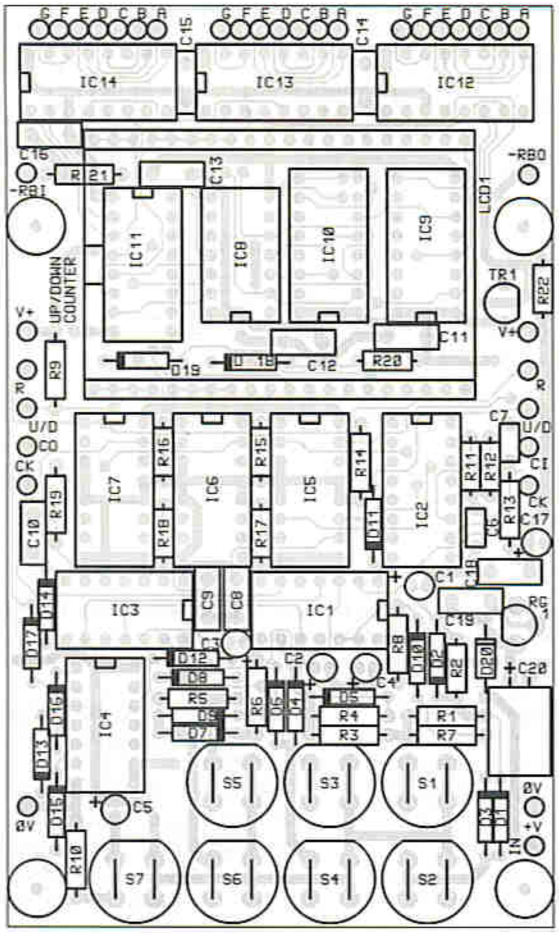


Figure 3. PCB Legend.

Figure 5. Game Scorer front panel label (two required if second PCB used). Scale 60%

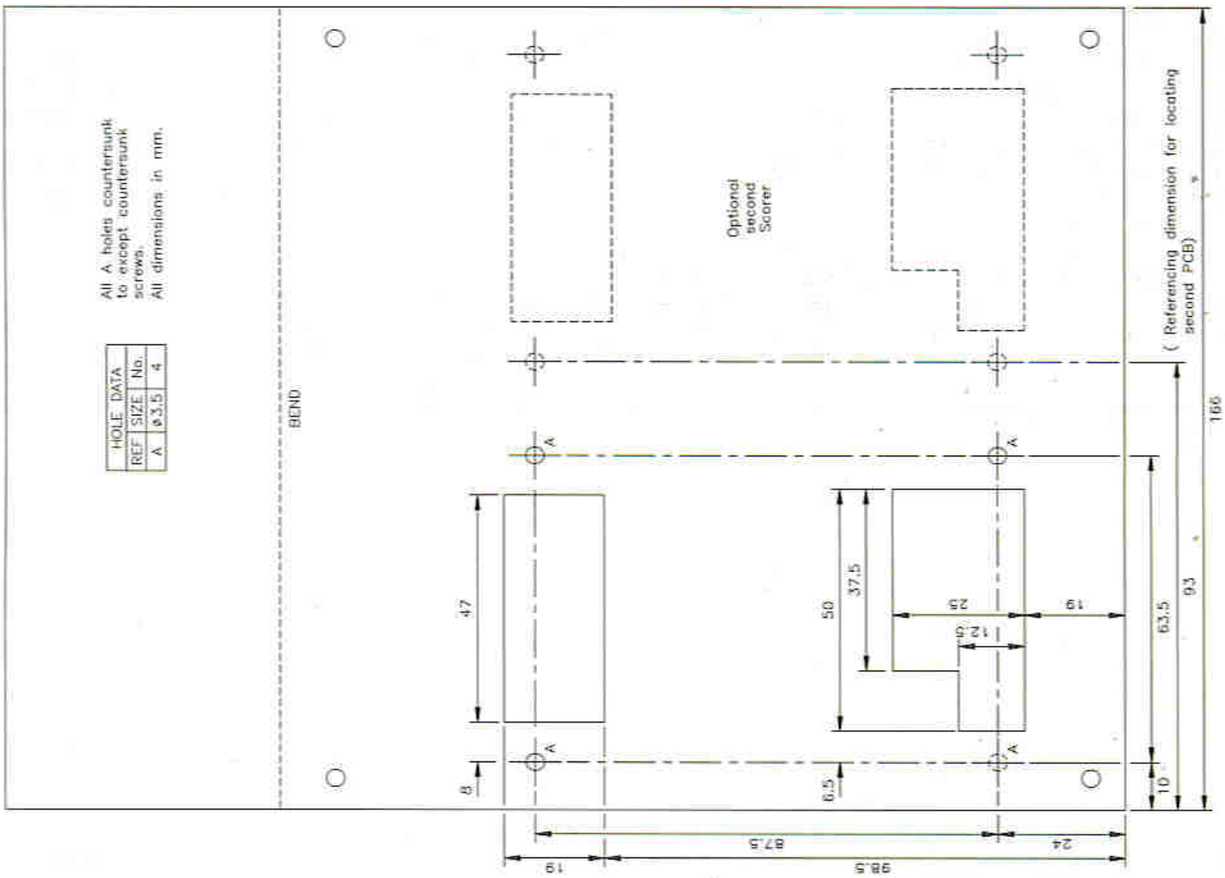


Figure 4. Box drilling details, with dimensions for locating the optional second PCB, if required.

and slow discharge; this is necessary to ensure that the up/down line changes state before the counting commences, and only changes back *after* the up/down debounce.

Ripple Counter

ICs 5 to 7 are cascaded 4029 up/down binary/decade counters, which are connected for 'normally up' decade counting.

IC5 receives its counting pulses from IC1a via an inverter IC3a and diode D12. IC6 receives its counting pulses from the 'carry out' pin (7) of IC5 via IC3d and IC4a.

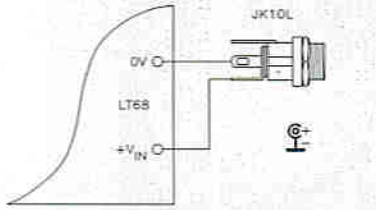


Figure 6. Wiring diagram for the 2·5mm power socket, note that the centre pin is connected to +V$_{IN}$ on the PCB.

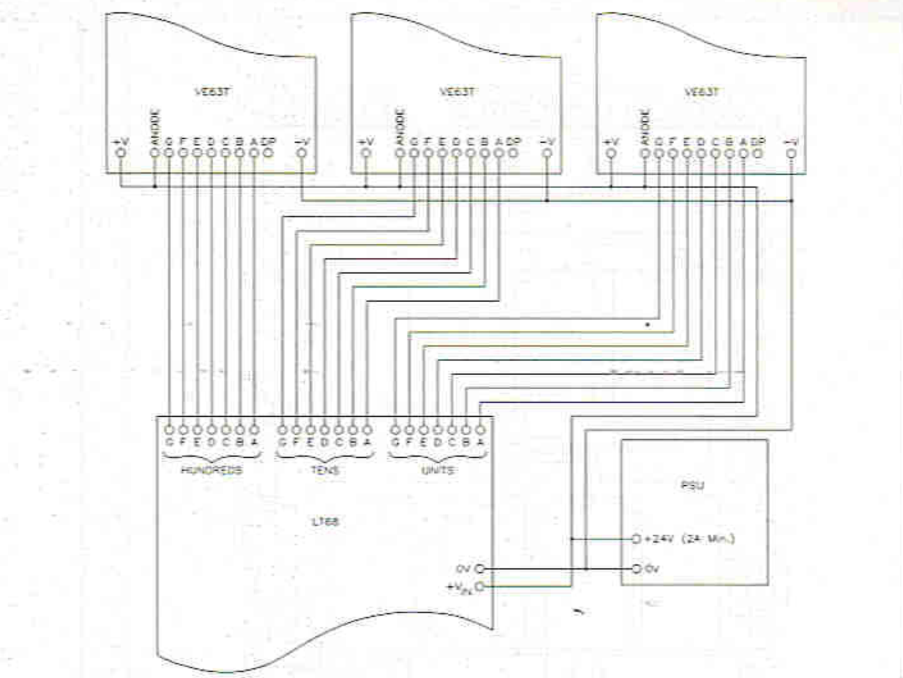


Figure 7. Wiring diagram for using the optional 7-segment display which uses 12 LEDs per segment; and the wiring of a +24V DC (2A minimum) power supply.

A standard ripple counter would normally have the 'carry out' pin directly connected to the 'clock' input, however, access to the 'Tens' and 'Hundreds' clock inputs would not normally be available. The commoned up/down inputs would also be gated with the clock signal to prevent spurious operation.

Logic Manipulation

Selecting the 'up' counting mode, the 'carry out' pin (7) becomes active low with a Binary Coded Decimal (BCD) value of nine (9); during 'down' counting, the 'carry out' pin becomes active low with a BCD value of zero (0). Changing the up/down line at this point would cause the 'carry out' pin to change back to logic 1 which would clock the next stage; this is where the 'extra' logic is required.

Assuming that the 'carry out' line of IC5 is active low, IC3d inverts the output and feeds it to one input of the AND gate IC4a.

Pressing any of the 'down' switches (S2,4,6) will cause the up/down line to change state *before* IC1a can gate a clock pulse to the second input of the AND gate; in doing so, the 'carry out' line is allowed to change state without clocking the next stage.

Assuming an 'up' counting mode with a BCD value of eight (8) the 'carry out' will become active on the next clock pulse. The 'carry out' and the next clock pulse would be ANDed together by IC4a which would then clock the next stage prematurely; the RC network (R17, C8) resolves this by providing a short delay. This allows the clock pulse to 'come and go' before IC3d changes state, thus preventing premature ANDing of the 'carry out'. The 'carry out' will then be ANDed with the following clock pulse.

The Reset Switch

Pin 1, of ICs 5 to 7 are the Preset Enable inputs which are commoned together to S7, the reset switch. Pushing S7 will load the binary number (in this case 0000) set on the *jam* inputs (pins 3, 4, 12, 13) into the internal flip-flop latches, overwriting any number that may have been previously stored. This event is a 'hard load' and does not require a clock pulse.

BCD to 7-Segment LCD

To prevent permanent polarisation of the liquid crystal display (LCD); a square-wave signal (derived from IC2) is applied to the backplane; the LCD backplane is also connected to the phase inputs of ICs 9 to 11, which are the BCD to 7-segment display drivers.

The A to G segment outputs of ICs 9 to 11 are square waves, at the same frequency as the LCD backplane. If a segment output is out-of-phase with the backplane (e.g. segment = logic 1, backplane = logic 0, or *vice versa*), the segment *will* be displayed; if the segment is in-phase, the display will be blank.

Binary values applied to the inputs of ICs 9 to 11 in the range of 0000 to 1001 will produce the digits 0 to 9, displayed on the LCD; the binary numbers between 1010 and 1111 are not produced by the ripple counter.

Leading zero suppression of the LCD is achieved with the aid of R20, D18, D19 and IC8, a dual packaged, quad input NOR gate.

The Tens and Hundreds segments of the LCD are blanked when a binary value of 0000 is applied to the inputs of IC10 and IC11, and when pin 7 (the blanking input) is at logic 1. A binary input above 0000 to IC11 will cause IC8b to output a logic 0 which will disable the display blanking of IC11, and IC10 via D19.

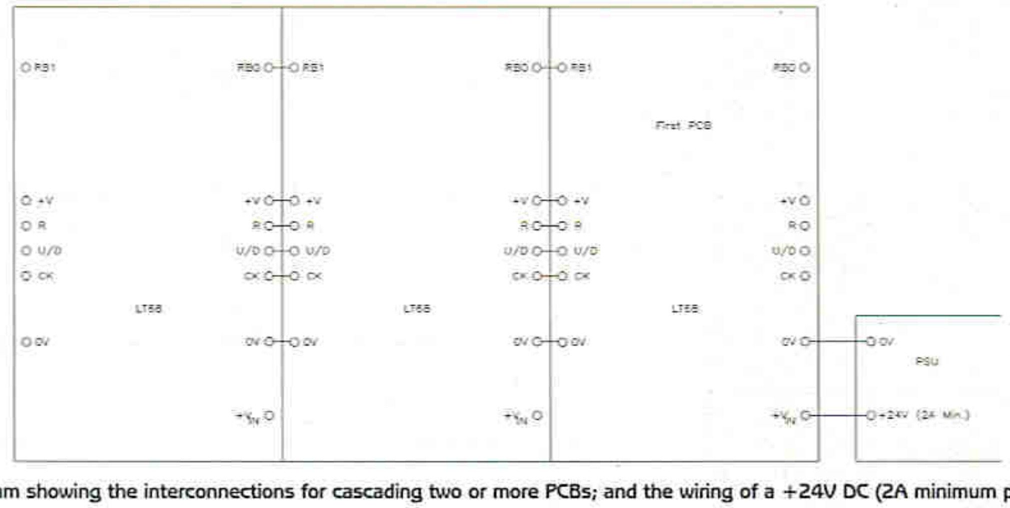


Figure 8. Wiring diagram showing the interconnections for cascading two or more PCBs; and the wiring of a +24V DC (2A minimum power supply).

Optional BCD to 7-segment LED Display Driver

The inputs of ICs 9 to 11 are paralleled with the inputs of ICs 12 to 14, the BCD to 7-segment display drivers; the outputs of which are non-multiplexed.

Leading zero suppression is somewhat simpler with these devices, which is achieved by simply connecting the Ripple Blanking Input ($\overline{RBI}$) to the Ripple Blanking Output ($\overline{RBO}$). The transistor TR1 is used as a saturated switch, the resistor R22 biases on TR1, which is required to prevent blanking of the UNITS digit when displaying 0; when counters are cascaded, the higher UNIT digit will be blanked due to R21 (on the lower digit counter) reducing the potential at the base of TR1 and therefore the potential at pin 4 of IC12.

Construction

Construction is fairly straightforward, refer to the Parts List and to Figure 3 for the PCB legend; all components are mounted on the (top) legend side.

Begin with the smallest components first, working up in size to the largest, insert the $+V_{in}$ and 0V PCB pins from the *component* side. Be careful to correctly orientate the polarised devices, i.e. electrolytics, diodes and ICs.

The LCD display is mounted into the 0·1in. socket strip, which will require slight modification; cut the strips into 2 × 20 way lengths and fit to the PCB.

The last stage of construction should be to insert the ICs into their sockets followed by the LCD display, noting the orientation notch.

Fit the optional components if the LED display is required.

Thoroughly check your work for misplaced components, solder whiskers/bridges and dry joints. Finally, clean all the flux off the PCB using a suitable solvent.

Optional Case Assembly

To complete the project; the drilling details of the optional box are shown in Figure 4; if one PCB is to be fitted then only drill the left-hand holes in the suggested layout. Drill, cut and file the holes, removing the burrs, refer to Figure 5 for the front panel label. When the box is prepared, the project can be installed.

Figure 6 shows the wiring details of the 2·5mm power socket, with the centre pin to $+V_{in}$ on the PCB.

Constructing the LED Display Only

Construct and fit all the components supplied in the kit as previously described, except IC2, IC8 to IC11, LCD1 and associated sockets (fit the 16-pin sockets in the IC12 to IC14 positions), diodes D18 and D19, capacitors C6 and C7, resistors R11 to R13; fit R20 in the R21 position.

Fit the following optional components: Capacitors C14 to C16, resistor R22, TR1, IC12 to IC14.

Figure 7, shows the optional Velleman common mode displays connected.

Cascading PCBs

You will have noticed a number of pins on the PCB and circuit; these are for cascading other PCBs to make higher digit counters. However, this is only possible with the LED displays.

First PCB

Build as described for LED display only.

Second and Subsequent PCBs

Build in the same way as the first, except do not fit diode D20, capacitors C19 and C20 and the regulator RG1; the switch S7 is a personal choice as to whether it is fitted or not.

Connect the PCBs together as shown in Figure 8.

Now the easy bit has been done, get your friends and family together and have a quiz, using your newly made Game Scorer. Good luck, and may the best team win! Remember, the scoreboard is the adjudicator.

GAME SCORER PARTS LIST

RESISTORS: All 0·6W 1% Metal Film (Unless specified)			
R1,3,5,7,20	4k7	5	(M4K7)
R2,4,6,8,9, 10,12-19	100k	14	(M100K)
R11	1M	1	(M1M)
CAPACITORS			
C1-5	470nF 63V Sub-min Radial Electrolytic	5	(YY30H)
C6,7	2n2F Metallised Ceramic	2	(WX72P)
C8-13,18,19	100nF 50V Mini Disc Ceramic	8	(BX03D)
C17	10µF 16V Sub-min Radial Electrolytic	1	(YY34M)
C20	47µF 50V Radial Electrolytic	1	(JL16S)
SEMICONDUCTORS			
D1-19	1N4148	19	(QL80B)
D20	1N4001	1	(QL73Q)
IC1	4093BE	1	(QW53H)
IC2	HCF4060BEY	1	(QW40T)
IC3	HCF40106BEY	1	(QW64U)
IC4	HCF4081BEY	1	(QW48C)
IC5-7	HCF4029BEY	3	(QW20W)
IC8	HCF4002BEY	1	(QX02C)
IC9-11	M74HC4543B1N	3	(UH45Y)
RG1	LM78L05ACZ	1	(QL26D)
MISCELLANEOUS			
LCD1	Liquid Crystal Display	1	(FY89W)
S1-5	Click Switch	5	(FF87U)
	Click Cap Black	5	(FF88V)
	14-pin DIL IC Socket	4	(BL18U)
	16-pin DIL IC Socket	3	(BL19V)
	Socket Strip	2	(DC17T)
	Single-ended PCB Pin 1mm (0·4in.)	1 Pkt	(FL24B)
	PCB	1	(GH97F)
	Front Panel Label	1	(KP77J)
	Instruction Leaflet	1	(XU95D)
	Constructors' Guide	1	(XH79L)

OPTIONAL (Not in Kit)			
R21	4k7 0·6W 1% Metal Film	1	(M4K7)
R22	22k 0·6W 1% Metal Film	1	(M22K)
C14-16	100nF 50V Mini Disc Ceramic	3	(BX03D)
TR1	BC547	1	(QQ14Q)
IC12-14	SN74LS47N	3	(QQ52G)
	16-pin DIL IC Socket	3	(BL19V)
	ABS Console Type M6007	1	(LH67X)
	Velleman Kit K2567	3	(VE63T)
	2·5mm Panel Mount Power Socket	1	(JK10L)
	10-way Ribbon Cable	As Req	(XR06G)
	Zip Wire	As Req	(XR39N)
	Single-ended PCB Pin 1mm (0·4in.)	1 Pkt	(FL24B)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.
The above items (excluding Optional) are available as a kit, which offers a saving over buying the parts separately.
Order As LT68Y (Game Scorer) Price £24.99
Please Note: Where 'package' quantities are stated in the Parts List (e.g., packet, strip, reel, etc.), the exact quantity required to build the project will be supplied in the kit.

The following new items (which are included in the kit) are also available separately, but are not shown in the 1995 Maplin Catalogue.
Game Scorer PCB **Order As GH97F Price £7.99**
Game Scorer Front Panel Label **Order As KP77J Price £2.29**

CIRCUIT MAKER

Circuit Maker is a forum for readers' circuits, ideas and tips. The circuits and information presented here must be considered as a basis for your own experimentation, no warranty is given for suitability in particular applications, reliability or circuit operation. Maplin cannot support, in any way, the information presented here. However, where possible, we will endeavour to check that information presented, is correct and that circuits will function as stated. If you would like your ideas to be considered for inclusion in Circuit Maker, please mark your submission 'Circuit Maker' and send it to: The Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Valve Regulators for the 'Valve Technology' Series Power Supply

by Mike Holmes

IN Part Two of Graham Dixey's splendid series – 'Valve Technology – A Practical Guide' (*Electronics*, Issue 68) – he describes a power supply circuit for the practical experiments in following parts. This power supply (Figure 5 on page 39 of Issue 68) uses a chain of Zener diodes to achieve a regulated supply rail of approximately 150V DC. However, the valve supply transformer used (XP27E) can deliver a greater HT level than that – up to 340V unregulated – and a higher regulated output is therefore possible, i.e. nearer the accustomed 250V level, which is more practical for most working valve circuits.

Readers following the series may be interested in building an alternative regulator circuit that I discovered some time ago (in a library book!), and subsequently developed into two variations. In keeping with the 'tradition', the circuit is, naturally, built around a valve. The valve used is a Mullard ECL82, a triode output-pentode with a B9A base, once very commonly found in 'cheap-and-cheerful' record players, radios and radiograms.

The circuit of the 150V variation of the regulator is shown in Figure 1. At first sight, this is somewhat confusing to follow, so the easier to understand transistor equivalent is also shown, in Figure 2.

As a thoroughly conventional supply regulator, it has three distinct stages: In Figure 2, these are a precision voltage reference (ZD1 and R1); a control amplifier (TR1 and R2); and a series pass element (TR2). VR1 taps off a proportion of the output to the inverting input of the control amplifier (base of TR1). Adjusting VR1 alters this ratio and, hence, is used to trim the output with reference to the precision source.

Transposing this arrangement to Figure 1, you will see that the voltage reference is identical – being ZD1 provided with current from the unregulated HT via a 220kΩ resistor, with any AC noise bypassed to 0V by the 220nF capacitor. V1, the triode section of the ECL82, is the control amplifier, with 470kΩ resistor as an anode load. The series pass element is the power pentode section, V2. Here, the screen grid is directly connected to the anode, so it actually behaves as a high-current triode in cathode follower mode.

The circuit simply replaces R2, and ZD1 to ZD5, in Figure 5 of Issue 68, where '340V DC' connects to the plus side of C2 (10μF) (where R2 used to be). VR1 is set to an approximate mid position prior to powering-up, and once warmed up and an output has been obtained, is used to trim the output to 150V, as monitored by a voltmeter. The output can be up to 20mA, and so it is ideal for small signal amplifiers requiring a smooth and steady supply, free of mains noise and fluctuations – useful for an audio preamplifier, perhaps?

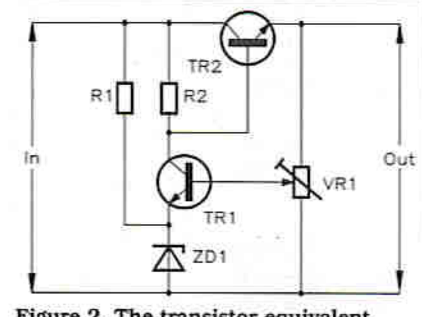


Figure 2. The transistor equivalent of the valve regulator circuit.

The design was taken further to produce the 250V regulator of Figure 3. There are only subtle changes to some resistor values, due to differing voltage levels, and two Zener diodes used in series for a reference of 102V instead of 51V. In this case, VR1 has more scope, and so the regulator can form the basis of a variable output power supply. All the resistors can be normal 0·6W metal film types, and VR1 is an ordinary, enclosed preset. The 220nF capacitor is a 250V polyester type, and the Zener diode is a BZY88C51V. Wiring-up around the B9A socket can be done with the help of a tag strip or tag board.

Of course, in the old days, Zener diodes did not exist, and so precision gas-filled tubes would have been used – commonly known as 'voltage stabilisers'. One experiment to duplicate this, using a wire-ended neon lamp in place of the Zenér(s) (RX70M), proved quite successful, with the neon holding steady at about a constant 80V.

The only real complexity that the regulator adds to the circuit is its heater power requirement. Unfortunately, it should not be taken directly from the main transformer's heater secondary; this is for two reasons: Firstly, the ECL82 draws 780mA of heater current, which is most of the heater secondary's capacity (which is better employed heating several other valves!). But, more urgently, there is the matter of the large potential difference between the two cathodes of the ECL82. For the 150V regulator, this will be 99V; for the 250V version, it will be 148V. Between these potentials is the common heater circuit of the valve which, if connected to 0V at some point, puts a stress between the cathode of V2 (pentode section) and its heater filament to the tune of the total output HT level!

The way round this is to have a dedicated heater supply circuit, which must be fully floating, i.e. not earthed at any point. In this case, the average cathode-to-heater potential will be 49·5V (150V output) or 74V (250V output) for each section, which is much more survivable. A second mains transformer (WB11M) has two 9V secondaries wired in parallel for a 1A total output, and a 3·3Ω 3W resistor, in series, to drop the voltage down to 6·3V. ∎

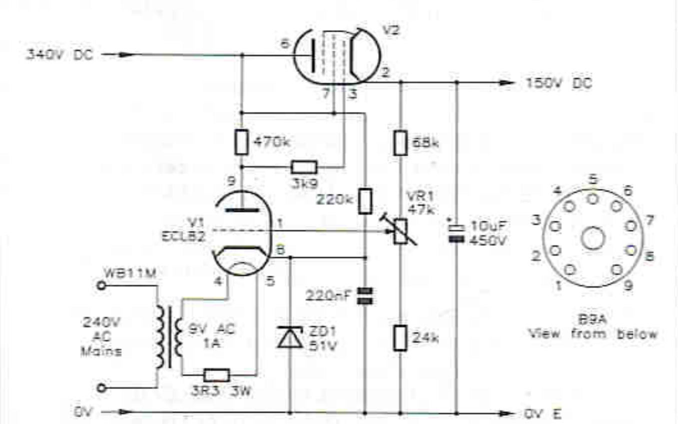


Figure 1. A 150V valve regulator.

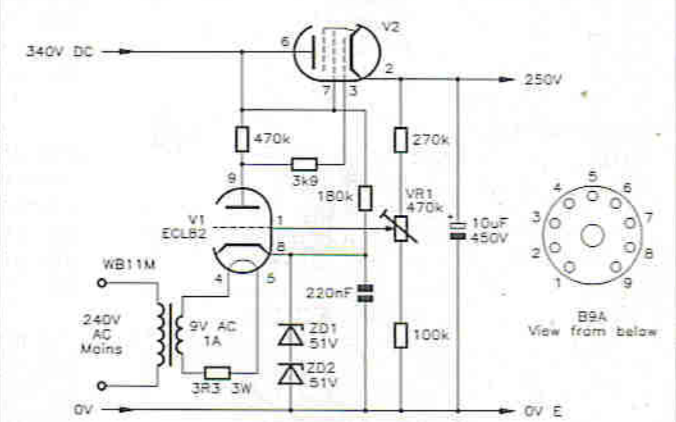


Figure 3. A 250V valve regulator.

PICTURES BY NUMBERS

Seeing the Future?

Most *Electronics* readers cannot have failed to have noticed Philips' glossy advertising campaigns for CD-i, or Compact Disc Interactive. This system, as promoted in the adverts, will play normal audio CDs, and allows users to participate in complex games, or educate themselves in what appears to be a very absorbing way.

Recently, though, Philips undertook the UK launch of its latest bid for mass CD-i acceptance – a full motion video (FMV) retrofit cartridge, shown in Photo 1, which plugs into a port at the back of the machine. The system was first demonstrated, with excerpts from the James Bond movie *Licence to Kill*, at a San Francisco multimedia conference in March 1992. FMV, which has been on sale for some time in the US, delivers full-length digitally-encoded movies, all on a single 5in. CD known as Video-CD. Current releases include *Top Gun*, *Star Trek VI* (see Photo 2) and *Naked Gun*.

Industry commentators are already numbering the days of the analogue laserdisc formats that have only found acceptance amongst wealthy videophiles and home cinema freaks. Another manufacturer, Nimbus, is planning a Video-CD add-on that plugs into the digital output connector found on most modern audio CD players, while other companies are beavering away at systems that will work on PCs equipped with CD-ROM drives. Far Eastern manufacturers are, it has been rumoured, gearing up to produce millions of Video-CD players next year.

Regardless of who is jumping on the Video-CD bandwagon, bearing in mind that a 5in. CD holds 80 minutes or so of full-bandwidth high-fidelity music, providing one and a half hours of colour pictures *and* high-quality audio seems, on the face of it, impossible!

In the US, LSI Logic and Zenith Electronics have joined forces to develop a cable system that offers potentially more than 1,000 TV-related services. The system will offer American couch potatoes pay-per-view movies, video-on-demand, interactive TV and CD-quality audio. But how do they intend to offer so much within the limits of practicality?

Meanwhile, closer to home, media baron Rupert Murdoch plans to operate 'digital' television services, via one of the Astra satellites, that would offer a number of channels using a single transponder – current analogue channels (including those using the partially-digital D2MAC system) occupy a transponder each. Industry pundits have hinted at satellite broadcast systems delivering more than 200 channels across 16 transponders.

This is not a far-off dream, either. BSkyB hope that domestic decoders will be available within the next two years. If successful, BSkyB are likely to go down in history as the first provider of digital television in Europe. But how do they hope to cram four or more channels into the space required by an existing one?

Back to earth, a controversy is currently raging. Should the Channel 5 frequencies be allocated to an analogue broadcaster, or to several digital services which could accommodate the same spectrum? If they are of sufficient quality to interest the public, terrestrial digital TV services could

Photo 1. This FMV cartridge upgrades Philips' CD-i players to Video-CD compatibility.

Photo 2. Screen shot from *Star Trek VI* – a currently available CD-Video movie.

Photo 3. NTL's 8-metre uplink dish, used for experiments with MPEG transmission via satellite.

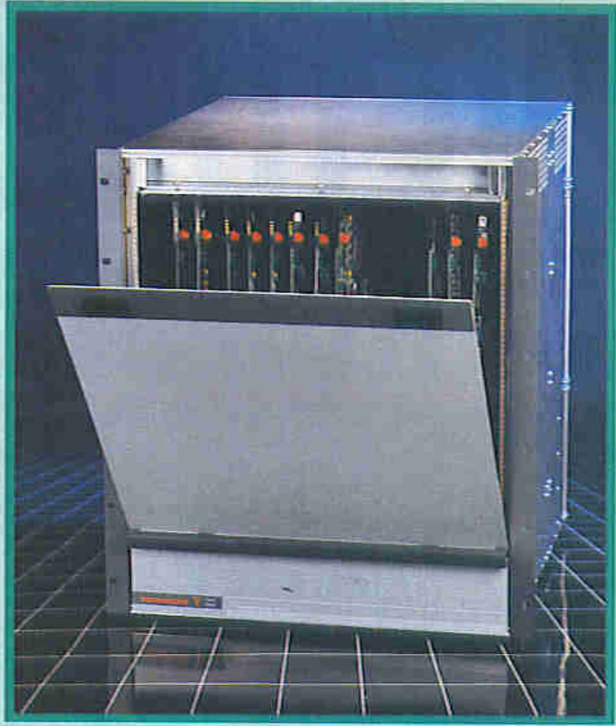


Photo 4. NTL's System 2000 MPEG encoder for broadcast applications.

electronics trade, since they could be received via an already-present set-top or roof-mounted aerial. Telecommunications operators, such as BT, are also evaluating digital TV, particularly for video-on-demand services.

Why Digital?

It has been widely regarded for some time that the future of television is digital. The standards in use today are, with the exception of teletext, stereo sound and some form of colour, basically the same as those developed by Blumlein, EMI *et al* in the thirties. Significant (and wasteful) parts of the analogue video signal originally intended to overcome the disadvantages of the primitive technology of the day have, for some reason, remained.

With the widespread acceptance of digital technology, new systems of flexibility and performance, unheard of in Baird's day, are possible. Digital pulse trains, with error correction, are potentially much more resistant to interference and degradations introduced by an analogue transmission path. The ghosting, atmospherics, grainy pictures and susceptibility to electrical noise that have plagued analogue television could disappear altogether.

Since colour television is now the rule rather than the exception, a digital television system would include colour from the outset – compare that with today's PAL, SECAM and NTSC standards, in which the colour (chrominance) information rides 'piggyback' on the original black-and-white (luminance) signal to provide compatibility with the monochrome sets that Granny may remember.

In these compromise systems, there is inevitably some interaction between the chrominance and luminance channels, which gives rise to well-known picture defects (such as the 'checked jacket' syndrome). Since any colour system had to occupy the same bandwidth as the equivalent monochrome signal, the colour information (chroma bandwidth) that can be provided is very limited. Yes, analogue colour systems were undoubtedly a great feat of engineering genius when they were developed in the fifties and sixties, but a replacement is overdue.

For the time being, the digital television systems to be covered in this article will be a 'half-way house' – in other words, they digitally encode a conventional composite colour signal, process it in the digital domain, send it across the transmission medium and unprocess/convert it at the other end, returning an accurate analogue representation of the original signal which will be compatible with existing TV sets.

Completely digital systems are some way off yet – not least for customer and studio equipment compatibility – but the systems to be discussed here do offer the important benefits of robustness and bandwidth economy. Looking into the crystal ball, CCD cameras, computer graphics equipment and the rapidly-advancing state of LCD matrix and plasma displays are just some of the key components of the broadcast chain bracing themselves for the all-digital systems of the future. That said, some recently-equipped TV studios – including a new Channel Four one – already process video completely in the digital domain. It is only in the final stages that it is converted into analogue PAL format; these stages would no longer be required if an MPEG encoder were to be used.

When analogue television systems were originally developed, communication satellites and cable television were not commercial realities. That, of course, has since changed with the ever-increasing band of subscription-based special-interest and premium channels – particularly those available via the Astra television satellite. To protect their investment and ensure that only paid-up subscribers can receive such channels, encryption is generally used.

Analogue scrambling systems used in the early days of satellite television were easily defeated, and so engineers came up with digitally-based systems, such as BSkyB's Videocrypt. Here, the analogue video signal is converted into digital form, manipulated by data supplied via a smart card, and converted back into analogue form. A completely digital television system would permit secure encryption to be implemented with ease – and the difference in picture quality between scrambled and clear channels would not be as obvious as it is today.

So then, it appears that a digital system would be the cure for all ills. But there is a problem – bandwidth. Even before we consider HDTV, the 625-line, 25 frames-per-second (interlaced to give 50) broadcast-standard colour television picture that we take for granted today would require raw data streams of around 200M-bits/s – clearly impractical when translated across to the transmission path! The key of getting this figure down to something manageable lies in the use of compression.

A Gallon into a Pint Pot?

The purpose of a digital video compression system is to convert the overwhelming amount of information, contained within the video signal, into a format which is easily transmittable and storable. *Electronics'* PC-literate readers might like to know that there is one crucual difference between video compression, and the type used for computer files – for example, the *PK(UN)ZIP* PC programs commonly used for files available on bulletin boards for downloading. Whereas *PKZIP* arranges the data in such a way that it can be reassembled in its original form (by *PKUNZIP*) at the other end, in video compression however, some of the information is lost for ever and cannot be recovered.

One of the most important objectives in any video compression system is to ensure that this paring down of the video data has no undesirable effects on the end product. It is possible because, on a frame-by-frame basis, much of the video information is the same – a system that eliminates this repetition will significantly cut down the data rates required, to (typically) between 1 and

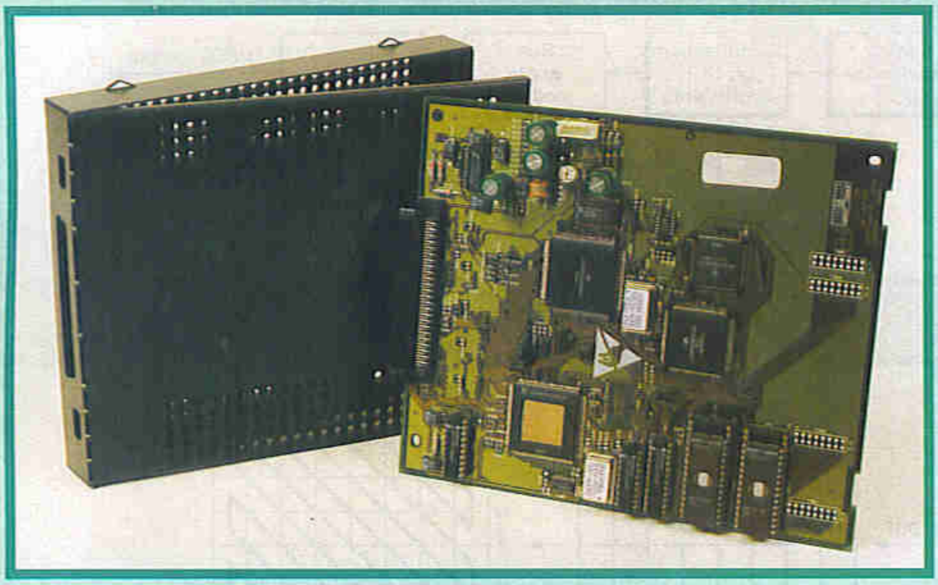


Photo 5. Inside the Philips Digital Video Cartridge... a Motorola MPEG chipset.

5%. For a video compression system to be viable, though, it needs to be robust. Problems encountered in the real world, such as multipath distortion (which causes ghosting with terrestrial systems) or random bursts of noise, must not cause the picture to disappear or be corrupted for long periods of time. Reliable forms of digital video compression have, consequently, been a long time in the making.

The 'VHS' of Digital Video?

Sensibly, a universal standard (well, group of standards) for digital video compression is emerging – compare this with the multitude of analogue standards – to the extent that it is being described as 'the VHS of the nineties'. Standardisation is a priority, since this will avoid any incompatibility problems, as well as bring down the cost of the silicon (increasing acceptance still further!). The standard in question, known as MPEG, is named after the ISO's (International Standards Organisation) well-coordinated Motion Picture Experts Group that, since its inception in May 1988, developed the technology.

MPEG is an offshoot of the Joint Photographic Experts Group (JPEG), which was concerned with data compression standards for digitised still pictures, intended for electronic still cameras, multimedia and electronic publishing; the progression to moving video was natural. Companies participating in MPEG include the vast corporate likes of IBM, DEC, AT+T, Matsushita, Sony, Mitsubishi, Intel, Philips and, not surprisingly, JVC, the originator of the VHS format. Video-CD is, after all, seen by many as an alternative to (or even eventual replacement for) movie rental on VHS tape. Video CD is more robust and longer-lasting than tape media, cheaper to manufacture in quantity than real-time duplication, and will deter piracy.

There are a number of MPEG standards, each of which is aimed at a different level. The first to be developed, now known as **MPEG 1**, is concerned with consumer (VHS) level applications such as Video-CD, video-on-demand (VOD) and PC multimedia applications. The data rate of MPEG 1 is optimised at 1·5M-bits/s. It can be less, though; after CD sectoring overheads, the bit rate of the MPEG data stream on a CD is a little less than 1·4M-bits/s. On most movie titles, the video takes about 1·15M-bits/s and the Hi-Fi stereo audio takes 224K-bit/s. Towards the end of 1992, the draft MPEG 1 standard was finalised, giving the IC manufacturers the cue for custom silicon development.

US companies C-Cube and Motorola have completed work on devices – the Motorola chips are used in Philips' FMV CD-i cartridge. FMV has been made commercially viable very quickly because MPEG 1 decoder chips are already selling in volume for less than $15, and this cost will inevitably decrease as acceptance and production increase – you cannot deny that one is helping the other! Video-CD, incidentally, will be featured in another article.

The **MPEG 2** committee was originally formed in 1991, following the successes being obtained with the original standard, to consider coding at higher data rates (between 2 and 10M-bits/s) for broadcasting and video recording. MPEG 2's brief has since been extended to include the even higher rates (between 10 and 20M-bits/s) that one would expect to encounter with high definition TV – this, out of interest, was originally handled by **MPEG 3**. High bit-rate digital video recording is currently in use by some broadcasters, since there is no noticeable loss of quality between dubbings. A domestic digital video system would be welcomed by home video enthusiasts – digital camcorder tapes could be edited, and copies, that are still watchable, be made for friends!

DTH (direct-to-home) satellite broadcasting (see Photo 3) is likely to make use of the MPEG 2 standard, when it eventually begins – suitable real-time MPEG 2 encoders are already available from companies like NTL/Pace, one example of which is shown in Photo 4. In fact, December 1993 saw MPEG 2 being adopted by the European Project Digital Video Broadcasting Group (DVB) as the standard for satellite broadcasting, with QPSK (quadrature phase-shift keying) as the modulation method.

Real-time encoding is essential for broadcasts – comparatively recently (the end of 1991), the best available encoders took 200 minutes to encode one minute of output! It just goes to show how fast (literally) these things are developing!

Although MPEG 1 can be used at much higher data rates than the 1·5M-bits/s quoted earlier, MPEG 2 will give better quality at higher bit-rates due to the fact that it can take account of interlaced format video (MPEG 1 being non-interlaced only). At bit-rates of up to 3M-bits/s, there is little difference between MPEG 1 and MPEG 2 in terms of perceived quality.

Since a Video-CD encoded in MPEG 2 would offer too short a playing time to accommodate a movie, due to the increased data rates, CD boffins are working on ways to squash more data onto a CD. The approach currently being considered is to reduce the size of the data pits on the surface of the disc, thereby increasing the number that can be crammed onto it. A laser with a short wavelength (blue light, rather than infra-red) would be required to read these higher-density discs – sadly, existing players would not be compatible with them.

In 1992, **MPEG 4** was formed to look into digital video transmission at very low bit-rates (in the order of tens of K-bits/s) for future applications, such as video-based cellular phones. MPEG 4 will make use of fractal and wavelet transforms.

Photo 6. The 3DO multimedia games machine will shortly be able to play MPEG-encoded CD-Video discs by virtue of an MPEG cartridge (available from November).

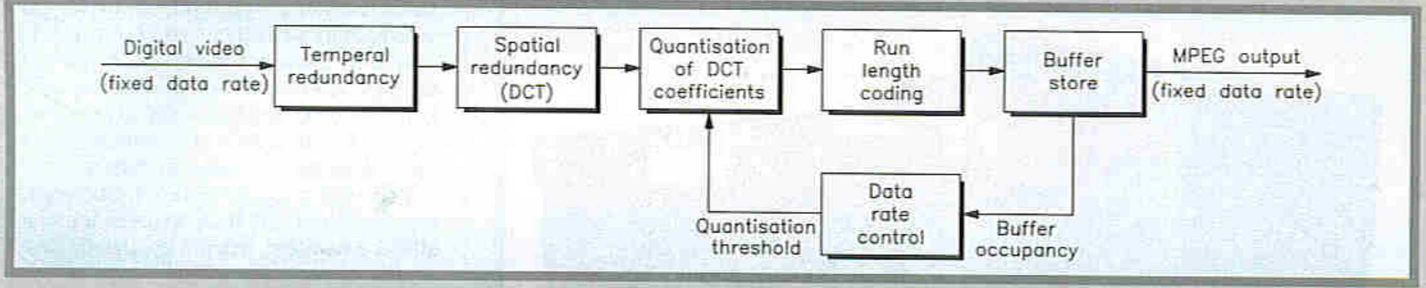


Figure 1. The MPEG compression process.

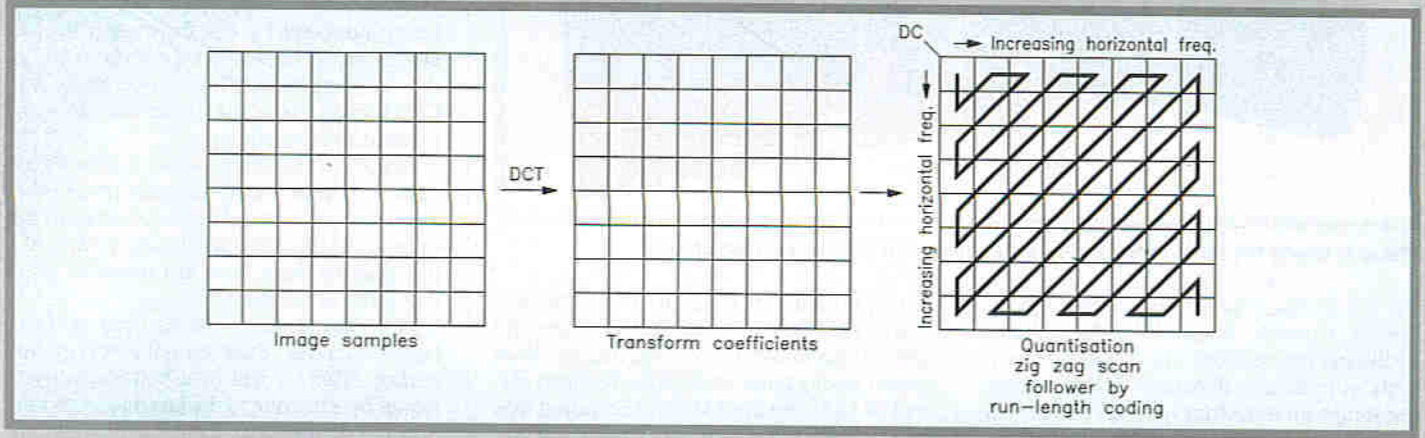


Figure 2. The frequency domain of DCT.

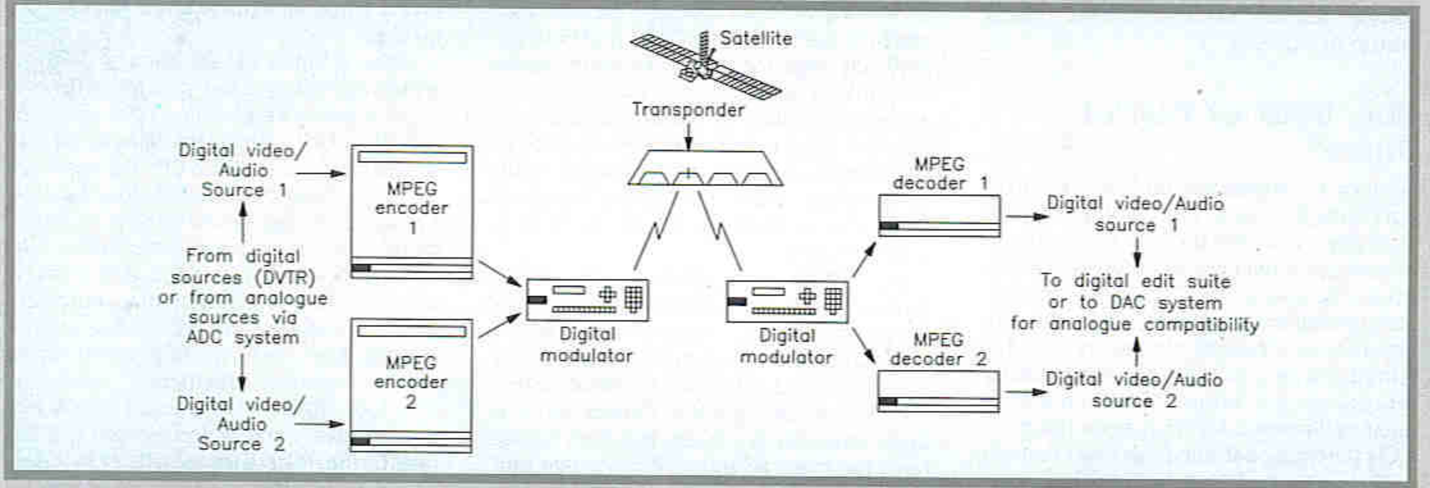


Figure 3. Programme distribution via satellite. This would be used for sending copyrighted material – such as a newsfeed or a concert broadcast – from one country or region to another. The system shown will allow two independent channels to be sent on the one transponder. Digital DTH will follow soon.

Current manufacturers of MPEG silicon include C-Cube, Motorola (see Photo 5), Texas Instruments, SGS-Thomson and LSI Logic. Other manufacturers are, of course, jumping on the bandwagon, in recognition of the fact that MPEG is a *de facto* standard. General Instrument's *Digicipher*, in continual development since 1987, is an example of one of the other systems available, but the company, recognising the importance of MPEG, has included an MPEG 2 mode on its latest generation of hardware.

MPEG – The Basics

So, how does MPEG 1 manage to reduce 200M-bits/s to 1·5M-bits/s? There are two main elements to MPEG bit-rate reduction – spatial and temporal redundancy. A block diagram of the process is shown in Figure 1. First of all, though, the video source needs to be digitised, if in the analogue form supplied by a video machine. This stage is likely to be dispensed with as digital VTRs and CCD cameras become commonplace.

Spatial redundancy arises because many frames contain unnecessary information – for example, certain areas (e.g., blue sky) contain little detail. In analogue systems, all this information is transmitted – great bandwidth savings can be made if this information can be imperceptibly removed. MPEG addresses this problem in a novel way.

During spatial redundancy encoding, the picture is divided up into blocks of 8 pixels by 8 pixels. Block by block, discrete cosine transform (DCT) coding converts the time-varying video signal into a frequency-like domain, designed to match the sensitivities of the eye. If the contents of a block are uniform, DCT coding results in only a few frequency terms. Conversely, in areas of great detail the coding process could generate many higher-order terms.

DCT coding does not save data in itself, but quantisation of the frequency terms is applied to remove the less important information. Figure 2 illustrates the 'frequency' domain, in which the lower order terms reside in the top-left area of the diagram, while the higher-order terms can be found on the bottom right. A process of 'zig-zag' scanning allows the coefficients to be taken in frequency order, with increasing likelihood of zero-value coefficients. The next stage is to apply run-length coding, which efficiently describes an uninterrupted run of zeroes; this results in further savings in bit-rate.

The amount of useful information generated by the process will vary according to the content of the video signal. An output buffer is used, with a feedback mechanism to regulate the quantisation thresholds of the DCT process, so that the output data rate is maintained at a constant level.

Temporal redundancy is the removal of information, from individual picture frames, in circumstances when the picture is not moving, or is moving in a predictable manner. This, as we have already seen, is the biggest waste of capacity. Using inter-frame coding, savings can be made by using motion-compensated prediction from preceding picture frames, and coding only the differences between the predicted and

Photo 7. A prototype Pace/NTL receiver/decoder for MPEG-encoded satellite broadcasts from the proposed Digital Sky service.

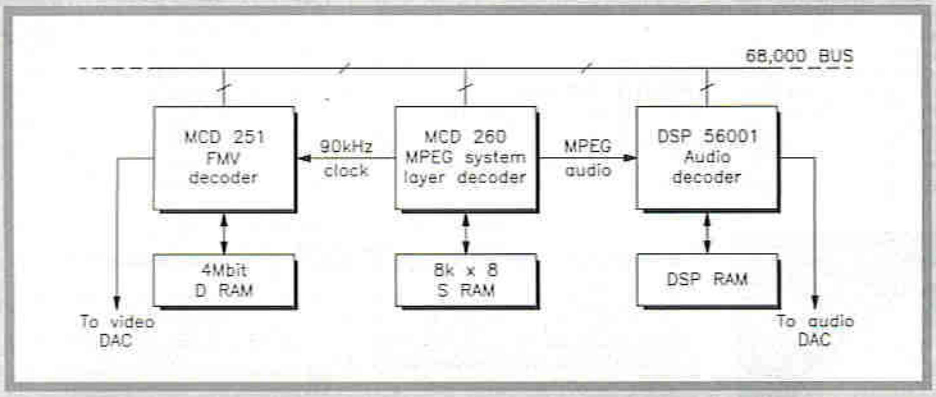


Figure 4. Motorola's MPEG 1 chipset, as used in the Phillips FMV add-on for its CD-i players

the actual picture. The more predictable the motion, the less data is required during transmission. This process requires a significant amount of memory.

Because of the importance of random access for stored video (e.g., CD-i) and the significant bit-rate reduction afforded by motion-compensated prediction, three types of picture are considered in the MPEG coding structure – intra-pictures (I), predicted pictures (P) and bidirectional pictures (B).

B-pictures provide the highest potential for compression and offer noise reduction by the resulting averaging, but require both past and future reference pictures for prediction – they cannot be used as references themselves. I-pictures provide access points for random access (I-pictures typically occur twice a second), but only offer moderate compression potential. P-pictures are used by subsequent P-pictures and B-pictures for prediction, but can propagate coding errors along the data stream. Since the MPEG encoder rearranges pictures into a different order for transmission, sound-resynchronisation is obviously of great importance at the decoder end!

During encoding, the picture is divided into a matrix of 'blocks', each of which is divided into 'macroblocks', consisting of sixteen lines by sixteen pixels. A motion vector, accurate to within half a pixel, is determined. This relates each block's content to the content of its counterpart in the previous frame. A 'matching' technique is used to find the previous block that matches the current block's contents the closest of all. The difference information between the previous block and the actual block is also transmitted to the decoder at the other end of the broadcast chain.

The system can be fooled – at low data rates – by fast-moving objects, for example a football, moving against a background. In this instance, the ball will appear sharp while any background detail will be lost. Material with considerable detail and irregular movement is the most critical test of a video compression system. It is important that the effects of such artifacts are reduced, or at least rendered 'subtle'. In the real world, however, cameramen and graphics operators working for digital broadcasters will be trained on the system's limitations so that programme material can avoid artifact-laden scenes wherever practically possible.

The video data stream is then formatted and multiplexed with the audio signal, which is itself digitised and compressed. Where several services are to be provided on a single carrier (e.g., cable system or satellite transponder), the combined services are multiplexed into a combined data stream prior to modulation.

Transmission over a broadcast medium (e.g., a satellite transponder) is normally achieved using quadrature phase-shift keying (QPSK), since it is very efficient for digital systems. If the data rate is 8M-bits/s, the bandwidth required would be 6·75MHz. It must be stressed that data rates in the order of 8M-bits/s are used only for broadcast-quality applications, such as satellite news-gathering and programme distribution, the equipment setup for which is shown in Figure 3. Those associated with consumer applications will be much lower, so that several digital channels can be squeezed onto a single 27MHz transponder of the type used on Astra's satellites. Digital satellite news-gathering feeds are already a reality – and owners of multi-satellite systems who like to eavesdrop on such transmissions are already getting worried!

The CD-i/Full Motion Video MPEG application is an issue in its own right, and will be featured in a future article. As an intended mass-market device, the price of the semiconductors used in its design has gone down dramatically. At the heart of the Philips CD-i FMV cartridge lies the Motorola chipset, which is shown in Figure 4. The MCD251 combines all of the functions necessary to implement MPEG 1 FMV decompression. The output from the MCD251 is fed into a 24-bit video DAC, the MC44200, and from there into a PAL or NTSC encoder (such as the MC13077) if a composite video signal is required. Audio decoding is catered for by a DSP56001 DSP chip, the output of which is fed into an audio DAC. The DSP56001 is fed by an MPEG system layer decoder, the MCD260. Future generations of MPEG hardware will combine most of this circuitry onto a single chip, bringing this cost down further. Low-cost hardware, of course, is essential in attracting the public to buy it – and this applies as much to digitally-delivered television services as it does to CD-i.

So then, what does the future hold? The basic technology has been established for some time, and the prices of ever more powerful MPEG chips are coming down. CD-i, aided by the best efforts of Philips' vast corporate marketing machine, is starting to take off, and we will be seeing Video CD movies and games (see Photo 6) appearing more often in the shops. These could supplement – and perhaps eventually replace – VHS rental tapes, although we are some time off from a domestic digital video recorder.

Another potential MPEG-spinner is the mooted Digital Sky service. Unfortunately, Sky already supports a large number of channels on Astra, and is likely to dual-illuminate its services digitally, rather than taking the expensive route of starting up new services and convincing the public of their value. This is particularly likely, since each of the themed channels has a big enough scope to appeal to the viewers required to make it profitable. This is not the US, which has a much bigger population and can support 24-hour kite-building and cat-aerobics channels. Unless there is an incentive (a year's free viewing, perhaps?), most of the Sky-viewing public will not see the point in forking out for another black box (see Photo 7).

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Acknowledgments

Acknowledgments are due to David Fisher of Motorola, Bruce Randall of National Transcommunications Limited and John Morris of Philips Research Laboratories for their assistance in producing this article.

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eWorld to Change Shape of Online Services

Apple has added a new dimension to the world of electronic information services with the introduction of eWorld (the easiest way for Macintosh users to become part of the world's fastest-growing community) the online community.

eWorld for Macintosh will be the first in a series of eWorld interactive services available to personal computer users. It uses real world images to give users an experience they will immediately feel comfortable with.

In its tradition of making technology easy for everyone to use, Apple has hidden the enormous complexity of a global communications network behind a bright, cheerful town square which has buildings that everybody will recognise – a Learning Centre, a Post Office (The Mail Centre), a Lifestyle Centre (Living & Leisure Centre), a Business Centre and even an information booth that tells the user exactly what they need to know about the online community, and how to get the information they need.

Once in eWorld for Macintosh and strolling around this 'virtual town square' users will find information laid out in a friendly yet logical way. Publishers will take advantage of the powerful 'eWorld Press' tools to provide innovative online publications that combine real-time useful information with analysis, comment and many opportunities for feedback and response by subscribers.

Users can easily communicate with users of the Internet with eWorld, as well as many other electronic mail services. eWorld offers a range of real-time interactive communications capabilities, including lecture and information sharing forums, or town meetings, that enable up to 250 people to participate simultaneously. Smaller groups of eWorld users can chat and collaborate electronically in both public and private forums.

eWorld services will be made available on a range of devices, including Macintosh personal computers, Windows PCs, and Newton devices, and people will be able to access common features across the different platforms. Contact: Apple Computers, Tel: (0800) 127753.

Net Assets

Carrera is flogging what is claimed to be the UK's first Internet-ready PCs – with easynet software and a US Robotics modem pre-installed. Hooking up to the Internet is then simply a matter of plugging the machine into a phone line. Internet subscription via easynet is included in the package – training is also available. Contact: Carrera Technology, Tel: (0171) 830 0486.

Paddy Online

Hey, who said politicians where slow to adopt to new technologies. Liberal Democrat leader Paddy Ashdown has followed in the footsteps of internet-guru President Clinton, and is now online.

By Autumn this year, it will be possible to contact all the liberal democrat MPs via the CIX bulletin board.

Paddy Ashdown can be contacted on paddyashdown@cix, although he has stressed that not everyone can expect a reply since he is presently deluged with hundreds of conventional letters a day.

Bill Clinton on the other hand, promises a personal reply to all who send an email to his office on president@whitehouse.tod.

Beeb into the Net

The BBC is offering public connection to the Internet, bringing together libraries, news services, databases, individuals and organisations from around the world.

The BBC Networking Club aims to make it as easy as possible for people to gain access to the internet, and as such operates on a non-profit making basis. A flat subscription fee of £12 a month means that there are no additional charges for being online to anywhere in the world, other than the phone call to servers at London, Cambridge, Edinburgh, Manchester, Birmingham or Bristol. Contact: BBC, Tel: (0181) 576 7799.

DIARY DATES

Every possible effort has been made to ensure that the information presented here is correct prior to publication. To avoid disappointment due to late changes or amendments please contact event organisations to confirm details.

1 November. Talk & Demonstration on First Aid by St. Johns Ambulance, Sudbury and District Radio Amateurs. Tel: (01787) 313212.

1 to 3 November. International Coil Winding Exhibition, Wembley Centre, London. Tel: (0181) 910 7910.

1 to 3 November. WINDOWS EXPO, Olympia, London. Tel: (01256) 381 456.

1 to 3 November. EMCOM – Mobile Communications Exhibition, Wembley Centre, London. Tel: (01322) 660070.

1 to 3 November. OPTI-COMM – European Optical Communications Show, Novotel, London. Tel: (01425) 473535.

5 to 6 November. Eighth North Wales Radio and Electronics Show, Aberconwy Conference Centre and The New Theatre, Llandudno. Tel: (01745) 591704.

8 to 10 November. Computer Graphics EXPO, Wembley Centre, London. Tel: (0181) 995 3632.

10 to 12 November. Design & Technology Exhibition, NEC, Birmingham. Tel: (01425) 272711.

13 November. The Fourth Barnsley Amateur Radio and Computer Rally, The Metrodome, Barnsley. Tel: (01226) 716339.

22 November. CIM – Computers in Manufacturing, NEC, Birmingham. Tel: (01932) 564455.

1 to 4 December. Christmas Computer Shopper Show, Grand Hall, Olympia, London. Tel: (0181) 742 2828.

6 December. Open Forum – Questions & Answers on Anything Related to Amateur Radio, Sudbury and District Radio Amateurs. Tel: (01787) 313212

6 to 7 December. DSP – Digital Signal Processing Exhibition, Ramada Heathrow, London. Tel: (0181) 547 3955.

6 to 8 December. International Online/ CD-ROM Exhibition, Olympia, London. Tel: (01865) 730275.

12 to 14 December. Digital Signal Processing for Communication Systems, University of Warwick, Warwick. Tel: (01254) 65201 Ext. 5822.

17 to 19 January. Outdoor Event & Live Music Production, Wembley Centre, London. Tel: (01203) 694393.

29 January to 1 February. European Light show Exhibition, Earls Court, London. Tel: (01952) 290905.

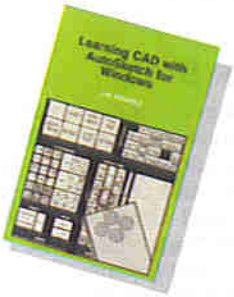
Please send details of events for inclusion in 'Diary Dates' to: The News Editor, *Electronics – The Maplin Magazine*, P.O. Box 3, Rayleigh, Essex, SS6 8LR.

New Books

Learning CAD with AutoSketch for Windows

by J. W. Penfold

Written with two main purposes, this book aims to both introduce the newcomer to CAD, and also to act as a training guide to using AutoSketch in the Windows environment. The divisions in the book make it easy for the first-time user to get to grips with AutoSketch in the minimum of time. One of the major advantages of using a CAD package under Windows is that information can be interchanged between the CAD program and other Windows applications. This makes anything that has been drawn in AutoSketch easier to use in word processors or other drawing programs. The first section of the book describes how to move around within the environment and how to navigate through the different pull-down menus and command boxes. The use of icons makes it easier to select commands, but only once you know what you need. As you progress through chapter one, you will be taught how to draw lines, load files and measure angles, etc. Some functions, like attach, grid snap and fillet, need to be practised just to get the hang of operating the program before you can steam ahead.



The book acts as a guide through all the teething problems that you may encounter, and helps in training you to use the commands that will form the basic bread and butter of getting drawings into the system, and therefore using it to its full potential. All through the book you will see screen output from the original program, showing what each menu looks like and how the screen should look at any one instance. The second section covers all the drawing commands, and builds skill and a knowledge of how to use the commands to the best effect. Subsequent chapters cover objects, parts and arrays, changing drawings, drawing assistance, measurements and printing. Considering the size and complexity of AutoSketch, with its many features and intricacies, this book goes a long way to teaching you how to use CAD and how to get the best out of AutoSketch.
1994. 104 pages. 198 x 130mm, illustrated.

Order As AN11M
(Learn CAD Autosketch) £5.95 NV

Integrated Digital Networks

by L. S. Lawton

Many organisations are now taking control of their communications requirements, and own private telecommunications equipment, rather than renting or leasing the services, as companies have done in the past. The aim of this book is to act as a source of information for those involved with the operation of such equipment, giving them an insight into how large systems like ISDN (Integrated Services Digital Network), PCM (Pulse Code Modulation), TDM (Time Division Multiplex) and PABX operate. As technology continues to advance, high-capacity digital systems and optical fibre transmitting mediums come into operation. This up-to-date book covers information on a large number of different systems, and goes a long way to offering an understanding of how these modem systems manage to cope with the amount of information we rely on them to deliver. Among the many areas covered by this book, information is included on: electronic telephones; facsimile systems; digital networks; digital transmission and PCM systems; digital switching; systems in digital exchanges; common channel signalling; System X; private digital telephone exchange systems; integrated services PBX; private digital networks; integrated services digital networks; digital transmission hierarchy; and optical fibre transmission systems.

All of the topics covered are discussed in great detail with a great deal of information that up until now has not been available to the public, unless you have either worked closely with British Telecom or Mercury services. Information in this book will appeal mainly to engineers in the telecommunications sphere who will be able to relate to the subject, or to those wishing to develop their understanding of modem telecommunications mediums, or people wishing to understand the systems which we have all come to rely upon.
1993. 395 pages. 250 x 130mm, illustrated.

Order As AN08J
(Integ Digital Netwks) £24.95 NV

Electronic Testing and Inspection

by Keith Brindley

A highly informative book aimed at test engineers, detailing basic information they will need in order to do their job. This book has been produced in association with the Engineering Training Authority, and can be used as a reference for trainees and students, or as a back-up reference for more experienced staff. The book details many aspects of test engineers' everyday tasks, including sections on tools and equipment; basic tools; meters; practical use of meters; insulation test meters; bridges; signal generators; oscilloscopes; timer counters; AF power meters and power supply units.

On the inspection side there are details for: inspection techniques; final inspection; and component identification including: transistors; integrated circuits; diodes; resistors; capacitors; inductors; and miscellaneous components. Inspection also covers: PCBs; terminals; component mounting; soldered joints; wrapped joints; crimped joints; wires and cable-forms. Testing instructions and drawings are supplied for: connecting equipment; circuit diagram conventions; receiver alignment; amplifier gain and frequency response; and special test jigs, together with test and inspection terminology. In addition to all the information that is provided on testing and inspection, there are sections on CEN, ISO, IEC and CENELEC specifications and standards, in order for the test engineer to keep within the appropriate guidelines for quality, safety and for working practices.

The book is packed full of hints, tips and precautions to allow the electronic test engineer to do his job with the highest level of safety and accuracy.
1994. 289 pages. 198 x 90mm, illustrated.

Order As AN09K
(Elec Testng & Inspec) £12.95 NV

Electronic Projects for Video Enthusiasts

by R. A. Penfold

Camcorders and home video production have become very popular in recent years and it is possible to have a great deal of fun without having to do any editing of the tapes you make. However, at some stage most video enthusiasts try their hand at producing a tape of recorded highlights, and there are many ready-made accessories which enable the enthusiast to undertake more professional editing. Many of these accessories can be constructed for a fraction of the cost. This book provides ten designs for video accessories – five circuits for audio processing including mixers, faders and dynamic noise limiters, and five for video processing which include faders, sideways wiper and video crispener. All the projects can be either battery powered or powered from a suitable mains power supply – a suggested circuit is included. All the projects use cheap and readily available components, and full construction details are provided, including stripboard layouts and wiring diagrams. No elaborate test equipment is required, and where appropriate, simple setting up procedures are included. Most of the projects are easy to construct, and several are suitable for the complete beginners at electronic construction.

A handy and inexpensive book that provides a number of practical designs for video accessories that will help the video enthusiast get the best result from a camcorder and VCR. Highly recommended.
1994. 124 pages. 178 x 110mm, illustrated.

Order As AN15R
(Prjts For Video Enth) £4.95 NV

Hands-On Guide to Oscilloscopes

by Barry Ross

Oscilloscopes have the ability to make voltages 'visible' and have become a very powerful diagnostic and development tool. With the spread of electronic control systems into all forms of science and industry, the oscilloscope has been introduced into many new disciplines. People in the most unlikely fields such as medicine and printing, now find themselves having to use an oscilloscope to control or maintain their own equipment, or to study phenomena which can be displayed through an appropriate transducer as voltage against time.

This book is for anyone who wants to learn about oscilloscopes, and all the topics covered assume that the reader has no previous knowledge or experience of how an oscilloscope works. Although the chapters follow a sequence, each chapter is treated as independently as possible,

and can be read separately for quick reference. The book allows the novice to become familiar with oscilloscope circuitry and the correct operation of the equipment in a wide range of applications. It then goes on to explain more complex functions such as digital storage circuitry and the correct use of digital storage oscilloscopes (DSOs). Other topics covered include probes and their use, choosing oscilloscopes and what to do when things go wrong. Practical application examples are included at the end of each chapter.

The comprehensive text and practical approach make this book ideal for engineers, scientists and electronics enthusiasts alike.
1994. 245 pages. 245 x 174mm, illustrated.

Order As AN13P
(Guide To Scopes) £17.95 NV

Maplin Key Call

by Robin Hall

Maplin tone encoder for use with a standard telephone.

Many readers will be familiar with the home banking services provided by some of the major banks and building societies. This enables account holders to conduct business over the telephone, using a DTMF (dual tone multi-frequency (tone dialling)) phone or a pocket DTMF dialler on a conventional telephone to access and then operate the various services provided. Maplin Electronics has a similar system for placing orders, known as Maplin key call.

The Maplin key call system means that you can place your orders directly onto the Maplin mainframe computer, 24 hours a day, seven days a week. Therefore, this super-quick alternative method to the normal voice order system is available outside of normal working hours. The method of using Maplin key call is given later in this article, but first I thought you'd be interested in how the system works.

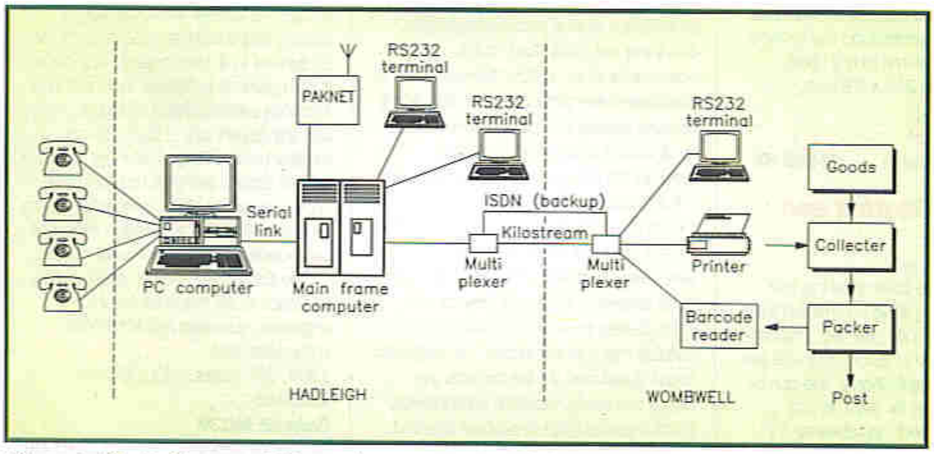


Figure 1. Block diagram of the main components of the Maplin key call system.

The Inside Story

The main components of the Maplin key call system are shown in Figure 1. As can be seen, after the telephone call has been put through, the start of the process is at the Maplin Head Office at Hadleigh near Rayleigh in Essex. There are four telephone lines which are interfaced to a dedicated IBM compatible PC. This runs the main Maplin key call program which works by responding to encoded tones from the user's telephone; prerecorded voice messages are programmed to respond to the tones keyed in.

The PC is connected by a real-time serial link to the Maplin mainframe computer. Stored here are all the customer records and stock details.

The mainframe computer has a number of outputs, one of which connects via another serial link to a PAKNET unit (for further information on PAKNET refer to *Electronics* Issue 78) which is then linked to a credit card clearing establishment. Also coupled are multiplexer units which connect to a BT Kilostream data highway to Wombwell near Barnsley in South Yorkshire (a backup ISDN (integrated services digital network) line is also available in case of failure) where asynchronous RS232 terminals are connected into the system and, all importantly, a printer for the orders to be printed out.

A = 11	N = 24
B = 12	O = 25
C = 13	P = 26
D = 14	Q = 27
E = 15	R = 28
F = 16	S = 29
G = 17	T = 30
H = 18	U = 31
I = 19	V = 32
J = 20	W = 33
K = 21	X = 34
L = 22	Y = 35
M = 23	Z = 36

Table 1. The standard Maplin key call alphanumeric codes.

The orders are removed from the printer, then 'collectors' fetch the required items which are given to the 'packers'. Before the order leaves the building at Wombwell, a bar-code number is read off the package and is automatically sent back down the Kilostream data highway to the mainframe computer in Hadleigh, thus completing the loop.

Types of Telephone Required

In order for Maplin key call to respond, audible DTMF encoded tones are required. Most modern telephones are able to produce DTMF tones.

Older telephones may not be able to produce DTMF tones, and an external tone dialler will be required. There are two DTMF tone diallers available from Maplin – the Pocket Tone Dialler Pad (ZB19V) and the Miniature Tone Dialler (CK25C). It is easy to use one of these diallers, and once the Maplin key call number has been dialled conventionally, the tone dialler is placed against the microphone and the required digits entered. The DTMF tones will then be transferred through the microphone onto the line, and the computer will respond to the tones.

Preliminaries

Before using the system, however, you will require a Customer Number. If you are already a Maplin Mail Order customer you will already have a customer number; this is normally found on an invoice/delivery note sent previously with an order, or it can be found on mailshots received from the company addressed to yourself. If you have not previously used Maplin's Mail Order Service, or don't know your customer number, call Customer Services on 01702 552911 and they will happily issue you with a customer number or tell you what it is if you've forgotten it.

You will also require a PIN (personal identification number); this can be obtained from Maplin by calling up Customer Services on 01702 552911, and asking for a PIN. Quote your customer number and you will then be given your PIN. Future invoice/delivery notes will show both numbers.

Once you have your customer number

Type	Description	Code Letter	Digit Code
Carbon Film 1/8W	Micro Res	U	80
Carbon Film 1/3W	Econ Res	B	81
Metal Film 0·6W	Min Res	M	82
Metal Film 0·6W in packs of 10	Min Res in 10's	A	83
Metal Film 2W	2W Res	D	91
Carbon Film 1W	W Res	C	84
Wirewound 2·5W	W/W	S	92
Wirewound 3W	W/W Min	W	85
Wirewound 7W	7W W/W	L	86
Wirewound 10W	10W W/W	H	87
Wirewound 25W	25W W/W	P	88
High Voltage Resistor	HV Res	V	89
Economy Resistors 1/4W in packs of 10	Econ Res in 10's	F	93
Economy Resistors 1/4W in packs of 100	Econ Res in 100's	E	90
Note: All resistor Starter Packs are coded as standard order codes.			

Table 2. The fixed resistor codes.

Value	Code	Value	Code	Value	Code	Value	Code
0Ω1	100	47Ω	140	2k2Ω	180	100kΩ	220
0Ω12	101	51Ω	141	2k4Ω	181	110kΩ	221
0Ω15	102	56Ω	142	2k7Ω	182	120kΩ	222
0Ω18	103	62Ω	143	3kΩ	183	130kΩ	223
0Ω22	104	68Ω	144	3k3Ω	184	150kΩ	224
0Ω27	105	75Ω	145	3k6Ω	185	160kΩ	225
0Ω33	106	82Ω	146	3k9Ω	186	180kΩ	226
0Ω39	107	91Ω	147	4k3Ω	187	200kΩ	227
0Ω47	108	100Ω	148	4k7Ω	188	220kΩ	228
0Ω56	109	110Ω	149	5k1Ω	189	240kΩ	229
0Ω68	110	120Ω	150	5k6Ω	190	270kΩ	230
0Ω82	111	130Ω	151	6k2Ω	191	300kΩ	231
1Ω	112	150Ω	152	6k8Ω	192	330kΩ	232
1Ω2	113	160Ω	153	7k5Ω	193	360kΩ	233
1Ω5	114	180Ω	154	8k2Ω	194	390kΩ	234
1Ω8	115	200Ω	155	9k1Ω	195	430kΩ	235
2Ω2	116	220Ω	156	10kΩ	196	470kΩ	236
2Ω7	117	240Ω	157	11kΩ	197	510kΩ	237
3Ω3	118	270Ω	158	12kΩ	198	560kΩ	238
3Ω9	119	300Ω	159	13kΩ	199	620kΩ	239
4Ω7	120	330Ω	160	15kΩ	200	680kΩ	240
5Ω6	121	360Ω	161	16kΩ	201	750kΩ	241
6Ω8	122	390Ω	162	18kΩ	202	820kΩ	242
8Ω2	123	430Ω	163	20kΩ	203	910kΩ	243
10Ω	124	470Ω	164	22kΩ	204	1MΩ	244
11Ω	125	510Ω	165	24kΩ	205	1M2Ω	245
12Ω	126	560Ω	166	27kΩ	206	1M5Ω	246
13Ω	127	620Ω	167	30kΩ	207	1M8Ω	247
15Ω	128	680Ω	168	33kΩ	208	2M2Ω	248
16Ω	129	750Ω	169	36kΩ	209	2M7Ω	249
18Ω	130	820Ω	170	39kΩ	210	3M3Ω	250
20Ω	131	910Ω	171	43kΩ	211	3M9Ω	251
22Ω	132	1kΩ	172	47kΩ	212	4M7Ω	252
24Ω	133	1k1Ω	173	51kΩ	213	5M6Ω	253
27Ω	134	1k2Ω	174	56kΩ	214	6M8Ω	254
30Ω	135	1k3Ω	175	62kΩ	215	8M2Ω	255
33Ω	136	1k5Ω	176	68kΩ	216	10MΩ	256
36Ω	137	1k6Ω	177	75kΩ	217		
39Ω	138	1k8Ω	178	82kΩ	218		
43Ω	139	2kΩ	179	91kΩ	219		

Table 3. The resistor value codes.

and PIN, you will also need your credit card to hand. To make it easier and to save your telephone charges, a removable order preparation form is provided at the rear of the Maplin Catalogue. Photocopy this and use it to prepare your order before making the call; enter your customer number, PIN, credit card number and expiry date.

Converting the Codes

The standard Maplin alphanumeric order codes must be converted into an all-digit number. This is so that you can dial the order code and the computer can process the information provided. The last letter of the order code is ignored when converting to numeric form.

For example:

Order Code
RW 67 X
ZA 11 M

Using the conversion chart in Table 1, R converts to number 28, W converts to number 33, and 67 goes through as it is. The X is ignored, so the alphanumeric code now takes the digital form of 28 33 67. The next order code is converted in the same manner, and becomes 36 11 11; the M is ignored. When the computer responds to the digital numbers the full order code will be repeated.

Resistor Codes

Fixed resistors use a separate coding system, see resistor conversion charts (Tables 2 & 3). To order a particular resistor simply convert the code letter into the digit code.

Tables 2 & 3.

For example:

Min Res	4Ω7	(M4R7)
Min Res	47kΩ	(M47K)
Min Res	4M7Ω	(M4M7)
1 Pack of 10 Min Res	470Ω	(A470R)
Wirewound 7W	0Ω47	(L0.47)
100 Econ Res	470kΩ	(E470K)

Using the conversion chart in Table 2, M converts to number 82. Looking at Table 3, 4Ω7 converts to number 120. So the alphanumeric code now takes the digital form of 82 120. The next order codes are converted in the same manner, and become as shown.

(M4R7) = 82 120
(M47K) = 82 212
(M4M7) = 82 252
(A470R) = 83 164
(L0·47) = 86 108
(E470K) = 90 236

When the computer responds to the digital numbers the full order code will be repeated.

Preparing the Way

First locate the Maplin key call order preparation form at the back of the Maplin Catalogue. This should be photostatted for multiple use or copied as a template. Figure 2 shows the same Maplin key call order preparation form.

MAPLIN
KEY CALL
01702 556751

ORDER PREPARATION FORM

Customer No. ☐☐☐☐☐☐☐☐ PIN No. ☐☐☐☐

Credit Card/ Account No. ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Date ☐☐☐☐☐☐ Card Expiry Date ☐☐☐☐

Order Code	Digit Code	Quality	Price

Confirmation No. ☐☐☐☐☐☐☐☐ **Total**

Figure 2. Maplin key call order preparation form.

Write your customer number and PIN, and then your credit card details, on your copy of the order preparation form.

Next select the items you wish to order from the catalogue, and write down the order codes and quantities. Remember to ignore the last letter of standard order codes. For fixed resistors write the order codes and quantities.

Using the charts, convert the order codes into digital format and write these down. Do the same for the fixed resistors using the special conversion charts provided.

With these details entered onto the form, you are now fully prepared for the next stage, to order the items.

Using the System

Dial 01702 556751 and wait for the announcement at the beginning. When prompted by the computer voice enter your order details from the preparation form. The reason why it is important to have the relevant details to hand will become clear, as any delay in entering certain details causes the computer to switch back to the beginning and automatically reprompt for the numbers.

After you have finished entering all your numeric order codes and quantities, the computer will read each item back to you with its normal stock item order code, the quantity you have ordered and the price. Check these items are correct and re-enter or delete any that have been entered in error.

When you are happy that all the items you have ordered are correct and have accepted them, the computer will give you the total amount that will be charged to your credit card. Make a note of this for your reference in the space provided on the form.

After accepting the order, you will be given an order confirmation number; write it on your form and quote this number if you ever need to contact Maplin regarding the order. Your credit card will be automatically debited.

Finally, replace the telephone receiver. The order will now be processed, and the goods despatched.

Welcome to the wonderful world of telephone/computer automation! E

REPAIRING RADIOS

Many a good transistor radio has had to be thrown into the rubbish bin after developing a fault. Unfortunately, servicing costs these days mean that it is not usually economical to have a radio repaired, particularly if it was not very expensive. However, with a little expertise and 'know-how' it is often quite easy to fix them and put an extra lease of life into an old radio. Sometimes it may only take a few minutes to effect a repair, other times it may take longer. But, either way, it will save some cash by saving the cost of the repair or a new radio, and it is worth having a go because there is nothing to lose. This month's article looks at basic radio principles.

PART ONE BY IAN POOLE

Equipment

It is surprising just how little test equipment is really needed to perform quite a comprehensive set of tests on a radio. The main requirement is obviously a multimeter. Even this need not be particularly fancy as most measurements only need to be approximate. Often measurements only need to indicate whether a voltage is there or not, rather than its exact value. This means that most of the cheap analogue test meters will be quite adequate. However, care is needed in some instances as a cheap meter will have a lower impedance. This will mean that it will load any high resistance circuits.

Digital multimeters are ideal. They are now coming down in price quite rapidly and often represent good value for money. This is particularly true when one considers that they often include many facilities beyond that of the standard amps, volts and ohms.

Other test equipment is obviously very useful. An oscilloscope and signal generator are two such items. However, the majority of people do not possess them and fortunately it is possible to do a lot of testing without them. Alternatively when they are needed a little improvisation can often pay dividends.

The Obvious

When starting to fault-find on a radio, it is very important not to overlook the obvious. It can be all too easy to look for a complicated fault in the midst of all the circuitry, when in reality it is something quite simple just waiting to be found.

Look for any telltale signs. For example, does the speaker make a 'plop' when the radio is turned on. If not, it is likely to be a problem with the power or the speaker may be disconnected somehow. Signs like these and many others help in the quick and speedy diagnosis of the problem. In fact, in most cases the faults are quite simple and they can often be located with the help of a few signs.

But before opening a radio up, beware! If it is operated from the mains there will be high voltages around, and great care should be taken at all times.

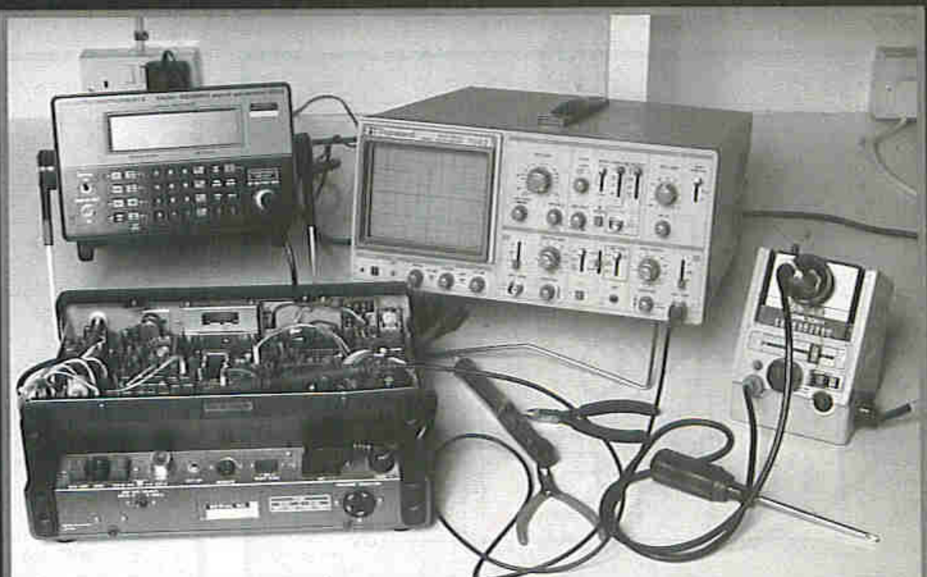
Fortunately many radios are battery operated but this can often lead to problems. A useful first check on any radio which shows no signs of life is the battery. Often people have spent a lot of time tracing a fault having been assured the batteries were new only to find that the batteries were as flat as a pancake and a new battery would indeed solve the problem.

Another problem with batteries occurs when they leak. When this happens the metal surfaces including the battery contacts, become badly corroded. The remedy is to remove completely any of the battery chemicals which have leaked out and thoroughly clean off the corrosion. All traces of corrosion need to be removed, because even the slightest amount can prevent the radio working. Better still, if the battery holder is replaceable, then a new one should be fitted.

Switches can be a major source of faults. They are particularly prone to failure in kitchens as a greasy film can easily build up on them. Smoky atmospheres also give rise to problems. Fortunately dirt from either of these environments can usually be removed quite easily by a small amount of switch cleaner. This should then be followed immediately afterwards by several rotations of the switch. If the dirt proves to be particularly stubborn then a piece of clean paper soaked in cleaner can be run through the contacts. Generally the paper has just enough abrasion to remove any dirt without damaging the contacts. If this is done then great care should be taken to ensure that none of the contacts on the switch are bent.

Another common problem is that of broken wires. Any wire which is moved is obviously likely to be broken sooner or later. This means that battery wires are particularly vunerable; often a quick inspection can reveal the offending wire and where it came from.

Telescopic aerials used for VHF FM reception are another main area for broken wires. Often a slight amount of movement at the base of the aerial can mean the wire connecting it to the main circuit board can become detached.



Ideal test equipment, signal generator, oscilloscope, plus standard tools.

Alternatively, the fixing nut for the aerial can become loose, resulting in the base of the aerial swivelling round and the wire breaking. If this is the case the radio will give plenty of background noise, but it will not pick up any signals. A quick inspection will reveal if the wire has actually broken.

Whilst talking of broken wires, it is not uncommon to come across broken printed circuit boards. These often result from the radio being dropped. Fortunately, it is often possible to fix them. If at all possible the board should be mechanically repaired, the actual method will depend upon the board and the nature of the break, normally a little ingenuity will provide the answer. Any broken tracks should have wires soldered across the break so that good electrical continuity is maintained.

Even though most breaks in the board will be obvious, this is not always the case. Even hairline cracks which are almost invisible can cause a break in continuity. If the radio has recently been dropped or knocked, then it is worth looking very carefully at the board for any signs of damage.

Once all the obvious problems have been eliminated it is necessary to look a bit deeper into the circuitry. However, to do this it is necessary to have an understanding of the basic circuitry of a typical transistor radio.

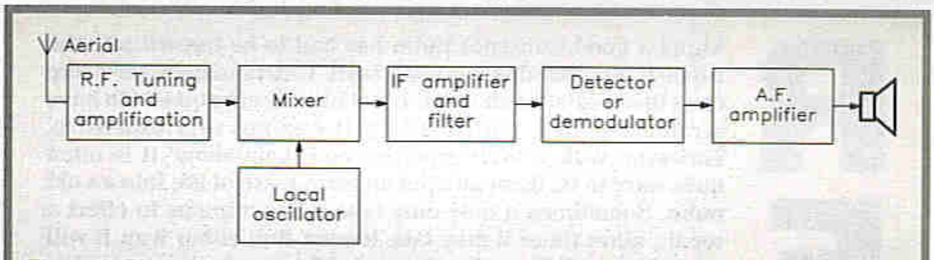
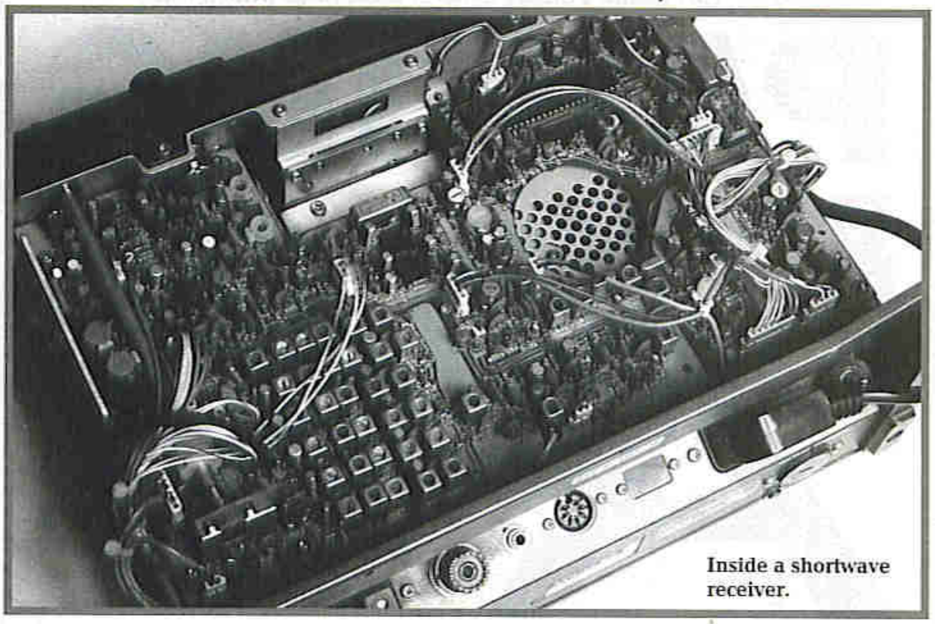


Figure 1. Block diagram of a superhet radio.



Inside a shortwave receiver.

Radio Basics

Virtually all transistor radios, and for that matter valve radios, are of a type called superhets (supersonic hetrodyne). This means that they convert the incoming signals down to a fixed frequency where most of the selectivity and amplification is provided. To see how this works a block diagram of a typical radio is shown in Figure 1.

The incoming signal is normally picked up on a ferrite rod aerial in the radio for AM transmissions on the long and medium wave bands. For VHF FM transmissions a telescopic aerial is needed.

The radio will have a certain amount of RF tuning. This is to allow signals in the right band to enter the next stage. In addition to the tuning, some radios will have a certain amount of amplification, although most medium and long wave ones will omit this stage.

Next, the signals enter a mixer. Here they are heterodyned or mixed with the signals from a variable frequency oscillator (VFO) in the radio. This process produces new signals at frequencies which are the sum and difference of two inputs. These signals are then presented to a fixed frequency intermediate frequency (IF) amplifier and filter.

The fact that two signals are produced by the mixer means that received signals on two different frequencies will appear on the right frequency for the IF stages. The RF tuning is used to allow only the correct signal to enter the mixer and it rejects what is called the 'image'.

The IF amplifier consists of one or more stages of fixed tuned amplifiers. For an AM radio the frequency of the IF amplifier is normally about 465kHz whereas, for FM a higher frequency of 10·7MHz is chosen.

Having been amplified and filtered in the IF stages the signal is demodulated to give the required audio. This is amplified to a level sufficient to drive the loudspeaker or headphones.

Radio Circuits

The actual circuits used in transistor radios will obviously vary from one radio to the next. This is particularly true when ICs are used, because the circuit is totally dependent on the IC. However, when discrete transistors are used it is surprising how similar the circuits can be. This makes the job of fault-finding very much easier. It is very useful because it is only rarely possible to obtain a circuit diagram.

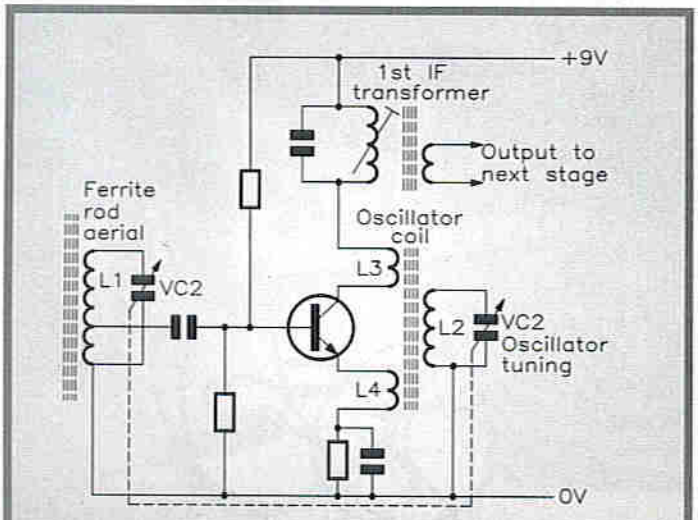


Figure 2. A typical self-oscillating mixer circuit.

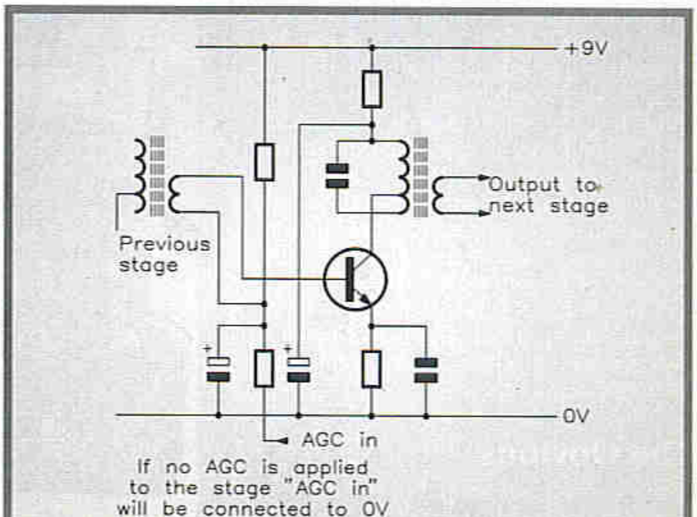


Figure 3. A typical IF amplifier stage.

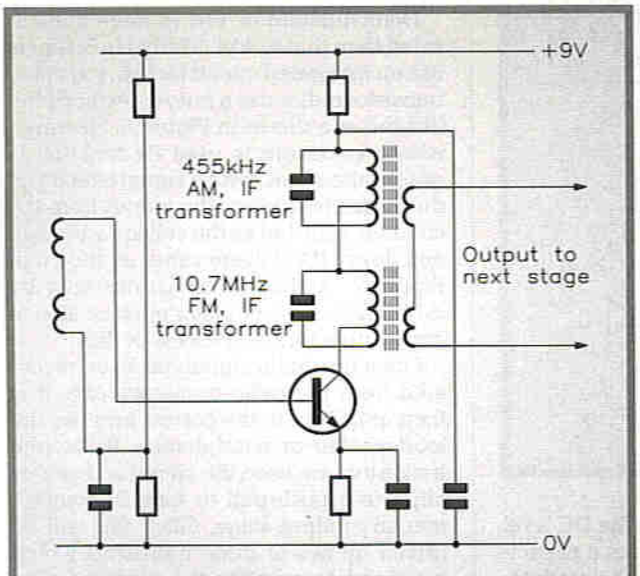


Figure 4. An IF amplifier for 455kHz AM and 10·7MHz FM operation.

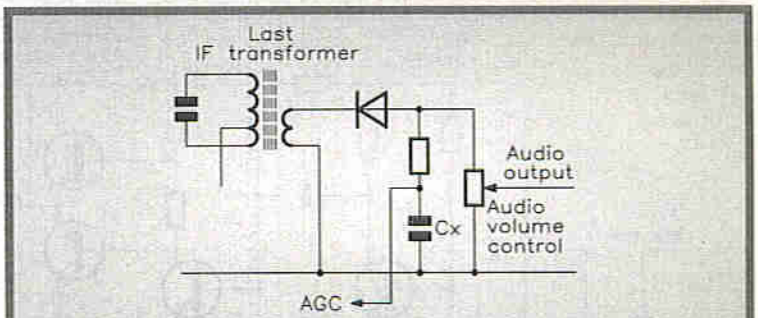


Figure 5. A simple AM detector.

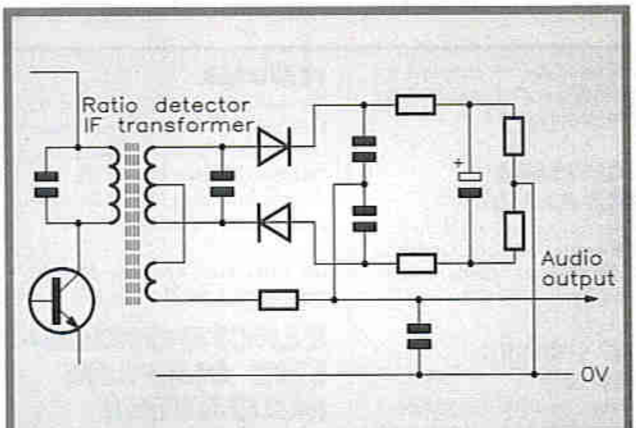


Figure 6. A simple FM detector.

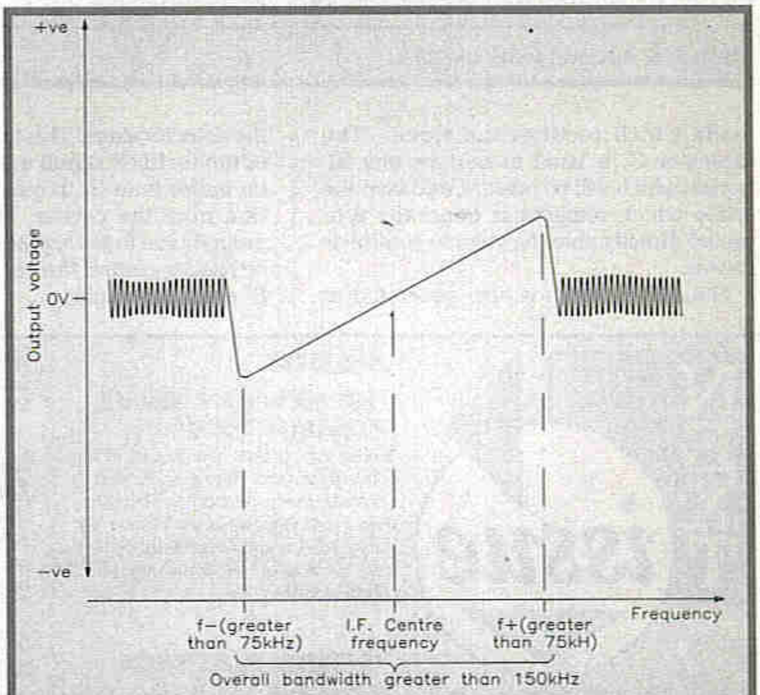


Figure 7. The voltage output from an FM detector as the signal frequency varies.

In most AM radios the RF tuning, mixer and local oscillator functions are performed by one transistor operating as a self-oscillating mixer. A typical circuit is shown in Figure 2. In this circuit the signal is picked up by the ferrite rod aerial which is tuned by the combination of VC_1 and L_1, the coil also acting as the pick-up coil for the ferrite rod. Normally there is a tapping on the coil so that the impedance is low for driving the transistor. The circuit oscillates at a frequency determined by VC_2 and L_2. The two coupling coils L_3 and L_4 provide the feedback path which enables the circuit to oscillate.

The signals from the aerial are made to beat with the oscillator signal to produce a new signal at the intermediate frequency. This is developed across the tuned IF transformer T_1 and then fed into the IF amplifier.

In virtually all circuits the RF and oscillator tuning capacitors VC_1 and VC_2 are ganged. This enables the circuits to 'track' together so that the resonant frequency of the RF tuning and the frequency of the oscillator always differ by the value of the IF. In this way the maximum level of the wanted signal is received and the maximum attenuation of image and unwanted signals are obtained.

Figure 3 shows a typical IF amplifier stage. Most radios have one or more stages which are virtually identical. It is fairly straightforward in its design. The signal comes in via an IF transformer. Again, this is tapped off part way down the coil. This is because transistors have low input and output impedances, and by using a tap they do not load the tuned circuit too much.

Contact cleaner and degreasing solvent.

Once the signal reaches the transistor it is amplified and presented to the next IF transformer. Normally the transformers are tuned on at least the input side, the adjustment normally being made by a single core.

The bias arrangements for the transistor are complicated slightly by the presence of an automatic gain control (AGC). This is required to keep the gain of the radio almost constant despite varying signal levels if the radio is moved or stations with different levels are tuned in. It also serves to help prevent very strong signals from overloading the receiver.

The action of the AGC is quite simple; the detector on the output of the IF amplifier generates a voltage dependent on the signal level. This voltage is then applied to the bias circuitry on each IF amplifier so that the level of bias and hence the gain is reduced for strong signals and increased for weak ones.

Many radios these days have both AM and FM wavebands. In these cases each IF amplifier stage will be made to operate on both. This is done by modifying the basic amplifier as shown in Figure 4. This arrangement operates quite satisfactorily because the resonant frequencies of the two IF transformers are sufficiently far apart. When the circuit is used on AM at 455kHz the effect of 10·7MHz FM transformer is negligible and the signals pass straight through it. Similarly when the circuit is used on FM the AM transformer will not affect the FM one.

The next stage is the demodulator. For AM signals this is done quite simply using a diode as shown in Figure 5. Here the last IF transformer is connected directly to the

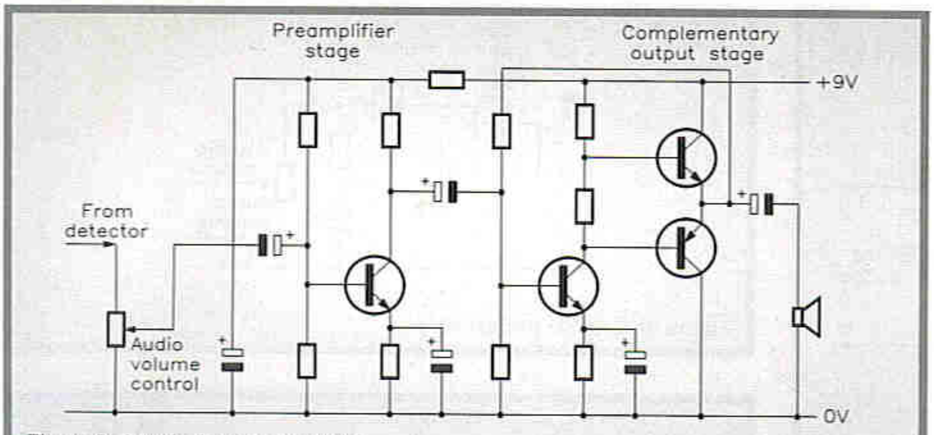


Figure 8. A typical audio amplifier.

diode which rectifies the signal. The capacitor C_x is used to remove any RF signals which will be present, and then the audio which remains is generally presented directly onto the volume control as shown.

The AGC voltage is also generated in the detector stage. This takes the DC level of the rectified signal and uses a capacitor larger than C_x to remove the modulation from the carrier. This DC level is proportional to the signal strength and can be used to control the gain of the previous IF amplifier stages.

Demodulation of FM is more complicated than that of AM. Many Hi-Fi tuners use an integrated circuit for this, but many transistor radios use a ratio detector circuit like the one shown in Figure 6. However, whatever design is used its function is exactly the same. With a signal exactly on the centre frequency, the output from the circuit is zero, but as the voltage varies up and down, the voltage varies as shown in Figure 7. As FM transmissions vary by ±75kHz the demodulator must be able to cope with a range in excess of this.

Once the audio signal has been recovered from the radio frequency one, it is then amplified to the correct level for the loudspeaker or headphones. If discrete transistors are used the circuit will generally use a push-pull or form of complementary output stage. Often this will be driven by two or three transistors which are used to amplify the signal to the required level for it. A typical circuit is shown in Figure 8.

Next month, practical fault-finding techniques are explained and applied.

NEXT issue

There are more terrific projects and features heading your way in next month's super issue of *Electronics – The Maplin Magazine*, including:

PROJECTS

THE NEWTON VALVE PREAMPLIFIER

Following on from the success of the Millenium valve amplifier. A superb modular stereo valve preamplifier project. From what we heard at Live '94, this is what everyone has been waiting for, and is again set to turn the Hi-Fi world upside down.

RECORD PLAYBACK MODULE

This Record Playback module uses non-volatile analogue EEPROM technology, and allows 16 seconds of speech to be written directly into the cells of a single special IC without A-to-D or D-to-A conversion!

VHF CROSSED DIPOLE AERIAL

The essential companion for the MapSat2 weather Satellite Receiver is presented in this issue; what's more it's easy to build too!

2M RF POWER AMPLIFIER

Two kits combined into one project for the radio amateur; to boost the power output of a handie-talkie for use in the car or at home.

FEATURES

Special features include an informative look at LEDs and Their Application', 'Video Termination', 'Fuzzy Logic, 'MapSat2 Satellite Receiver Review', a thought provoking look at light pollution at night and lots, lots more.

All this, plus all your favourite regulars as well!

ELECTRONICS– THE MAPLIN MAGAZINE

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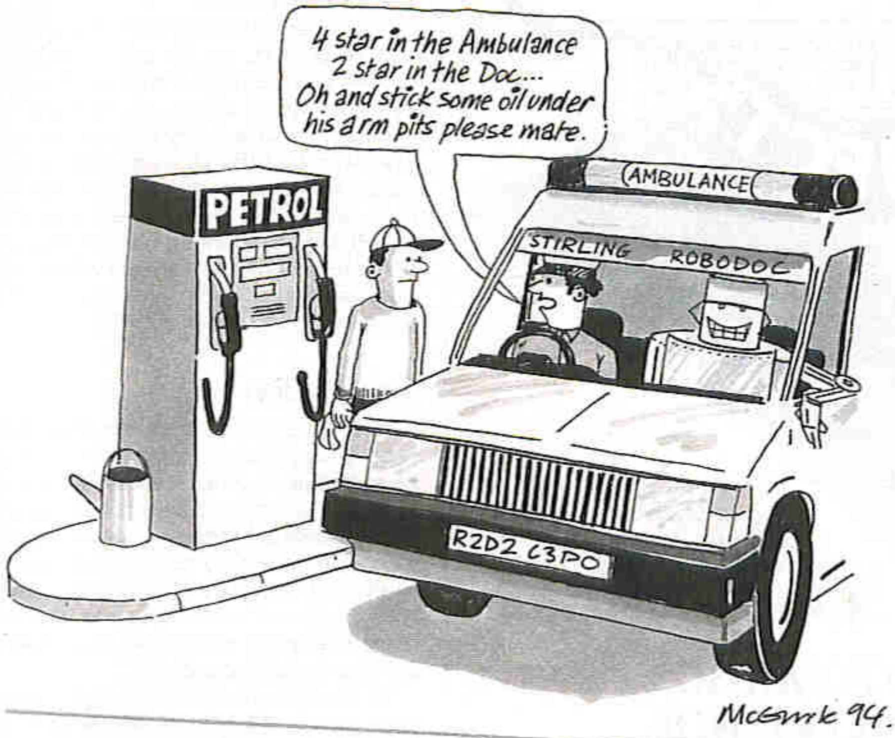
Stray Signals

by Point Contact



Mind My Mains!

My description, in Issue 79 of this magazine, of the rather hairy approach to powering the PC abode from a 1kW generator during power cuts, elicited an interesting letter from G. C. of Staffordshire. He recommended that PC should fit an ELCB, or RCCB (residual current circuit breaker as it is now called) to his generator – a sensible step which had, in fact, occurred to PC soon after writing the said piece. I looked for one in the September 1994 – August 1995 Maplin Catalogue; and found *three* on page 554! As it happened, I already had one anyway, as I always use one when cutting the hedge, or any other job needing a portable power tool. So, *that* RCCB (another one protects the supply to my electronics laboratory bench) now lives permanently plugged into the output socket of the generator when not otherwise in use.

G. C.'s interesting letter goes on to describe his own moves in the direction of electric power autonomy during the spate of power cuts during the Electricity strikes of 1974. Having obtained his generator, he contacted the local Customer Service Department of the electricity board for advice. They were 'co-operation itself', for a reason which soon became apparent. They recommended a changeover switch to transfer the house wiring to the generator output in the event of a mains failure – it sounds as though a contactor with changeover contacts, with its coil energised from the mains, would fill the bill – together with an RCCB for the generator. This is not only a safe and sound way from the customer's point of view, it also safeguards 'Fred the Faultsman', as he reconnects the ends of a mains cable that the Gas Board, cable TV cable-layer or whoever has accidentally dug through. Otherwise, poor old Fred may find the (supposedly) dead downstream end of the cable he is working on suddenly becomes live in his hands! Of course, readers of this magazine would automatically isolate their house wiring from the mains supply before powering up a generator, if only to protect the latter from the mains supply when it suddenly reappears without warning. But, apparently there are a lot of very non-technical people out there who have gone out and bought generators, to whom this thought (let alone Fred's safety) just never occurs. Hence the electricity board's eagerness to help G. C., and any other enquirers, to get it right.

News from Erehwon (and Everywhere)

The German Government has approved the construction of what is claimed will be the world's first commercial magnetic levitation train. It will run between Berlin and Hamburg at up to 400km/hour, cutting the present $3\frac{1}{2}$ hour journey time to just one hour. There will, doubtless, be a lot of sophisticated electronics (not to mention software) to control it all, ensuring absolute safety – one hopes. After all, with BR's all steel coaches, travellers have a fair chance of surviving a rail crash involving present-day conventional trains. But, a smash at 250mph does not bear thinking about, and rail crashes are by no means confined to this country. Still, there is a financial hurdle to be overcome before the project has any chance of coming to fruition. Over 8 billion DM will need to be found for the joint private-public venture, assuming parliamentary approval is forthcoming.

The day after the announcement of the above project, there was an intriguing announcement from surgeons at the Hotel-Dieu de Montreal Hospital, in Quebec. It seems that a robot that they operated from another room had successfully carried out three gall bladder operations. A robotic arm in the operating theatre, with a tiny TV camera and a laparoscope attached to it, was controlled by a joystick and push-buttons. The team said that the technique could be especially useful in rural hospitals, permitting an operation to be carried out by remote control where there was no surgeon available locally with the necessary skill to carry out the operation. One hopes that there will always be a handy back-up link via radio or satellite – it could be rather awkward if halfway through an operation the telephone line went dead due to an inconsiderate tree falling across it.

In November 1993, NASA, in Washington, D.C., announced that it had completed the first phase of a programme to build a supersonic airliner which could replace Concorde, and that it would begin the second phase. The first phase had evaluated environmental considerations, and the second would develop the airframe, propulsion, and system technologies over a seven year timeframe, and at a cost of 1·2 billion US dollars. Planned to enter service 'early in the next century', the plane will carry twice as many passengers as Concorde and have double its 5,600km range – if it ever happens.

Tailpiece

PC does not number numismatics among his many hobbies but, when an impecunious student, was always on the lookout for ways to 'turn an honest penny'. About that time, in the 1950s (long before decimalisation was thought of), the withdrawal from circulation of 'bun pennies' (pennies bearing Queen Victoria's head, with her hair done up in a bun) was imminent, and somehow, PC had come across the fact that very very few had been minted in 1863.

Our Mechanics of Machines lecturer (in those days, all engineering undergraduates – except the chemicals and the aeros – took the same first year course) was a real down-to-earth engineer. On hearing of some of our difficulties with the maths syllabus, he advised us not to worry, as maths was all abstractions anyway. In the real world, 2 + 2 did not really equal 4 but, for example, in the case of a couple of mechanical piece parts, 3·999-- inches, or two tenths of a thou' over, or whatever. PC, being well into Logic and Philosophy at the time, jumped to his feet announcing that that was only because the two piece parts were not themselves both exactly two inches in the first place, and that undoubtedly 2 and 2 made exactly 4. "All right," said our lecturer, "give us an example!". "Er – " followed by a bit of quick thinking, "twopence and twopence make exactly fourpence." "Very good – " conceded the lecturer, but he was interrupted by 'Smithie' (or was it Smorthit? – I forget which) expostulating "But, BUT – that's the man who only yesterday was offering anyone one shilling and threepence each for any 1863 pennies!" Well, every rule has to have its exceptions, I suppose.

Yours sincerely,

Point Contact

The opinions expressed by the author are not necessarily those of the publisher or the editor.

by Robert Kirsch

HEADLAMP AND TAIL-LAMP CONTROL

AUTOMATIC LOOP CONTROL

TRACK CIRCUITING

This article describes several circuits that may be added to a layout which uses the Maplin digital control system, described in Issue 71. These circuits have been in use on the author's 00 gauge indoor layout for some time and have been found to greatly improve the realism and enjoyment of the railway layout.

HEADLAMP AND TAIL-LAMP CONTROL

This circuit enables the head- and tail-lamps to be automatically operated from the receiver unit fitted in the locomotive, and controlled by the direction of travel. This unit may be fitted to dual ended locomotives to enable the headlamps to light only in the direction of travel, or to a complete train that is to operate in both directions, for example a High-Speed Train (HST) set, providing white lights at the front and red lights at the rear, depending on which way the train happens to be moving.

The circuit is fed from the output of the decoder in the receiver module.

When a receiver is selected by the control unit, and the speed control is advanced, pulses appear at one of the two outputs of the decoder, with the number of pulses being dependent on the speed setting. These pulses are fed via R1 and D1 (see Figure 1) to C1, causing it to charge rapidly. It is prevented from discharging when the input goes low by D1 being reverse biased.

The voltage developed across C1 is used to turn on TR1, via R2, and in so doing, causes current to flow through the lamp in the collector circuit. R3 reduces the voltage to enable a 12V lamp to be used. The lamp and the LED are effectively in series, across the supply, so that when TR1 is on, the LED is extinguished, and when it is off, the LED will light via the resistance of the bulb filament. The lamp will not light because the LED only draws about 10mA (because it is in series with R4).

Installation

Examples of installation for various applications are shown in Figures 2 and 3. It will be seen that, to control headlamps at both ends of a locomotive, two control circuits will be needed. In the case of a complete train, it is necessary to electrically couple all vehicles together. This is useful, as it enables several track pickups to be made along the length of the train, also making carriage lighting possible.

Three wires are required to enable headlamp control. A bridge rectifier and control circuit are required at the non-driving end of the train, with the pulse signals being fed on the third wire. A very flexible type of wire should be used between carriages, and the wire used in telephone cords has been found suitable for 00 gauge applications. Enough slack must be left to allow for negotiation of sharp curves. A single lamp may be used for the headlamps, and a flexible light guide (XR56L) can be used to transfer the light to the front of the vehicle. The ends of the light guide may be shaped into a lens by holding it near to a heat source, and allowing the plastic to melt, forming a small dome. Two LEDs may be used, if required, by connecting them in series, although it may be necessary to try several LEDs before installation to ensure they are both of the same brightness.

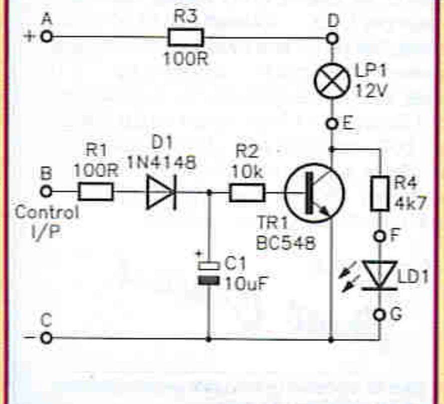


Figure 1. Train lamp control circuit diagram.

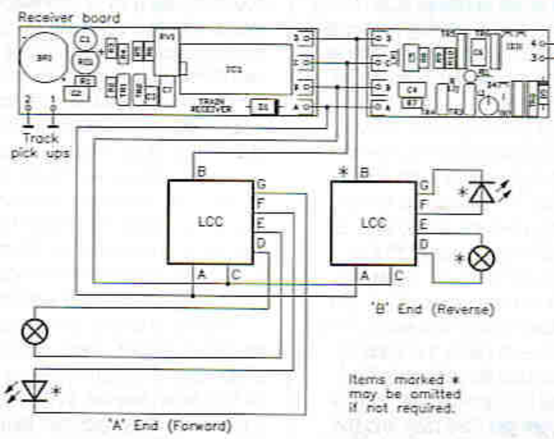


Figure 2. Typical locomotive installation.

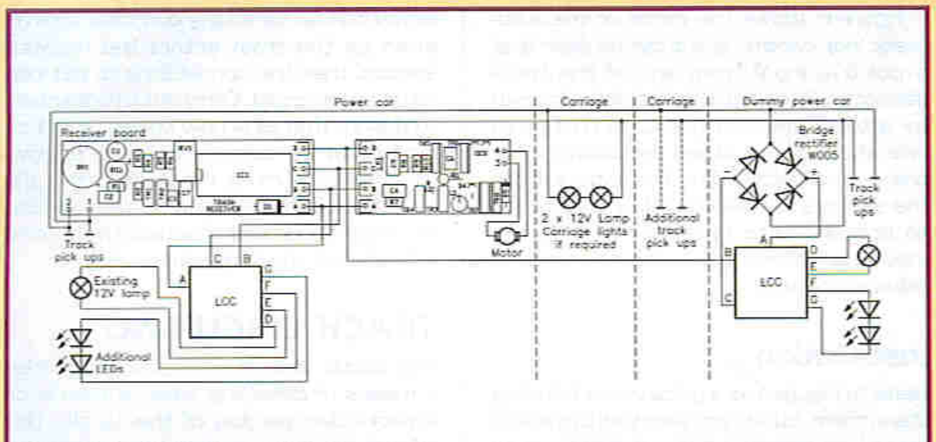


Figure 3. Installation in an HST set.

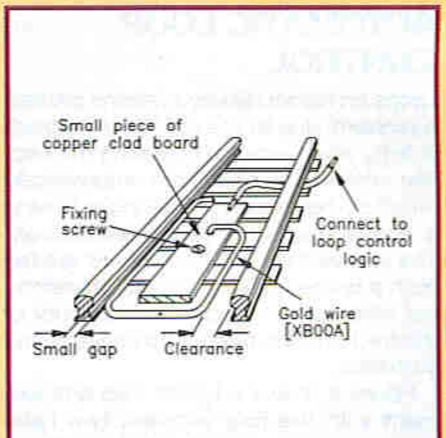


Figure 5. Track sensor detail.

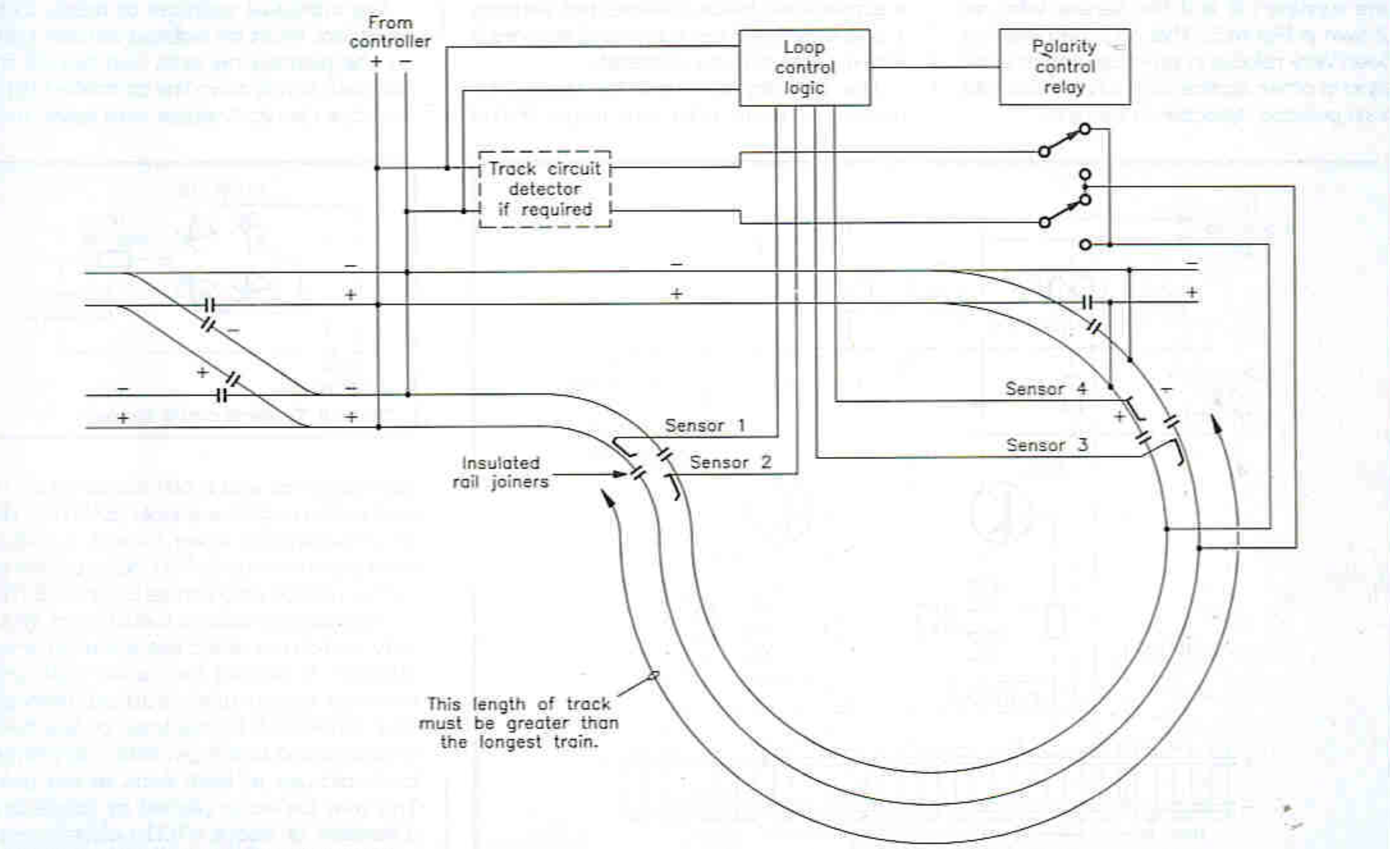


Figure 4. Automatic loop control schematic.

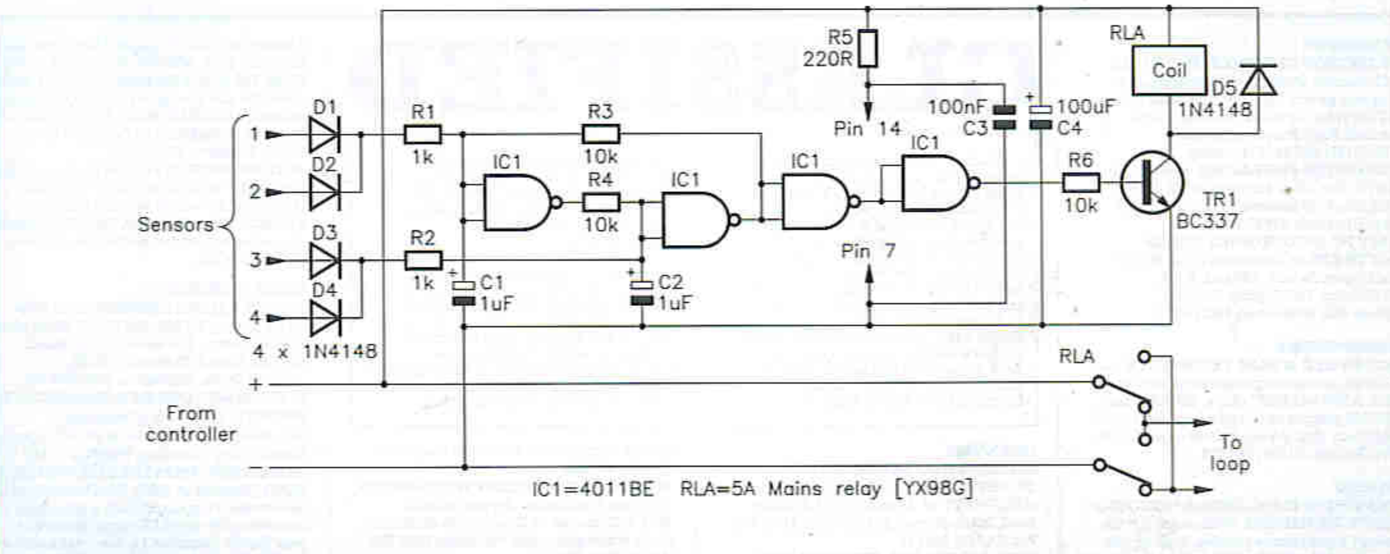


Figure 6. Automatic loop control circuit diagram.

AUTOMATIC LOOP CONTROL

Loops on model railway systems present a problem, due to the confliction of track polarity when entering or leaving the loop. The system described here automatically detects when a train is entering or leaving a loop, and sets the polarity accordingly. The receivers used in locomotives are fed from a bridge rectifier, and are, therefore, not affected by the change in polarity of the track; hence, there is no pause during switching.

Figure 4 shows a typical loop arrangement with the four sensors; two have been placed at each end of the loop. These sensors are simply made from gold plated wire, and arranged so that the wheel flanges of the train make contact between one running rail and the sensor wire, as shown in Figure 5. This arrangement has been very reliable in practice, and may be used in other applications where accurate train position detection is required.

Figure 6 shows the circuit of the automatic loop control, and it can be seen that a positive input from any of the track sensors will cause the bistable, formed by gates 1 and 2 of the IC, to change to one state or the other, depending upon the sensor activated. The inputs from the sensors are decoupled by C1 and C2 to prevent false operation due to the inevitable voltage spikes found on model railway systems.

Installation

Refer to Figure 4 as a guide when installing the system, but do not worry at this stage about the polarity of the connections to the loop section. When the sensors are in position, check their operation by shorting them to the appropriate running rail with a screwdriver blade. Ensure that sensors 1 and 2 operate the relay, and sensors 3 and 4 cause it to be released.

The polarity can now be tested by driving a train into the loop; if the protection circuit on the controller trips as soon as the train enters the isolated section, then the connections to the loop must be reversed. Carry out a further test to ensure that all is now correct. It will be noted that the distance between the two inner sensors must be greater than the longest train that is likely to use the loop to prevent both sets of sensors from being activated at the same time.

TRACK CIRCUITING

The circuit shown in Figure 7 provides a means of detecting when a train is on a particular section of the track. This information may be used to provide an indication on a track layout diagram, or may be interfaced with signalling equipment.

The individual sections of track, to be equipped, must be isolated at both ends, on the positive rail only, and fed by the common supply from the controller via the detector circuit. A single wire feeds from each detector, and is connected via a 12V bulb to the negative supply (EARTH). The lamp illuminates when current is drawn from the track due to TR1 being turned on by the voltage drop across D1 and D2. The two diodes only allow a reduction of about 1·4V, and do not affect the operation of the system. It should be noted that only vehicles which draw current through their wheels will be detected by the track circuiting, and so it is necessary to provide track pickups at both ends of the train. This may be accomplished by connecting a resistor of about 470Ω between both wheels on an axle of the last vehicle, or a tail-lamp may be provided using the circuit shown in Figure 8.

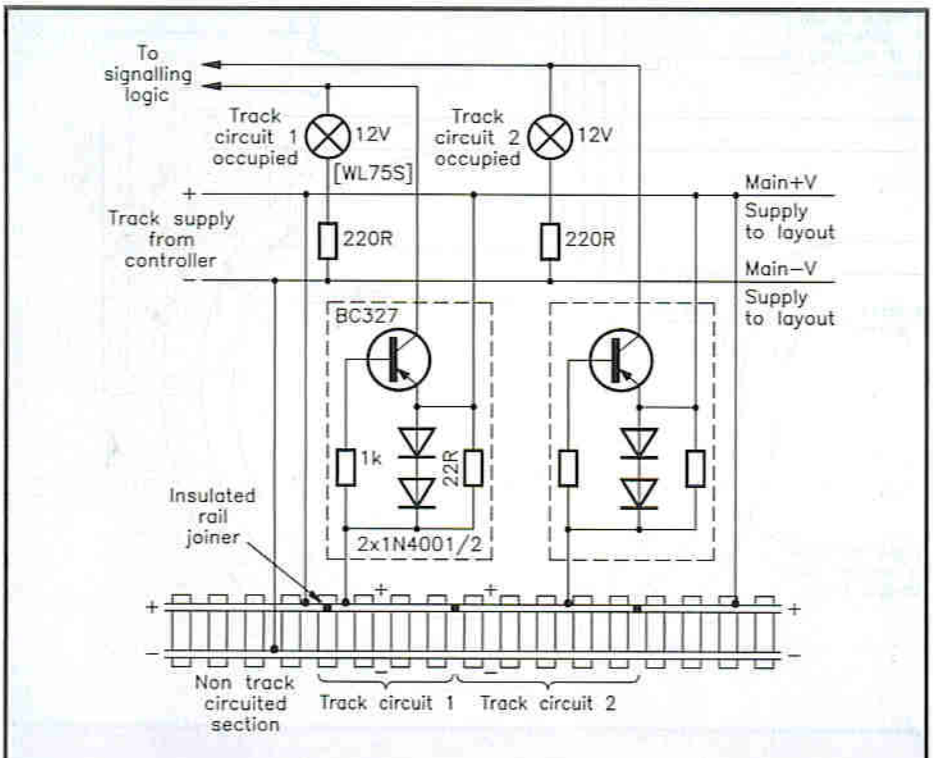


Figure 7. Track circuiting circuit diagram.

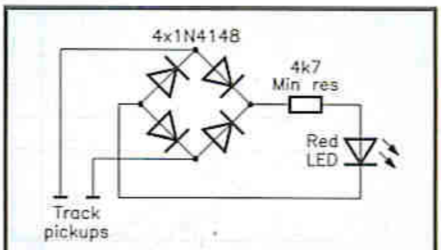
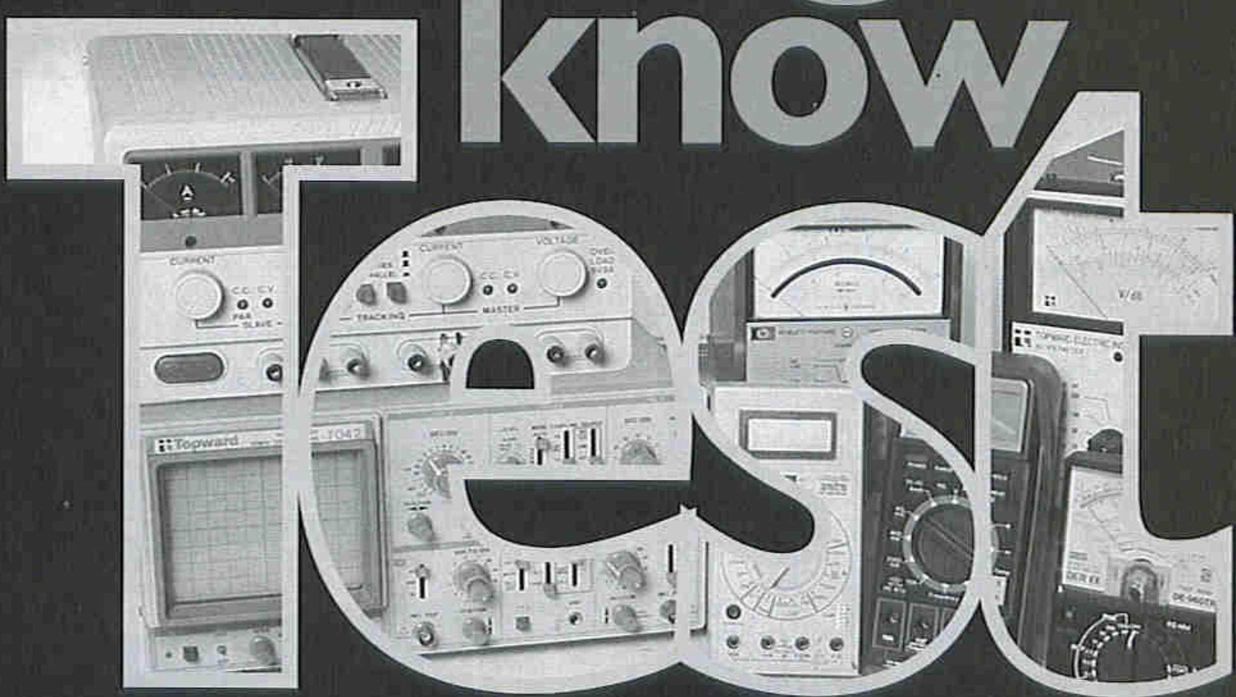


Figure 8. Tail-lamp circuit diagram.

Parts Lists are printed on page 55.

by Keith Brindley

Getting to know Test EQUIPMENT



PART 5

Counters and Signal Sources

In this part, we look at two of the most important types of test equipment. Counters and signal sources are used, almost nonchalantly, by engineers in the laboratory or workshop, often without regard to the equpment and its capabilities. This is a pity, because both counters and signal sources are often capable of far more complicated measurements, and uses, than they are given immediate recognition for.

Counters can measure frequency, time, and events relating to measurands. Sometimes, because they have so many uses, they are given the name *universal counter timers* (UCTs). Counters are, generally, digital in operation, and so have a digital display (usually LED, LCD, vacuum fluorescent or similar) similar to digital meters (see last month's issue).

Operation of all counters depends upon the principle of 'gating' a signal over a time period, whilst counting the number of pulses of the signal during that period. Figure 24 illustrates the principle, where a signal of unknown frequency is gated for a specified time period, during which a number of pulses of the signal are counted and displayed. If, say, the signal is of a frequency of 500Hz, and the gating period is 1 second, then the counted and displayed result will be 500Hz.

It does not take long to figure out that the gating period is quite critical. If, say, the gating period in this example is 1·1s (a difference of 10%), then the displayed result will be 550Hz; an error of 10%. In *direct gated counters*, the gating period is normally achieved by dividing down the output signal of a stable high-frequency reference oscillator, sometimes called the timebase, or clock, as shown in the block diagram of Figure 25, to give accurately controlled time periods. Also shown in Figure 25 are a signal amplifier and conditioner block, which accepts an input signal from a wide range of sources, and conditions them to a pulse-type form which the digital counter block can directly count. Waveforms at various points around the counter are also shown.

High-Frequency Measurement

Direct gated counters are very accurate within the limitations of the method. They are particularly useful for the measurement of reasonably high-frequency signals or events – direct gated counters measuring signals over 500MHz are common – and, indeed, the upper limit of measurement depends upon the speed of the logic circuits in the digital counter, not on the accuracy of the gating period. For even higher frequencies, however, the direct gating method may be adapted in a number of ways. First, *prescalers* can be included, as shown in Figure 26, either within the counter or, normally, as an extra add-on device. They divide down the input signal frequency to a frequency which the direct gated counter can measure. Prescalers are simple dividing circuits and, as such, do not have the high-frequency limitations of digital counters. In use, the gating period of the counter must be made longer, by the same factor that the prescaler divides the input signal.

Another method of adapting direct gated counters to measure higher frequencies is by mixing or heterodyning the input signal down to a lower frequency, much as a higher radio-frequency signal is heterodyned down to a lower one in a radio receiver, as illustrated in Figure 27. The resultant signal is counted during a gating period which is dependent on the heterodyning signal, and then is displayed as usual. Heterodyne counters are much more complex than other types, but have the advantage that they can measure input signal frequencies of over 20GHz. Even higher frequencies may be measured using an adaptation of the heterodyne counter, the synthesised heterodyne counter, which uses a microprocessor to form a synthesised oscillator timebase, and control the measurement procedures. The resultant test equipment will measure up to about 40GHz and is highly specialised.

Low-Frequency Measurements

Although direct gated counters can measure reasonably high-frequency signals, they are not so useful for low-frequency measurements, where accuracy depends, largely, upon the length of time that the user is prepared to wait for counting and display to take place. A frequency of 10Hz, for example, needs to be counted over a period of 100s for an accuracy of ±1%.

Low-frequencies can, in fact, be measured using the same principle but with one major, extremely clever, yet beautifully simple adaptation: by gating the timebase with the input signal, as shown in the block diagram of Figure 28. An input frequency of, say, 1Hz, gates the timebase frequency for a 0·5s interval every second. So, with a timebase frequency of, say, 2MHz, a count of 1,000,000 pulses is made. The reciprocal of this count is calculated by an arithmetic unit, and the result, 0·000001, is displayed on a MHz scale. Now, 0·000001MHz is, of course, 1Hz. Counters of this type are called reciprocating gated counters.

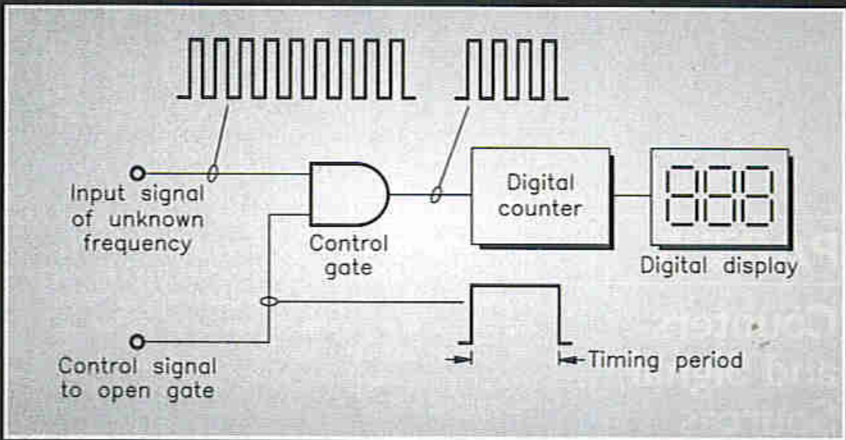
Another method of measuring low-frequency events is with the inclusion of a phase-locked loop circuit to multiply the frequency of the input signal, before gating, counting, and displaying the result. A block diagram of a multiplying counter using a phase-locked loop multiplier is shown in Figure 29. The voltage controlled oscillator's output frequency is equal to the input signal frequency multiplied by the divider circuit's division ratio.

Equipment and Operation

Most counters are not formed by just one of the previous counting methods, but are, generally, a combination of two or more. General-purpose counters are typically able to measure frequencies from DC through to about 500MHz, and so are combinations of the direct gated and either the reciprocating gated, or multiplying methods. Counters which are able to measure higher frequencies will usually maintain this combination, merely adding a third, or even a fourth method. Front panel controls determine which measurement method is in operation, although higher frequency measurements are accomplished by using a totally different input terminal from the lower frequency measurement input.

So far, we have been looking at the counter's ability to count and display a measurement of input signal frequency. Counters are, however, capable of much more than this. Typically, a counter has two general-purpose input channels, each with its own input terminals, normally marked Channel A and Channel B. These channels are identical in performance and operation, and frequency measurements of input signals can be made using either channel. Various switches or controls allow user-control of signal conditioning; in particular, signal attenuation and trigger level – these are much like the same controls of an oscil-

Below: A 1GHz universal counter timer (Stock Code GL47B).

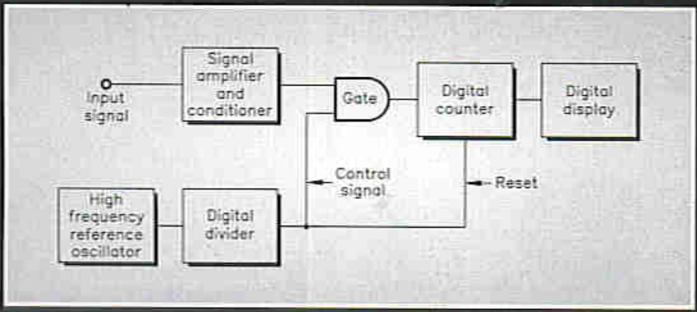


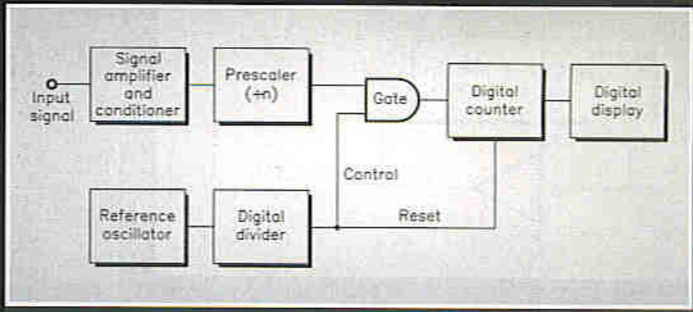
loscope (see Part 2 of this series in Issue 81). The circuits corresponding to channels A and B are, generally, direct gated counters, combined with reciprocal gated or multiplying counters, so that either channel may be used to measure frequencies from DC to a maximum of, say, 500MHz. If the counter is capable of measuring higher frequencies, a third circuit, Channel C, is included, which operates using one of the higher frequency adaptations of the direct gated counter. Channel C is used to measure input signal frequencies of, say, 100MHz through to the counter's maximum. Usually, though not necessarily, channel C is physically separate from the other two channels within the counter – this allows the equipment manufacturer to provide adequate screening against the possibility of high-frequency interference

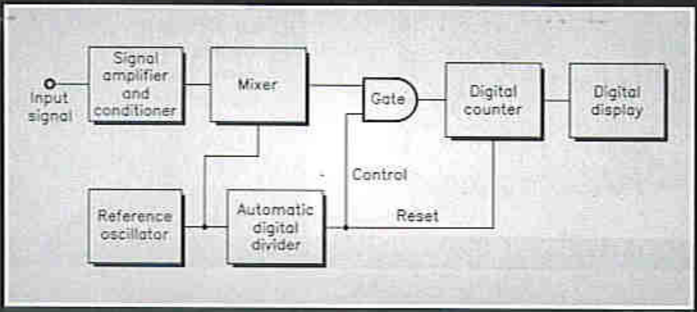
In frequency measurements, the counter gate is controlled automatically by the internal timebase. By allowing the gate to be controlled externally, and counting the number of timebase signal pulses, a measurement and display of the time interval between the opening and closing of the gate can be made. This is illustrated in Figure 30. If, say, the start and stop control signals are 1s apart, and the timebase is 1MHz, then a count of 1,000,000 is made.

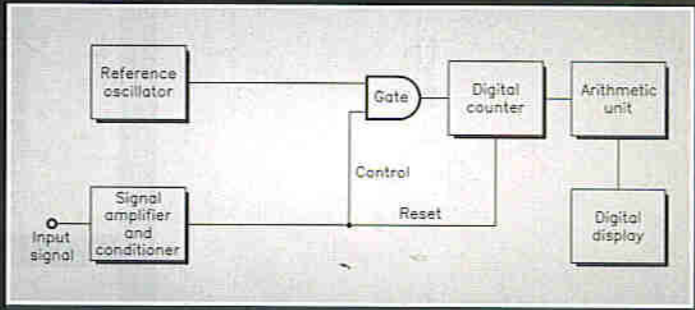
Above: Figure 24. The direct gated counter principle.

Left: A Low Distortion AF Signal Generator (Stock Code GL46A).









Top left: Figure 25. Using a high-frequency reference oscillator and divider.

Top right: Figure 26. A prescaler can be used to measure high-frequency signals.

Above left: Figure 27. A heterodyne counter.

Above right: Figure 28. A reciprocating gated counter.

Below left: Figure 29. A phase-locked loop multiplying counter.

Bottom left: Figure 30. Measuring the time interval between pulses at a counter's inputs.

Below right: An AM/FM Modulated Function Generator (Stock Code XM32K).

Simply by positioning the display's decimal point correctly, a display of 1·000000 shows the time interval between start and stop signals to be 1s. In start-stop time measurements of this kind, a received pulse to Channel A is used to open the gate, and a received pulse to Channel B closes the gate – hence the importance of two identical input channels.

Finally, event counting is accomplished by opening the counter gate, manually with a front panel control, or remotely with a pulse input, and letting the counter simply add the received signal pulses to Channel A. A received pulse to Channel B closes the gate, and the counter displays the number of pulses received at Channel A during the period between opening and closing the gate. The timebase itself is neither counted nor used to gate the counter in this mode.

Signal Sources

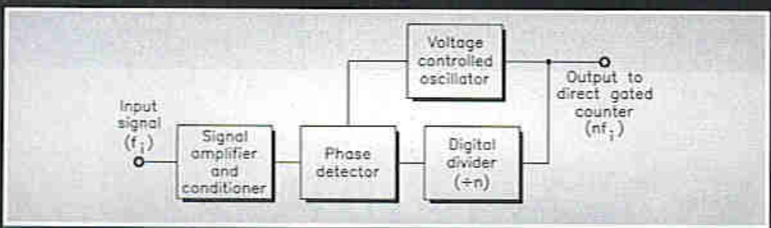
The term *signal source* is quite a loose term really and, more by default than by design, signal sources are generally categorised into two areas: audio frequency and radio frequency sources. Again, by default, those sources which produce audio frequency signals are usually called *low-frequency oscillators*, and those which produce radio frequency signals are usually called *signal generators*. However, there is no logical reason for all of this and, quite often, all types of signal sources are called signal generators or even sig-gens, for short.

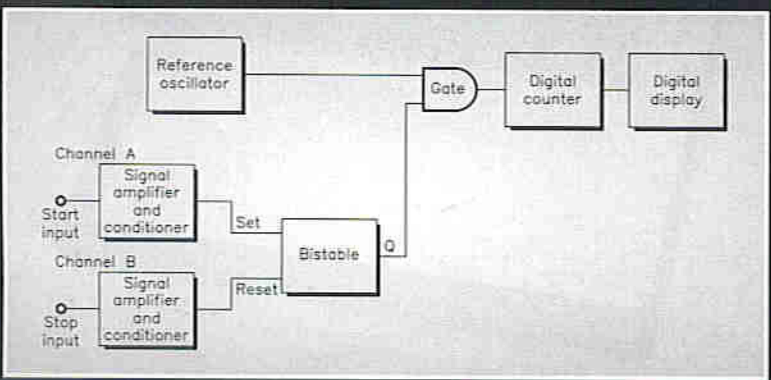
Signal sources are generally used to produce signals which are applied to circuits to test their performance during the design, manufacture, and service stages of their lives. It follows that the signal source used to test any particular circuit must be of the right type; for example, an audio amplifier could not be tested with a radio frequency signal – rather obvious, but it needs stating. This, of course, is why the main categorisation of signal sources into audio and radio frequencies came about. Generally, it is the low-frequency type of signal generator which is of interest to us here.

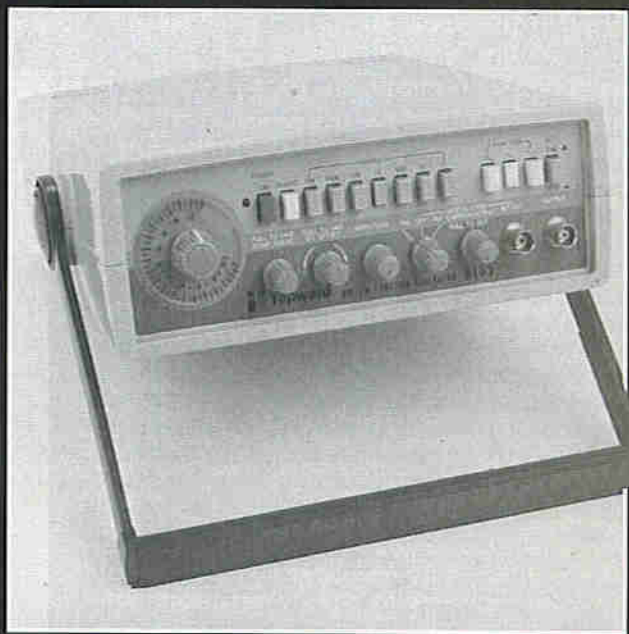
Low-Frequency Oscillators

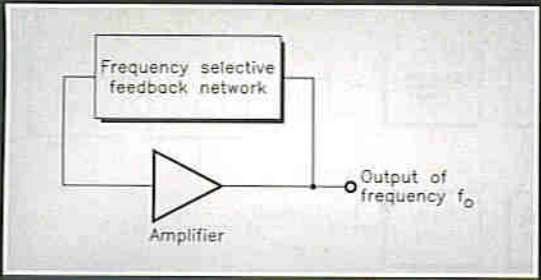
The oscillator circuits traditionally used in low-frequency oscillator test equipment are *harmonic oscillators*, that is, they produce sinusoidal output signals. In strict electronic terms, an harmonic oscillator is an amplifier which derives its input from its own output. Only part of the output signal is fed back to the input; the remainder is available as an output signal to following equipment. Figure 31 illustrates the basic principle of an oscillator. For the oscillator to function, two main criteria must be fulfilled. First, at some frequency f_0, the total phase shift caused by the amplifier and the feedback network must be zero. Second, at the frequency f_0, the amplifier gain must be sufficient to just compensate for the loss caused by the feedback circuit.

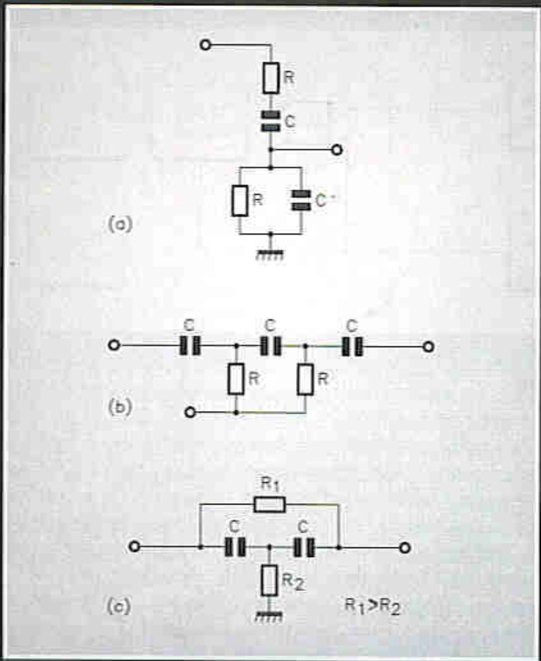
All practical harmonic oscillators fulfil these criteria. At

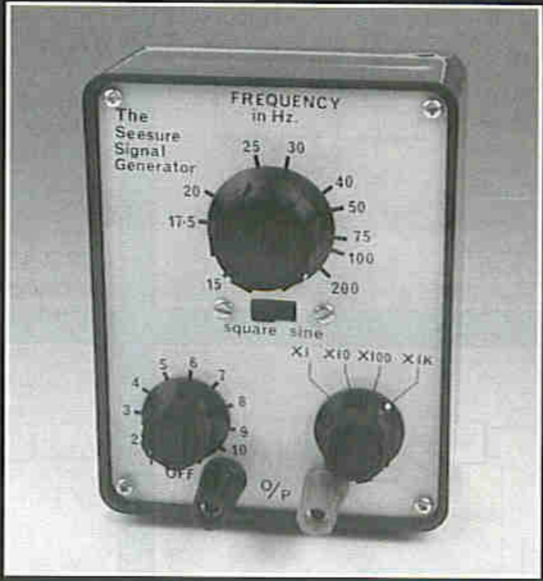








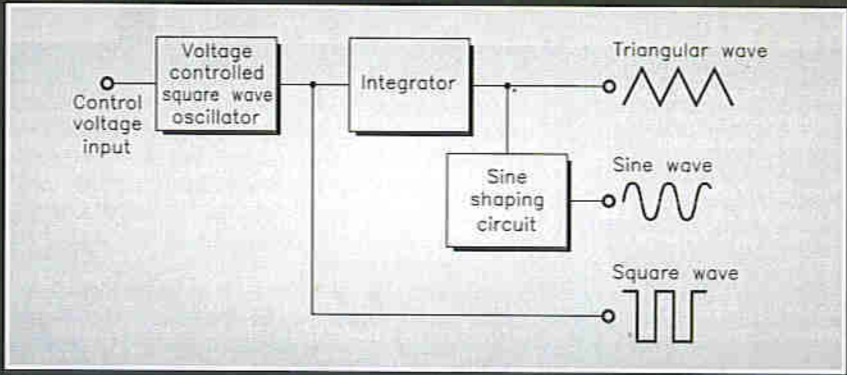




Top left: Figure 31. The harmonic oscillator principle.

Far left: Figure 32. Frequency selective feedback circuits used in harmonic oscillators: (a) Wien bridge; (b) phase shift; (c) bridge-T.

Left: A Wien bridge signal generator (Stock Code YB81C).



Above: Figure 33. The function generator principle.

frequencies other than f_0, however, one or other of the criteria is not fulfilled so that oscillation cannot occur – in other words, the oscillator only oscillates at a particular frequency, f_0. A resistor-capacitor network, whose phase shift and attenuation is dependent on frequency, is used as the feedback circuit which, together with an amplifier, forms the oscillator. Three main types of resistor-capacitor networks are used in low-frequency harmonic oscillators: the *Wien bridge* network; the phase shift network; and the *bridged-T* network (see Figures 32a, b, and c). The Wien bridge type of oscillator is the most common. By using a ganged potentiometer for the resistances of the feedback network, the oscillator frequency can be tuned over a limited range and, by switching a number of capacitors into and out of circuit, different ranges of frequency are obtained.

Typical distortion of harmonic oscillator test equipment is around 0·1%, but specialist equipment with distortion of only 0·001% is available.

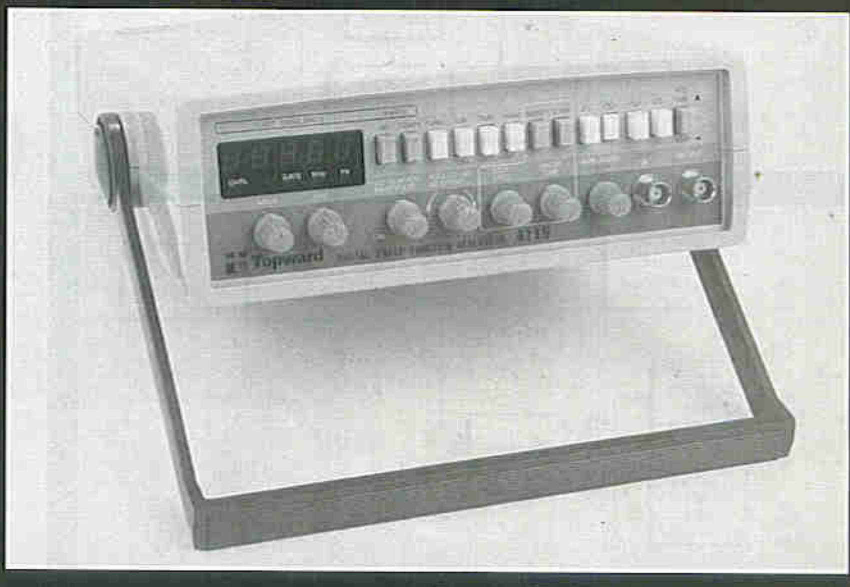
Function Generators

In low-frequency oscillator test equipment of a more modern design, *relaxation oscillators* are common. A relaxation oscillator is one in which one or more voltages or currents changes suddenly during each cycle of the oscillation. There are a number of circuit possibilities, common examples being the astable multivibrator and the unijunction transistor oscillator, but the design which is now most regularly used in low-frequency oscillator test equipment is known as the *function generator*, a block diagram of which is shown in Figure 33. The heart of the function generator is a voltage controlled squarewave oscillator which produces a squarewave signal at the required frequency. An integrator produces a triangular waveform from this squarewave signal, and a sinewave-shaping circuit produces a sinusoidal-type waveform from the triangular waveform. This sinewave-shaping circuit can only approximate a true sinusoidal waveform, however, and distortion of around 1·5% is common. Some high-quality function generators are also capable of producing sawtooth waveforms and pulse waveforms.

In a practical circuit, the squarewave oscillator and the integrator are not truly separate blocks because they closely interact. For example, the value of the integrator capacitor also determines the basic frequency range of the squarewave oscillator. So, by switching different capacitor values into and out of the circuit, different frequency ranges can be covered by the function generator. A typical frequency range covered by function generators is from about 0·01Hz to 2MHz.

Fine tuning of the function generator's signal frequency is accomplished by varying the voltage at the voltage controlled squarewave oscillator's control input. Further, as frequency *is* voltage controlled, it is a simple step to provide a second oscillator circuit within the equipment to sweep the oscillator frequency within a chosen range. A high quality function generator's second oscillator will have a controllable frequency, and amplitude, allowing the user to control the sweep range and speed. Medium quality generators only have a fixed-speed second oscillator, and

Below: A digital sweep function generator (not available from Maplin).



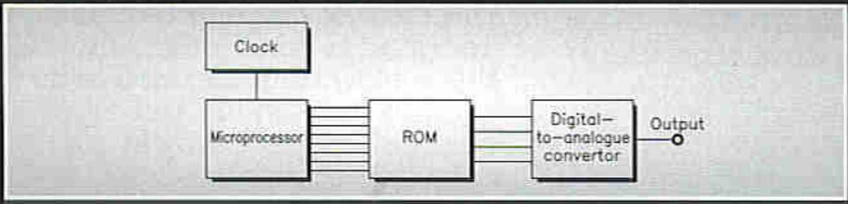


Figure 34. Using sampled waveforms stored in ROM to digitally synthesise required output waveforms.

cheaper function generators merely have a sweep input terminal which allows the user to connect an external low-frequency oscillator for this purpose.

Digital Low-Frequency Oscillators

Some of the most modern (and expensive) low-frequency signal sources use digital microprocessor-controlled techniques. In test equipment of this type, an analogue waveform output signal is synthesised from stored digital information. The digital information corresponding to the required analogue waveform is stored in a ROM device, and is read out, step-by-step, before being converted to an analogue form by a D-to-A converter. The principle of operation is shown in Figure 34. Waveforms of, literally, any type (for example, squarewaves and triangular waves) may be stored in the ROM and read out as required. The digital information is initially stored in the ROM after sampling accurate examples of each of the required waveforms, and making an A-to-D conversion of each sample.

Choosing which waveform to be output from the digitally synthesised oscillator is simply a matter of reading the corresponding ROM locations of each waveform. The microprocessor accesses that part of ROM which contains the chosen waveform, and one location at a time is read in sequence with each clock cycle. Signal frequency is, therefore, determined by the frequency of the clock; if there are, say, 100 stored data words for each cycle of the waveform, then the signal frequency is equal to the clock frequency divided by 100.

This method of signal generation has a number of advantages. First, the clock can be frequency locked to a submultiple of a crystal reference oscillator, so that an oscillator output signal of accurately fixed frequency is obtained – accuracies of ±0·0005% are possible. Second, the clock frequency may be voltage controlled, allowing extensive sweep facilities with little extra cost. Third, amplitude stability is extremely good due to the digital generation techniques.

A disadvantage, on the other hand, is distortion, which is around 1%, and is due, mainly, to quantization in the A-to-D and D-to-A processes. This can be reduced in two ways: by increasing the number of quantization steps, and by using low-pass filters in the output stage to filter out distortion components. High-quality (and hence, expensive) synthesised low-frequency oscillators have typical distortion figures of less than 0·1%.

Output

Output level amplitude of a signal source must be accurately maintained. Automatic level control systems, constantly monitoring output level and adjusting accordingly in a feedback loop, are usual in quality equipment. Cheaper equipment may use simple switched resistor-network attenuators. Generally, output level stages are calibrated so the user can choose an accurately maintained signal level.

Some way of metering the output signal level and frequency is useful, and analogue meters *can* be used for this purpose but, in the case of most oscillators, particularly of the microprocessor-controlled kind, it is a relatively simple task to provide a digital metering display.

Two further requirements of output stages of signal generators are: good screening of attenuator stages to prevent interference from higher level signals elsewhere in the equipment, and reverse power protection, that is, protection against damage by signals generated in other equipment connected to the signal generator. E

THREE MINI MODEL TRAIN PROJECTS – *Continued from page 50.*

PARTS LISTS

TRAIN LAMP CONTROL

RESISTORS: All 0·6W Metal Film			
R1,3	100Ω	2	(M100R)
R2	10k	1	(M10K)
R4	4k7	1	(M4K7)
CAPACITOR			
C1	10μF Radial Electrolytic	1	(FF04E)
SEMICONDUCTORS			
D1	1N4148	1	(QL80B)
LD1	5mm Red LED	1	(WL27E)
TR1	BC548	1	(QB73Q)
	W005 Bridge Rectifier	1	(QL37S)
MISCELLANEOUS			
LP1	Tubular LES Bulb	1	(WL75S)

AUTOMATIC LOOP CONTROL

RESISTORS: All 0·6W Metal Film			
R1,2	1k	2	(M1K)
R3,4,6	10k	3	(M10K)
R5	220Ω	1	(M220R)
CAPACITORS			
C1,C2	1μF Radial Electrolytic	2	(FF01B)
C3	100nF Ceramic Disc	1	(BX03D)
C4	100μF Radial Electrolytic	1	(FF11M)
SEMICONDUCTORS			
DI-4	1N4148	5	(QL80B)
IC1	4011BE	1	(QX05F)
TR1	BC337	1	(QB68Y)
MISCELLANEOUS			
RLA	5A Mains Relay	1	(YX98G)
	Gold Contact Wire	As Req.	(XB00A)

TRACK CIRCUITING

RESISTORS: All 0·6W Metal Film			
	1k	1	(M1K)
	220Ω	1	(M220R)
	22Ω	1	(M22R)
SEMICONDUCTORS			
	1N4001	2	(QL73Q)
	BC327	1	(QB66W)
MISCELLANEOUS			
	Tubular LES Bulb	1	(WL75S)

TAIL-LAMP CIRCUIT

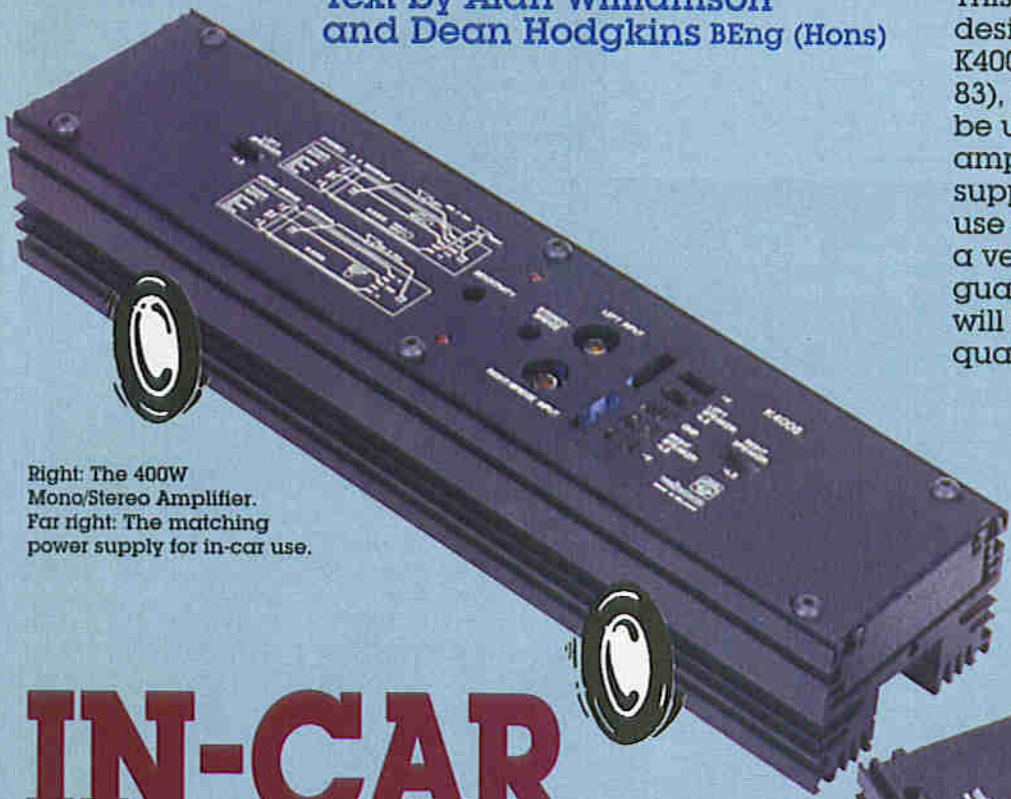
RESISTORS: All 0·6W Metal Film			
	4k7	1	(M4K7)
SEMICONDUCTORS			
	1N4148	4	(QL80B)
	5mm Red LED	1	(WL27E)

The Maplin 'Get-You-Working' Service is not available for these projects.

The above items are not available as a kits.

Text by Alan Williamson
and Dean Hodgkins BEng (Hons)

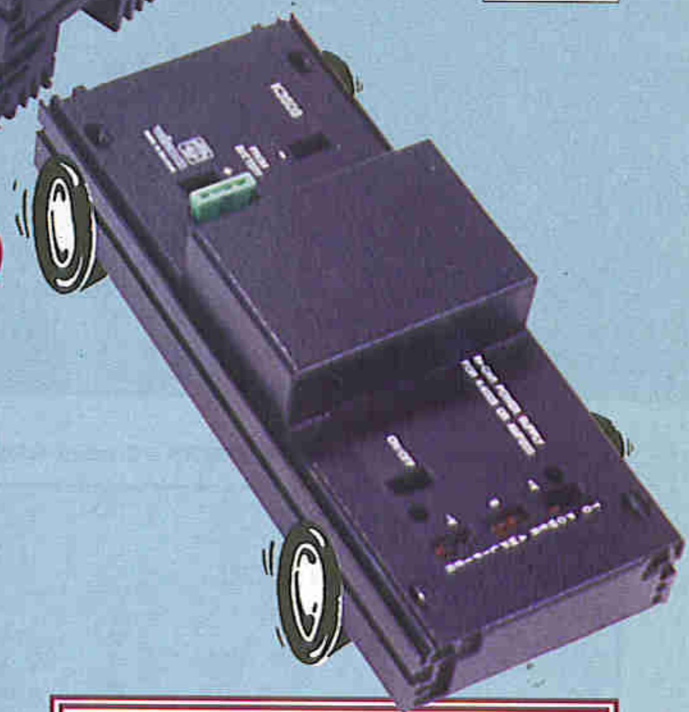
This module has been especially designed to complement the K4005 400W amplifier (see Issue 83), and the AMP200, but it can be used for almost any in-car amplifier requiring a ±35V DC supply. The PSU makes extensive use of decoupling to provide a very 'clean' output, which guarantees that your amplifier will 'pump out' stunning high quality sound.



Right: The 400W Mono/Stereo Amplifier.
Far right: The matching power supply for in-car use.

2 PROJECT RATING

IN-CAR AMP PSU



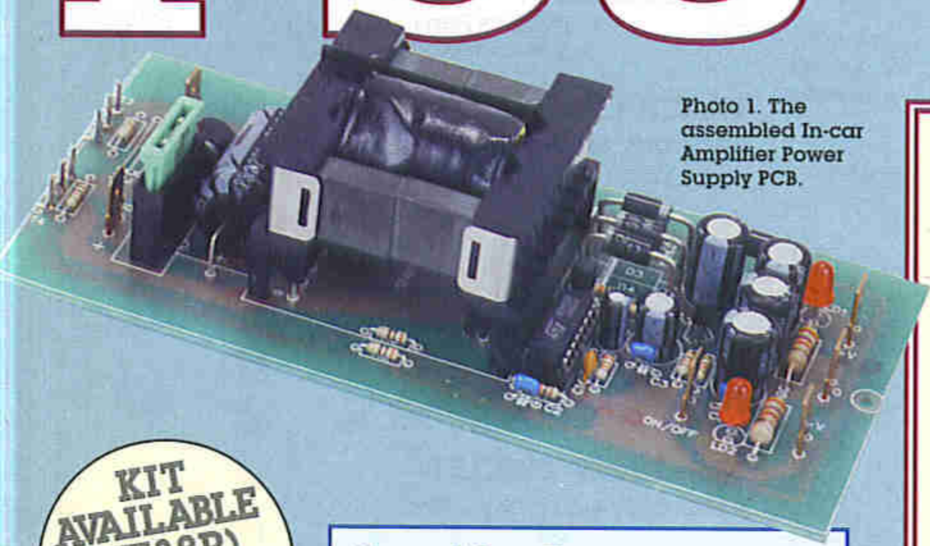


Photo 1. The assembled In-car Amplifier Power Supply PCB.

FEATURES

- Especially designed for use with K4005/AMP200
- Ground Isolated Output
- Attractive modern casing
- 300W power output
- Switched by 12V DC remote control
- Ready-built version also available

KIT AVAILABLE (VF38R) PRICE £66.99 H0

Specification

Input voltage:	10 to 15V DC (30A maximum)
Output voltage:	±35V (unregulated)
Maximum output power:	300W
Efficiency:	90% maximum
Dimensions:	210 × 84 × 50mm

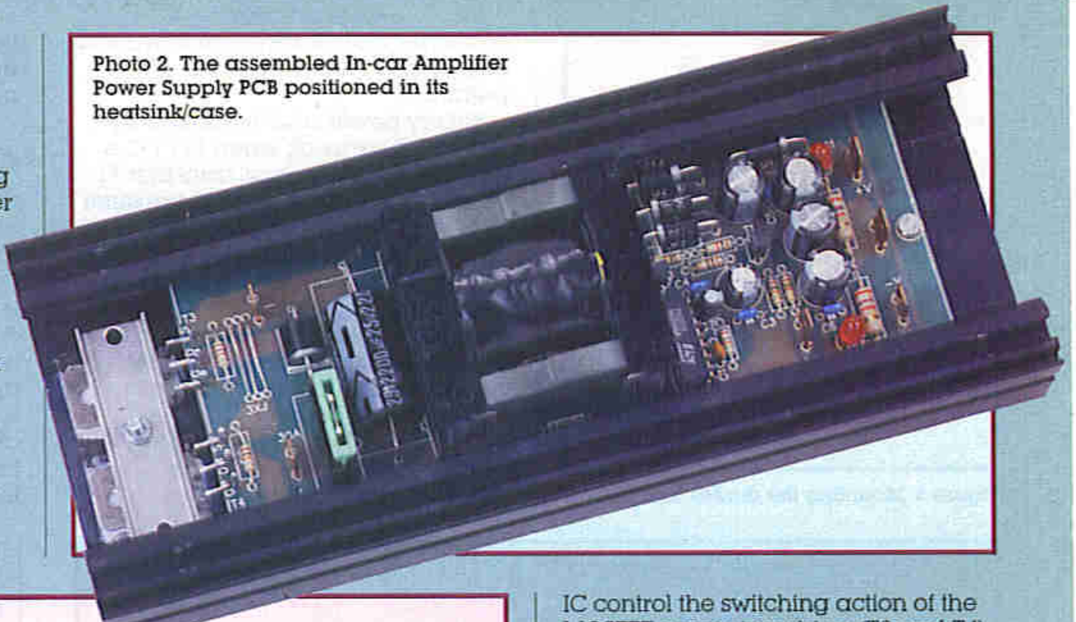
THERE are two main advantages of having a separate amplifier and PSU: First, the PSU can be located near to the vehicle's battery and, therefore, the power leads can be kept as short as possible, reducing power losses to a minimum. The other advantage is that the amplifier can be placed near to the speakers; this helps to maintain an optimal level of damping, resulting in a better reproduction of bass sounds.

The PSU is housed in a sleek, black metal case, very similar to the K4005 400W amplifier, and a ready-built 'Gold Line' version of the PSU, the SPS200, is also available (VF47B).

Construction is reasonably straightforward; the component count is fairly low, and no elaborate test equipment is required for setting up the completed module.

Note that this module is only suitable for negative earth vehicles.

Photo 2. The assembled In-car Amplifier Power Supply PCB positioned in its heatsink/case.



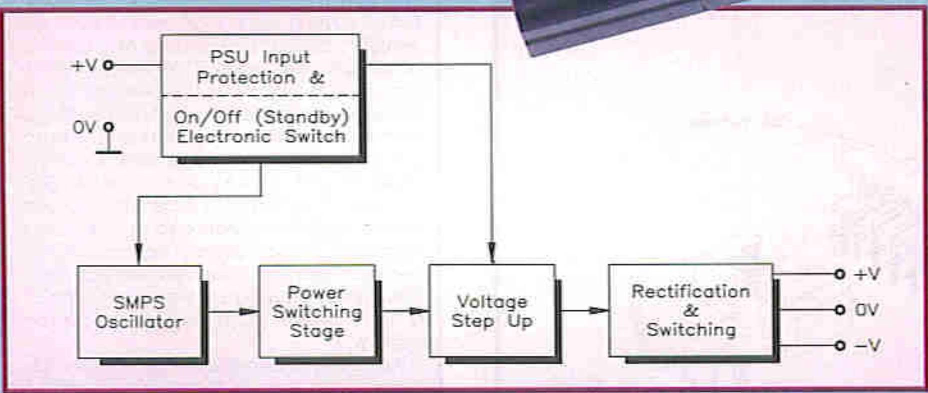


Figure 1. Block Diagram of the In-car Amplifier PSU.

Circuit Description

As an aid to understanding the circuit's operation, refer to the block diagram of Figure 1 and the circuit diagram, presented in Figure 2.

At the heart of the PSU's voltage conversion system, there is a dedicated switch-mode power supply (SMPS) IC (IC1), which produces a square wave output. The frequency of this wave is determined by components R11 and C1 – in this case, it has been set to approximately 53kHz. Capacitors C4 and C12 provide high- and low-frequency decoupling, thus ensuring that the IC has a noise free power supply.

The output pins (11 and 14) of the IC control the switching action of the MOSFET power transistors (T3 and T4), which form a push-pull stage to drive the transformer (strictly speaking, it is a pull-pull circuit).

The transformer steps up the high-frequency switched input to a higher potential; the output waveform is then rectified (diodes D1 & D2 for the positive (+) rail, and D3 & D4 for the negative (–) rail) and smoothed, with the aid of capacitors C8, C9 & C5 for the positive (+) rail, and C10, C11 & C6 for the negative (–) rail. Resistors R12 and R13 simply limit the current flow through LEDs LD1 and LD2.

Fuse F1 provides protection for the circuit in the event of wrong polarity connection; the diode (D5) will conduct, creating a short circuit across the battery which will blow the fuse. This method is preferred over a diode being connected in series with the supply rail because there is no voltage drop across the diode (a diode connected in series would cause a small (approximately 1·1V) voltage drop), and this is

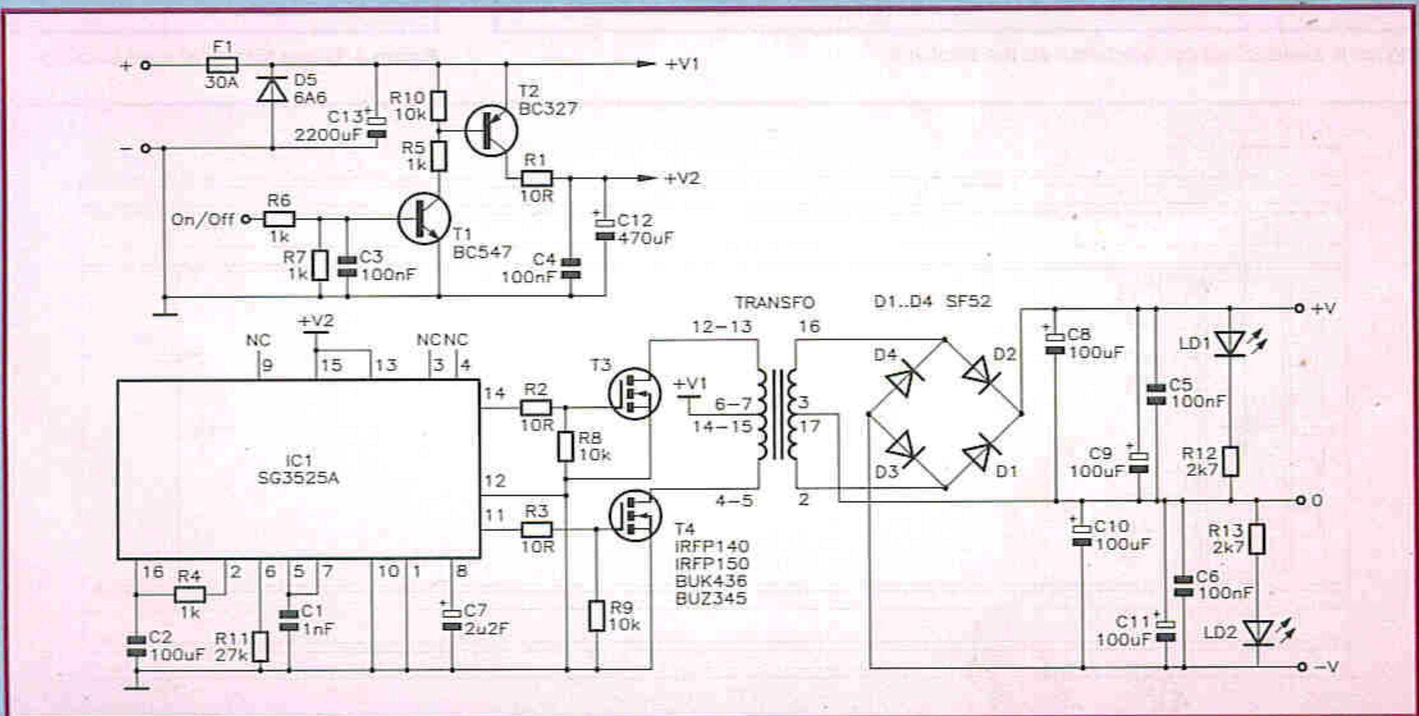


Figure 2. Circuit Diagram of the In-car Amplifier PSU.

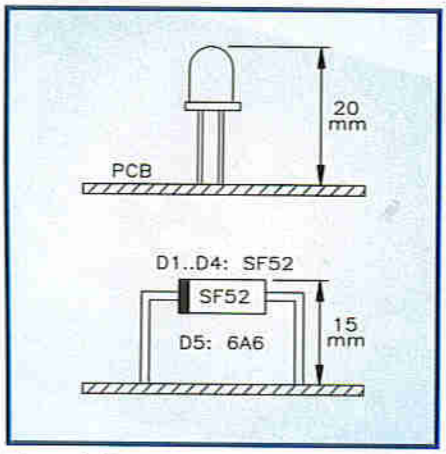


Figure 3. Mounting the diodes and LEDs.

important when batteries are involved; energy and efficiency are at a premium.

Battery power is further saved by the 'on/off' terminal; when 12V DC is applied to this terminal, transistor T1 turns on, pulling the base of transistor T2 low. Hence, T2 turns on, and power is supplied to the IC. If T2 is off, practically no current is drawn from the battery; only the leakage current through C13 flows. Capacitor C3 provides decoupling for T1; C13 is the main decoupling capacitor in the circuit.

Note that, when in the 'off' state, potential is still present on the transistors; the circuit is not isolated from the power supply and is, therefore, really in a standby mode, rather than being 'off'.

Construction

Construction is straightforward, with all of the components being mounted on a single-sided PCB (see Photo 1). Removal of a misplaced component is, however, quite difficult, so double-check each component's type and value (and polarity where appropriate) before soldering! If you require any additional information about soldering and assembly techniques, they can be found in the Constructors' Guide (XH79L). The

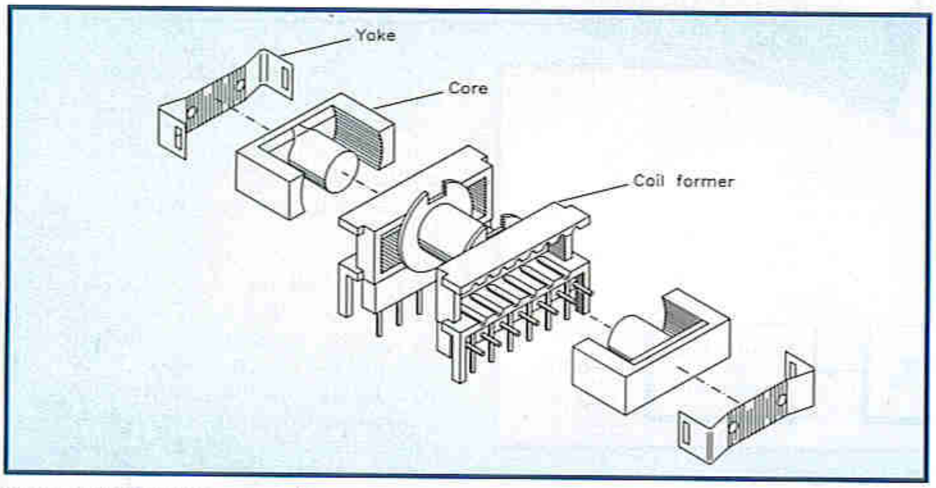


Figure 4. Transformer assembly.

Important Safety Warning

Before starting installation work, consult the vehicle's manual regarding any special precautions that apply. Take every possible precaution to prevent accidental short circuits occurring since a lead-acid battery is capable of delivering extremely high current. Remove all items of metal jewellery, watches, etc., before starting work. Disconnect the vehicle's battery before connecting the module to the vehicle's electrical system. Please note that some vehicles with electronic engine management systems will require reprogramming by a main dealer after disconnecting the battery.

Assuming a negative earth vehicle, disconnect the battery by removing the (−) ground connection first; this will prevent accidental shorting of the (+) terminal to the bodywork or engine. It is essential to use a suitably rated fuse in the supply to this project. For the electrical connections, use suitably rated wire able to carry the required current. If in any doubt as to the correct way to proceed, consult a qualified automotive electrician.

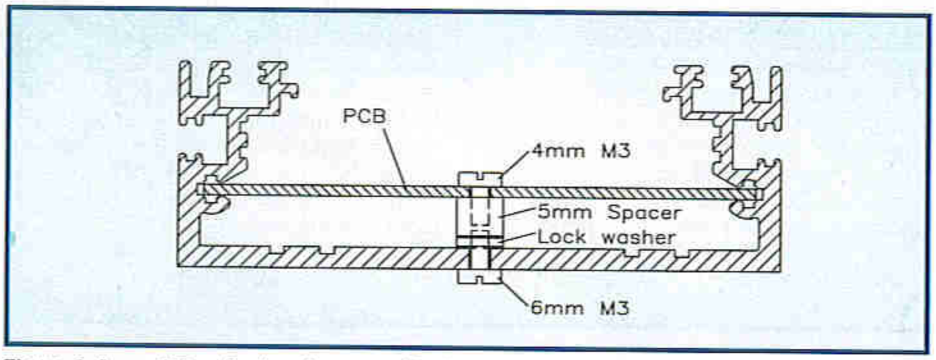


Figure 5. Assembling the hardware on the heatsink.

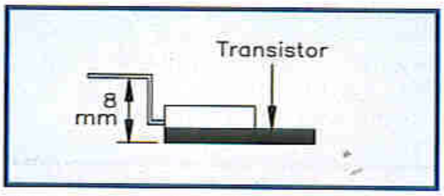


Figure 6. Power transistor lead forming.

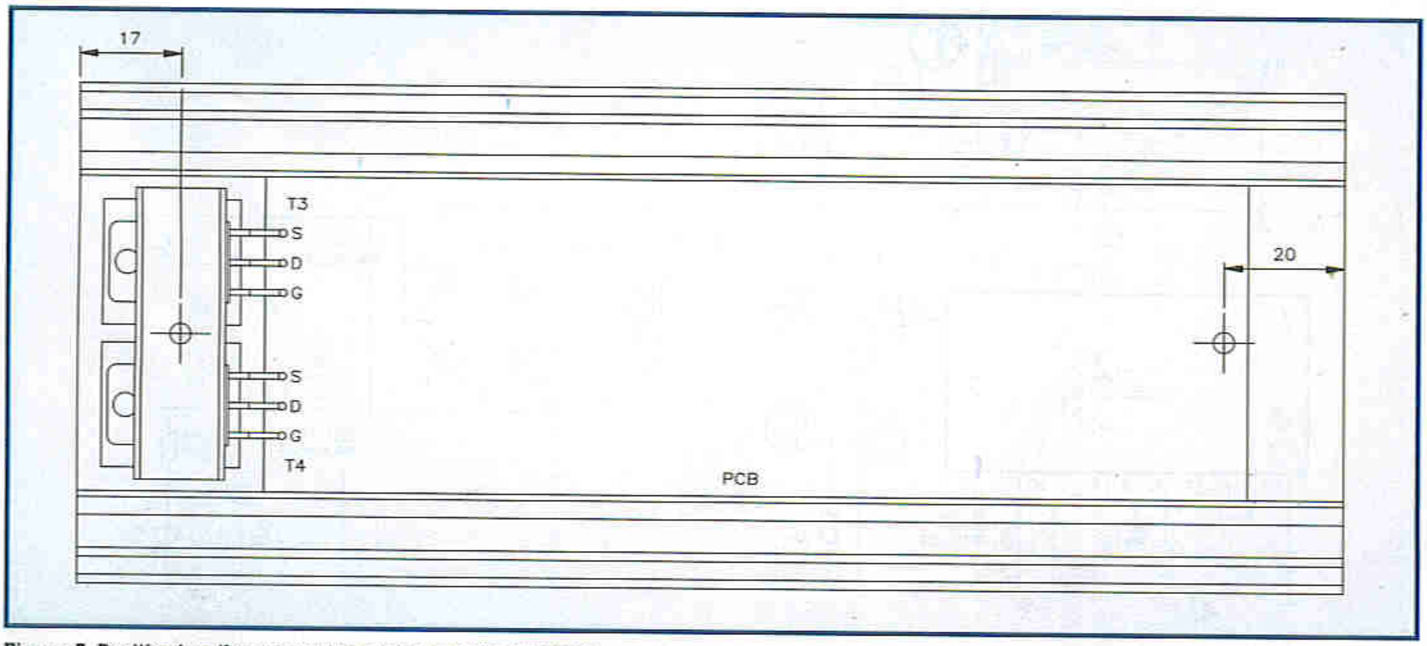


Figure 7. Positioning the power transistors on the heatsink.

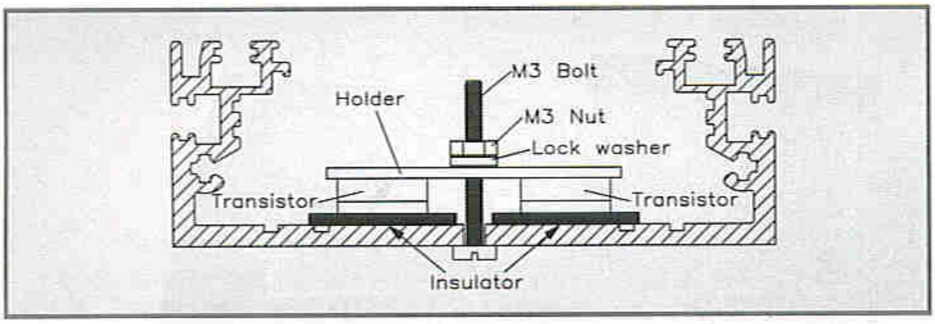


Figure 8. Attaching the power transistors to the heatsink.

PCB has a printed legend to assist you in correctly positioning each item.

The order in which the components are mounted is important, and is described below; the general rule being: begin with the smallest components first, working up in size to the largest. Note that any component offcuts can be used to form the wire jumpers.

First, fit the five wire jumpers. Next, fit the ¼W resistors (R1 to 11), followed by the larger 1W resistors (R12 and 13). Take care to ensure that the resistors are lying flat on the PCB.

The diodes (D1 to 5) come next. Care must be taken to fit the diodes the right way around; the cathode is indicated by a grey band on the body of the diode, and this must face the thick white band on the PCB legend. When mounting the diodes, it is *very important* to leave a space of 15mm between the PCB and the top of the diode, as shown in Figure 3.

Mount the IC DIL socket next, followed by capacitors C1 to C6. Now, fit the transistors TR1 and TR2, taking care to ensure that the flat side of the device matches the straight edge on the PCB legend. Try not to keep the soldering iron in contact with the device leads for longer than two seconds.

Mount the polarised capacitors (C7 to C12) next, taking care to insert the devices correctly – the negative lead is identified by a black band and (–) symbols on the capacitor's body. Finally, mount the largest capacitor, C13, again taking care with polarity.

Fit the LEDs next, making sure that the 'flat' on the LED's body (indicating the cathode lead) corresponds to the straight line on the PCB legend. Note that not all LEDs have a flat side, and if that is the case, the cathode can be taken as the shorter of the two leads. The tip of the LED should be approximately 20mm from the PCB, as shown in Figure 3.

Now, mount the male blade connectors, followed by the six PCB pins, ensuring that they are pushed (from the component side) as fully as possible into the board. Next, mount and solder the fuseholder (as closely as possible to the PCB), and fit the fuse.

The next step involves the assembly of the transformer. Referring to the assembly diagram of Figure 4, insert both 'core' sections into the core former, and fit the metal yokes, ensuring that they hold the transformer securely together. Once assembled, mount the transformer onto the PCB, taking care that the pins match the legend.

Finally, solder a 1mm diameter wire along all of the tinned tracks on the PCB, and build up the tracks with solder. This is very important because these tracks must be able to conduct currents of up to 30A.

This completes the assembly of the PCB. Thoroughly check your work for errors, such as misplaced components, solder bridges, and dry joints, etc. Clean any flux off the PCB using a suitable solvent.

Module Assembly

During assembly, you may find it useful to refer to Photo 2, which shows the completed project.

Fix the threaded spacer over the hole which is located at 20mm from the edge of the heatsink by using a lock washer and a 6mm M3 bolt. Next, slide the PCB into the largest slot in the heatsink, positioning the PCB so that the hole at one end aligns with the spacer, and secure it into place with a 4mm M3 bolt, as shown in Figure 5.

Use a pair of pliers to carefully bend the leads of the power transistors (T3 and T4) until they are at right angles to the transistor body

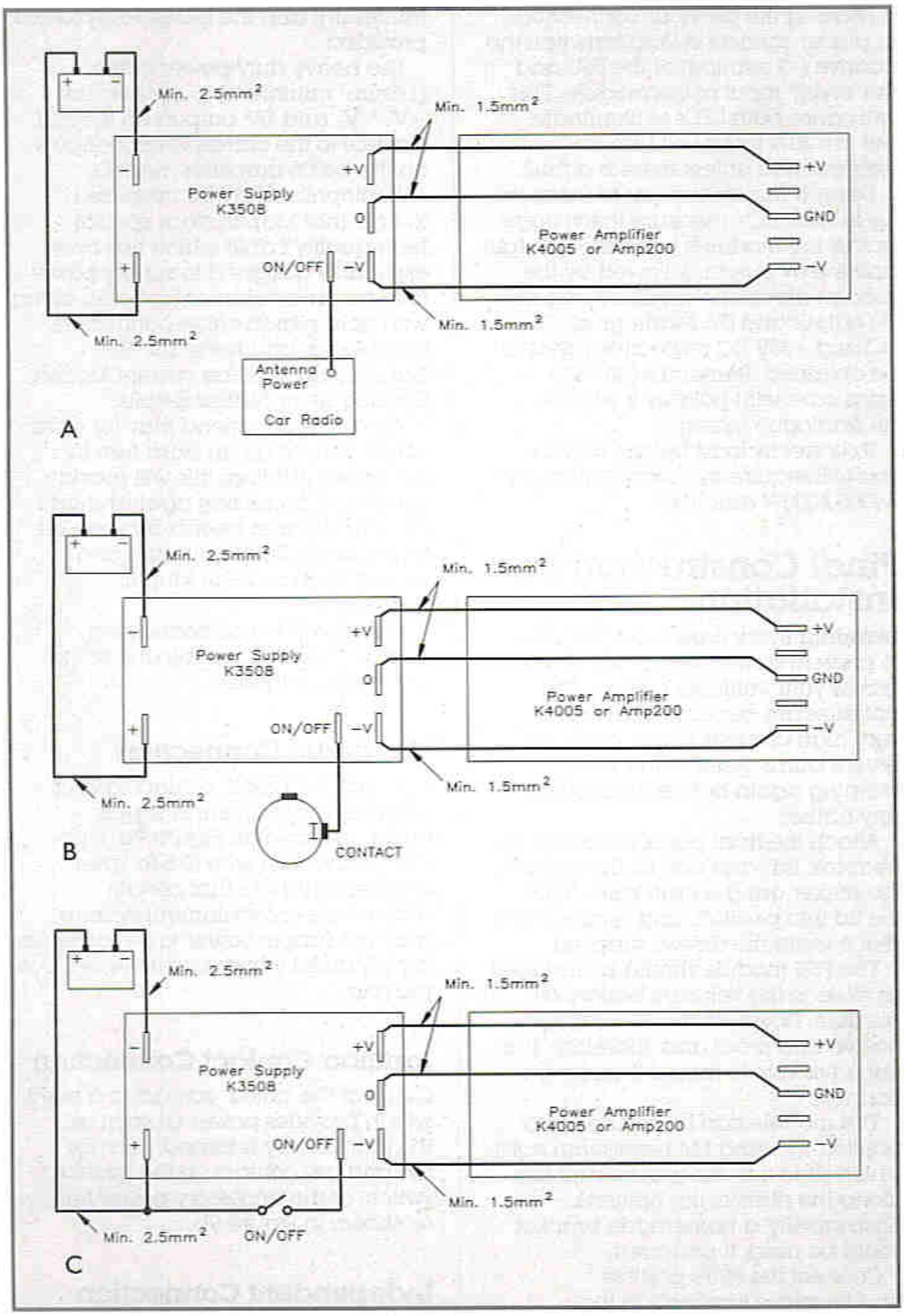
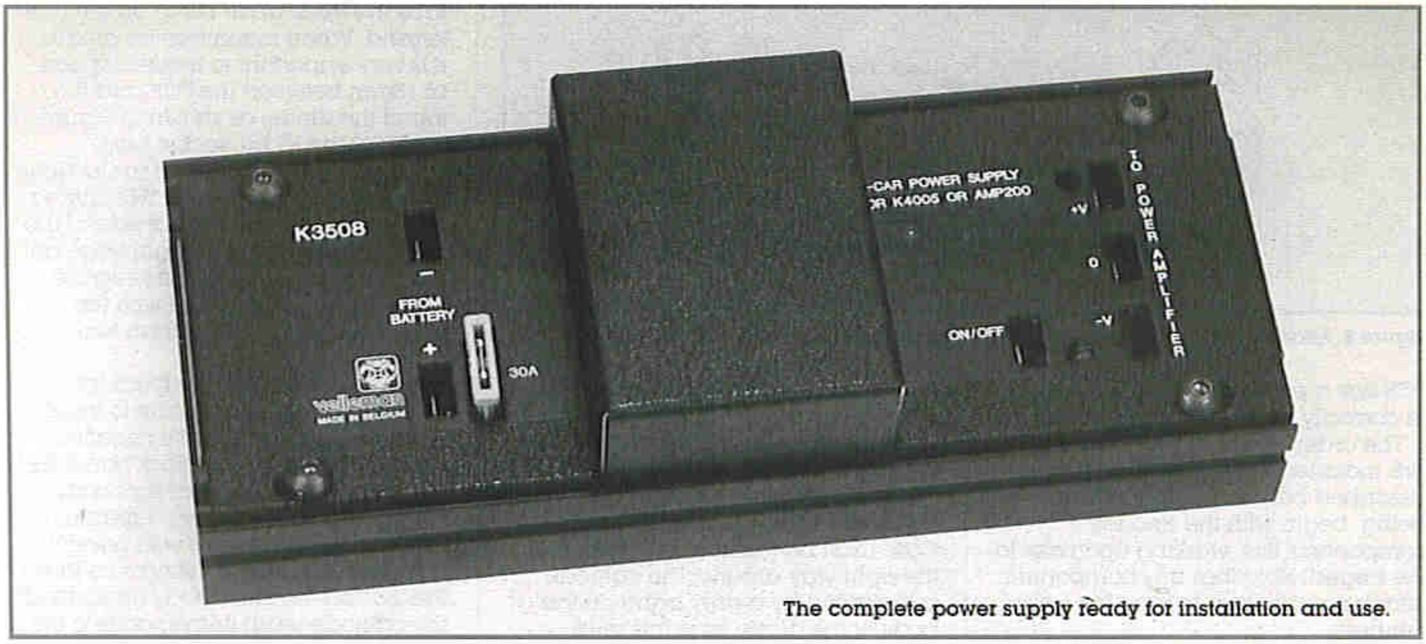


Figure 9. Wiring Diagrams: (a) connecting the module to a car radio antenna supply outlet; (b) connecting the module to a car ignition contact; (c) connecting the module via an independent switch.



The complete power supply ready for installation and use.

(see Figure 6). Smear some thermally conductive paste (included) on to the surface of the transistor which will be in contact with the heatsink, and place an insulating mica over the paste. Apply a small amount of paste to the mica, and place the transistor in the correct position on the heatsink (refer to Figure 7). Fix the transistors in place by sliding an M3 bolt (supplied) into the other hole in the heatsink (shown in Figure 8). Place a metal retainer plate over the transistors (the bolt must pass through the hole in the centre of the plate), and secure the retainer by using a locking washer and nut. *It is important to ensure that the transistor connection leads do not come into contact with the metal plate.* Finally, carefully bend the transistor leads again, so that they make contact with the appropriate PCB pins, and solder into place.

Finally, insert the IC, making certain that all the pins go into the socket, and that the pin 1 marker is at the notched end. Remember to observe the standard antistatic precautions before you handle the IC – ensure that you touch an 'earthed' conductor (domestic water pipes, for example) to remove any static charge which you may have accumulated.

This completes the assembly of the module.

Testing

The only equipment required for testing the module is a multimeter and a regulated (and preferably current limited) PSU.

Connect a 12V 20W lamp between the positive (+) terminal on the PSU and the positive (+) input of the module, and connect a lead between the negative (–) terminal of the PSU and the negative input of the module. Set the PSU to 12V DC, and switch it on. The lamp will only illuminate if there is a fault (the lamp also limits the current flowing through the module).

Leaving the previous connections in place, connect a lead between the positive (+) terminal of the PSU and the 'on/off' input of the module. This will cause both LEDs to illuminate, but the 20W lamp will remain extinguished unless there is a fault.

Using a multimeter (set to measure up to 100V DC), measure the voltage across the module's positive (+) output and the 0V output, followed by the voltage across the module's negative (–) output and 0V; readings of +35V DC and –35V DC respectively should be obtained. Remember to take extra care with polarity if you use an analogue meter!

To correctly load test the module, you will require the complementary K4005 4000W amplifier.

Final Construction and Installation

Warning: Every care must be taken to prevent a short circuit occurring across your vehicle's battery. Car batteries are capable of delivering very high currents which could cause severe burns. Refer to the safety warning again before proceeding any further.

Attach the front panel stickers to the heatsink 'lid', and cut out the holes in the sticker using a craft knife. Slide the lid into position, and secure it into place using the screws supplied.

The PSU module should be installed as close to the vehicle's battery as possible. However, the PSU casing is not weatherproof and, therefore, it is not advisable to mount it under the bonnet.

The module can be secured into position by using M4 hexagonal bolts, which slide into the groove running along the sides of the heatsink. Alternatively, a homemade bracket could be used, if preferred.

Connect the PSU's positive and negative terminals to the corresponding terminals on the vehicle's battery by means of extra heavy duty power cable (2·5mm^2 minimum) and the blade receptacles provided.

Use heavy duty power cable (1·5mm^2 minimum) to connect the '+V', '–V', and '0V' outputs on the PSU module to the corresponding inputs on the K4005 amplifier module.

Audiophiles may be interested to note that Maplin stock special high-quality cable which has been especially designed to supply power to in-car entertainment systems, along with gold-plated cable connectors, fuse blocks, and fuses; see the Cables section of the current Maplin Catalogue for further details.

We also recommend that, for extra safety, you install an extra fuse in the power cabling; this will provide additional protection against short circuits. Suitable fuseholders can be found in the Entertainments and Leisure section of the Maplin Catalogue.

The 'on/off' switch connection can be made using any one of the following methods:

Car Radio Connection

Connect the 'on/off' contact to your vehicle's radio antenna supply outlet, as shown in Figure 9a. Only thin connection wire (0·5 to 1mm^2) is necessary. Note that certain automotive entertainment systems may not supply power to the antenna supply outlet whilst a cassette or CD is playing.

Ignition Contact Connection

Connect the 'on/off' contact to a point which provides power as soon as the ignition key is turned, such as the primary contact on the ignition switch, or the accessory power line, as shown in Figure 9b.

Independent Connection

The 'on/off' contact may be connected, via a switch, to the battery's positive terminal, as shown in Figure 9c.

IN-CAR AMPLIFIER POWER SUPPLY PARTS LIST

RESISTORS: All 0·25W (Unless specified)

R1-3	10Ω	3
R4-7	1k	4
R8-10	10k	3
R11	27k	1
R12-13	2k7 (1W)	2

CAPACITORS

C1	1nF	1
C2-6	100nF	5
C7	2µ2F 50V Miniature Electrolytic	1
C8-11	100µF 63V Electrolytic	4
C12	470µF 16V Electrolytic	1
C13	2200µF 25V Electrolytic	1

SEMICONDUCTORS

D1-4	SF52	4
D5	6A6	1
T1	BC547	1
T2	BC327	1
T3, T4	IRFP150/BUK436/ IRFP140/BUZ345	2
LD1, LD2	5mm Red LED	2
IC1	SG3525A	1

MISCELLANEOUS

	16-pin DIL socket	1
	Spade Connectors	6
	Spade Posts	6
	PCB Pins	6
	PCB	1
F1	30A Fuse	1
	Fuseholder	1
TR1	Transformer	1
	Yoke	2
	Core	2
	Coil Former	1
	Case	1
	Front Panel Labels	2
	Insulating Micas	2
	M3×6mm bolt	1
	M3×4mm bolt	1
	M3×18mm bolt	1
	M3 Nut	1
	M3 Locking Washer	2
	M3×5mm Spacer	1
	Metal Retainer Plate	1
	Thermal Paste	1

OPTIONAL (Not in Kit)

Black High Current Wire	As Req.	(XR57M)
Red High Current Wire	As Req.	(XR59P)
Car Audio Fuseholder	1	(BZ95D)
30A Fuse	1	(CK32K)
10A Toggle Switch SPST	1	(JK25C)
Red Car Power Cable	As Req.	(BZ92A)
Black Car Power Cable	As Req.	(BZ93B)
Red Power Connection Cable	As Req.	(XR36P)
Black Power Connection Cable	As Req.	(XR32K)
Green Power Connection Cable	As Req.	(XR35Q)

The Maplin 'Get-You-Working' Service is available for this project, see Constructors' Guide or current Maplin Catalogue for details.

The above items (excluding Optional) are available in kit form only.

Order As VF38R (In-car Amplifier Power Supply) Price £66.99H0

Please Note: Some parts, which are specific to this project (e.g., PCB), are not available separately.

Part Two by Jason Sharpe **AN INTRODUCTION TO**

DIGITAL SIGNAL PROCESSING

This month, we take a look at various types of filter response.

Digital Filters

Digital filters are constructed using the three building blocks shown in Figure 10. The delay block can be thought of as a one stage shift register. If x is the input at time n–1, it will be output at time n. The initial content of the delay block is assumed to be zero.

Figure 11 shows a simple low-pass filter, called a two term moving averager. The output is the average of the present and last input, y[n] = 0.5(x[n] + x[n–1]). A rapidly changing input such as {0,100} will produce the output {0,50}. This has halved the value of the slope. While a slowly changing input such as {1,3} will produce little change, {0.5,2}.

Impulse Response

The systems in this series are Linear Time Invariant systems. If an input x1 causes an output y1 and an input x2 causes an output y2 then, if the system is linear, the input x1+x2 will produce the output y1+y2. If x_1=x2 then the output will be 2y1. From this it follows that an input ax1 will produce and output ay1, a is a constant. If an input x applied to a time invariant system at time T1 causes an output y, then it will produce the same output if the input is applied at time T2.

The sequence x[n]=1 if n=0
=0 else

(i.e. {1,0,0,..}) is known as the unit impulse sequence. We have worked out the frequency components of a square wave, as the width of the wave is reduced, the frequency spectrum spreads out. An infinitely thin square wave has a totally flat spectrum, as shown in Figure 12.

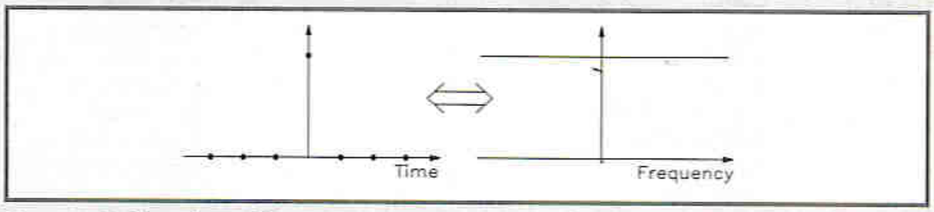


Figure 12. Unit impulse and frequency spectrum.

When an impulse is input into a system, the output produced is called the impulse response (IR). A system's impulse response can be used to predict the response of the system to any input sequence. From the scaling property, described above, it is obvious that if the impulse response (the output caused by the impulse sequence) is known, the output caused by a sequence {a,0,0,...} will be a{y[0],y[1],.....}. As the system is time invariant, each element of the sequence can be thought of as a scaled impulse, as shown in Figures 13(a) to (e), each producing a scaled impulse response. Due to the linearity property, these outputs can be added to produce the final filtered signal.

Step Response

A unit step input is defined as x[n]=0 if n<0
=1 else

(i.e. {1,1,1,...}). It is also useful for examining a systems behaviour and will be discussed later.

Frequency Response

Normally the most important characteristic of a filter is its frequency response – how much various frequencies are attenuated or amplified. As an impulse has a flat spectrum, plotting the frequency components of the IR results in the frequency response of the filter. The frequency components can be found using a Discrete Time Fourier Transform (DFT). Finding the frequency response analytically will be discussed later.

DSP Workbench

Program 2 can be used to experiment with the effects of various filters. Note: This program joins the discrete outputs with lines for clarity only; they do not represent a final analogue output.

Next month, the program will be used to examine various filters and their responses.

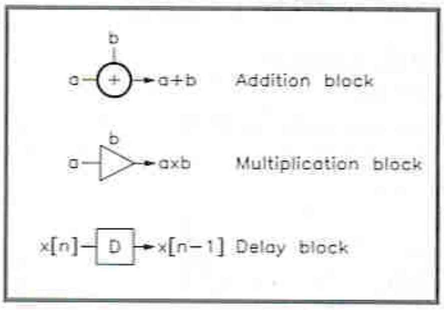


Figure 10. Filter building blocks.

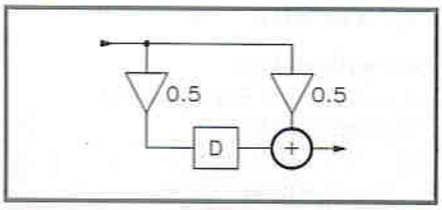


Figure 11. A simple digital low-pass filter.

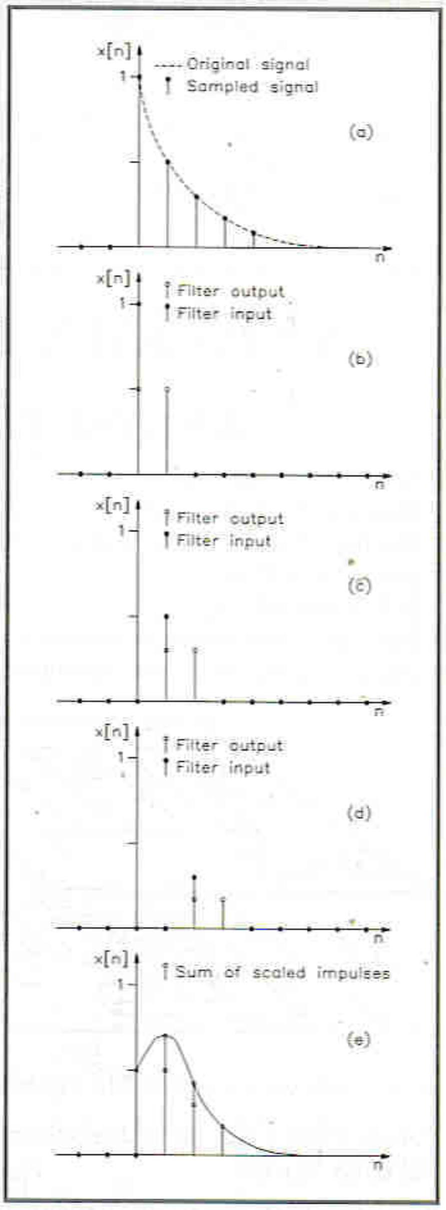


Figure 13. A system's impulse response: each element of the sequence can be regarded as a scaled impulse, each producing a scaled impulse response. These may be added to produce the final filtered signal.

```
REM /----------------------- DSP Workbench -----------------------\
REM | QBasic version 1.2                              J.M.Sharpe 1993 |
REM \-------------------------------------------------------------/
CONST PI = 3.141592654#                        'PI
CONST PB2 = 1.570796327#                       'PI/2
CONST XL% = 640                                'Screen X resolution
CONST YL% = 480                                'Screen Y resolution
CONST GC% = 14                                 'Graph colour
CONST AC% = 15                                 'Axis Colour
CONST SC% = 8                                  'Colour of Squares

DECLARE SUB plotgraph (xn%, max, min, y, col%, n$, cont%)
DECLARE SUB filter (order%, p, q, x, sl%, y)
DECLARE SUB fft (m%, n%, a)

TYPE cmplx                                     'Complex number type
     RE AS SINGLE
     IM AS SINGLE
END TYPE

'$DYNAMIC
DIM SHARED p(0 TO 2), q(1 TO 2), fx(1 TO 32), y(1 TO 32)
DIM SHARED a(1 TO 32) AS cmplx
nl$ = CHR$(10) + SPACE$(5)                     'Formating string

REM ******************************DEFAULT SETTINGS******************************
xn% = 2: p(0) = .5: p(1) = -1: p(2) = 1: q(1) = -.5: q(2) = -.125
psl% = 5: sl% = 2 ^ psl%

REM **********************************MAIN LOOP**********************************
DO
CLS : PRINT nl$; "DIGITAL FILTER WORKBENCH"; nl$; "------------------------"
PRINT USING "&Current filter: &p(0)       : ##.###&"; nl$; nl$; p(0); nl$;
FOR n% = 1 TO xn%:
        PRINT USING "p(#)  q(#): ##.###  ##.### &"; n%; n%; p(n%); q(n%); nl$;
NEXT
PRINT nl$; "1. Define new filter"; nl$; "2. Set Sequence length (Current=";
PRINT sl%; ")"; nl$; "3. Test Filter Response"; nl$;
PRINT "4. Filter Custom Sequence"; nl$; "5. Exit"; nl$; "Enter Number:";
DO: c$ = INKEY$: LOOP WHILE c$ = "": PRINT c$; nl$; nl$;

SELECT CASE c$
 CASE "1"
   DO: INPUT "Number of delay units (order):", xn%: PRINT nl$;
   REDIM SHARED p(-0 TO xn%), q(0 TO xn%)
   LOOP WHILE xn% < 1
   INPUT "Enter coeffcient p(0):", p(0)
   FOR n% = 1 TO xn%
   PRINT nl$; "Enter coeffcient p("; n%; "), q("; n%; "):";
   INPUT p(n%), q(n%)
   NEXT n%

 CASE "2"
     DO: INPUT "Enter new length (will be rounded to a power of 2):", sl%
     PRINT nl$; : LOOP WHILE sl% < 2
     psl% = INT(LOG(sl%) / LOG(2)): sl% = 2 ^ psl%
     REDIM SHARED fx(1 TO sl%), y(1 TO sl%), a(1 TO sl%) AS cmplx

 CASE "3"

     REM ****************************Unit Step Response****************************
     FOR n% = 1 TO sl%: fx(n%) = 1: NEXT
     CALL filter(xn%, p, q, fx, sl%, y)
     max = 0: min = 0
     FOR n% = 1 TO sl%                                          'Find max and min
      IF y(n%) > max THEN max = y(n%) ELSE IF y(n%) < min THEN min = y(n%)
     NEXT
     CALL plotgraph(sl%, max, min, y, GC%, "Unit Step Response", 0)


     REM *************************Unit Impulse Response*************************
     FOR n% = 2 TO sl%: fx(n%) = 0: NEXT: fx(1) = 1             'Impulse sequence
     CALL filter(xn%, p, q, fx, sl%, y)                         'Get I.R.
     max = 0: min = 0
     FOR n% = 1 TO sl%                                          'Find max and min
      IF y(n%) > max THEN max = y(n%) ELSE IF y(n%) < min THEN min = y(n%)
     NEXT
     CALL plotgraph(sl%, max, min, y, GC%, "Unit Impulse Response", 0)


     REM **************************Frequency Response**************************
     FOR n% = 1 TO sl%: a(n%).RE = y(n%): a(n%).IM = 0: NEXT
     CALL fft(psl%, sl%, a)                                     'FFT of I.R.
     max = 0: min = 0
     FOR n% = 1 TO 1 + sl% / 2
      y(n%) = SQR(a(n%).RE ^ 2 + a(n%).IM ^ 2)                  'Y=magnitude of A
      IF y(n%) > max THEN max = y(n%)                           'find max and min
      IF y(n%) < min THEN min = y(n%)
     NEXT
     CALL plotgraph(1 + sl% / 2, max, min, y, GC%, "Frequency response", 0)


     REM ******************************Phase Response******************************
     FOR n% = 1 TO sl% / 2                                      'Y=argument of A
      IF a(n%).RE = 0 THEN y(n%) = PB2 ELSE y(n%) = ATN(a(n%).IM / a(n%).RE)
     NEXT
     CALL plotgraph(sl% / 2, PB2, -PB2, y, GC%, "Phase Response", 0)

 CASE "4"
  REM ************************ Filter Custom Sequence ****************************
  RESTORE: max = 0: min = 0
  FOR n% = 1 TO sl%: READ fx(n%): NEXT                   'Read Signal data into fx
  CALL filter(xn%, p, q, fx, sl%, y)                     'Filtered signal in y
  FOR n% = 1 TO sl%                                      'Find max/minimum values
   IF y(n%) > max THEN max = y(n%) ELSE IF y(n%) < min THEN min = y(n%)
   IF fx(n%) > max THEN max = fx(n%) ELSE IF fx(n%) < min THEN min = fx(n%)
  NEXT
  CALL plotgraph(sl%, max, min, y, GC%, "", 1)
  FOR n% = 1 TO sl%: y(n%) = fx(n%): NEXT
  CALL plotgraph(sl%, max, min, y, 12, "Original(RED) & filtered signal", 0)

 CASE "5"
  PRINT "Are you sure (Y/N)?": DO: c$ = UCASE$(INKEY$): LOOP WHILE c$ = ""
  IF c$ = "Y" THEN END

END SELECT
LOOP

REM ******************************* DATA FOR CUSTOM SIGNAL ******************************
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
DATA 1,.5,.25,.125,.0625,.03125,.01563,0,1,.5,.25,.125,.0625,.03125,.01563,0
REM ************************************************************************************

REM $STATIC
'/---------Fast Fourier Transform routine (After Cooley, Lewis & Welch)---------\
'|             Converted from Fortran routine by J.M.Sharpe 9/93                 |
'|              n%=2^m%=sequence length, a(1 to n%) complex data                 |
'\-------------------------------------------------------------------------------/
SUB fft (m%, n%, a)
DIM u AS cmplx, w AS cmplx, t AS cmplx, tt AS cmplx
nv2% = n% / 2: nm1% = n% - 1: j% = 1
FOR i% = 1 TO nm1%
 IF i% < j% THEN SWAP a(j%), a(i%)
 k% = nv2%
 WHILE k% < j%: j% = j% - k%: k% = k% / 2: WEND
 j% = j% + k%
NEXT i%

FOR l% = 1 TO m%
 le% = 2 ^ l%
 le1% = le% / 2
 u.RE = 1: u.IM = 0
 w.RE = COS(PI / le1%): w.IM = -SIN(PI / le1%)
 FOR j% = 1 TO le1%
   FOR i% = j% TO n% STEP le%
    ip% = i% + le1%
    t.RE = a(ip%).RE * u.RE - a(ip%).IM * u.IM
    t.IM = a(ip%).IM * u.RE + a(ip%).RE * u.IM
    a(ip%).RE = a(i%).RE - t.RE: a(ip%).IM = a(i%).IM - t.IM
    a(i%).RE = a(i%).RE + t.RE: a(i%).IM = a(i%).IM + t.IM
   NEXT i%
  tt.RE = u.RE * w.RE - u.IM * w.IM: tt.IM = u.RE * w.IM + u.IM * w.RE: u = tt
  NEXT j%
NEXT l%
END SUB

SUB filter (order%, p, q, fx, sl%, y)
DIM s(1 TO order%), sn(1 TO order% + 1)                   'State storage
FOR n = 1 TO order%: s(n) = 0: NEXT                       'States initially zero
sn(order% + 1) = 0                                        'dummy state
FOR n = 1 TO sl%                                          '1 to Length of sequence
 y(n) = p(0) * fx(n) + s(1)                              'Calculate output
 FOR c = 1 TO order%: sn(c) = s(c): NEXT                 'Make copy of states
 FOR i = 1 TO order%
  s(i) = q(i) * sn(1) + sn(i + 1) + (p(i) + p(0) * q(i)) * fx(n)
 NEXT i
NEXT n
END SUB

SUB plotgraph (xn%, max, min, y, col%, n$, cont%)
IF min > 0 THEN min = 0                                   'Ensure origin on
IF max < 0 THEN max = 0                                   'screen
IF min = max THEN max = min + 1

ys = (YL% - 1) / (max - min)                              'y scale
xs = XL% / (xn% - 1)                                      'x scale
yo = max * ys                                             'location of line y=0
SCREEN 12: WIDTH , 60                                     'Graphics screen
IF cont% = 0 THEN
 LOCATE 1, 40, 0: PRINT n$; "   <KEY>";
 LOCATE 1, 1, 0: PRINT max; : LOCATE 60, 1, 0: PRINT min;
 FOR n = 0 TO XL% - 1 STEP xs: LINE (n, 0)-(n, YL% - 1), SC%: NEXT
 FOR n = yo + ys TO YL% - 1 STEP ys: LINE (0, n)-(XL% - 1, n), SC%: NEXT
 FOR n = yo + ys TO 0 STEP -ys / 2: LINE (0, n)-(XL% - 1, n), SC%: NEXT
 LINE (0, yo)-(XL%, yo), AC%: LINE (0, 0)-(0, YL%), AC%'Draw axis
END IF
PSET (0, yo - ys * y(1))                                  'Move to first point
FOR xc% = 2 TO xn%: LINE -(xs * (xc% - 1), yo - ys * y(xc%)), col%: NEXT
IF cont% = 0 THEN DO WHILE INKEY$ = "": LOOP: SCREEN 0
END SUB
```

Program 2.

Satellite-Based Networking Overview

by Frank Booty

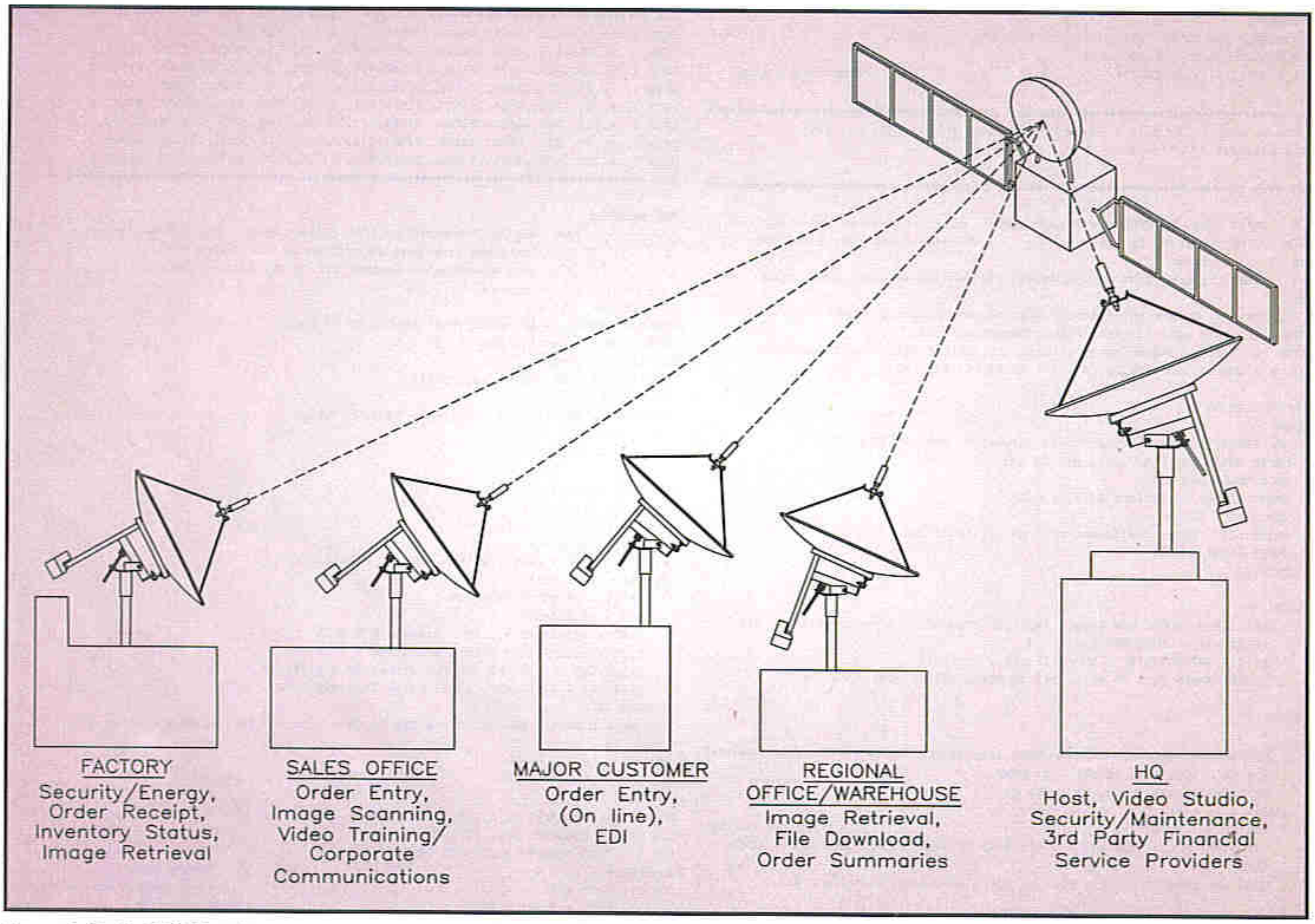


Figure 1. Typical VSAT environment.

SATELLITE-BASED networking has emerged from modest beginnings in the early 1980s to become a mainstream wide area communications solution for corporations throughout the world. Very Small Aperture Terminal (VSAT) networks are now regarded as the most flexible platform in the communications marketplace, allowing many remote locations to communicate with a centralised computing facility.

The star configuration of a VSAT network provides an efficient, cost-effective method for distributing data, video, audio, voice and fax through a widely dispersed organisation, while maintaining the same level of performance at each site regardless of location. It has proved an ideal way of linking retailers with their customers, automobile manufacturers with their dealers, and bank headquarters with their branch offices. It allows for such typical applications as point-of-sale updates, credit and cheque authorisation, order entry, claims processing, Electronic Data Interchange (EDI), video training, in-store music and more (see Figure 1). This article intends to describe satellite-based networking, and address such questions as whether VSAT networks are being accepted in the marketplace; how they work; what the advantages are over terrestrial networks; what business applications best fit a VSAT network; and what the future holds for this technology.

The Current State of VSAT

The world-wide market for VSAT equipment and services is currently estimated to be worth some $350 million per year. The industry has been experiencing tremendous growth since the late 1980s and market analysis estimates it will stabilise at 20% growth per annum through the 1990s. As of today, there are in excess of 100,000 VSATs installed or on order world-wide (see Figure 2). Much of this growth can be attributed to a high level of customer satisfaction. Indeed many users have credited their VSAT networks with increasing network availability, containing staff growth, and improving control over communications costs within their companies.

Future market growth will be driven by traditional dial-up network users adopting VSAT, having an increasing demand for the improved services of on-line communications due to 'mission critical' applications. A VSAT network will be able to respond to higher capacity, more volatile traffic, with increased bandwidth and more stringent response time and availability. Key industry sectors, who are expected to make this transition, will be

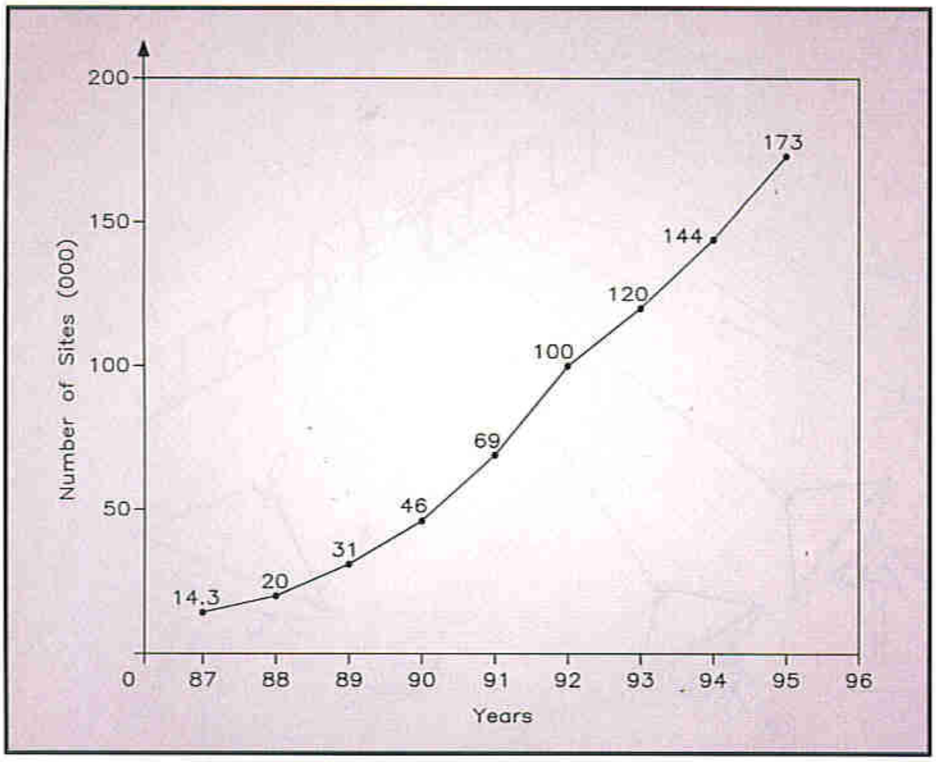


Figure 2. World-wide VSAT market (cumulative).

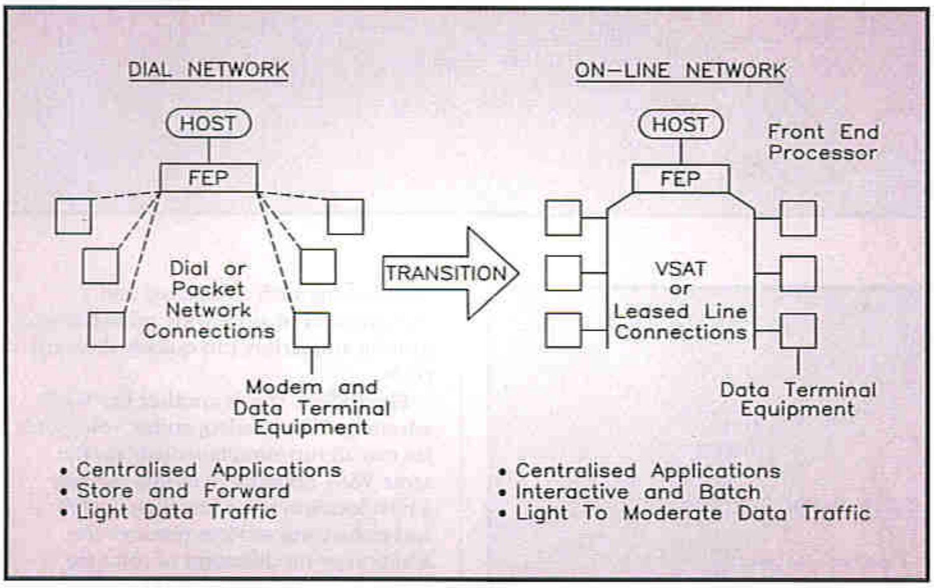


Figure 3. Dial users in transition.

supermarkets, petrol stations, insurance agents, retail speciality outlets and fast food chains (see Figure 3).

A growing movement towards deregulation and privatisation of communications services world-wide is another factor driving the market growth for VSATs. Great strides towards deregulation are being made in Latin America, the Pacific Rim and Western Europe. Then there is the demand for a high quality communications infrastructure in developing countries. Countries like Indonesia, Chile and the Philippines are natural locations for satellite communications, because they have geographical difficulties that impede the use of terrestrial alternatives. Regions such as Eastern Europe and Latin America are VSAT growth areas as well because of their almost complete lack of a land-based communications infrastructure.

What is VSAT?

A VSAT network comprises a central master earth station or 'hub', and geographically dispersed VSATs (see Figure 4). The hub consists of a satellite antenna (5 to 9 metres), Radio Frequency (RF) and Intermediate Frequency (IF) equipment, a Network Control System (NCS) and a switching element that connects to a user's mainframe computer(s). The switching element is at the heart of the hub, and it provides the necessary capabilities to route data from any point in the network to any other point. The NCS permits the network operator to configure, download, monitor and troubleshoot the entire network from other central hub location.

The geographically dispersed VSATs consist of small, easily installed antennas (between one to two metres in diameter), an OutDoor RF Unit (ODU), and an Indoor Digital processing Unit (IDU). A single cable connects the ODU with the IDU, which is typically installed in the location's back office. The IDU is responsible for communications functions related to transmitting and receiving data. It typically features two to four RS232 ports on its back panel, and supports up to three protocols simultaneously. This enables the user to connect a variety of data terminal equipment to the network.

A remote VSAT installation is a simple three step process. First, a local ordinance review is performed to determine the local permit and licensing requirements, and a site visit is made to verify site conditions and to plan the installation. Presence of the landlord or similar authority may be desirable during the survey to ensure approval of the antenna location and mounting approach. Second, the antenna is installed and positioned for a clear line of sight to the satellite. Third, communications are established between the hub and the user's computer to verify proper operation of the VSAT.

In order to send and receive data between the hub and the remote VSATs, information is transmitted to a Ku- or C-band geosynchronous satellite. Since geosynchronous satellites orbit at the same angular velocity as the earth, they maintain a constant position relative to a network's antenna dishes, eliminating any need for repositioning.

A private VSAT network is ideally suited for companies with more than 200 remote sites. The same technology, however, is also affordable to companies with as few as 10 remote sites through shared hub services. Providers of shared hub services offer their customers access to a centrally-located hub that can be shared with several users. The communication between the shared hub site and the user's computer centre is achieved through a terrestrial, microwave or satellite connection. By utilising a shared hub, users eliminate the significant capital investment of a private hub while gaining all the advantages of high performance, satellite-based networking. In addition, network operations are managed by the shared hub provider, reducing the user's costs associated with network operations personnel and training.

Once a company reaches the 200 site threshold it can realise significant savings by owning a private hub, while gaining the added security that comes from maintaining complete ownership and control. Private networks can be operated by the user or managed by the network vendor through a variety of network operations services, ranging from full-time, on-site facilities management to part-time remote monitoring during off peak hours.

VSAT in Action

VSAT networks offer many advantages not found in terrestrial networks: lower cost; flexibility; reliability; speed; and simplicity.

Lower cost. Unlike land-based networks, VSAT networks are insensitive to distance. Transmission costs remain fixed regardless of distance, and network costs can be

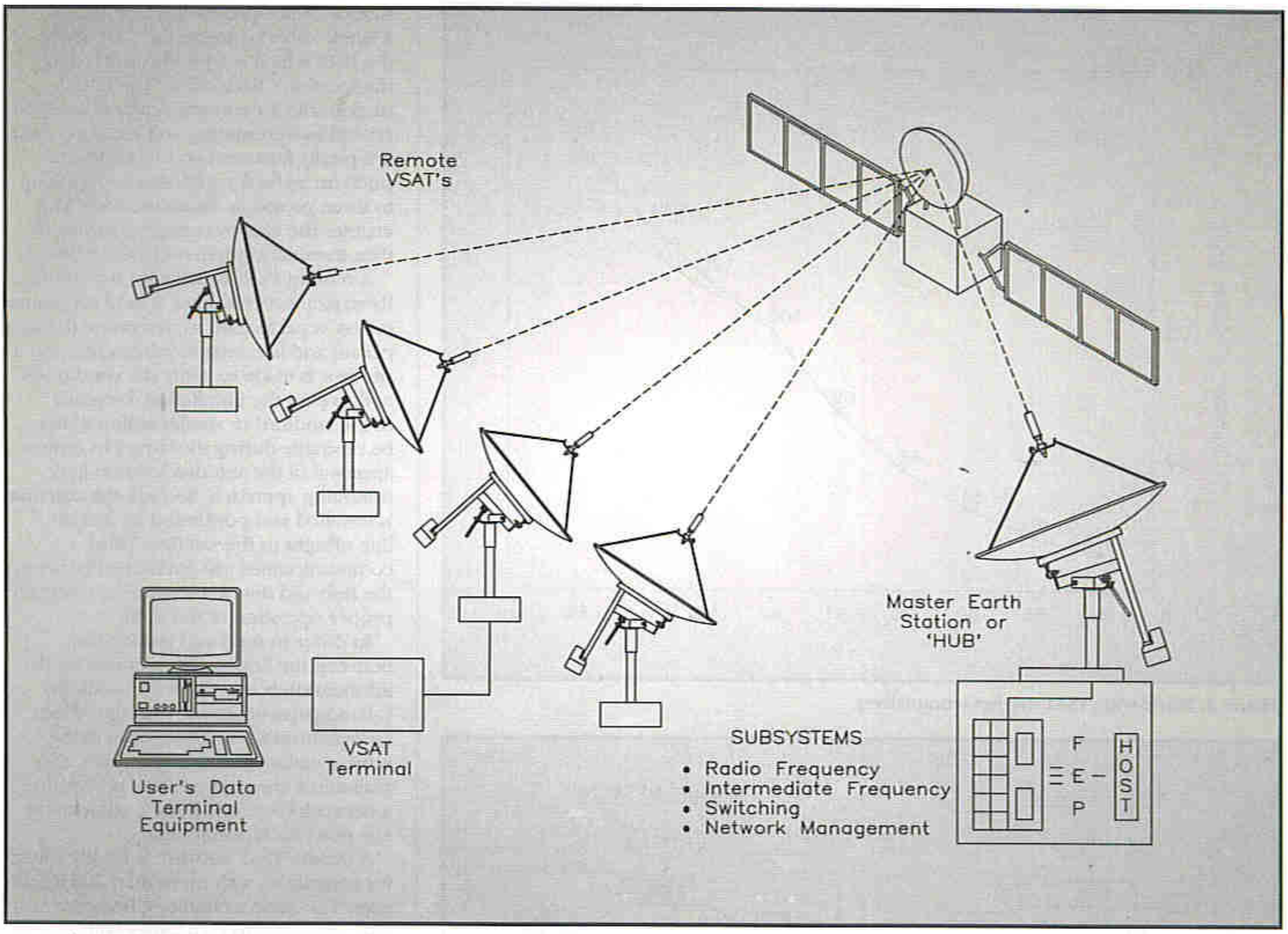


Figure 4. VSAT network architecture.

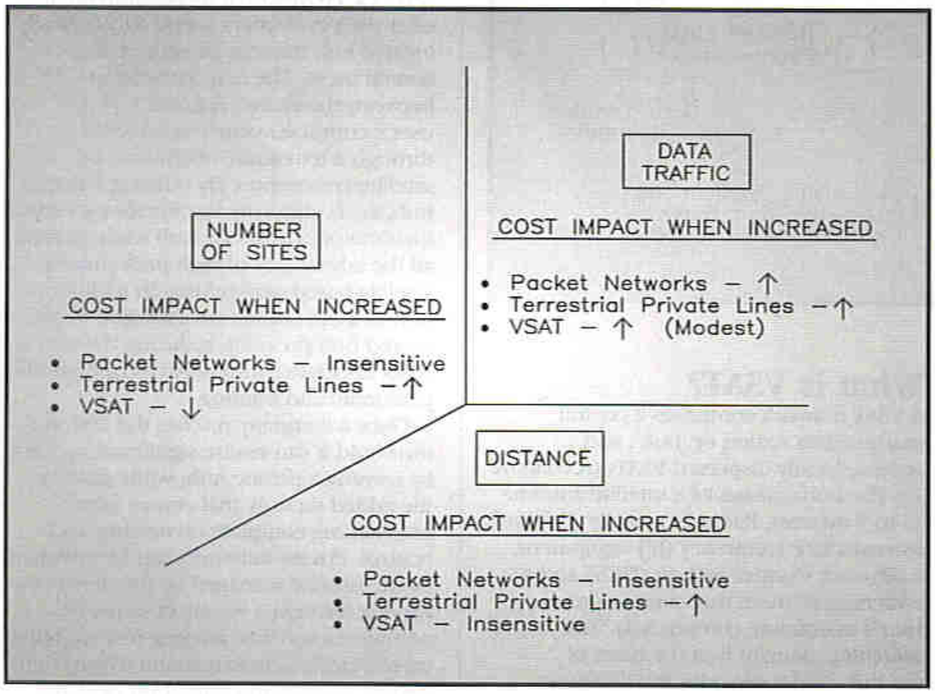


Figure 5. Key cost drivers to competing networking technologies.

fixed for several years. Transmission costs for land-based networks, on the other hand, increase as distance increases. Land-based networks are also vulnerable to changing tariffs, which can increase communications costs (see Figure 5). Since most VSAT costs are fixed, new applications and services can be added with only incremental increases in monthly operating expenses. Not so with distance-sensitive, terrestrial networks, when the addition of new services often requires larger, more expensive communications lines (for more bandwidth) at substantially higher monthly costs. Adding high volume applications such as imaging and supermarket or store-wide price changes from headquarters can quickly drive up costs.

Flexibility. This is another key VSAT advantage. Data, video, audio, voice and fax can all run simultaneously on the same VSAT network platform. Adding a new location takes less than a week, and enhancing services requires the addition or modification of software at headquarters. With a VSAT network, projects such as adding a new application or reconfiguring the network can be managed and implemented easily. By comparison, modifying a terrestrial network is much more difficult. The typical network of today has to be re-engineered as new services and locations are added. Indeed, this process can take months to perform and can involve many vendors.

Reliability. Terrestrial 'outages' (power or communication breaks) do occur, and major outages can overwhelm even the most advanced terrestrial networks. But VSAT networks are off the ground and, therefore, not susceptible to problems on the ground such as poor quality telephone lines. VSAT networks provide uniform, clear communications to all sites, regardless of their location. VSATs also offer numerous backup systems, including disaster recovery services and other failsafe systems that automatically re-route communications in the event of a failure.

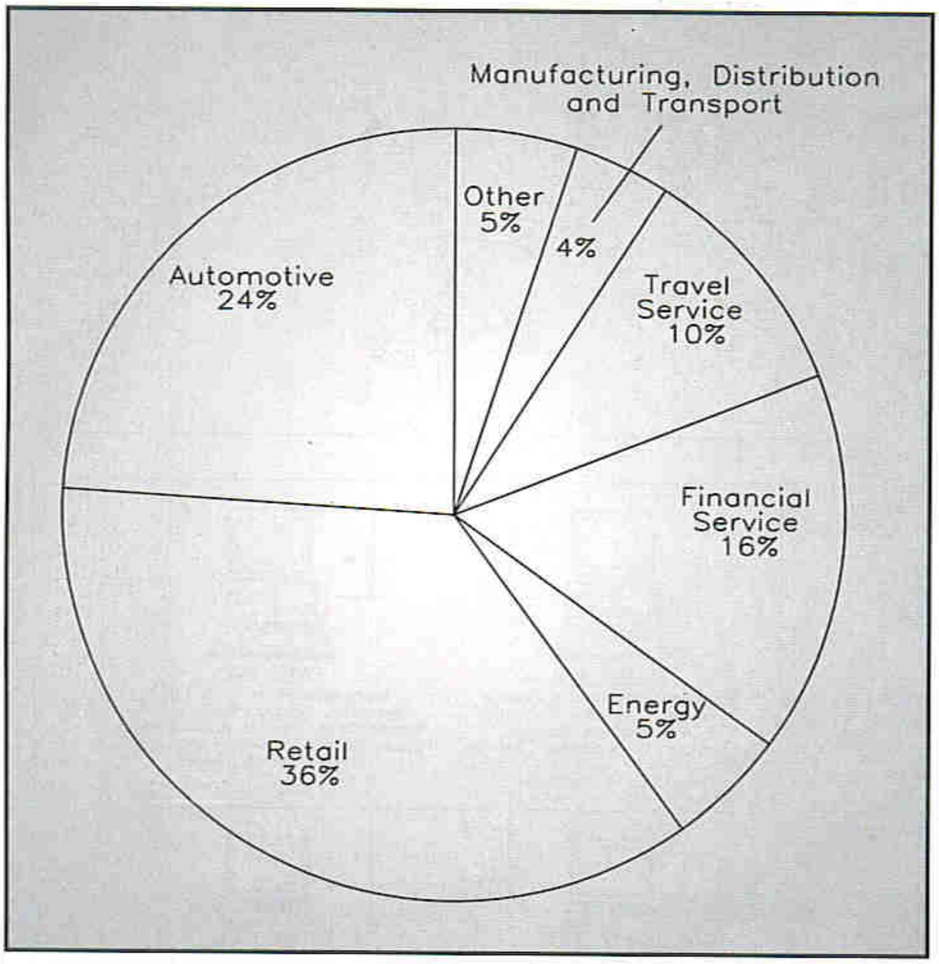


Figure 6. Distribution of the number of sites by industry.

Speed. VSAT networks are faster than most dial-up and leased-line networks. The increased speed permits instantaneous on-line communications, which is a prime requisite for such applications as electronic payment systems. Additional bandwidth can be added incrementally, enabling the addition of high bandwidth broadcast applications such as video, data and audio.

Simplicity. VSAT networks are claimed to be easier to manage and operate than their terrestrial counterparts. Compare a VSAT network's three components – a satellite, central hub and remote VSATs – to a terrestrial network with its multiple communications lines. These land lines may be shared by multiple sites and managed by several vendors. Because there are fewer elements in a VSAT network, there is less to monitor and less to go wrong. The network can be monitored and controlled by the customer at headquarters, or the day-to-day operations can be outsourced completely or partially to the satellite networking vendor.

Three industries – retail, automotive and financial – account for over 75% of the current VSAT market. Each utilises a VSAT networking solution to address its own distinctive competitive pressures and communications requirements. Other industries that are using VSAT technology include manufacturing, travel services, energy, distribution and transportation (see Figure 6).

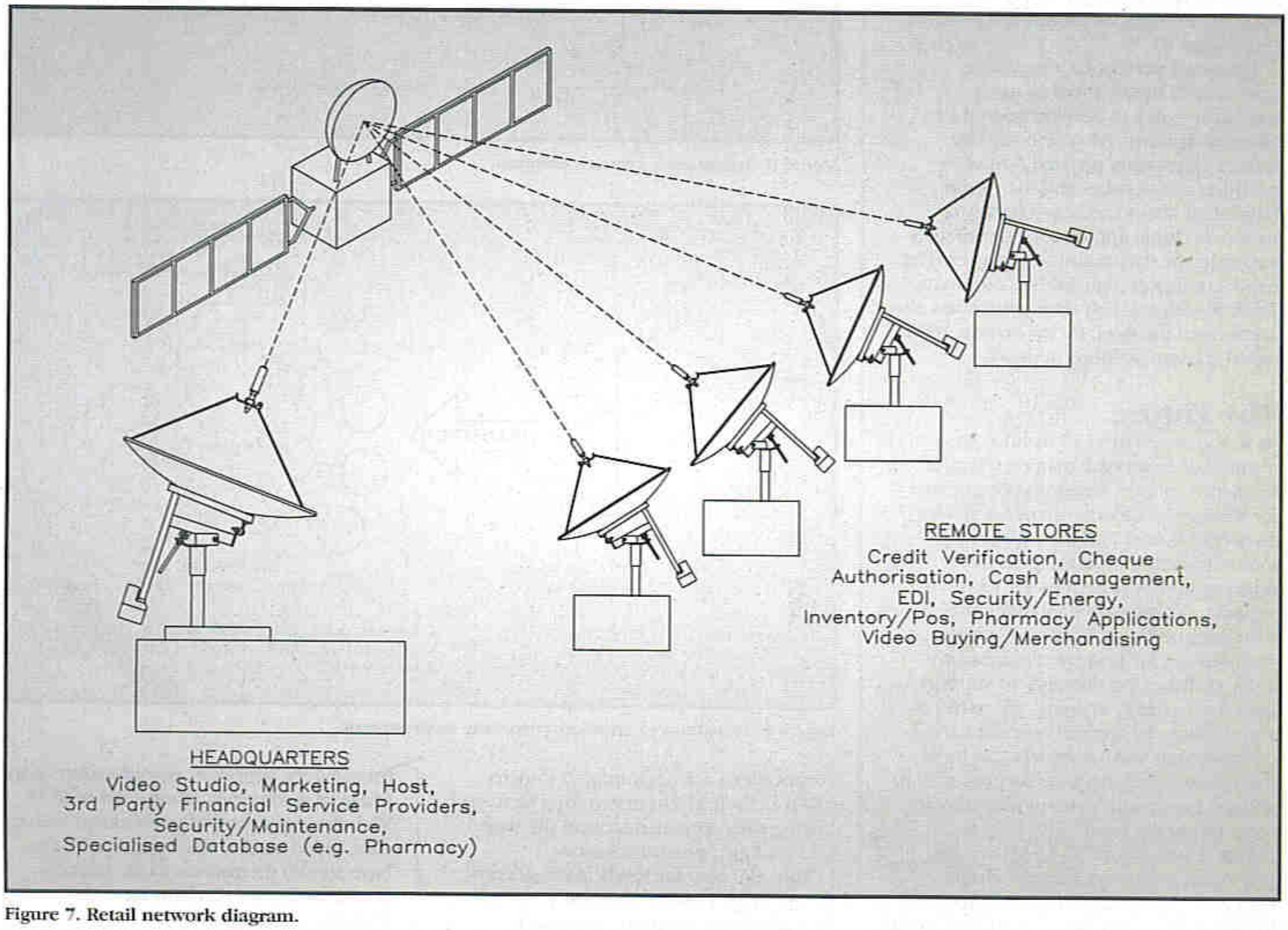


Figure 7. Retail network diagram.

Retailing. In the retail industry, organisations use VSATs to gather and process financial data from each store on a daily basis. Point of Sale (POS) and credit card verification are the leading applications in this market. Daily pricing information is fed to electronic checkout systems in each store. In return, the POS systems feed merchandise movement, inventory and accounting data back to the host computer system. The use of video and audio over the network is also becoming popular in the retail market. Advertising and programming can be broadcast over the network and into the store to reach consumers right at the point of purchase. Video is also widely used for training, remote buying and corporate communications (Figure 7).

Automotive. Until recently, the communications focus of the automotive industry has been on such back office processing applications as inventory control, general ledger and payroll, and remote computing service applications such as accounting time-sharing, credit check and finance company access. However, this focus has shifted to interactive dealer-to-manufacturer communications, which include on-line warranty, order entry, credit check authorisation and the locating of vehicle parts. There has also been an increased demand for manufacturer-to-dealer communications, such as video training for sales and service personnel, new car introductions and in-dealership music. VSAT technology is seen as the ideal platform for these broadcast applications (see Figure 8).

Financial services. Competitive pressures in the financial industry have lead banks to develop several key communications requirements. The industry's growing proliferation of products and services and the rise in fraudulent acts are pushing banks to handle multiple applications per branch and enhance data security measures. The need to support high volume Automatic Teller Machine (ATM) transactions has also accelerated the need for an on-line, VSAT based communications network.

The Future

As to the future of VSAT technology, a number of factors are coming together to ensure an increasingly important role for VSATs. The emergence of Local Area Networks (LANs) and their associated internetworking requirements are opening up opportunities for VSATs to support a company's LAN traffic over a wide area network. There is a growing requirement for dedicated bandwidth links, available 'on demand' to support database updates, imaging, file transfers and multimedia applications in a LAN environment. VSAT networks can meet this requirement, because they are able to allocate bandwidth dynamically, allowing users to pay for bandwidth only as required (see Figure 9). VSATs are also playing an important role in hybrid networks supporting terrestrial links in the same wide area network. Multinational corporations are beginning to look to VSATs in their global networking strategies, linking their locations around the world into a single network solution.

Thus the case for VSATs is considered strong. They have emerged as a mainstream networking technology for retailers, suppliers, manufacturers and financial institutions around the world. With the expansion of networks to include data, video, audio, voice and fax, VSATs have shown themselves to be a flexible communications platform for today's industries.

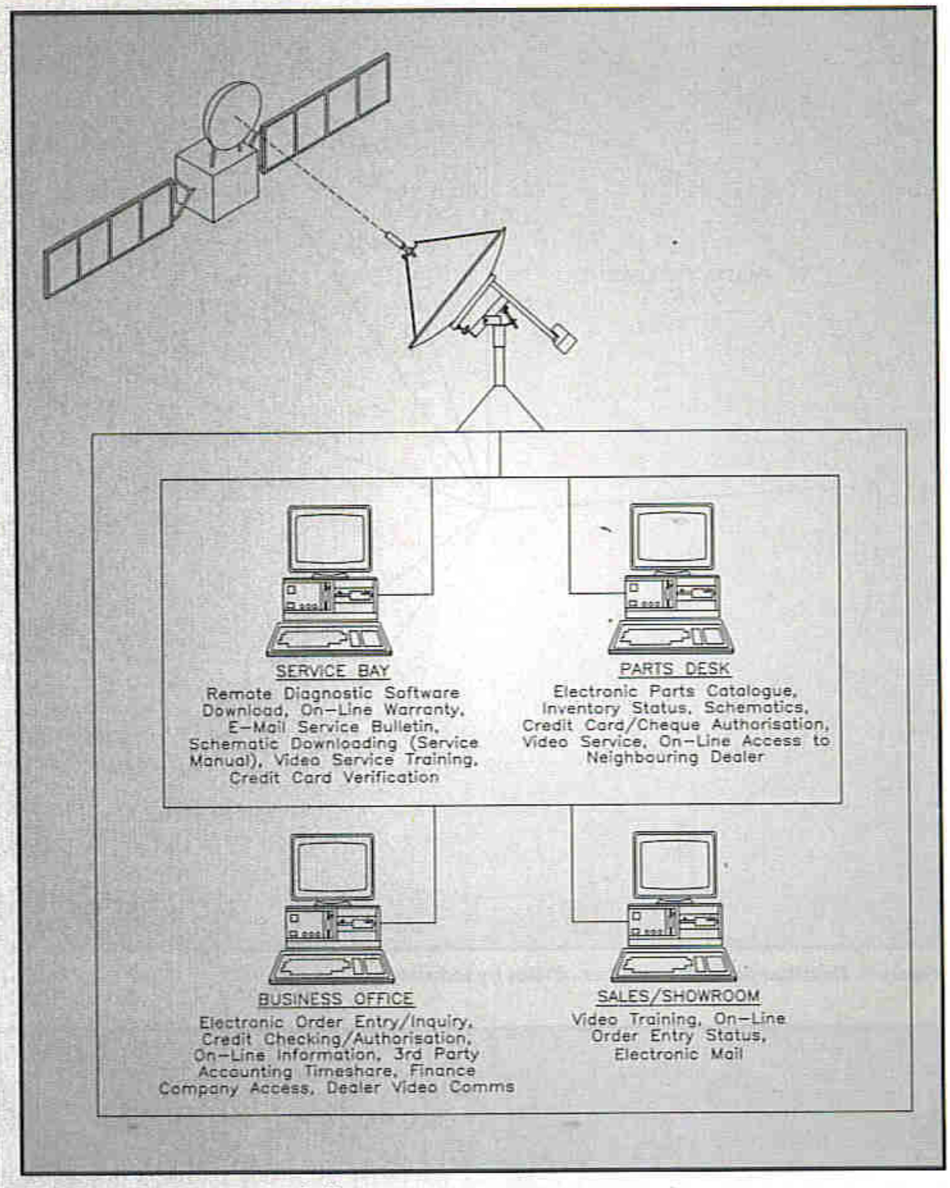


Figure 8. Automotive network diagram.

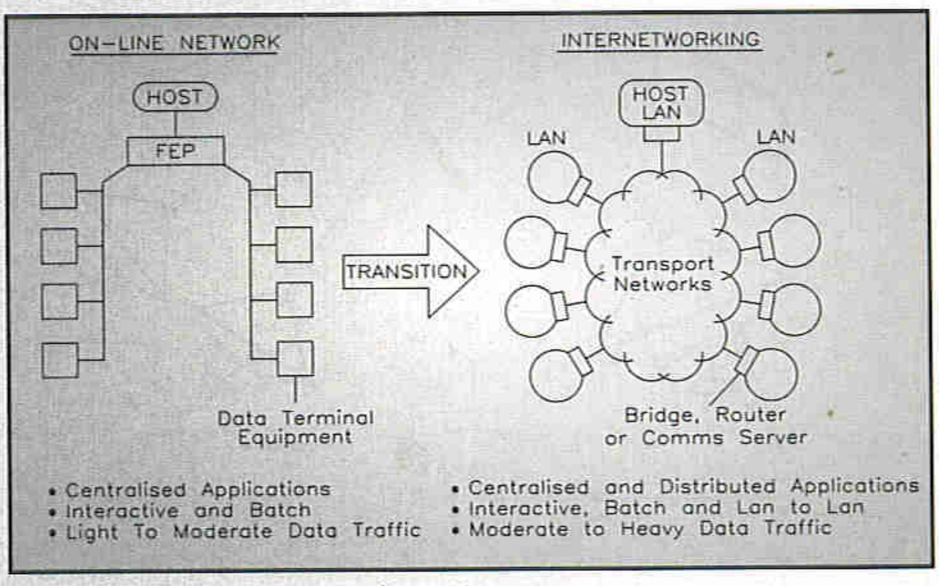
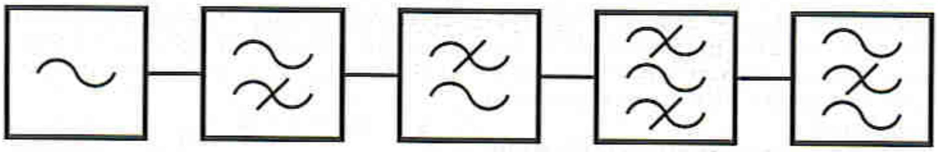


Figure 9. Transition to an internetworking environment.



FILTERS

Part 3: Band-pass and Band-stop

J. M. Woodgate B.Sc.(Eng.), C.Eng., M.I.E.E., M.A.E.S., F.Inst.S.C.E.

This month, the concepts and practicalities of designing band-pass and band-stop filters are examined.

In Parts 1 and 2, we looked at low-pass and high-pass filters, and we saw that we can take the low-pass filter as the basis for designing high-pass filters (we could take the high-pass filter as basic instead, but that is slightly more complicated). We also saw that analysis and design can be much simplified by the process of 'normalization'. This means reducing every input value that can be so reduced without introducing errors, to a value of 1, by scaling processes and, after analysis, rescaling the results.

There was a fairly modest venture into the mathematical basis of modern filter design, which showed how various filter response shapes can be produced, and how they are related. To reduce the number of possible cases of passive filters to a practical minimum, we have concentrated on those fed from a very low impedance into a specified resistive load impedance, a condition which is usually fairly easy to achieve. For active filters, there are not such strict limitations on source and load impedance, although the principle of low source impedance and high load impedance still applies. However, there are infinitely many possible active filter configurations, so we are mostly concentrating on the 'unity-gain, single feedback' or Sallen and Key type, which will do all that is normally required in home constructor projects.

Band-pass and Band-stop Filters

We now go on to look at band-pass and band-stop filters, and these, too, can be derived from a basic low-pass filter. However, if the required bandwidth is wide, another approach is more useful. To decide what 'wide' means in this context, we take the ratio of the upper corner frequency to the lower corner frequency. The corner frequency is the frequency at which the filter first begins, clearly, to attenuate the signal as we move from the pass-band to the stop-band. It is usually taken as the half-power point, the frequency at which the response is −3dB, referred to the response in the centre of the pass-band. If the upper corner frequency is two or more times the lower corner frequency, we have a wide-band filter, and we make a band-pass filter simply by cascading a low-pass and a high-pass filter. The high-pass corner frequency obviously has to be lower than the low-pass corner frequency, otherwise we get an 'all-stop' filter, which is only useful on 1 April! We get a band-stop filter by paralleling a low-pass and a high-pass filter; we can usually do this directly at their inputs, but at the outputs we may need a summing amplifier. With our approach to passive filters, restricted to filters working from a very low source impedance, we usually have to include a buffer amplifier or follower between the two parts of a band-pass filter (Figure 26). When using passive high- and low-pass sections in cascade, it is usually better for the high-pass section to precede the low-pass section. These restrictions do not apply to active filters, at least of the type we have looked at, which are built round a follower – an amplifier with 100% negative feedback, giving a gain of 1.

Figure 26. Wide-band filter structures: (a) band-pass filter; (b) band-stop filter.
Figure 27. Wide-band active band-pass filter using only one op amp.

One consequence of building a wide-band filter from two separate filters is that the two 'ends' of the response can have very different shapes, simply by using different types and orders of filter at each end. Most CD players have filtering of this type: a (possibly not clearly defined) high-pass filter with some corner frequency below 20Hz (since the response does not go right down to DC!), and a very well defined and very steep-slope phase-corrected reconstruction filter with corner frequency near 20kHz.

Small Economy-size Wide-band Filters

It is possible, if the ratio of the corner frequencies is large enough, to build both filters in active form around one op amp, and an example was given in my series on audio frequency induction loop systems, in Issues 39 to 43 of *Electronics*. This circuit (Figure 27), part of a magnetic field-strength meter, has −3dB frequencies of 630Hz and 5kHz. In this case, the low-pass section comes first, because the impedances of the

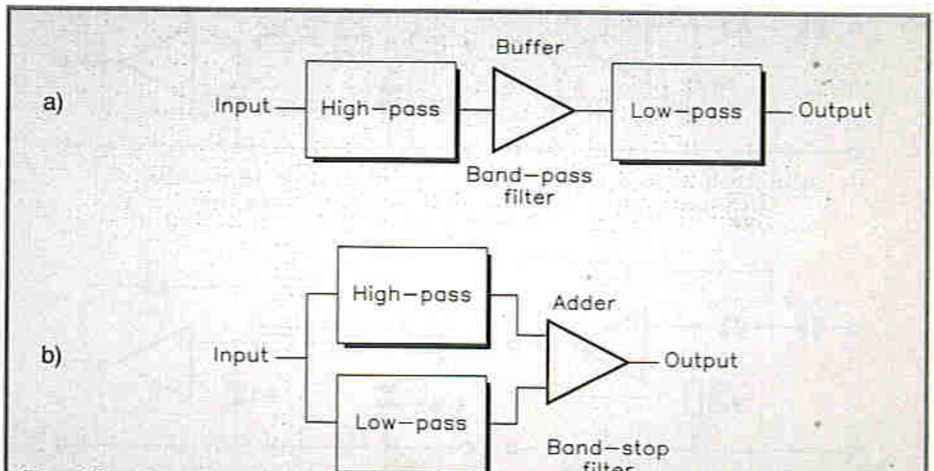


Figure 26.

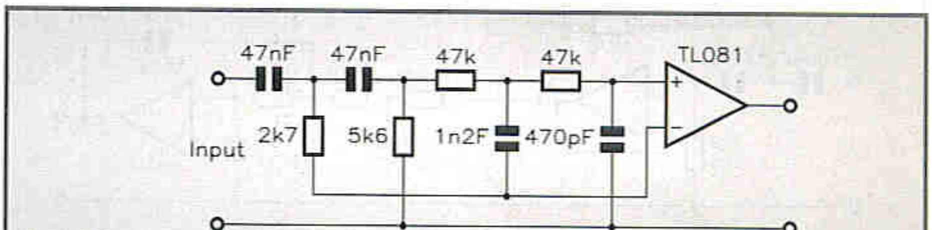


Figure 27.

series capacitors are low at the high-frequency end of the pass-band, whereas the series resistors are not of negligible impedance at the low-frequency end and, therefore, they have to be inside the feed-back loop of the low-pass filter. A small amount of 'tweaking' of component values may be required in order to get precisely the desired response shape, but some tweaking is always necessary unless, by chance, the required component values correspond exactly with preferred values (and preferred values which are actually obtainable; things like 8·2nF and 12nF capacitors can be elusive).

A Practical Example

As you might expect, wide-band band-stop filters are not very often required, and I cannot readily think of an excuse for one, so we shall look at a band-pass filter for simulating 'telephone speech', which has a response restricted from 300Hz to 3·4kHz (−3dB points). We will assume that the low end response should fall at 12dB/octave and the high end response should fall at 18dB/octave. The low frequencies involved suggest that inductor values would be quite high, leading to difficulties in supply and cost, so we choose active filters – Butterworth (maximally-flat) responses are quite suitable for this application. The steps are shown in Figure 28, and follow the design procedures given in Parts 1 and 2.

Narrow-band Filters

These are designed by first looking at a low-pass filter, whose characteristics can be derived from those of the required filter. In principle, there is a one-step process from this low-pass filter to the band-pass filter, but if a band-stop filter is required we should use a two-step process. This means going from the low-pass filter to a high-pass and from there to the band-stop but, with practice, the two processes can be combined.

To recap from earlier parts of the series, we analyse filters by looking at their transfer functions (ratio of output voltage to input voltage), expressed in terms of a variable $s = \sigma + j\omega$, which incorporates both frequency and power loss aspects. We usually make the analysis as simple as possible by normalization, so we look at the transfer function of a filter which has a corner frequency ω of 1 rad/s ($f = 1/2\pi$ Hz), and has (in our restricted case) a source resistance of zero and a load resistance of 1Ω. (To consider all the possibilities, we would have to deal also with cases where the *source* resistance was 1Ω and the load resistance was either 1Ω or zero.)

The transfer function $T_L(s)$ of a Butterworth (maximally-flat) second order low-pass filter is:

$$T_L(s) = \frac{1}{s^2 + \sqrt{2}s + 1}$$

We transformed this to a high-pass filter transfer function $T_H(s)$ by the substitution of $1/s$ for s, leading, after algebraic simplification, to the transfer function:

$$T_H(s) = \frac{s^2}{s^2 + \sqrt{2}s + 1}$$

We can transform the low-pass filter to a band-pass filter by the substitution of $s + 1/s$ for s. This gives the band-pass transfer function $T_{BP}(s)$:

$$T_{BP}(s) = \frac{s^2}{s^4 + \sqrt{2}s^3 + 3s^2 + \sqrt{2}s + 1}$$

The s^2 in the numerator tells us that, like the high-pass filter, the band-pass filter has a double zero at $s = 0$, and if we divide the top and bottom of the right-hand side by s^2, we find that the denominator becomes:

$$s^2 + \sqrt{2}s + 3 + \frac{\sqrt{2}}{s} + \frac{1}{s^2}$$

which is symmetrical in s and $1/s$. This means that the frequency response curve is symmetrical on a logarithmic frequency axis. Also, since the denominator contains only even powers of s, the response is symmetrical about $\omega = 0$. There is a response for negative frequencies of exactly the same shape as that for positive frequencies. Luckily, we almost never have to bother with negative frequencies; they do not have any effect, or cause any problems.

It can be shown that the transfer function has four poles, which are symmetrically placed about the lines $j\omega = \pm 1$ in the complex plane. They all have the same value of σ, negative, of course, because we are not dealing with an oscillator. The calculation of the precise co-ordinates of the poles is tedious and, luckily, unnecessary for our present purposes.

To plot the actual frequency responses, we substitute $s = j\omega$ and rationalise the resulting equation for $T(j\omega)$ (see Part 1) to get $|T(j\omega)|^2$, and then plot −10 times the logarithm of this to get the response in decibels. Using decibels means that we do not have to find the square root in the rationalisation process, which avoids much complication.

Time (Out) for *t*

The results of all this manoeuvring are shown in Figure 29a. The centre of the pass-band of this filter is at $\omega = 1$ rad/s, and the half-power points are at the interesting values of $\omega = 1{\cdot}618$ and $0{\cdot}618$, so the −3dB bandwidth of the filter is 1 rad/s as well. Mathematicians know those values of ω as t and $1/t$ respectively, and $1/t$ is called the 'golden ratio'. t is another of those numbers, like π and e, which seem to occur naturally in the universe, and were discovered rather than invented. t occurs in nature, in nautilus shells and sunflower seed heads, and in many geometric figures and art forms, yet here it turns up, uninvited, in electronics! As you may expect, the value 1·618 is an approximation of an endless decimal, but budding mathematicians will have already twigged that is a bit less abstract than π or e, in that it is a solution of the algebraic equation $|T(j\omega)|^2 = 2$. It is, therefore, (at most) an irrational number, unlike π and e, which are transcendental numbers and cannot be found as a root of any finite algebraic equation. However, since our equation for t is a quartic in ω^2, I will spare you the trouble of solving it and say that $t = (\sqrt{5} + 1)/2$. You may have noticed another property of t, suggested by the numerical values, which is that $t = 1 + 1/t$ and, in fact, this is the basic 'golden ratio' equation which generates it. Try it on your calculator!

I have to admit that, however interesting t is as pure mathematics, you do not need to take it into account during the filter design process. The correct answers come out without its presence being obvious.

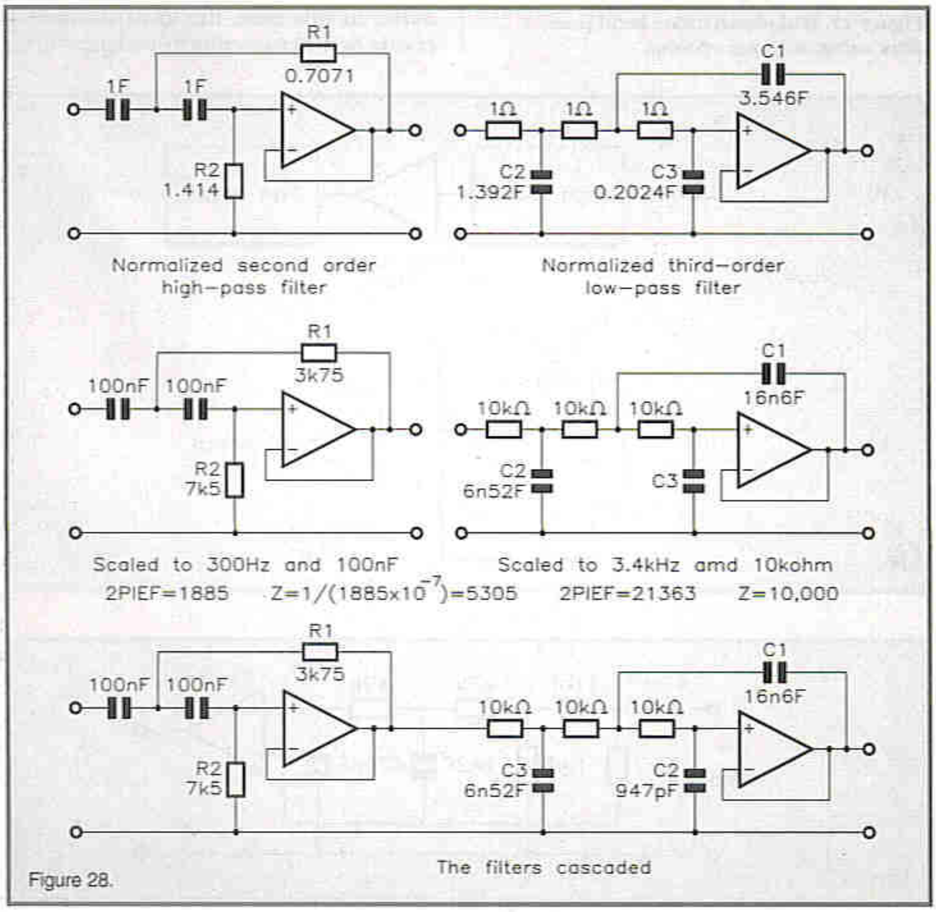


Figure 28. Wide-band band-pass filter using two op amps.

What Does the Graph Tell Us?

There are some special things to note about the band-pass filter response, as shown in Figure 29b. Like the low-pass and high-pass filters, we can draw straight 'semi-infinite approximation' lines which converge with the actual filter response at high attenuations. But for the band-pass filter, these lines lie *below* the actual response, and start at $\omega = 1$, not from the corner frequency. The other major peculiarity is that, whereas the stop-band responses of the low-pass and high-pass filters tend to be straight lines at high attenuations, on a normal graph with logarithmic frequency axis and attenuation in decibels, the flanks of the band-pass response are distinctly curved. If the response was plotted with a special form of logarithmic frequency axis which extends both ways from an unattainable 'log of zero' point at $\omega = 1$, which few computer graph packages will do, the flanks do trend to straight lines. In other words, we plot the *frequency difference* from $\omega = 1$ logarithmically. We may come across this type of graph again in a later Part, if I can find a sensible way of producing it!

Form an Orderly *Q*

In Part 2, we found a distinction between the *Q* of a filter and the *Qs* of the capacitors or (more notably) inductors. For band-pass and band-stop filters, we have to accept yet another sort of *Q*. This is the ratio of the centre frequency to the −3dB bandwidth, and is 1 for the normalized filter. However, for a filter whose centre frequency is 1kHz, and whose −3dB bandwidth is 20Hz, as might be useful for CW reception, the *band-pass Q* is 50. It is quite difficult to achieve such high values with passive filters, since the component *Qs* must be much higher still; perhaps 500 in this case. The necessary component *Q* depends on the type and order of the filter. Bessel filters (see Part 2) are the least demanding but are not very often used. Butterworth filters up to 4th order require minimum component *Qs* of the order of 10, unless the values are tweaked or 'pre-distorted' to compensate for losses. This can be done by designing the filter with the poles shifted towards the $j\omega$ axis (less loss), so that the component losses move them back to the correct positions, but this process requires computer-aided design or reference to extensive tables of normalized component values, found in books on filter design.

If the band-pass *Q* is high enough, we do not have to be too concerned that the response shape is symmetrical on a logarithmic frequency scale, and is, therefore, strictly not symmetrical on a linear scale. This is helpful, because filter specifications are often written with linear symmetry implied, as in the following example:

Band-pass filter, centre frequency 800Hz; −3dB at 700Hz and 900Hz.

Here, the pass-band is 200Hz wide, so the band-pass *Q* is 800/200 = 4. The geometric centre frequency (which, curiously, is what you get from logarithmic symmetry) is $\sqrt{700 \times 900} = 793{\cdot}7$Hz, which is close enough! However, it is as well to remember that you may have to tweak the centre frequency a bit in some cases. You might find even that the specification is not symmetrical at all. For example, the −3dB points might be 750Hz and 900Hz, giving a geometric centre frequency of 821·6Hz. This might well lead to unacceptable attenuation at 800Hz, so it would be better to design on the basis of the specified centre frequency and the closer −3dB point, i.e. 800Hz and 750Hz. The upper −3dB point would then be at $800^2/750 = 853$Hz, and the attenuation at 900Hz would be more than 3dB. If this is unacceptable, more complex design methods have to be used. One of the simpler of these is to use two filters in cascade, with different centre-frequencies. Alternatively, the attenuation at 800Hz can be reduced, while keeping the same −3dB points, by using a filter with a sharper corner; either a higher order Butterworth filter or one of a different family, which we shall meet later.

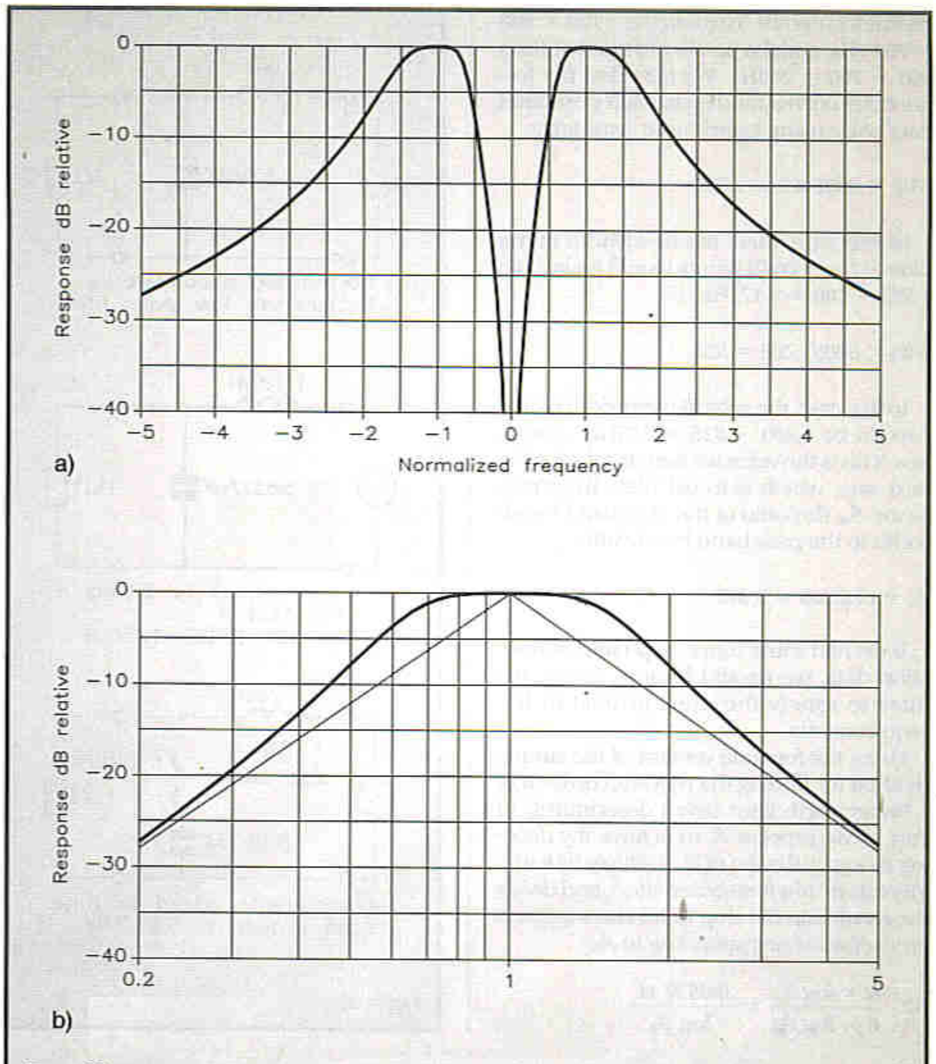


Figure 29.

Figure 29. Frequency response of the normalized Butterworth second-order band-pass filter: (a) response plotted on a linear frequency scale, including negative values; (b) response plotted on a logarithmic frequency scale, showing 'semi-infinite approximation' lines.

Components in Passive Band-pass Filters

It is all very well to transform equations by changing *s* to *s* + 1/*s*, but what does that do to the components? Well, the impedance of an inductor *L* in the low-pass filter is simply *sL*, so replacing *s* by *s* + 1/*s* gives an impedance *sL* + *L*/*s*. This is a series combination of an inductor *L* and a capacitor whose value is 1/*L*, forming a series resonant circuit, resonating at $\omega = 1$. Similarly, we can show that each capacitor *C* in the low-pass filter is transformed into a parallel resonant circuit containing capacitor C and an inductor of value 1/C.

When we do the scaling operation to change the centre frequency of the filter from $\omega = 1$ to the value of ω that we want, say ω_0, the component values of the original low-pass filter stay unchanged, but the tuning components now resonate them at ω_0. The corner frequency of the original low-pass filter defines the bandwidth (*not* the half-*bandwidth*, as perhaps seems logical) of the band-pass filter.

A Practical Example

Let us continue with the design of the band-pass filter mentioned above. The complete specification might read:

Centre frequency: 800Hz.

Pass-band attenuation: −3dB frequencies 700Hz and 900Hz.

Stop-band attenuation: More than 20dB at 400Hz and 1,200Hz.

Source impedance: 50Ω.

Load impedance: 1kΩ.

Since the ratio of load impedance to source impedance is 20, we are justified in using our 'zero source, finite load' design values. The response shape data are given in linear-symmetry form, so we have to convert to logarithmic symmetry. The geometric centre frequency is $\sqrt{700 \times 900} = 793{\cdot}7$Hz, and the pass-band bandwidth is $900 - 700 = 200$Hz. We next find the frequencies corresponding to each stop-band data point using logarithmic symmetry:

$(700 \times 900)/400 = 1{,}575$

In this case, then, the bandwidth of the filter at the −20dB points would have to be $1{,}575 - 400 = 1{,}175$Hz.

$(700 \times 900)/1{,}200 = 525$

In this case, the −20dB bandwidth would have to be $1{,}200 - 525 = 675$Hz – much less. This is the value we have to take for the next step, which is to calculate the *shape factor* A_s, the ratio of the stop-band bandwidth to the pass-band bandwidth:

$A_s = 675/200 = 3{\cdot}375$

If we had some more stop-band attenuation data, we should have to design the filter to satisfy the most critical of the requirements.

Using the formula version of the simple method for finding the required order n of a Butterworth filter (given descriptively in Part 2), we express A_s in octaves (by dividing its log by the log of 2), multiply by 6 (the 'dB/octave' of a first-order filter), and divide the result into the stop-band attenuation α (in decibels) corresponding to A_s:

$$n \geq \frac{\alpha \times \log 2}{6 \times \log A_s} = \frac{0{\cdot}05 \times \alpha}{\log A_s}$$

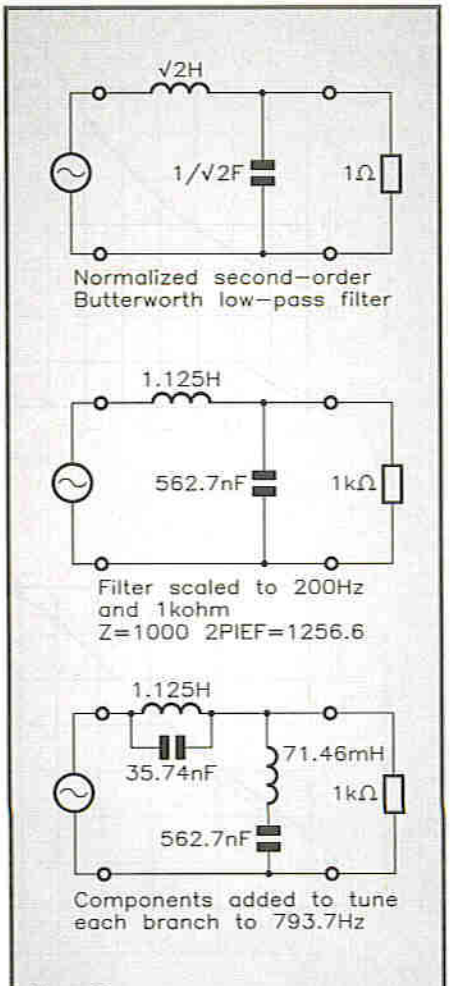


Figure 30.

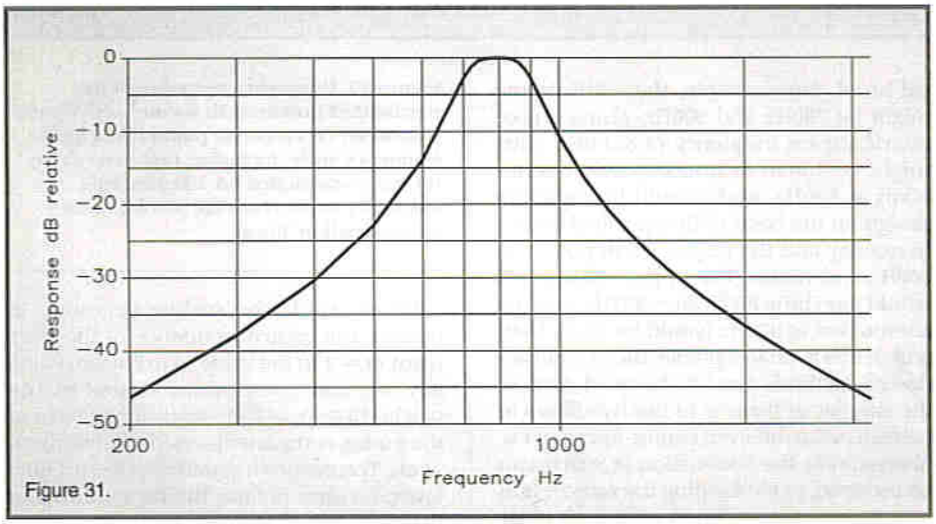


Figure 31.

Figure 30. 800Hz band-pass filter.
Figure 31. Frequency response of the 800Hz band-pass filter.

Here, we get $n \geq 1{\cdot}89$, so, provided we use low-loss components, $n = 2$ should be OK. In fact, the attenuation at 400Hz will be quite a bit more than 20dB, because, as we saw above, the attenuation requirement at 1,200Hz imposes a narrower bandwidth. (We could have guessed this from the log symmetry property, because $1{,}200/800 = 1{\cdot}5$ but $800/400 = 2$, so 400Hz is further away, on a log scale, from 800Hz than 1,200Hz is.)

Figure 30 shows the normalized second-order Butterworth low-pass filter; the filter being scaled to the pass-band bandwidth of 200Hz, and a load resistance of 1kΩ (see Part 1). The band-pass transformation is made by tuning each capacitor and inductor to the centre frequency of 793·7Hz. Since the band-pass Q is $793{\cdot}7/200 = 3{\cdot}97$, and we have a Butterworth filter with modest component Q requirements, there should be no major problems with losses, even for the inductors, although they must be ferrite-core types. Figure 31 shows the computed frequency response of the filter as designed. The 50Ω source resistance and 1kΩ load inevitably produce an insertion loss of 0·42dB, which would be there even if there was no filter. The response is a little broader than required: the attenuation at 700Hz and 900Hz is 2·8dB. This can be corrected by slightly lowering the pass-band frequency to, say, 190Hz, which will also increase the attenuation at 1,200Hz. At present, this only just meets the 20dB requirement, whereas the attenuation at 400Hz is much larger, as we predicted, than the specification requires as a minimum.

Active Narrow-band Band-pass Filters

These require a large number of op amps, and are best realised with special filter chips rather than general-purpose op amps. I hope to deal with these in a later Part of the series.

Band-stop or Band-rejection Filters

We have already dealt with the seldom-needed wide-band variety, but now we have *two* other types to consider. As we saw above, narrow-band band-reject filters are derived by transformation from a high-pass filter, which in turn is derived from a low-pass filter. Notch filters, however, work by having (at least) two paths from input to output, and arrange for the two signals arriving at the output to be equal in voltage and opposite in phase at the notch frequency, so that they cancel. In theory, this produces infinite attenuation, with very steep reduction of attenuation either side of the notch frequency. You pay a stiff price for this, however, because the response shape cannot easily be tailored to suit a specification, and the notch frequency and 'depth' (attenuation) are critically dependent on exact and stable component values. For this reason, notch filters are often made with a fairly accessible tuning control, perhaps more than one. One common use is in distortion-factor meters.

We shall not be considering notch filters further in this Part, so we will press on with the narrow-band type.

Narrow-band Band-stop Filters

If we replace s in the transfer function of a high-pass filter with our old friend $s + 1/s$, we get a band-stop filter. This is equivalent to replacing s in the transfer function of a low-pass filter by $s/(s^2 + 1)$. For our second-order Butterworth filter, this gives the band-stop transfer function T_{BS}:

$$T_{BS} = \frac{s^4 + 2s^2 + 1}{s^4 + \sqrt{2}s^3 + 3s^2 + \sqrt{2}s + 1}$$

You can see that there is no zero at $s = 0$, because of the 1 in the numerator, but there are two, at $s = 0 \pm j\omega$, which means infinite attenuation at $\omega = 1$. The denominator is the same as for the band-stop filter, so the poles are in the same (boring to calculate) places.

A Really Practical Example

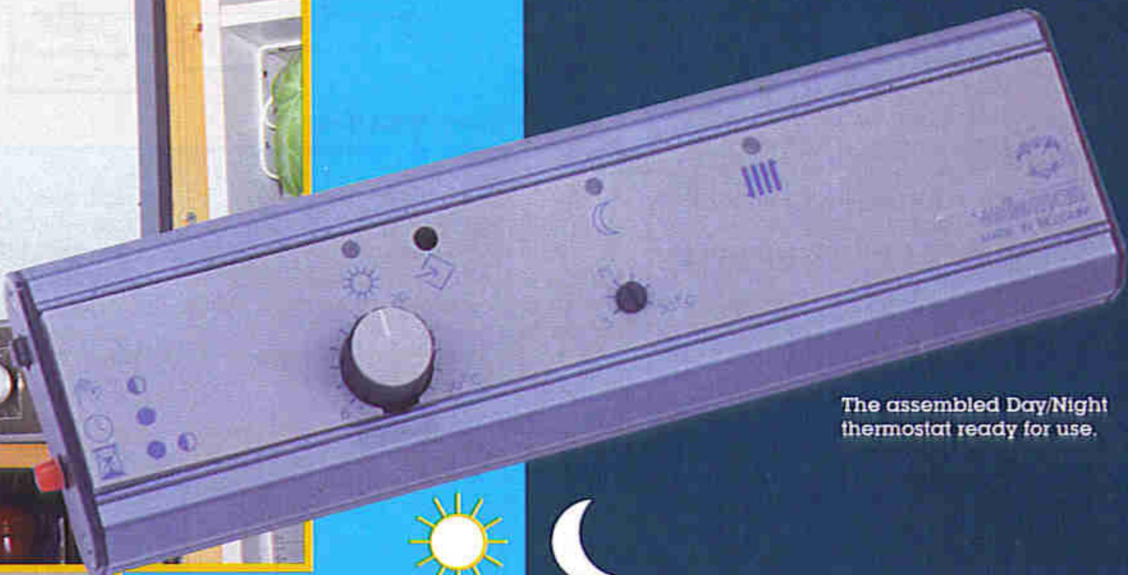
This example is based on the specification of a band-stop filter designed for possible inclusion in the revision of the international standard IEC315-4 for methods of measurement of FM radio receivers. This filter is used for removing the 1kHz modulation signal from the audio output of the receiver, so that noise and/or distortion can be measured in the presence of a modulated signal. There is, for example, a very

Continued on page 79.

KIT AVAILABLE (VF36P) PRICE £49.99

4 PROJECT RATING

This ingenious and compact thermostat module will make a useful addition to your domestic heating requirements, for example, you could use it to control your central heating system or immersion heater. The unit is able to provide separate temperature references for daytime and night-time, with switch-over times between day and night repeated automatically every 24 hours once the unit has been programmed. The 'program' can have up to 19 possible steps, the output changing state on each successive step, i.e. from on to off then off to on.



The assembled Day/Night thermostat ready for use.

Text by Nigel Skeels, Alan Williamson and Mike Holmes

DAY NIGHT THERMOSTAT

19-STEP MEMORY with adjustable day and night temperature ranges

FEATURES

* Relay output
* Low-temperature alarm output
* Mains frequency clock
* 'Sleep' mode
* Selectable hysteresis
* Only simple AC supply required
* Compact wall-mounted module
* Superbly finished alloy case and front panel

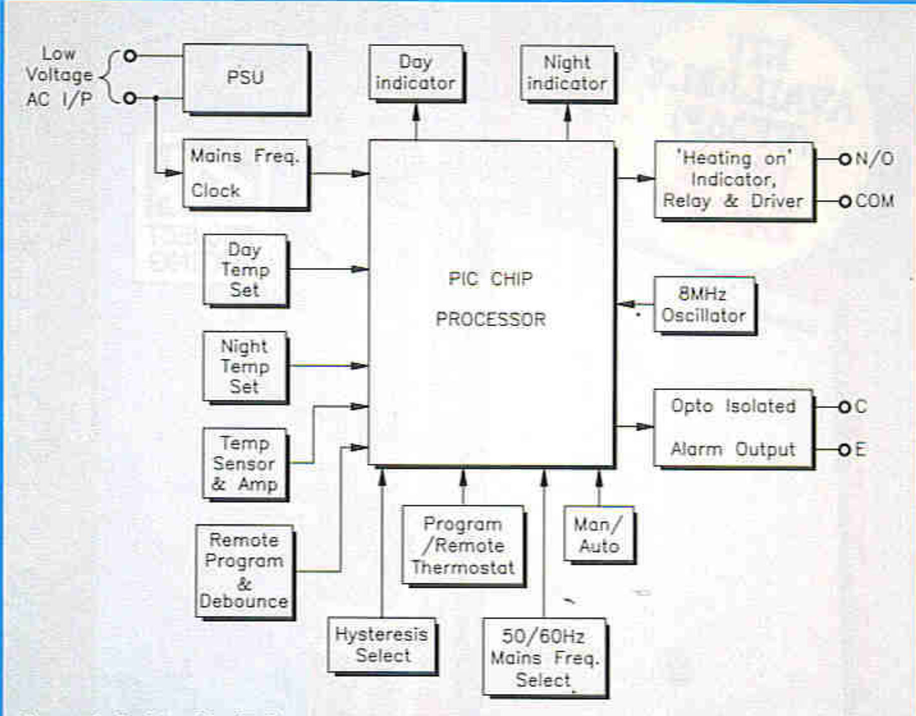


Figure 1. System block diagram.

A block diagram showing the day/night thermostat is shown in Figure 1. The output is in the form of a single pole change-over relay, offering normally open (NO) and normally closed (NC) configurations for connection. The contacts' side is isolated from the thermostat electronics and connections are made using PCB mounted screw terminal blocks. The contacts are rated at 250V AC at 10A, but PCB connections should not exceed 50V, so a second (slave) relay, suitably rated, will be needed, and will be controlled by the thermostat's relay.

Control of both daytime and night-time temperatures may be set using the easy-to-use rotary controls. The 'daytime' control has a conventionally sized knob for easy adjustment during the daytime by the user, while the 'night-time' control is a 'preset', and adjustable only with the aid of a screwdriver. This avoids confusion between the two and prevents the 'night-time' setting being accidentally changed.

Manual switch-over from day to night temperature is also possible by means of a push-button on the end of the unit, which is also used to select 'sleep' mode. This is a one-hour sleep function, which can be used to maintain the *day* temperature setting for one hour in rooms that are only used briefly, such as bathrooms, utility rooms, etc.

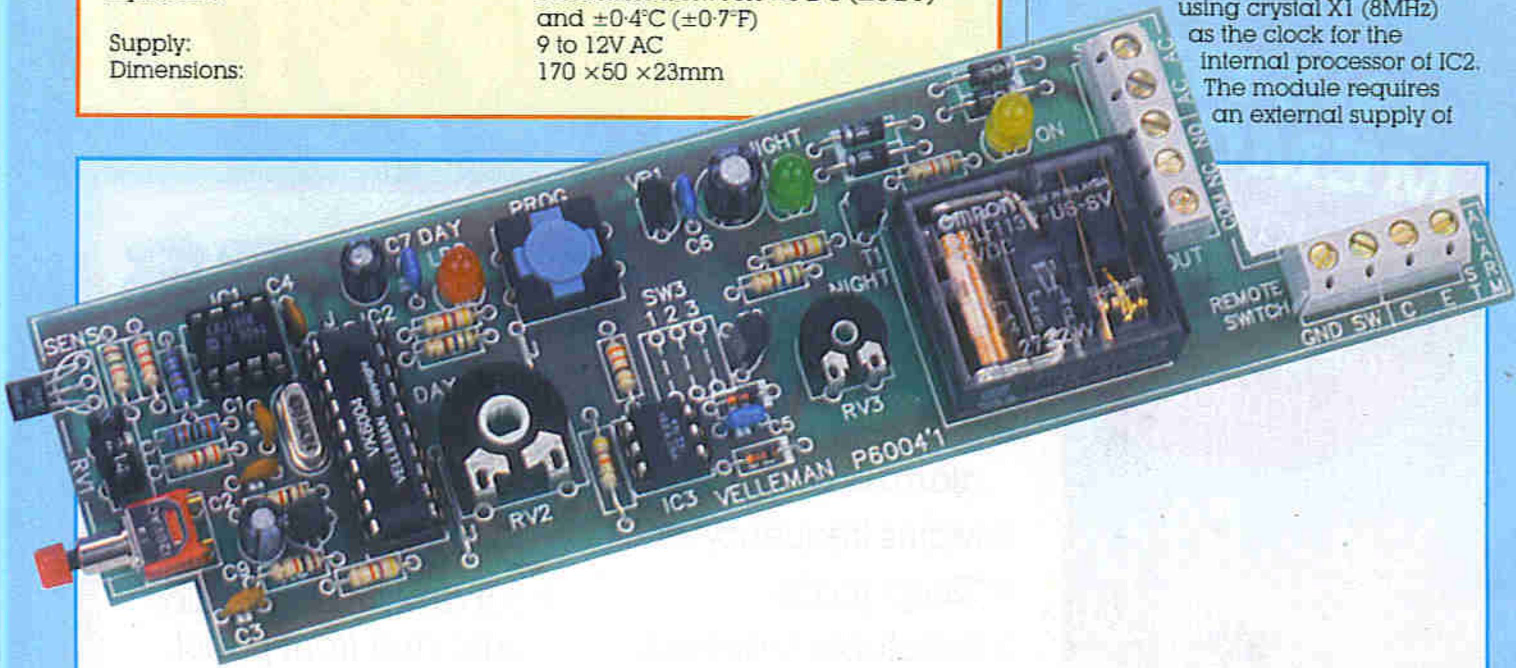
The thermostat also has a low-temperature alarm output that activates if the room temperature falls below 5°C (41°F). The output is simply an open collector transistor, which is actually the output side of an optoisolator IC, so that the alarm circuit, in whatever form it might take, is again electrically isolated from the thermostat electronics.

Specification

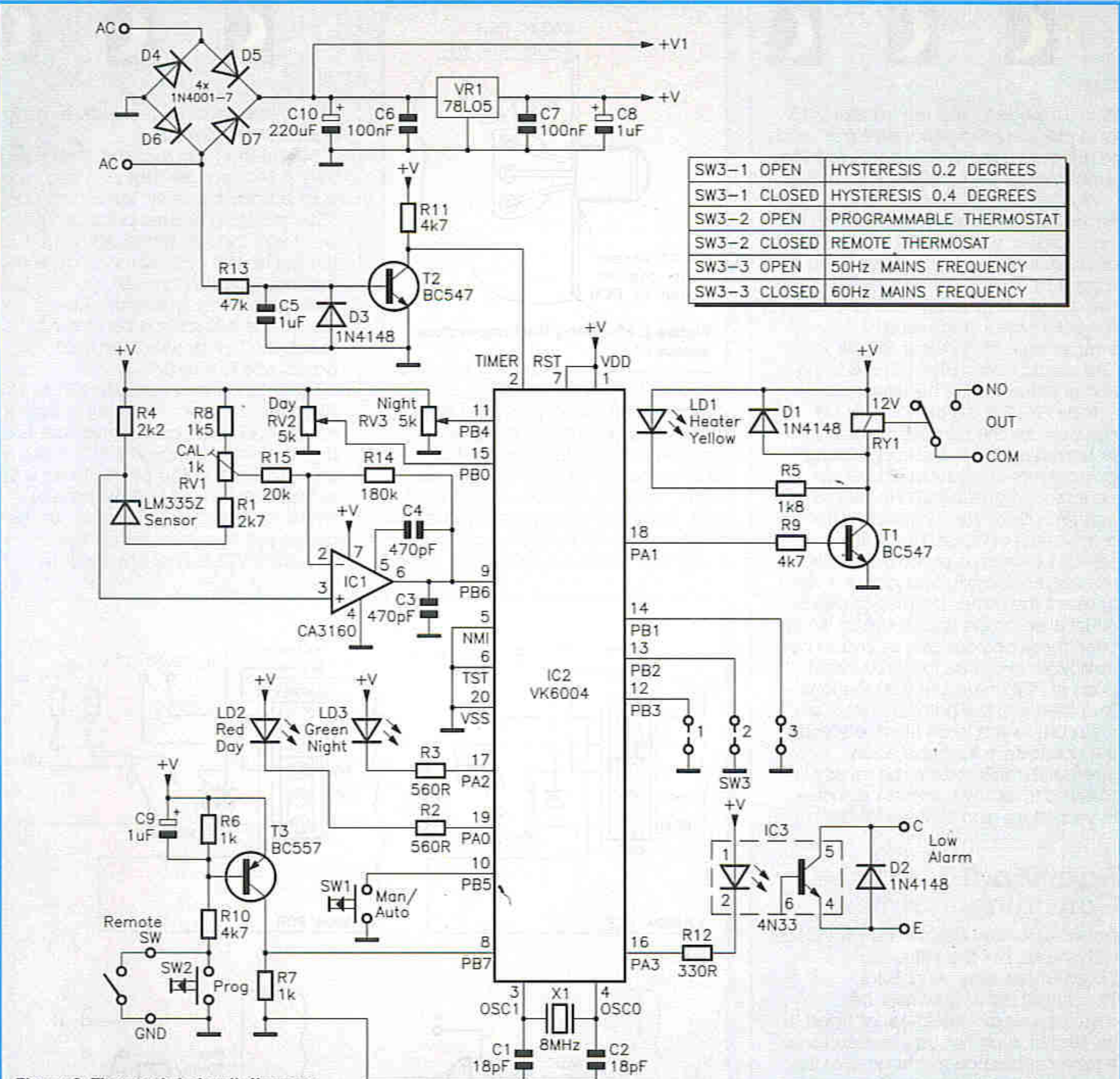
Memory capcity:	19 steps
Minimum time between two steps:	4 seconds
Temperature adjustment range:	5°C (41°F) to 30°C (86°F)
Relay contact rating:	10A/50V
Low-temperature alarm threshold:	5°C (41°F)
Low-temperature alarm output:	Open collector 70V/50mA max.
Timer accuracy:	Mains frequency dependent at 50 or 60Hz:
Manual options:	Day, night and 'sleep' modes
Hysteresis:	Selectable between ±0·2°C (±0·2°F) and ±0·4°C (±0·7°F)
Supply:	9 to 12V AC
Dimensions:	170 ×50 ×23mm

Circuit Description

The circuit is based around a single-chip microcontroller, IC2 in the circuit diagram (Figure 2). This contains the main processor, the ROM that contains the program and a number of external I/O lines that can be configured in various ways. These microcontrollers are specifically developed for real-world, interactive uses; for instance, there are Analogue to Digital Converters (ADCs) provided on-chip also. An oscillator is included using crystal X1 (8MHz) as the clock for the internal processor of IC2. The module requires an external supply of



The assembled PCB.



SW3–1 OPEN	HYSTERESIS 0.2 DEGREES
SW3–1 CLOSED	HYSTERESIS 0.4 DEGREES
SW3–2 OPEN	PROGRAMMABLE THERMOSTAT
SW3–2 CLOSED	REMOTE THERMOSAT
SW3–3 OPEN	50Hz MAINS FREQUENCY
SW3–3 CLOSED	60Hz MAINS FREQUENCY

Figure 2. Thermostat circuit diagram.

9 to 12V AC to operate (i.e. an external mains transformer). In the module the remaining power supply components consist of D4 to D7 forming a bridge rectifier, followed by reservoir C10 and HF suppression capacitor C6. From here a stabilised voltage of 5V DC is provided by VR1 and decoupled by C7 & C8. R13 is used to tap off a sine waveform from one side of the rectifier, and this signal is converted into a logic level compatible square wave with the help of C5, D3, T2 & R11. This is the mains frequency timing signal and is used as the clock for IC2, at the 'TIMER' input.

The ambient room temperature is detected by a temperature sensor identified as 'SENSOR' in Figure 2. This is a 3-pin LM335Z IC in a TO92 package; the 'Adjust' input pin is not used so the device behaves as a basic temperature sensor with a linear output of 10mV/°K. The potential across the sensor is applied to the non-inverting input of IC1, used as a differential amplifier, with a divider chain (R1, R8 & RV1) biasing the inverting input of IC1 to cancel out the fixed DC offset. This leaves only the change in voltage, caused by temperature variations, to be amplified to a suitable level, the gain being determined by R14 divided by R15. The output is passed to an ADC in the microcontroller via PB6.

RV2 & RV3 are the front panel temperature adjustment potentiometers for 'daytime' and 'night-time'. Again these are connected to ADCs in IC2 via PB0 & PB4. In operation IC2 compares the output voltage of IC1 (room temperature) with the wiper voltage of the relevant potentiometer as indicated by either LD2 ('daytime') or LD3 ('night-time'). R2 & R3 are current-limiting resistors for the LEDs. If the room temperature level is less than the reference level, it will cause PA1 (pin 18) of IC2 to become active high, turning on the transistor T1 which will in turn operate the relay RY1 and illuminate the 'Heating On' LED, LD1. Diode D1 is present to protect T1 against induced EMF generated from the collapse of the magnetic field when the relay coil is switched off.

SW1 selects manual or automatic operation and is externally accessible as the red button on the left-hand end of the finished unit. SW2 is the programming button, and in parallel with it are the terminals 'SW' and 'GND' for remote control operation if required. Both of these switches are

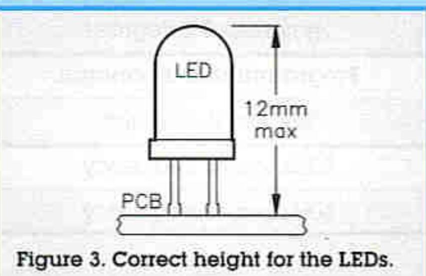


Figure 3. Correct height for the LEDs.

normally open, and the transistor T3 and associated components are used to debounce the switch and produce a positive going pulse for IC2 via PB7.

PA3 (pin 16) of IC2 is the 'low temperature alarm output', which is optoisolated with the aid of IC3. The open collector output can be used to trigger or operate an external alarm, and for lighting yellow LED LD1 on the front panel, if the room temperature falls below 5°C (41°F). This would obviously indicate some sort of failure in the heating system.

Ports PB1, 2 & 3 (pins 12, 13 & 14) are used by the microcontroller for determining some basic operating parameters on start-up. Each can be linked to ground (0V) to set the configurations. Pin 12 selects between a hysteresis of 0·2 or 0·4°C; pin 13 selects between a programmable or remote thermostat, and pin 14 is used to select the mains frequency (50 or 60Hz) used as the timing signal. Most often these choices can be made by installing wire links in the relevant pairs of PCB holes, but the positions and layout of the holes allow for a 6-pin DIL switch to be fitted, allowing the configurations to be easily altered. For this reason the facility is referred to as 'SW3'. Table 1 denotes the functions and settings for 'SW3'.

Additional Construction Notes

Full construction details are provided with the kit, but the following observations may be helpful.
The actual order in which the components are installed, as listed in the leaflet, may not be the most ideal. A better sequence might be to fit the smallest components first followed by successively larger items, and leaving the ICs last. ICs are susceptible to electrostatic and heat damage, even while other components are being soldered.

Begin by mounting the wire links in the positions marked 'J', but not the group 'SW3' yet. Fit all diodes D1 to D7, ensuring correct polarity. Then fit all resistors, double-checking their values and correct placement.

Mount all variable resistors, followed by the capacitors. Note that the electrolytics are polarised; the

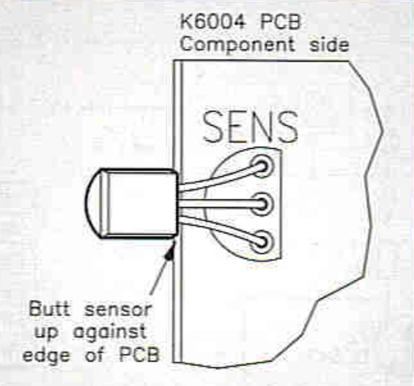


Figure 4. Mounting the temperature sensor IC.

negative lead, identified by a stripe and (–) symbols on the body, is inserted in the hole *opposite* that marked as (+) on the PCB legend.

The clock crystal can be installed next, although some care is needed to avoid overheating during soldering. It may be prudent to pause for several seconds between making each soldered joint.

Mount the push-to-make switches SW1 & SW2; ensure that they are pushed down evenly. Mount the three LEDs ensuring correct polarity. The shorter of the two leads, adjacent to the flat on the base of the body, is the cathode. Colours are LD1, yellow; LD2, red; LD3, green. Maximum height above the PCB should be 12mm to reach the 'windows' in the front panel, see Figure 3.

Mount the three transistors T1 to T3. Align the shape of the body to that of the legend and carefully spread the legs to insert through the PCB holes until the base of the plastic body is 4 or 5mm above the PCB. Be careful when soldering as transistors can be damaged by overheating. The regulator VR1 is similarly mounted,

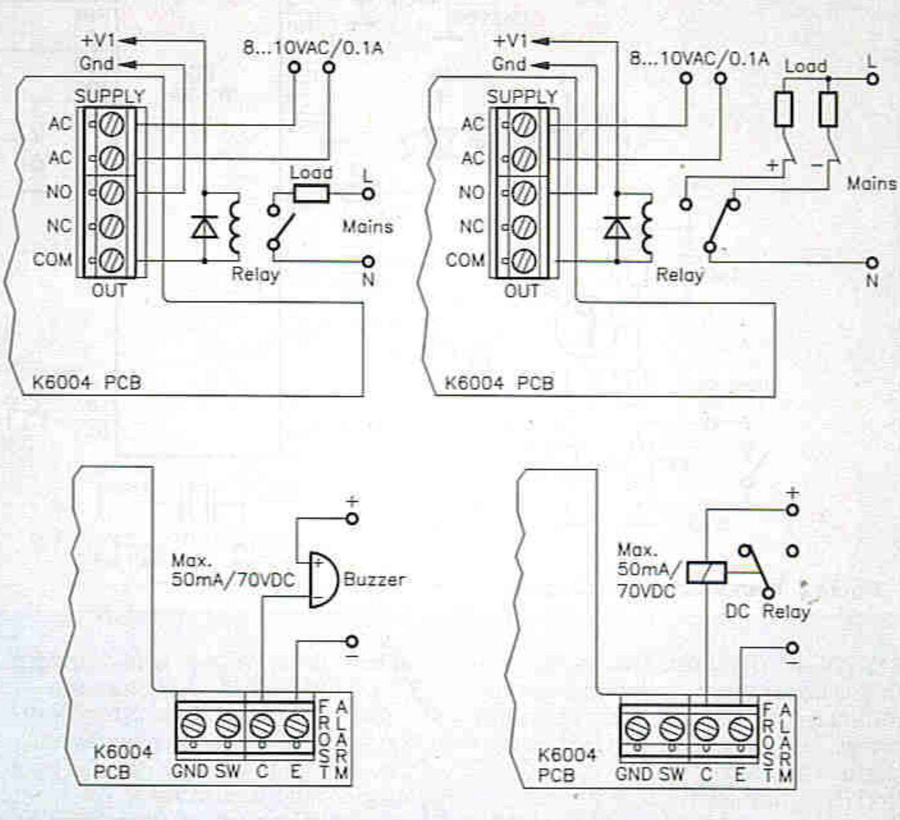


Figure 5: a, connections for AC supply input and output for a mains powered circulation pump, fan or valve; b, connection for a motor-controlled mixing valve; c, connecting an audible buzzer to the alarm output; d, connecting an alarm triggering relay to the alarm output.

SW3-1	OPEN	Hysteresis 0·2 degrees
	CLOSED	Hysteresis 0·4 degrees
SW3-2	OPEN	Programmable thermostat
	CLOSED	Remote thermostat
SW3-3	OPEN	50Hz mains frequency
	CLOSED	60Hz mains frequency

Table 1. Link function table (SW3).

and is in the same size and style body. So also is the sensor IC, but this is mounted at right angles to the PCB by bending the leads and fitting as shown in Figure 4.

The relay, as one of the largest components, is fitted last, as are the PCB mounted terminal blocks. Three of these are 2-way and one is 3-way, used to make up complete 4-way and 5-way terminal blocks for electrical connections at the L-shaped end of the PCB.

Possible Configurations

The basic operating configuration is set by either fitting or leaving out the wire links marked 'SW3 1, 2 & 3', or setting the 3-pole DIP switch if one is fitted.

SW3-1 determines the 'hysteresis'. Two ranges of upper and lower temperature thresholds are possible: if NO link is fitted the range is ±0·2°C (±0·4°F); or if it is fitted then the range is ±0·4°C (±0·7°F). The temperature must fall below the lower limit to energise the output relay, and increase above the upper limit to turn it off.

SW3-2 is for selecting remote control mode. However, the extra hardware is not available, so please do not fit this link.

SW3-3 selects the AC mains frequency standard depending on the location. For a frequency of 50Hz, as in the UK, do NOT fit this link.

Important Safety Note

Because of the wide range of possible final construction methods, ultimately determined by the constructor, full details of wiring connections are not shown in this article. However, for safety reasons it is essential that a suitably rated mains fuse and switch is used for the mains supply. Whilst by no means exhaustive, the following recommendations are made:

The PCB connections are not suitable for UK mains voltage, levels should not exceed 50V. Class I construction techniques must be employed; both the case of the unit and the metalwork of the mains transformer must be earthed.

Other precautions and steps necessary to comply with published safety standards must be employed to ensure safety of the user and servicing personnel.

Every possible precaution must be taken to avoid the risk of electric shock during maintenance and use of the final unit. Safe construction of the unit is entirely dependent on the skill of the constructor.

For *your* safety, it is important that insulation is applied to all the exposed mains connections.

On no account must mains power be connected to the circuit while the unit is out of its case, as mains voltage is potentially lethal. The mains must, therefore, always be treated with the greatest respect.

If in any doubt as to the correct way to build or use this unit, seek advice from a suitably qualified engineer.

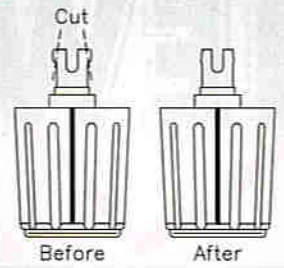


Figure 6. Trimming the locking tabs from the large control knob.

Testing and Adjustment

A supply of 9 to 12V AC at 100mA maximum is required, connected to the 'AC' screw terminals on the PCB. The DC offset null preset RV1 needs to be set up to calibrate the unit. A calibration method more accurate than that described in the kit instructions is as follows: Turn RV1 fully anticlockwise, then press the manual operating (red) button once or twice, until the day indicator flashes or is continuously lit. Place a thermometer near to the sensor.

Adjust the day control until the temperature reading, as it would be indicated on the front panel scale, corresponds to the thermometer reading. Adjust the trimmer RV1 until the relay is just energised. This means that the thermometer reading corresponds to the thermostat scale. The night-time setting will follow suit.

Mechanical Assembly

The unit is housed in an extruded alloy case with a blue/grey finish, containing slots to hold the edges of the PCB. The stick-on front panel must be attached to the housing ensuring that the holes correspond. Alloy end plates cover the ends and retain the PCB; the one with large holes is at the left-hand end allowing the 'MAN/AUTO' button and temperature sensor to protrude through. All inputs and outputs must be connected to the screw terminals before the PCB is slid into the case. Figures 5a to 5d show the various connections. Finally the large and small adjusting knobs can be pushed into place and the end plate fitted. The large knob for the day control has locking tabs on its shaft which are not required; these should be carefully cut off with a sharp knife, as in Figure 6.

The Thermostat in Use

The required day and night temperatures are set using the variable resistors. At first glance this device may seem difficult to program: without a display, how could you possibly set the time? But really it is quite simple, all you have to do to program the day to night temperature change is to press one button at the actual time. Every day from then on it will switch over at that precise time. Of course, you are not limited to this convention as you can bypass it manually. The program button has to be operated with a long thin object, for example, a matchstick, inserted through the front panel hole. This is a precaution to prevent accidental alteration. Each time the thermostat is switched over using this program key, the switch-over will be repeated at the same time each day.

Erasing all Program Steps

Press and hold the program key until the day and night indicators are both lit. On releasing the program key the night indicator should flash. It is recommended that this is done on installation when the unit is powered up for the first time.

NOTE: All program steps will be lost if the power is interrupted.

Manual Setting of the Day/Night and Sleep Functions

Depending on the present condition, press the push-button on the side once or more times to switch from day to night or select the sleep position. When the indicator starts to flash the thermostat will stay in this position. The program will no longer be followed. When the LED is continuously lit, the program will again be followed, starting with the next program step. If the day LED is continuously lit and the night indicator starts to flash the thermostat is in the sleep position. Day temperature will be maintained for one hour and then the thermostat will switch to night. No program steps can be entered in the sleep position. E

Parts List printed on page 80.

Dear Editor

AIR YOUR VIEWS

Endangered Species?

Dear Sir,
I have two points I would like to share with fellow readers:
I really enjoy reading Electronics – The Maplin Magazine but I would find it more enjoyable if there was a page purely for readers to print their own circuit ideas and diagrams, even if they are quite basic projects. I think many people would agree that this is a good idea and would write in with interesting projects.
My other point is that you are having less projects in the magazine and I am sure that readers would enjoy the magazine a lot more if there were more projects for them to build.
Oliver Lindley, Buckfastleigh, Devon.

Thank you for your comments about readers circuits, we already publish such circuits in Electronics, *under the title Circuit Maker (see page 30), but this is on an 'as and when' basis and it has been quite some time since the last Circuit Maker was published. If I receive readers' simple circuits on a regular basis, I will certainly consider making them a regular feature.*
The R&D team are currently looking at ways of developing more projects every month, but this is a considerable task since we don't just slap any old ideas together and publish them. Projects are all fully developed, tried and tested so we can guarantee that they are easy to build, and they'll work safely and consistently well if built as described. We try to make projects as flexible as possible, so that they can be used as building blocks to form larger systems. Also we ensure that all of the components are going to be readily available for the next few years, as well. We think this is a responsible attitude to our readers and customers – quality is far more important than sheer quantity as I'm sure you'll agree. You won't get this kind of commitment from any other magazine.

S·T·A·R L·E·T·T·E·R

In this issue, Mr J. Connell, of Plean in Stirling, wins the star letter award of a Maplin £5 Gift Token for his letter about. . . well read it and find out!

£5 Gift Token

★★★★★★★★★★★★★★★★★★★

Just Joking!

Dear Sir,
I have a project that I have been thinking about building for some time, but never seem to have the time to do anything about. It would consist of a small infra-red remote control transmitter which would output random valid codes. The idea being to sit in my local pub whilst everyone was watching football or some other rubbish on the TV, switch the transmitter on and wait. The sound on the TV would go up/down, channels would change, etc. Ideally it would be small enough to hide in an empty packet of cigarettes (it would also save me from being thrown in the canal). Thanks for a great mag, a very fast and efficient delivery service and innovations such as CashTel. Along with the Bank of Scotland's Home and Office Banking Service, I can sit at my Amiga, play games, pay my gas bill and order all my electronics stuff at the touch of a button (and the wife doesn't even know!).

With friends like you, who needs enemies? If any of your drinking mates read Electronics *watch out because you might still end up in the canal, or worse . . . You'd better hide this issue from you wife as well otherwise she'll realise what you're up to when she thinks your zapping up some innocent alien creatures on your computer! Your practical jokes remind me of when I used to work for a certain TV and Video rental company. I frequently played jokes on the rest of the engineers – they didn't always appreciate it and usually managed to get their own back some way or another, but that's another story . . .*

★★★★★★★★★★★★★★★★★★★

Bells and Boilers

Dear Sir,
In the November 94 issue you published an article on a Telephone Bell Repeater. I have required one for some time but have not had the time to sit down and make one, problem now solved, well partly. I also need a delay system to trigger the answer phone. In a large house such as ours we cannot get to the phone before the answer phone picks up the call, be it incoming or external (we have a PABX). What is the possibility of you producing a delay switch for this purpose so that we could leave the machine switched on but delay the pick-up for about 40 seconds. I could do it on the system if I had a spare extension, purely for the answer phone, but none are available.
In the December 94 issue I note that you are featuring a Day/Night Thermostat [see page 73 – Ed.]. This is another device I have been planning to make myself, and already have in crude form, as we require to maintain heating at all times, but lower at night. I look forward to this article and kit. Will you also extend this and produce a boiler optimiser which delays boiler firing – according to the various firms now producing such devices they show savings of at least 20% on heating bills.
R. D. Simmons, Uffculme, Devon.

I am pleased to hear that you will find the Telephone Bell Repeater and Day/Night Thermostat projects useful. A delay unit for an answer phone is a good idea and technically quite simple, but since it would require direct connection between the line and the answer phone the unit would require BABT type-approval for it to be used legally. This unfortunately rules out a Maplin kit being produced. The answer phone itself will already have an answer delay circuit (so it doesn't answer immediately) and the timing components could be modified to increase the delay, but strictly speaking, such a modification would technically invalidate the BABT approval on the unit. A typical arrangement would be a bridge rectifier connected to an optocoupler, so as to trigger a monostable, if the ringing signal is still present after the monostable has timed out, the answer phone will answer the call. Fortunately, boiler economisers are not subject to BABT approval requirements! So no problems there – would any other readers be interested in a project to reduce heating bills? Silly question really, I'll pass the idea on to the boys in the lab!

Bright Sparks

Dear Sir,
It was interesting to see the design for the Live Wire Game (June 94 Issue) just as I was about to go off to my first fête with a game of my own design, also based around a 555 but with a different life-counting arrangement. Surprisingly, in an age used to sophisticated computer games, such a simple device still generates a lot of interest and fun.
Although 99% of people play fair, there is always a cheat that is worth knowing about before you start giving away prizes. If the loop is touched onto the wire and then rapidly moved along while still in contact, you can cheat your way along sections of the wire. In fact, keep the loop firmly in contact with the wire and you can complete the course for the loss of only one life.
A solution, which involves no change to the electronics, is to insulate a number of points along the wire, using little rings of heat-shrink sleeving, plastic beads, or simply dabs of paint or glue. Pulling the loop along will now generate a series of makes and break rather than a steady contact, and the lost lives will clock up. For more entertainment value, build a big scale circuit on a baseboard and operate it with no cover [the project is extra low voltage powered so this is quite safe – Ed.]. Youngsters will crowd round to see how it works, and who knows, you may even foster an interest in electronics. Add excitement by using the output to drive sirens, big clicking relays or an electro-mechanical counter. As the game will have to work for four to five hours at a stretch, consider using Yuasa sealed lead-acid batteries as the power source – mine uses two 6V 4Ah types.
M. Ashby, Southgate, London.

Thank you for your comments and suggestions. Along with many other projects, we exhibited the Live Wire Game on the Maplin stand at the Earl's Court Live '94 exhibition in September – it proved to attract a great deal of interest, often there would be a queue of people waiting to have a go! In practice, we found the Live Wire Game very cheat proof, and believe me some pretty diverse cheats were tried – and all failed! (Someone even tried disconnecting the power whilst we weren't looking!) Whilst in theory, the method of cheating you mention is quite valid, in practice the surface imperfections in the wire, plus the deliberately introduced bends, ensure that there is sufficient contact bounce to prevent this cheat from working. Add the insulating sections by all means, but it really isn't a problem. For those readers who didn't build a Live Wire Game during the summer, the dark evenings will provide an excellent opportunity to build one ready for next year's fête, nothing like forward planning eh? I am sure that it would also provide much family fun during the festive season and come as a welcome relief from the normal repeats on TV.

Diesel Dilemma

Dear Sir,
I was pleased to see the recent Lamp Failure Monitor project. It made a change from the run-of-the-mill automotive projects, not that they are not all good!
Suggestion for a future project, a non-contact method of determining engine speed by means of a variable frequency strobe light complete with a meter calibrated in RPM and flash frequency. The idea being that you increase the strobe flash frequency until a dot on a rotating part appears stationary. Ideal for determining the speed of diesel engines or any rotating object.
Publishing an index for *Electronics* is a great idea. I assume that the editorial department has it stored on computer. How about selling copies of the data on disc? Most applications can import files so the choice of output format would not appear too difficult.
It seems superfluous to say what a consistently high standard *Electronics – The Maplin Magazine* maintains.
R. Savage, Hayes, Kent.

Thanks for the positive feedback about the magazine in general, and specifically car projects. All such suggestions are most welcome. We will investigate the possibility of making the magazine index available on disk, would other readers find this useful? We might even consider posting a copy of the index, in several different file formats, on an Internet ftp server or a BBS or even both!

FILTERS – *Continued from page 72.*

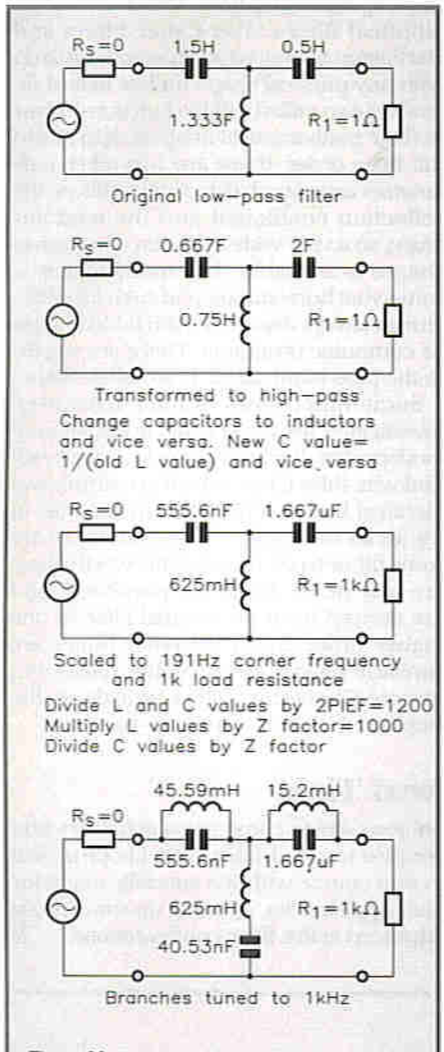


Figure 32.

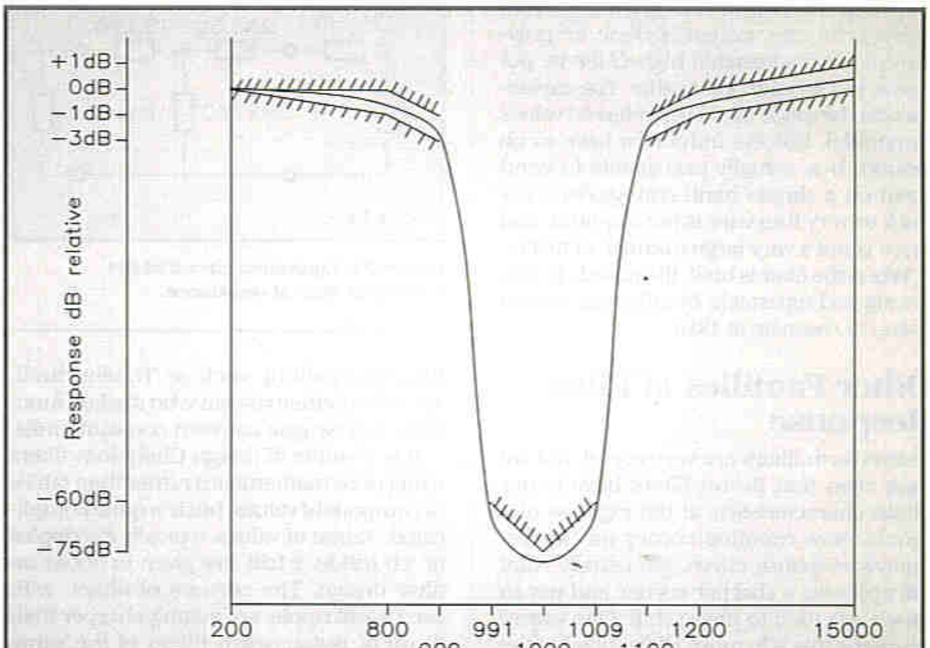


Figure 33.

complex effect in FM receivers which causes the noise output in the presence of a weak, modulated input signal to be very much greater than with no signal input. The filter must not attenuate frequencies other than 1kHz by very much, and must accommodate the tolerances on modulation frequency of typical FM signal generators. In spite of the steep sides of typical passive notch filters, their *band-stop Q* is low, so that there is a very large bandwidth over which the attenuation is 3dB or more. This leads to unacceptable attenuation of the signals to be measured. Also, the uncertain notch attenuation and centre frequency of a notch filter can affect the accuracy of measurements. For these reasons, a narrow-band band-stop filter is required; this is best realised as a passive filter because, like band-pass filters, active band-stop filters require several op amps.

A slightly modified version of the specification is:

Centre frequency: 1kHz.

Attenuation −1dB maximum at 800Hz and 1,200Hz.

Attenuation −3dB at 909Hz and 1,110Hz.

Attenuation −60dB minimum at 991Hz and 1,009Hz.

Attenuation −75dB minimum at 1kHz (this affects the Q requirements of the components).

First of all, we note that there are two pass-band attenuation requirements, and two in the stop-band. Of the latter, the limit at 1kHz is special because it is determined only by the resistive losses in the components, not by the filter shape.

It is most straightforward to base the design on the −3dB bandwidth and the −60dB bandwidth, and check the design afterwards to see if it satisfies the other requirements. We need to check for logarithmic symmetry:

$\sqrt{909 \times 1{,}110} = 999{\cdot}95$

$\sqrt{991 \times 1{,}009} = 999{\cdot}96$

These are adequately close to each other and to 1kHz (which, you may guess, is no accident).

The shape factor A_s = pass-band width/stop-band width, which is:

$191/18 = 10{\cdot}6$

So, we need a basic low-pass filter, whose attenuation α is at least 60dB at 10·6 times the corner frequency. Using the formula for the order of filter required:

$$n \geq \frac{\alpha \times \log 2}{6 \times \log A_s} = \frac{0{\cdot}05 \times \alpha}{\log A_s} = 2{\cdot}94$$

This indicates that, with accurate component values and low losses, a third-order Butterworth filter will do. We need low losses anyway, to meet the attenuation requirement at 1kHz. However, we have to check whether a third-order filter will meet the −1dB attenuation limit at 800Hz and 1,200Hz. The attenuation α in decibels of a third-order Butterworth filter is given by:

$\alpha = 10 \times \log(1 + \Omega^6)$

Ω is the normalized frequency, which is what we have. For practical reasons, it is also called the shape factor. The shape factor for the 1dB bandwidth is 191/400 = 0·4775, so that attenuation of the third-order filter is:

$\alpha = 10 \times \log(1 + 0{\cdot}4775^6) = 0{\cdot}05\text{dB}$

which is well within the specification.

We are not given any specification for load impedance, but the filter will be connected to the loudspeaker output of a radio receiver, which presents a very low source impedance. We, therefore, assume for the moment a load impedance of 1kΩ, which we can alter by scaling if the filter component values prove impracticable. The design steps are shown in Figure 32, while the specification of the filter is shown graphically in Figure 33. It turns out that we do not need to alter the load impedance, because all the component values are practicable.

It remains to check the component Q requirement in order to meet the specified attenuation at 1kHz. To do this, we replace all the tuned circuits by their resonant impedances, which are pure resistances of value $Q/\omega C$ for the parallel circuits and $\omega L/Q$ for the series circuit (Figure 34). Since the overall attenuation is high (75dB minimum), we can assume that:

$3{,}927/Q \ll 95{\cdot}49Q$

and

$95{\cdot}49Q \gg 1{,}000$

These assumptions change the problem of finding Q from solving a cubic equation to calculating a cube root, which is much simpler. The circuit breaks into two L-pads, whose attenuations are:

$286{\cdot}5Q/(3{,}927/Q) = 286{\cdot}5Q^2/3{,}927$

and

$95{\cdot}49Q/1{,}000$

So the overall attenuation is the product of these, which is $0{\cdot}00697Q^3$. We want this to be at least 75dB, which is 5,623, so:

$Q^3 = 5{,}623/0{\cdot}00697 = 807{,}136$

giving

$Q = 93{\cdot}1$

Figure 32. Practical band-stop filter.
Figure 33. Frequency response limits of the 1kHz band-elimination filter.

This is the minimum value of Q, and requires the use of low-loss capacitors (polycarbonate, polypropylene or polystyrene) and adjustable high-Q ferrite pot cores, but is quite practicable. The capacitors can be made up from preferred values in parallel, but the inductors have to be wound. It is actually practicable to wind them on a simple hand coil-winder; very thick or very thin wire is not required, and there is not a very large number of turns.

When the filter is built, the tuned circuits are aligned separately, by adjusting the pot cores, to resonate at 1kHz.

Other Families of Filter Response

Butterworth filters are very useful, but we have seen that Bessel filters have better phase characteristics, at the expense of a much more rounded corner on the frequency response curve. We usually want the opposite: a sharper corner and not so much attention to phase shift. One way of achieving this is to move all the poles of the filter closer to the $j\omega$ axis, by the same amount. This corresponds to a higher filter Q: the reactances increase while the load (and source) resistances stay the same. The poles then lie on an ellipse instead of a circle, and the frequency response in the pass-band wriggles (or ripples) between constant limits. If these limits are small enough (such as ±0·2dB), we may well accept them. Such filters are called Chebyshev filters (or other versions of the Russian spelling, such as Tchebycheff), after the mathematician who studied functions that wriggle between constant limits.

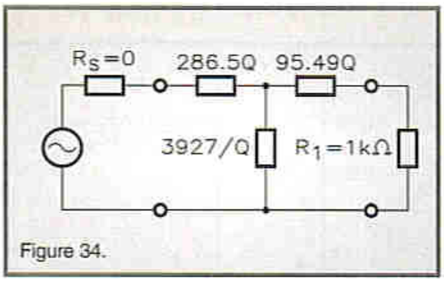


Figure 34. Equivalent circuit of the band-stop filter at resonance.

It is possible to design Chebyshev filters using pure mathematics rather than tables of component values, but it is quite complicated. Tables of values, typically for ripples of ±0·1dB to ±1dB, are given in books on filter design. The corners of filters, with even 0·1dB ripple, are notably sharper than those of Butterworth filters of the same order, but the phase shifts are larger and less uniform. The demands on component Q are also considerably increased, and the response shape is much more sensitive to changes in component values. For this reason, the home constructor is probably confined to using only active Chebyshev filters of low order and low values of ripple.

Another family of filters has zeroes in the stop-band, which are very useful if there are particular unwanted frequencies which are present at high levels, and thus need special attention. These are called elliptical filters (also Cauer filters and Darlington filters), which has nothing to do with any physical shape (unlike helical filters!), but so-called 'elliptic functions' occur in their mathematical analysis. Apart from the filter order, there are two other parameters associated with elliptical filters; the reflection coefficient and the modular angle, so a very wide selection of response shapes is available. The mathematics is somewhat horrendous, and such filters are almost always designed from tabled values or computer programs. There are ripples in the pass-band, as for Chebyshev filters.

Some other types of filter have been investigated for the specific application of loudspeaker dividing networks. I dealt with Linkwitz-Riley filters, which are simply two identical Butterworth filters in cascade, in my series on woofer design, but there are some other types. Quasi-Butterworth filters are very nearly flat in the pass-band, and are derived from the normal filter of one higher order. Sub-Chebyshev filters are similarly related to Chebyshev filters, but inverse Chebyshev filters wriggle in the stop-band instead of the pass-band.

Next Time

Subjects still to come are notch filters and coupled tuned circuits. Also, I hope to deal in due course with ICs specially made for filter applications, opening up some more advanced active filter configurations.

DAY/NIGHT THERMOSTAT – *Continued from page 77.*

DAY/NIGHT THERMOSTAT PARTS LIST

RESISTORS: All 1/4W Carbon (Unless specified)		
R1	2k7	1
R2,3	560Ω	2
R4	2k2	1
R5	1k8	1
R6,7	1k	2
R8	1k5	1
R9-11	4k7	3
R12	330Ω	1
R13	47k	1
R14	180k 1% Metal Film	1
R15	20k 1% Metal Film	1
RV1	1k	1
RV2,3	5k or 4k7	2
CAPACITORS		
C1,2	18pF	2
C3,4	470pF	2
C5	1µF	1
C6,7	100nF	2
C8,9	1µF Electrolytic	2
C10	220µF Electrolytic	1
SEMICONDUCTORS		
D1-3	1N4148	3
D4-7	1N4001	4
T1,2	BC547	2
T3	BC557	1
VR1	µA78L05	1
IC1	CA3160	1
IC2	ST6210	1
IC3	CNY17-2	1

SENS	LM335Z	1
LD1	5mm Red LED	1
LD2	5mm Yellow LED	1
LD3	5mm Green LED	1
MISCELLANEOUS		
	8-pin DIL Socket	1
	20-pin DIL Socket	1
	6-pin DIL Socket	1
X1	8MHz Crystal	1
SW1	Right-angled PCB Click Switch	1
SW2	Low Profile PCB Click Switch	1
J1,3,4	2-way PCB Screw Terminal	3
J2	3-way PCB Screw Terminal	1
RY1	SPCO 12V PCB Relay	1
	PCB	1
	Case	1
	Large Knob	1
	Small Knob	1
	Front Panel	1
	Leaflet	1
	Component Schedule	1

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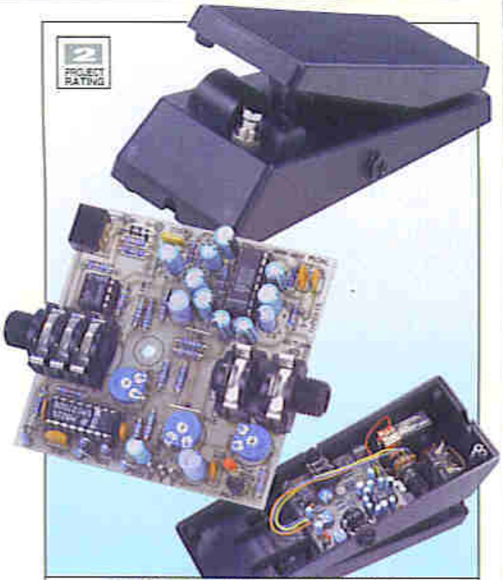

PSYCHEDELIC WAH WAH PEDAL

Recapture the classic sound of the '70s with this superb '90s technology Wah Wah Pedal. The kit includes a ready-made foot pedal and is ideal for electric guitars and other musical instruments.
Order as: LT43W, **£34.99** B3. Details in *Electronics* No. 82, October 1994 (XA82D).

2 PROJECT RATING

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2 PROJECT RATING

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1 PROJECT RATING

INDUCTANCE/CAPACITANCE METER ADAPTOR

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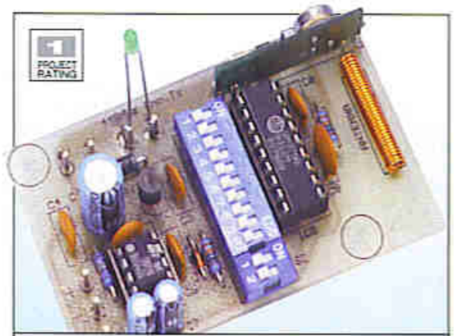
1 PROJECT RATING



418MHz ENCODED FM TRANSMITTER

A DTI approved transmitter which can be encoded with one of over 4,000 different codes. The transmitter can be triggered by a closing switch contact, which can be simply a push-button, or a negative going pulsed output from other equipment, e.g., the Telephone Bell Repeater kit, LT67X. Applications include remote control, wireless security systems, paging, help buttons, and much more.
Order as: LT87U, **£26.99**. Details in *Electronics* No.83, November 1994 (XA83E).

2 PROJECT RATING

418MHz ENCODED FM RECEIVER

A DTI approved receiver for use with the 418MHz Encoded FM Transmitter. The receiver will only respond to a transmitter set with the same code.
When a correctly coded signal is detected by the receiver, an LED lights and a piezo sounder operates. Fitting a relay (not supplied) in place of the piezo sounder allows the receiver to operate other electrical equipment for remote control applications. (Case not included in kit.)
Order as: LT88V, **£39.99**. Details in *Electronics* No. 83, November 1994 (XA83E).

2 PROJECT RATING

LOUDSPEAKER PROTECTOR

Help protect your valuable high-power loudspeakers from being damaged by DC voltages produced by a faulty amplifier. This unit constantly monitors the input to the speaker and 'disconnects' it if a DC voltage is detected.
Order as: VF44X, **£9.49**. Details in *Electronics* No. 82, October 1994 (XA82D).

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2 PROJECT RATING

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2 PROJECT RATING

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