BRITAIN'S BEST SELLING ELECTRONICS MAGAZINE

No. 45

ELECTRONICS

The Maplin Magazine

AUG-SEP '91 · £1.45

IMPORTANT ANNOUNCEMENT FROM THE EDITOR!

See page 63 for details.

HOW SAFE IS YOUR HOME?

Low Cost Alarm System for you to build.

How to build a Wiring Allocation Tester • Low Cost Counter • Galactic Relay Card • Data File: ZN419 Servo IC • Low Cost Home Alarm • Read all about Predicting Waveshapes • Phase Shift and Wien Bridge Oscillators • Circuit Testing • Win a Trip to the Spitting Image Rubber-works!

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AUGUST TO SEPTEMBER 1991 VOL.10 No.45

EDITORIAL

This is a sad and exciting time for me. Exciting because from the next edition, your favourite magazine will be available twice as often as usual. YES – 'ELECTRONICS' IS GOING MONTHLY!!! This will mean that you'll have 60 projects a year to build instead of 30; no more long waits between parts of serials and larger projects which are published in two or three parts; more informative articles; more reader's letters; more up-to-date news. In fact, more of everything through the year – you could say we're doubling your pleasure! Turn to page 63 for a sneak preview of the first monthly edition, which will be on sale from 6th September. We already have an impressive list of projects, which are currently under development and will appear in future issues of 'Electronics'. Projects such as a Low Cost PSU, a Rugby Clock and an Amplifier Monitor.

"That's great news, but what is the sad bit?" I hear you ask! Well, due to the increased monthly schedule and my commitment to other Maplin publications (such as our massive 600 odd page annual component buyer's catalogue; mail shots; etc.), I will be vacating the editor's chair and passing on my old, very battered editor's hat (you know the one that all the competitions are drawn from) into the very capable hands of Robert Ball. I am sure he will guide the magazine as well (if not better) through the nineties, as I did (hopefully) through the eighties. I would like to thank all of you loyal, dedicated, regular readers who have helped to make this magazine the best of its kind in Britain. And so, for the last time I say; READ ON AND ENJOY!

R. T. Smith

ABC 33,837

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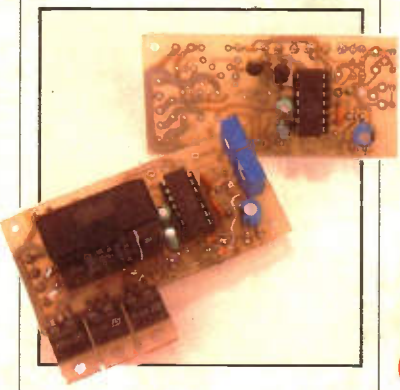
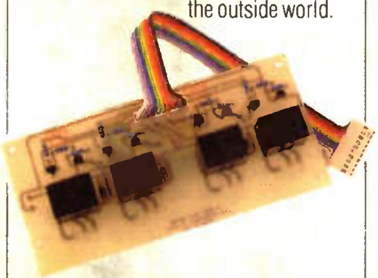
PROJECTS





FEATURES

REGULARS

CORRIGENDA

June to July 1991 Vol. 10 No. 43
Galactic Timer Unit
Page 13, Figures 5 and 6 are transposed.
Page 23, Parts List does not include:
14-Pin DIL Sockets, quantity 4, order code BL18U.
The kit however, is supplied with these items.

NEWS Report

On Safari with Maplin

The *Save The Children Fund's* organisation has endorsed a planned cycle ride by a small group of friends, through various African countries, in order to raise funds for the charity. The team of four is made up by Michael Bassett, Mark Lewis, Andy Ware and Nadia Jennings. The team (and the project) are now officially known as *Africa in The Saddle*, an idea which was first conceived by Michael during his final exams at Bangor University. After consulting a map, and having a few pensive discussions in Mark's back garden, the plans were laid down. Andy was persuaded that there was nothing he would rather spend a year of his life doing, and shortly afterwards Nadia decided to suspend her academic career and join the team.

Having agreed that the team complied fully with their fund-raising guidelines, the *Save The Children Fund* gave *Africa in The Saddle* their full endorsement in October last year. The team then set the target of raising £12,000, £1 for every mile covered on the trip home from Kenya as a starting point. This money is to be donated in full to the charity; the riders are funding their travels privately!

Wiggins & Teape promptly donated 2,500 sheets of paper for fund-raising purposes, *Express Printing* of Blyth printed the letterhead onto the supplied paper free of charge, and *OES* completed the materials by donating 2,000 recycled paper envelopes. Rob Tickell, a local photographer and artist, designed the project logo for the letterhead, as well as supplying the T-shirt design, both donated! Appeal letters are now being sent out seeking charitable sponsorship deals and donations from local and national companies, and sponsorship forms are being used to pull in private donations. *Bangor University, Formica* and *Norstead Group plc* (the latter two both in the North East) have all been forthcoming with charitable donations. However, the team are still looking for a sponsorship deal and further donations.

The Ride and Objectives

The ride, starting in June, is a nine to twelve month marathon which will see the team cover a total of 12,000 miles passing through sixteen countries between Kenya and England. The team will endure a great variety of the World's different climates, the tropical plains and forests, the Sahara desert and latterly the less hostile European Alpine and temperate climates. Travelling by bicycle, the team will have total independence and guaranteed direct human contact with the various cultures they are to encounter. Travelling in the saddle sets a pace which readily enables the riders to appreciate the geography and climate, as a consequence of being closer to and more in tune with the immediate environment. The team plans to take advantage of the opportunity to study water resources, waste management, adapting technology and recycling in the smaller communities along the route, the aim being to highlight some of the fundamental problems faced on the African continent.

The principle objectives of the team are to raise £12,000 for the *Save The Children Fund*, and to increase public awareness of the charities global concern, and action, to benefit children from all cultures. Their work includes immunisation programmes in Africa, funding and setting up city farms for children in the UK, establishing clean water supplies to Central American villages and providing vegetable seeds to families in the Himalayas so as to provide the children with an adequate diet.

The team is taking every feasible precaution on health and safety – the team's medical guidelines were drawn-up by Michael during his stay at the Hospital for Tropical Diseases (just a few things left over from his trip to Camaroon two years ago!). Fully comprehensive medical kits will be carried, and obviously the team have to be prepared for the worst.

Bikes and Equipment

The bikes are made-to-measure *Joe Waugh* touring bikes, built by *Steel's Cycles* of Gosforth, who are also providing specialist advice and repair training. The components have been individually selected for their suitability to endure one year of extreme conditions, from the mud roads of Zaire to the desert tracks of Egypt. The team will be using *Vaude* panniers and barbags, which *Vaude UK* have supplied at discount prices. The remaining equipment necessary is being researched as to its suitability.

And not least, Maplin have donated components with which a custom charging control circuit, for cycle lighting batteries, can be built for each team member. The controllers are housed in tough, alloy cases and will provide the means for recharging the batteries from the bicycle's dynamo.

And Finally

1991 is the year of the first United Nations 'Summit for The Children', but the *Save The Children Fund* has been putting children first since 1919! Why the concern? Very simply because 7,000 children die each day from Diarrhoea alone (yes, *diarrhoea*). Children are the first to suffer at times of war and disaster. For the sake of 10p for a vaccination, *thousands* of children die from Polio each year, while in the UK, some children go without alternative education schemes and are left with no choice as to playtime venue other than the streets.

There is no doubt that the *Save The Children Fund* is one of the most established and successful aid groups operating today. The charity offers training and educational schemes in order to prevent foreseeable problems, long term aid programmes to aid the safe development of children within the community and immediate relief campaigns when catastrophic events occur. The *Africa in The Saddle* team feel that the £12,000 that will be raised is worth both their efforts and the generosity of their supporters, and it *will* make a difference!

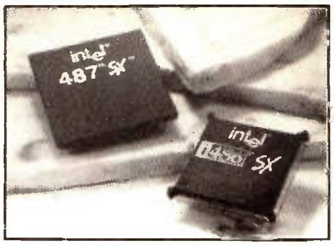
Don't Bank on IT

'Computing' magazine reports that an unsuspecting user of a Barclays Bank cash dispenser in South London asked for £40 in notes. Instead he got £20 worth of Marks and Spencers gift vouchers. Inflation it seems strikes again.

DTI Frees the Airways

The DTI Radiocommunications Agency has announced new licensing arrangements for radio microphones used inside buildings such as theatres, concert and conference halls, and churches. Licenses will now be more readily available from the one source, ASP Frequency Management Ltd, acting as the DTI's agent. Tel. 0296 770458. At the same time the agency has relaxed regulations in operating at 50MHz to permit mobile use and vertical polarisation. Also revised is the allocation of an additional spot frequency of 70·3125MHz for the unattended operation of digital communications.

Which Microchip



The highlight of this year's 'Which Computer? Show' was the launch by Intel, the inventor of the microprocessor (the computer inside the computer) of its i486 SX 32-bit chip. Hailed as the 'second wave' in personal computing, the high-powered chip was welcomed by such industry giants as Olivetti, Hewlett Packard, Nokia Data, and Siemens/Nixdorf. Details: 0793 696000.

With IBM unveiling its new 486 SX based PS/2 machines at the show, a computer operating in a fish-tank, and the adjacent 'Comms 91' event, a trip to the NEC Birmingham was not to be missed.

Recreating History

According to 'Computer Weekly', French architects have built a 1,000 year-old building, not in some secluded abbey, but in an IBM workstation. No need now, it seems, to organise passports, visas, and travel tickets. You can just take a trip around your local virtual-reality PC.

Cordless LANS

The UK says The TRR Review is to press ahead with the allocation of frequencies to allow cordless local area network products.

A timely review of the cordless and related technologies in the office will be provided in the conference 'InfraStructure 91' which takes place in London on the 26th and 27th of September. Details: 081947 2684.

Police Line

Faced with increasing nation-wide pressure on UHF and VHF radio capacity, the police have asked BT to develop an alternative system to link its hilltop radio sites to take advantage of modern digital technologies. The problem is that the MegaStream system was not designed to do what the police quasi-synchronous radio system needed. MegaStream's service strength is its ability to automatically take an alternative route when direct route lines are busy. In conventional applications the user is not aware of this, since there is no difference on the line. But the millisecond differences which could arise in a police message, taking non-direct routes to several different transmissions, would render the police communications system useless. BT has now refined the system so that two or more potentially competing signals arrive at their transmission destinations and are broadcast simultaneously.

At the same time, a labour MP has called for the plugging of loopholes in the Data Protection Act, in order to avoid accusations that the present law is open to abuse by the police.

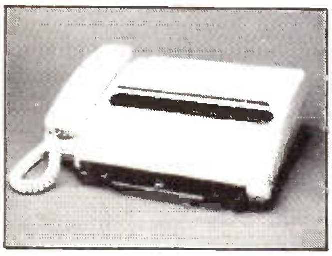
Just why the police did not enjoy exemption from the act in the first place continues to surprise many industry commentators.

Meanwhile, an enterprising UK PC company is calling his business 'PC Plod'. "It shows our products to be simple, straightforward and trustworthy".

Fax It

Not content with having the UK's best selling fax machine, Samsung have launched three new fax machines. These are tailored specifically to meet the needs of domestic users, small businesses and the medium-sized company. Details: 081 391 0168.

Not to be outdone, Canon have announced what they describe as being the ultimate 4 in 1 personal communications system. The new Canon Fax 170 is a compact unit which incorporates state of the art fax, answerphone, telephone and personal copier. The all-in price is a handy £799 including VAT. Details: 081 773 3173.



Apparently one in three businesses in the UK now have a fax machine, says UK fax authority *Vernon del Espino*. The current UK fax installed base, says Vernon, is now approaching 750,000 machines.

Meanwhile Fujitsu have developed the world's first super high-speed Group 111-compatible plain paper laser fax machine. This takes just one and a half seconds to read in an A4 page, reducing transmission time from a typical 14 seconds to just four. The price however, at some $70,000, equals the high performance.

STOP PRESS! STOP PRESS! MPS is a Winner!

Maplin Professional Supplies – the trade division of Maplin Electronics – who recently exhibited at the NEC Nepcon '91 Exhibition, has won the 'Best Pre-show Publicity Campaign' award. Their highly effective, informative and original, pre-show publicity and press material promoting the launch of the new MPS Courier Service has proved to be a winner!

Using the nation-wide network of Maplin stores, each of which will have a trade counter tended by specialist staff, orders placed will be on their way within moments. In many cases, trade customers could actually receive their orders within the hour, depending on their proximity to their local Maplin store. For further information, please contact: Nick Fogg on 0702 554155.

Picture Caption Challenge

What's going on here? No, it's not BT fixing their new logo onto local community trees. Despite being advised to 'leaf' it alone, what is BT up to now? Is it:

★ BT tackling the growth of branch lines;
★ BT getting to grips with their cutting-back programme;
★ BT trying to trace a problem with a local network;
★ BT looking for a long lost engineering colleague;
★ BT rehearsing their next Xmas panto – BT Jack and the Beanstalk?

Close, but no! Actually British Telecom has heeded a 'save-our-wistaria' plea from residents in Duck Lane, Canterbury, and spared a telegraph pole entwined by one of these plants. Over the years, the 32ft high wistaria had become so dense and tree-like that no engineer could climb the pole with safety.

But a BT plan to demolish the pole horrified local residents. The wistaria, they claim, is unique and a real tourist attraction when in bloom. BT responded with a 'green' solution to the residents' objections, by only removing the lines and sparing the Jack-and-the-Beanstalk pole. Cables will now go underground in Duck Lane, and the wistaria will remain to be seen by all those who visit the ancient city. A genus of papilionaceous plants, the wistaria is one of the most magnificent 'ornamental climbers' known in English gardens.

Pictured here is BT engineer Cedric Oxford, jointing the underground cables.

Continued on Page 63

PART ONE

The Resistor-Capacitor Circuit

by Philip Lawton

PREDICTING WAVESHAPES USING A COMPUTER

Introduction to the Series

Waveshapes can be produced on the screen of a computer by a variety of methods.

These methods include:

1) Graph plotting programs.
2) Electronic circuit design programs.
3) Interactive simulation languages.
4) Data logging interfaces.
5) A few lines of code.

In practice a designer might use all these methods to support his experimental work.

This series of articles explains how a few lines of code can solve equations, especially rate of change equations, which are associated with particular parts of electronic circuits.

Program listings are given in both GW BASIC, as used on the IBM PC and compatibles; and BBC BASIC, as used on the Acorn BBC micro. However there is nothing to stop the reader from adapting the programs for other machines. The statements used in the programs in order to plot the waveshapes on the screen are the ones that will need to be changed for different computers.

For example: PLOT69,x,y is used to 'set' a single pixel in BBC BASIC, whilst if GW BASIC is used it will have to be changed to PSET(x,y) (note that '0,0' is the top left pixel). Also MODE 4 will have to be changed to SCREEN 2 (note that the screen resolution is 640 by 200 pixels).

The Acorn computer was used in MODE 4 because it can be connected directly to a video recorder and the screen displays recorded as examples of the use of the computer and to practice skills of communication. Similarly the computer can be connected directly to a video projector for use in the lecture theatre.

The skills involved in using computers to predict and plot waveshapes are well worth developing.

Philip Lawton B.Sc. Tech.; M.Sc.; C.Eng.; MIEE Senior Lecturer, Department of Electronic and Electrical Engineering, Leicester Polytechnic.

Introduction

The purpose of this article is to explain how to predict some of the transient and steady state waveshapes that are observed in electronics.

A recent series of articles entitled 'Square One' (reference 1) has provided an excellent introduction to electronics. These articles are regarded as prior knowledge, along with the ability to use a computer for repetitive arithmetic and plotting.

The Resistor-Capacitor series circuit shown in Figure 1 is used to illustrate how to apply the fundamental laws in order to obtain a very useful 'rate' equation.

This is followed by a description of a computer program to evaluate the 'rate' equation for any applied input emf and to plot the predicted waveshapes.

The input chosen is a sine wave at a frequency equal to the break frequency of the Resistor-Capacitor series circuit (RC circuit). The predicted potential of the capacitor illustrates a transient followed by a steady state sinusoid whose magnitude is $\pm 0{\cdot}7$ (-3dB) and whose phase shift is -45 degrees (a lag of 45 degrees).

Finally the predictions are discussed and related to the phasor diagram.

Fundamental Laws

The simplest laws are always the best!

A useful law for the capacitor relates the current (i) to the product of the capacitance (C) and the rate of change with respect to time of potential difference of the capacitor (sv).

The law is:

$i = C \times sv$ (derived from $q = C \times v$)

This law predicts the fact that when a current exists then the potential difference of the capacitor will change.

Equations

Equations to model the RC circuit can be derived using the above capacitor law, Kirchhoff's voltage law, and Ohm's law. Note that the waveshape of the applied input signal is represented by the symbol e (volts) and that the resultant effects are a current i (amps) and a capacitor potential v (volts)

```
10 REM RC1 Philip Lawton Sept. 1990
20 REM Resistor-Capacitor circuit
30 REM Evaluate capacitor volts
40 SCREEN 2:CLS   :REM for graphs
50 LET R=10000    :REM Time Constant?
60 LET C=.0000001:REM R*C is .001s
70 LET V=0        :REM At switch time
80 LET H=.00004   :REM time step
90 FOR T=0 TO .00628 STEP H:X=T*100000
100 LET E=1*SIN(1000*T+0)   :REM volts
110 PSET(X,100)             :REM zero
120 PSET(X,100-E*50)        :REM volts
130 PSET(X,100-V*50)        :REM volts
140 LET SV=(E-V)/(R*C)      :REM rate
150 PSET(X,100-SV*.05)      :REM v/s
160 REM At time T+H secs:-
170 LET V=V+SV*H            :REM volts
180 NEXT T:REM E=1*SIN(2000*T+0/57.3)
```

Listing 1. Resistor-Capacitor program in GW BASIC.

```
10 REM RC1 Philip Lawton Sept. 1990
20 REM Resistor-Capacitor circuit
30 REM Evaluate capacitor volts
40 MODE 4        :REM for graphs
50 LET R=10E3    :REM Time Constant?
60 LET C=100E-9:REM R*C is 1E-3 sec
70 LET v=0       :REM At switch time
80 LET h=.04E-3:REM time step
90 FOR t=0 TO 6.28E-3 STEP h:x=t*1E5
100 LET e=1*SIN(1000*t+0)   :REM volts
110 PLOT69,x,200            :REM zero
120 PLOT69,x,e*200+200      :REM volts
130 PLOT69,x,v*200+200      :REM volts
140 LET sv=(e-v)/(R*C)      :REM rate
150 PLOT69,x,sv*0.2+200     :REM v/s
160 REM At time t+h:-
170 LET v=v+sv*h            :REM volts
180 NEXT t:REM e=1*SIN(2000*t+0/57.3)
```

Listing 2. Resistor-Capacitor program in BBC BASIC.

These equations are:

$i = C \times sv$

$e = R \times i + v$

(or $e - R \times i = v$

or $e - v = R \times i$

or $e - v - R \times i = 0$)

where:

- i is the value of the current
- C is the value of the capacitor
- sv is the rate of change of the capacitor potential
- e is the value of the applied emf
- R is the value of the resistor
- v is the value of the capacitor potential

From these two equations an equation to predict the rate of change of capacitor potential with respect to time (sv) can be obtained:-

eliminate i by rearranging the second equation in terms of i and equating the two equations:

$i = C \times sv = (e - v) \div R$

hence:

$sv = (e - v) \div (R \times C)$

which is a rate of change equation.

This equation is used to evaluate the rate of change with respect to time of the capacitor potential (sv). The rate of change is equal to the difference between the input to the RC circuit (e) and the capacitor potential (v) divided by the value of the time constant (R × C)

Programs

The above rate of change equation can be evaluated for any input emf (e) using a computer and a suitable language. Note that the evaluation can be for *any* input waveshape, and that this is a good reason for considering this program.

The program shown in Listing 1 is coded in GWBASIC for an IBM PC or compatible computer and Listing 2 is coded in BBC BASIC for an Acorn computer.

It predicts, at successive steps of time, the capacitor potential v (volts) when the applied emf e (volts) is varying sinusoidally. The predicted waveshapes are described in the next section.

This program is based on a FOR STEP NEXT loop and contains several very interesting statements as follows.

Line 90: time is stepped from 0 up to 6·28 milliseconds in intervals of h milliseconds in order to evaluate the equations for one cycle of the input (h has to be relatively 'small', at present h = 0·04ms)

Line 100: the applied emf is specified as a sine wave whose angular frequency is 1000 radians per second and whose periodic time is 6·28 milliseconds.

Line 140: the rate of change equation is evaluated as volts per second (alternatively volts per time constant)

Line 170: is a method of predicting the changing potential. It can be stated as; LET the new value of v become the old value of v plus an increment, where the increment is the product of the rate of change and a step in time. Provided the step in time h is relatively 'small' then the predictions will be useful (compare h with the time constant R × C of 1ms).

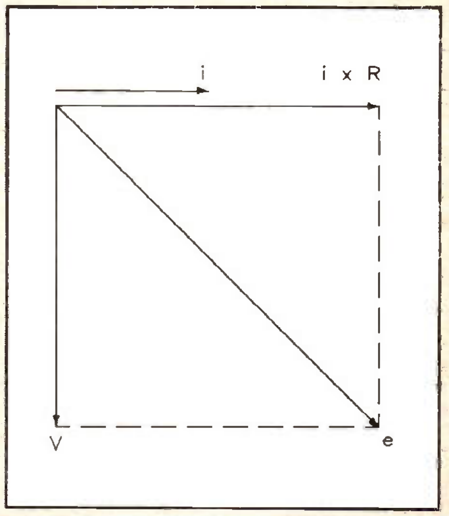


Figure 1. The Resistor-Capacitor series circuit.

Waveshapes

The predicted waveshapes at the frequency equal to the break frequency are shown in Figure 2a. The transient appears during the first half cycle of the input. Note that as i = C × sv then the waveshape of the rate of change also represents the current in the circuit as well as the volt drop across the resistor.

The horizontal time axis is 6·28 milliseconds. This is equal to the periodic time of the input sinewave whose frequency is equal to the break frequency of the circuit (1000 radians per second). As the time constant of the RC circuit is 1 millisecond then the periodic time is equal to 6·28 time constants.

The transient appears for approximately 3 milliseconds which is equal to 3 time constants.

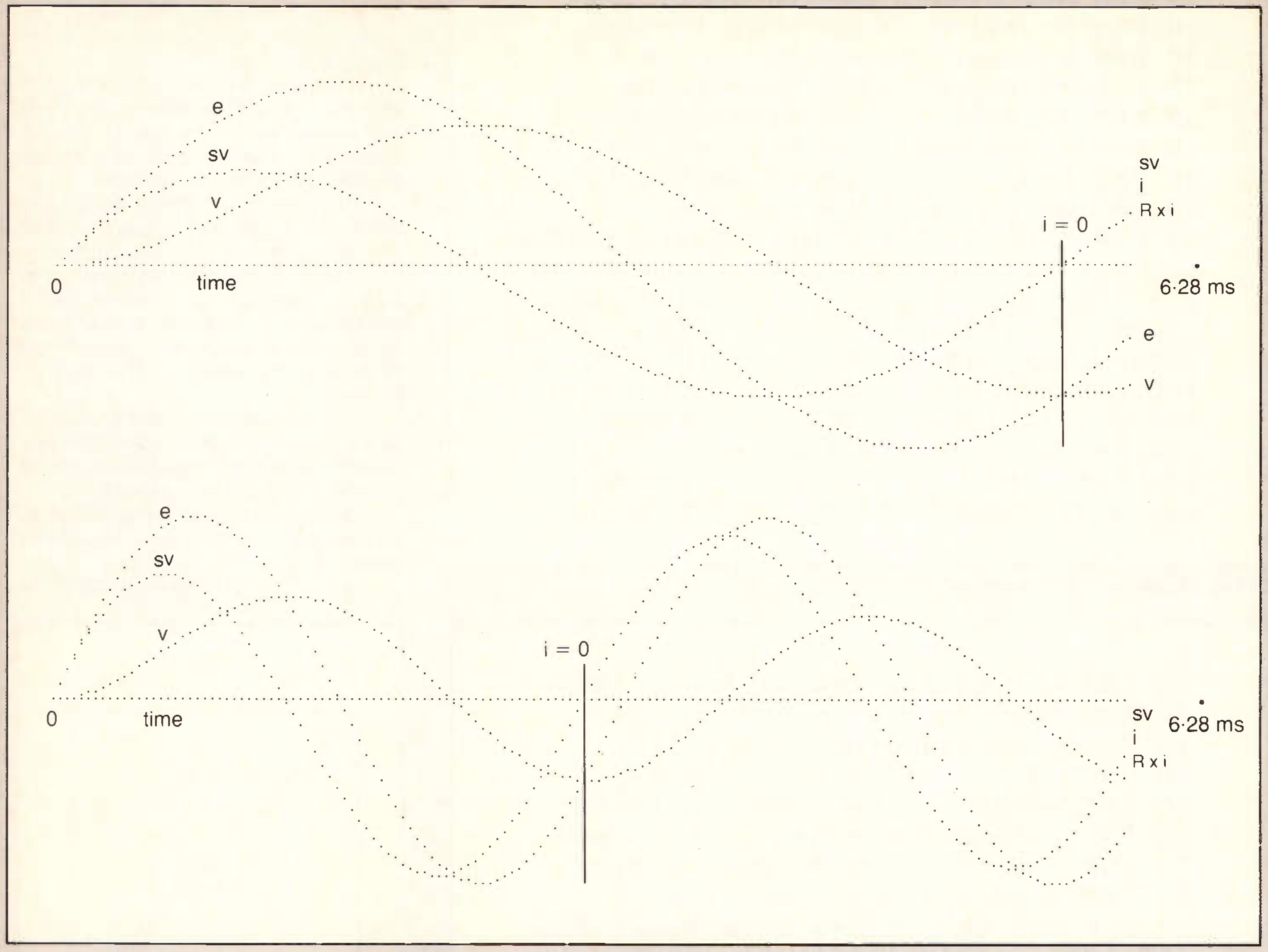


Figure 2a. (above) Computer plot of waveshapes for the Resistor-Capacitor circuit at 1000 r/s.
Figure 2b. (below) Computer plot of waveshapes for the Resistor-Capacitor circuit at 2000 r/s.

At any moment in time the three voltage waveshapes summate to zero:

e − v − R × i = 0 (Kirchhoff's voltage law)

Also the current leads the capacitor potential. The capacitor potential is less than the input potential and the sinusoid lags the input sine wave (magnitude of ±0·7 volts, phase shift of −45 degrees, phase lag of 6·28 ÷ 8 milliseconds).

If the frequency is doubled (line 100) the transient still appears for a time approximately equal to 3 time constants (Figure 2b). This is now the duration of the first cycle. The steady state magnitude is reduced to ±0·45 (−7dBs but often approximated to −6dBs)

An input to represent a constant emf is easy to specify (line 100 e = 1), the usual exponentials are predicted.

Phasor Diagrams

Phasor diagrams represent sinusoids and are an alternative method of calculating the steady state response (Figure 3).

The straight lines are assumed to rotate with positive angular velocity (anti-clockwise) and are related to the horizontal. Thus the vertical component is the instantaneous value of a sine wave.

The phasor diagram shown in Figure 3 represents the waveforms at the moment when the current is zero, positive going. This moment in time, when the current is zero, is shown on Figure 2a at t = 6·28 × 7 ÷ 8 ms. The resistor volt drop is zero, the capacitor potential is −0·7 (minimum), and the input emf is −0·7 (positive going). This situation repeats every cycle.

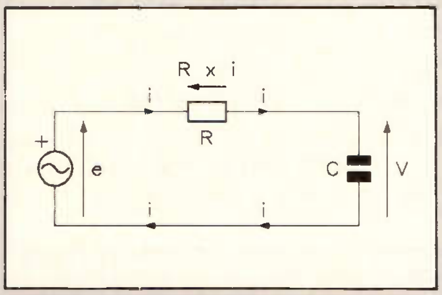


Figure 3. Phasor diagram for the Resistor-Capacitor circuit.

The phasors are based on the fact that the current sine wave leads the capacitor potential sinusoid by a quarter of a cycle. They predict that the capacitor potential with respect to the input will be reduced in magnitude and lag in phase.

Things to Do

It is left to the reader to change the frequency, predict the waveshapes, construct the phasor diagram, and to measure the actual response using an oscilloscope.

Useful frequencies are ω = ωb, ωb × 10, ωb ÷ 10 where ωb represents the break frequency of 1000 radians per second. (These are 'decades' of frequency, alternatively use 'octaves').

Note that the break frequency is the reciprocal of the time constant of the circuit (ωb = 1 ÷ (R × C), omegabee equals one over tau). The break frequency is a useful number in relation to the frequency response diagram (Bode diagram), and relates to some interesting arithmetic involving equal numbers and 1 ÷ 1·414 (0·707).

Finally

The Resistor-Capacitor series circuit and a computer program have been used to explain how to predict the waveshapes of the response of the RC circuit to *any* input.

A sinusoidal response has been predicted for a sine wave input using the equations:

i = C × sv, sv = (e − v) ÷ (R × C),
and the statement LET v = v + sv × h.

This is a very powerful method for predicting the dynamic responses of complicated systems using existing simulation programs.

References

1. 'Electronics – The Maplin Magazine' Issue Numbers 37, 38, 39,40.

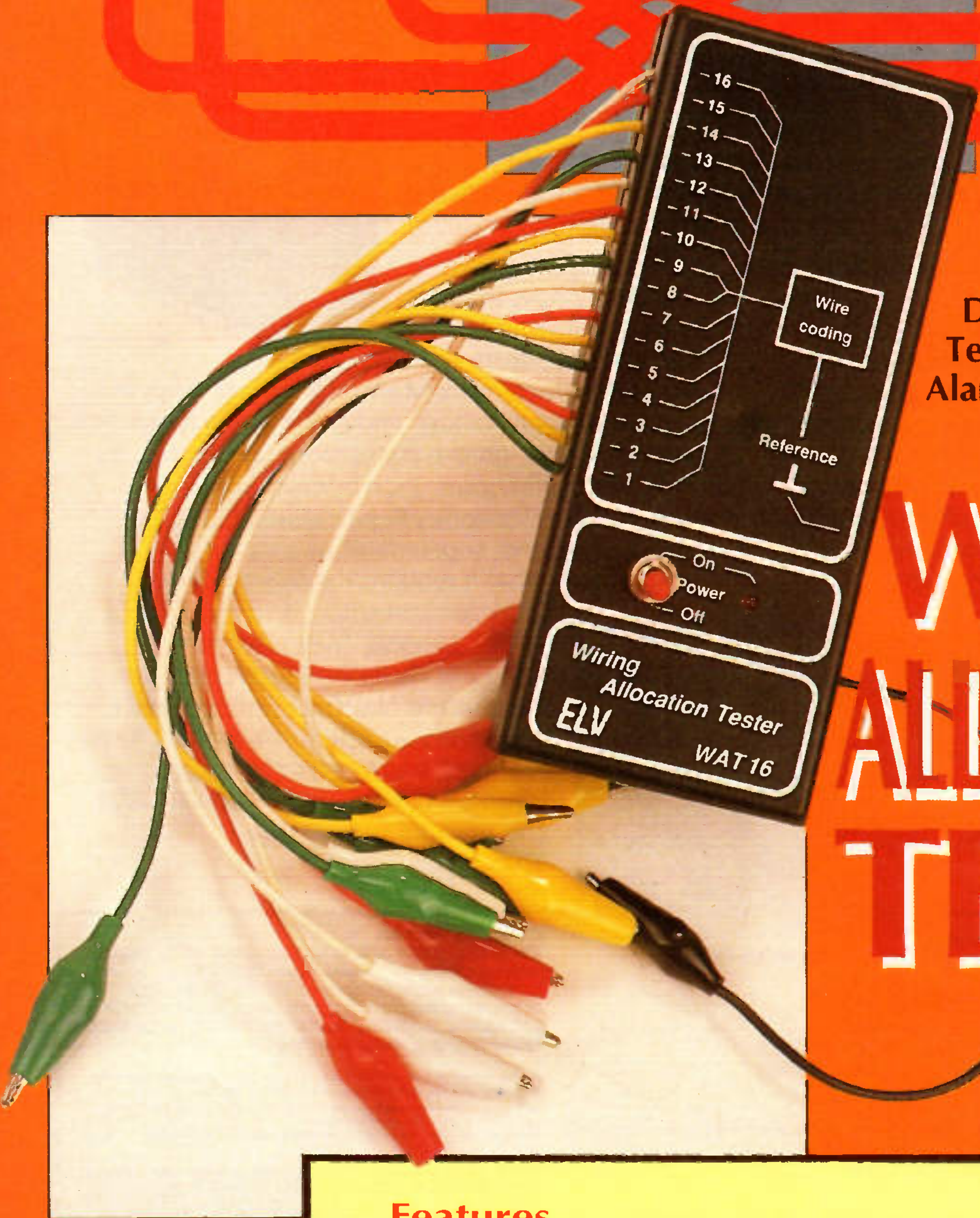


Photo 1. Transmitter with test leads.

Design by ELV
Text by Alan Wilson

WIRING ALLOCATION TESTER

Features

- ★ Electronic Wire Identification
- ★ Independent Sender and Receiver
- ★ Up to 16 Wires Encoded Simultaneously
- ★ One Person Operation
- ★ Digital Readout of Wire Number
- ★ Crystal Controlled Accuracy

Introduction

This project is a handy test instrument which takes the hassle out of identifying and trouble-shooting multi-way cable installations.

Anyone who has ever installed a multi-way cable between two locations in the home or the office is probably familiar with the problem of wire identification. Often the connections must be made in awkward, difficult-to-reach corners, while communication with an assistant at the 'other end' may be difficult or impossible (or you may have no assistant). Such multi-way cables are commonly used in telephone, intercom and alarm systems.

Obviously a cable of only 2 conductors does not raise these sorts of problems, similarly if each conductor in a multi-way bundle has a unique colour. In many alarm systems, however, multi-way cables without colour coded conductors are in common use for security reasons. Also difficulties with wiring allocation may arise where a cable is extended by adding a length of multi-way cable that happens to be available, but is not identical.

In these instances it would be reassuring to be able to check and record the function or number of each conductor in the cable. The Wiring Allocation Tester provides this service in a fast and efficient manner that eliminates the risk of wrong connections. The system has two parts: at one end of the cable a code transmitter is used to send a unique signal on each conductor, while a special receiver at the other end checks whether each wire's code is coming through with the aid of a digital read-out. Both the transmitter and receiver are light-weight, battery-powered units in rugged ABS enclosures.

Principle of Operation

The transmitter can encode up to 16 different conductors at once by attaching small crocodile clips to the cable. If a cable has fewer than 16 conductors, the remaining transmitter connectors are simply not used. If there are more that 16 conductors in the cable, then these can be allocated in groups of 16 at a time. It is important however to make sure that the conductors to which the transmitter is connected have no voltages present or power applied, nor should they be shorted together or cross connected at any point.

At the transmitter end, each conductor must be labelled with numbers 1 to 16, corresponding to the numbers printed on the front panel of the transmitter. The single lead at the opposite side of the transmitter box is marked REFERENCE and must be connected, for any test, to the corresponding REFERENCE lead on the receiver. In many cases it is possible to make use of the cable screening braid if it has one, or a conductor in the bundle with some distinguishing feature that makes it identifiable from the others. If neither of these actions is possible then the REFERENCE leads on both the transmitter and the receiver may be clipped to a nearby earth connection such as a metal water supply pipe, or a central heating pipe.

The receiver has two leads, one for ground (REFERENCE) and one for testing any of the conductors previously allocated at the other end of the cable. Both receiver leads have crocodile clips as used on the transmitter. The signal input lead of the receiver is connected to the required conductor in the cable. The instrument indicates the number of the wire as defined at the transmitter side (1 to 16) on a liquid crystal display (LCD). Short-circuits to the REFERENCE potential are indicated by the display reading '36'.

Both the transmitter and the receiver are each powered by a 9V battery. The battery in the transmitter may be installed by unlocking the cross-head screw at the back of the instrument and removing the top half of the enclosure. The receiver has a separate battery compartment that may be opened without unlocking a screw.

The transmitter's battery will typically last for about 400 hours and the receiver's battery about 2,000 hours of operation assuming that a PP3 size Alkaline type is used (e.g. FK67X). The transmitter has a red flashing LED to indicate that the unit is switched on, which goes out if the battery voltage drops below about 6·5V, thus

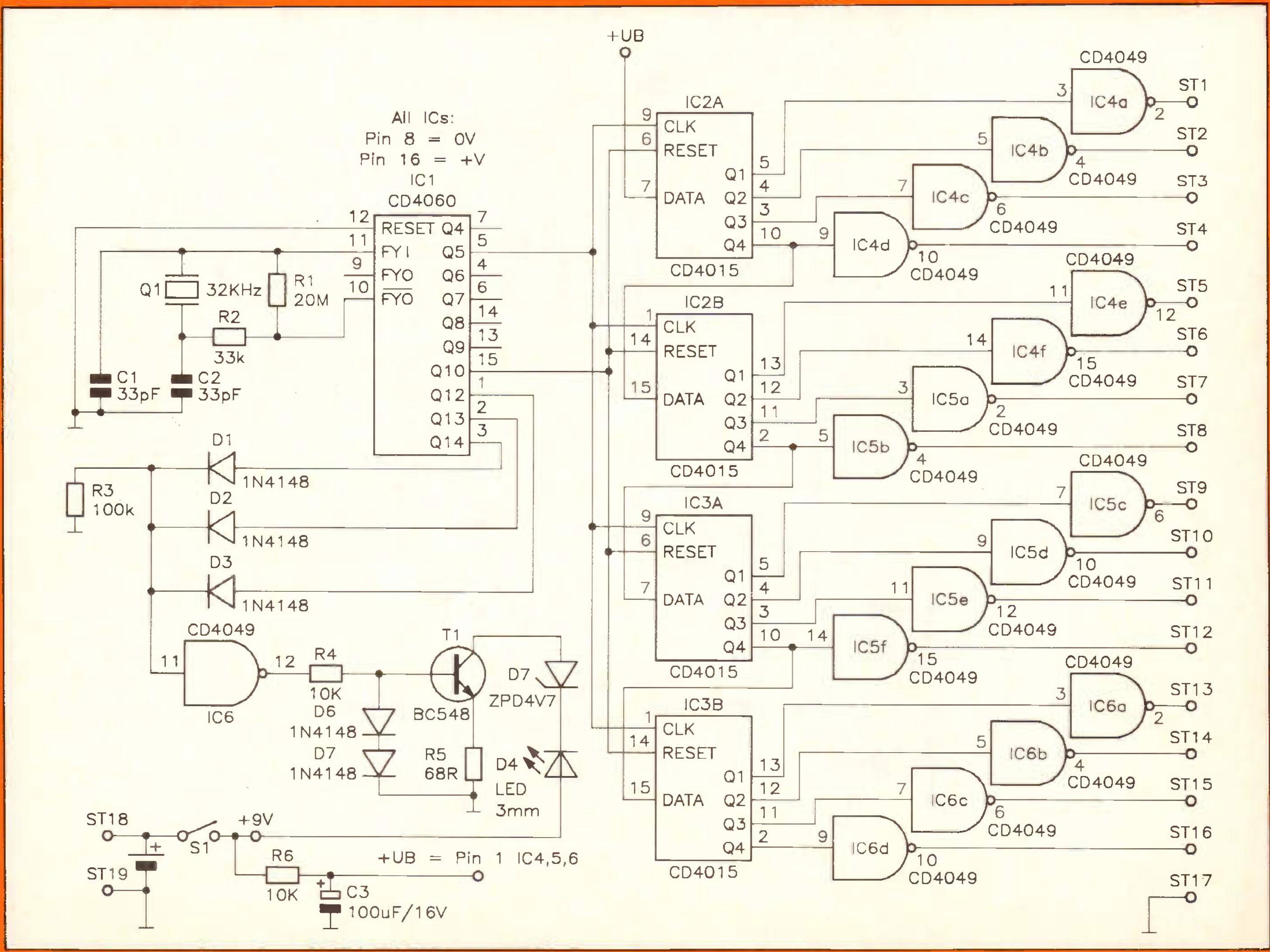


Figure 1. Circuit diagram of the transmitter unit.

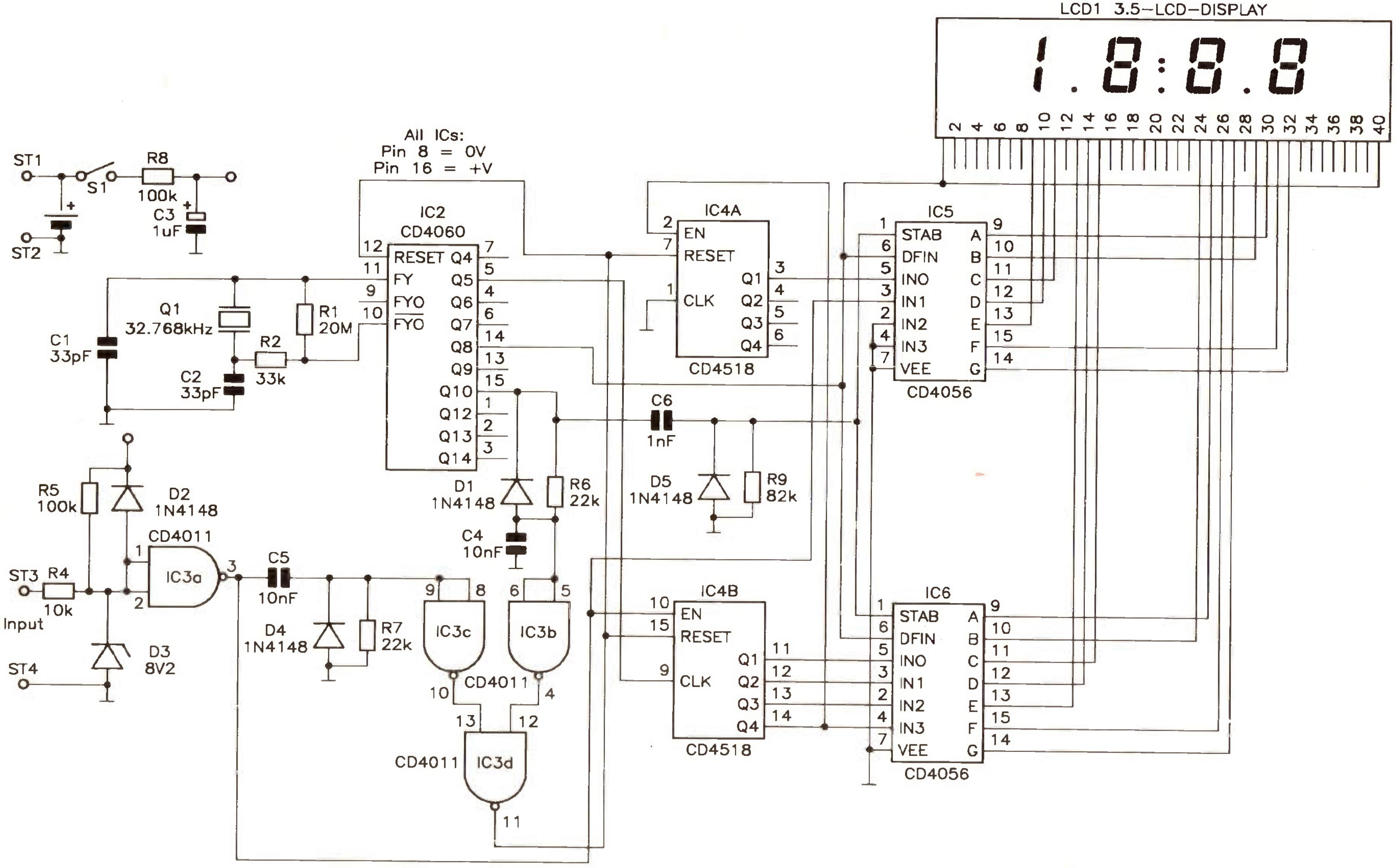


Figure 2. Circuit diagram of the receiver unit. The use of a battery is optional since the circuit may be powered by the transmitter.

indicating that a new one should be installed, but the instrument will continue to operate for a couple more hours.

The receiver's on/off slide switch is located on the left-hand side panel of the instrument. A conductor number is displayed when a valid code from the transmitter is received.

The Transmitter

The circuit diagram of the transmitter is given in Figure 1. The 9V supply voltage is applied to decoupling capacitor C3 via switch S1 and R6. The voltage across C3 is used to power all transmitter circuits with the exception of the LED. The actual circuit supply voltage is of relatively little importance and lies between 5V and 8V depending on the number of conductors connected since CMOS ICs, as used here can usually operate from supplies between 3V and 15V.

IC1 is a 14-stage, binary ripple up-counter containing an oscillator operating at 32·768kHz as determined by the quartz crystal Q1. Divider stages in IC1 provide a number of control signals for the other parts of the circuit. Output Q5 supplies a frequency of 1024Hz, used to clock all of the four 4-bit shift registers in IC2 and IC3 in parallel. The data input of IC2a is tied to the positive supply line, resulting in a logic one being transferred first to Q1 and then to all outputs of IC2a on each low to high transition of the clock pulse received from IC1.

As IC2a Q4 is the data source for the second shift register, IC2b, then Q1 of the second stage goes high on the fifth clock pulse applied to IC2a, and then outputs IC2b Q2, Q3 and Q4 go high on the sixth, seventh and eighth clock pulses respectively. This process continues through IC3a and b until the last output to go high is Q4 of IC3b. In other words all 16 outputs change state from low to high one after the other so that while the last, number 16, is high for just one clock cycle, the first is high for a full 16 clock cycles.

At the end of this Q10 of IC1 is used to clear or reset all shift registers to zero. The reset state is of the same duration as the period in which all 16 clock pulses are produced, so that when Q10 goes low again after 32 clock pulses, the shift registers are enabled again to accept the clock pulses supplied by Q5 of IC1. This sequence is repeated, starting with the low-to-high transition of Q1 of IC2a. The 'on' (logic high) time of any shift register output depends on its position in the chain, so that while IC2a Q1 has the maximum on-time of 16 clock periods, IC3b Q4 is high for only one period. It is by these time periods that the receiver recognises each of the 16 conductors. Hex inverters IC4 to IC6d buffer the 16 lines for output to the crocodile clips as active low.

The power on indicator D4 has its anode connected to the 9V supply voltage directly behind the contact of switch S1. The cathode is connected to the collector of T1 via 4·7V Zener diode D5, and these together with associated components D6, D7 and R5 form a 10mA current source. The LED will light at constant brightness

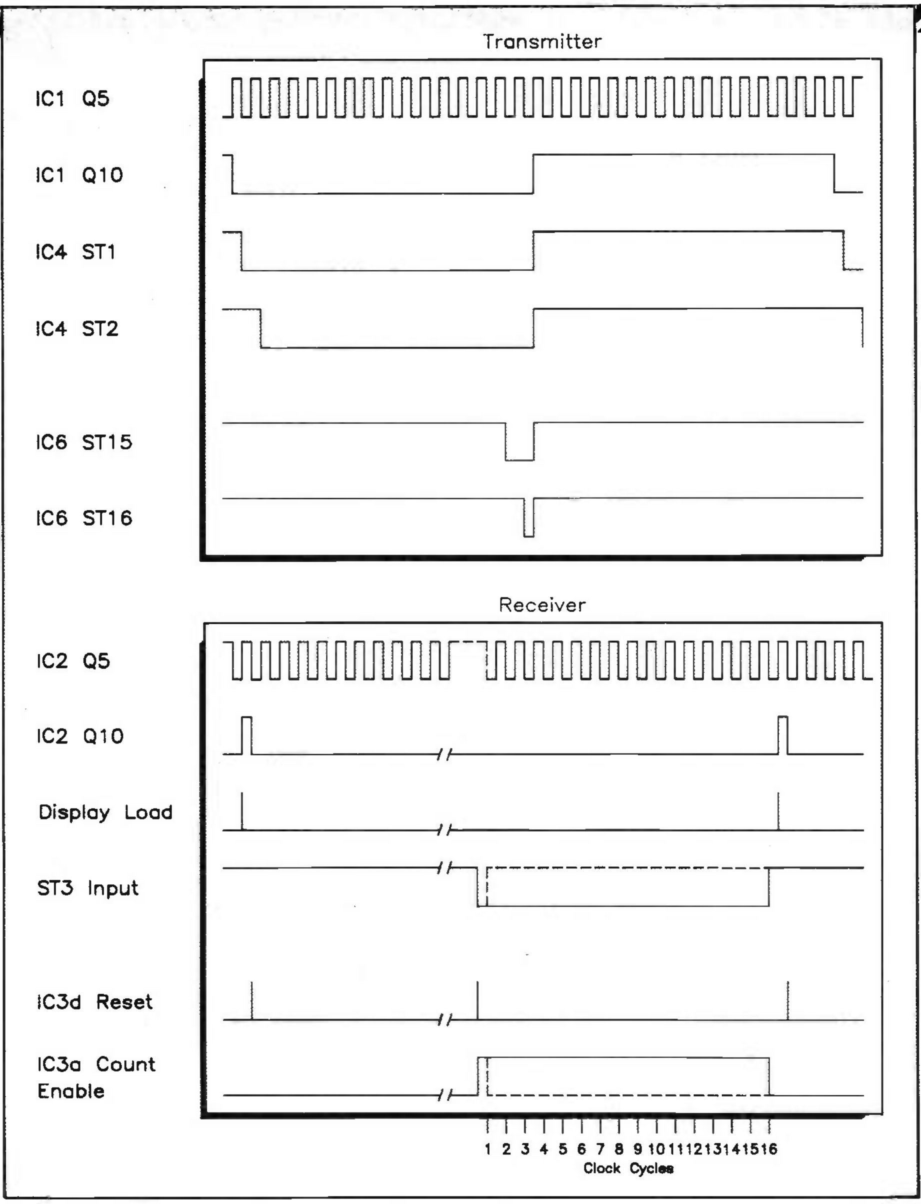


Figure 3. Timing diagrams to illustrate the operation of the code transmitter and receiver.

while the battery voltage exceeds about 6·7V. This value is obtained by subtracting the sum of the voltage drops across R5 (0·7V), D5 (4·7V), and D4 (1·3V) from the nominal battery voltage of 9V; there is negligible voltage drop across the collector-emitter junction of T1. If the battery voltage drops below 6·7V, the LED is rapidly reduced in brightness until it goes out at about 6·0V.

This current source is pulsed, thereby flashing the LED to keep the overall current consumption as low as possible. IC1 outputs Q12 – 14 are combined with a wired OR function provided by D1 – 3 and R3 to produce an LED flash rate of about 2Hz. This arrangement results in a power saving of around 12·5%.

The Receiver

The circuit diagram of the receiver is given in Figure 2. Like the transmitter, the receiver is powered by a 9V battery via S1 and an RC network, R8 and C3. R8 has a relatively high value which ensures a circuit supply voltage of around 5V. Since the receiver circuit does not contain current-hungry components, the battery capacity will be sufficient for about 2,000 hours of operation.

Again a CD4060 oscillator/divider is used as the central clock source, IC2. The clock pulse frequency at output Q5 is also 1024Hz as derived from the quartz crystal, Q1, frequency of 32·768kHz. This signal is applied to the clock input of a first decade counter, IC4b at pin 9. The sampling period of the counter, during which a number of these clock pulses can be counted, is determined by the duration of a 'gating' or enable signal applied to pin 10. This period 'gate' control originates directly from the receiver's input.

The sequence of events can be followed commencing with the moment when output Q10 of IC2 supplies a reset pulse. This low-to-high transition is delayed by the integrator network R6 and C4 and inverted by IC3b which connects to IC3d. Because of the NAND logic function of IC3d, this now inverted low level input forces it to output a low-to-high transition which is used to reset the counters in both halves of IC4, as well as the oscillator/divider, IC2. Consequently output IC2 Q10 goes low again, terminating the reset pulse, and the circuit is then ready to begin a new count cycle.

If the receiver's input at ST3 is open circuit then the inputs of gate IC3a are pulled high by R5. As IC3a is wired as an inverter, its output is then at a constant logic low level that maintains the first stage counter IC4b in a disabled state by tying the enable pin low, even though this counter is receiving clock pulses. The display indicates '00' in this condition.

If however ST3 and ST4 are connected, then IC3a outputs a logic high that enables counter IC4b. Also on this transition a monostable made up from C5, D4, R7 and IC3c generates a very short, logic 0 pulse for the other input of IC3d, which again will reset the two counters in IC4, as well as the oscillator/divider, IC2. Since the pulse is very short, these circuits are re-enabled almost immediately afterwards, so that the clock pulses supplied by output Q5 of IC2 may again be counted by IC4b and IC4a from the beginning. It can be seen from this that, since the timebases of both the transmitter and receiver are identical, pulses from any of the transmitter's outputs when applied to ST3 will exactly synchronise both timebases.

Display

The four outputs of IC4b are in binary format but only register '0' to '9' (BCD). After '9' the counter rolls over to '0' again, but a carry is effected by Q4 going low while connected to the enable input of IC4a. With the 'CLK' input permanently grounded, 'EN' of IC4a becomes effectively a negative edge triggered clock input to register a count of 10.

Because it need only discriminate between 0 and 1 (higher values than 16 do not occur), only Q1 of IC4a is connected to the least-significant input of the associated BCD to 7-segment latch/decoder/LCD driver IC5. The next higher input of IC5, pin 3, is driven by IC3a, so that if a short-circuit exists between a conductor and the reference (ground) potential, this gate supplies a permanent logic high level causing the value received by IC5 to be increased by '2'. As a result, the count of '1' from IC4a is changed into '3', and this is why short-circuits in the cable are indicated by the unique value '36' on the display.

The low to high reset transition from IC2 Q10 is also communicated via a simple non-inverting monostable contrived from C6, D5 and R9 to the 'STRB' inputs of both IC5 and IC6, to latch the count into the drivers for display. This is why there is a need to delay the reset pulse with R6 and C4, so that the value can be retrieved before the counters are cleared by the same output, Q10. Since the previously established counter states are latched in IC5 and IC6, the display reading does not change. When the input terminals are disconnected, the display shows '00' after the next count cycle. Since the measurement rate is about 30 per second, the display changes for each wire connection test virtually immediately.

Since the LCD needs an AC backplane signal, the Q8 output of IC2 is utilised for this purpose, thus obviating the need for another special backplane generator chip. The frequency of the backplane signal is 128Hz.

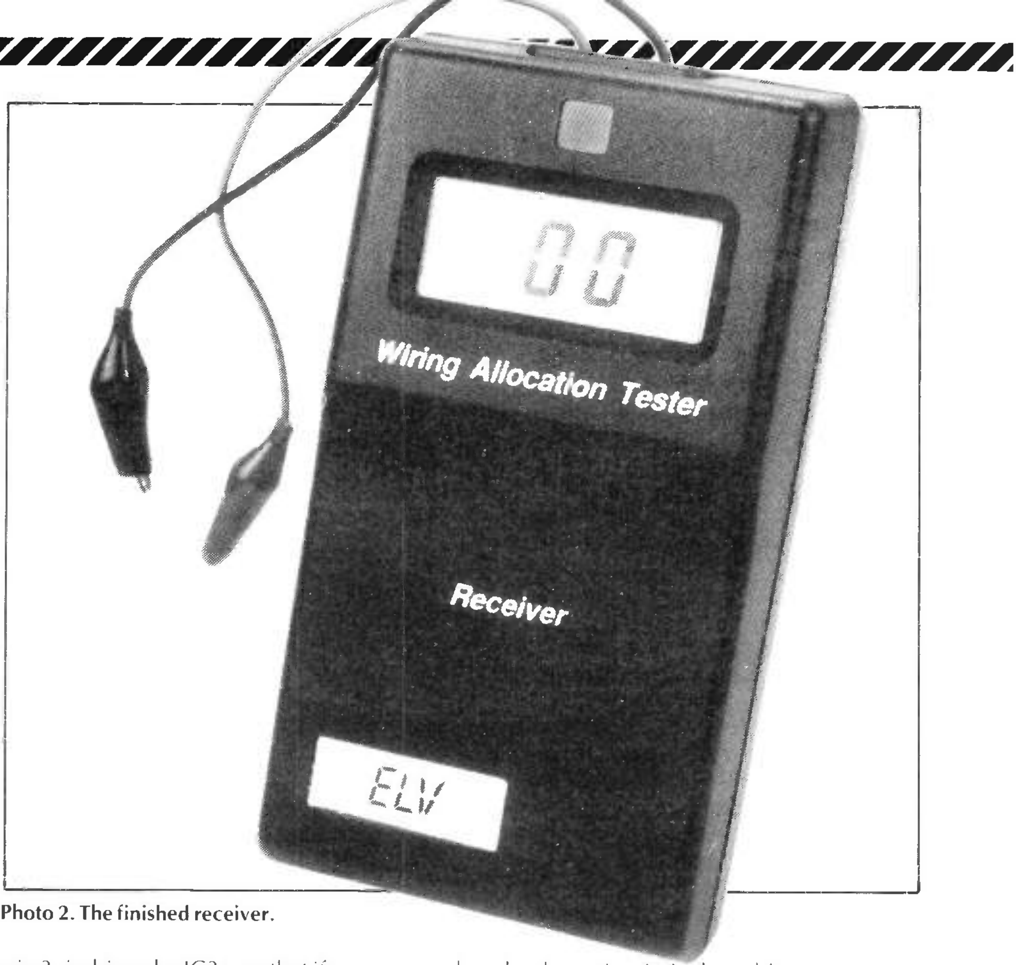


Photo 2. The finished receiver.

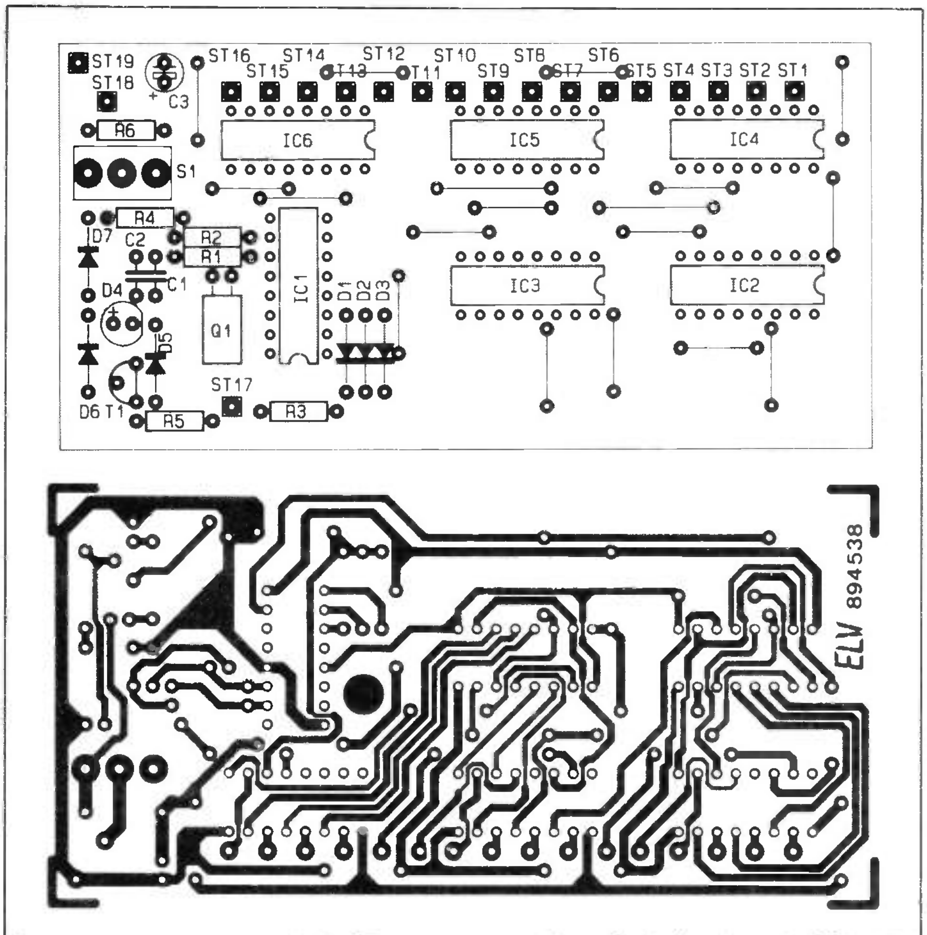
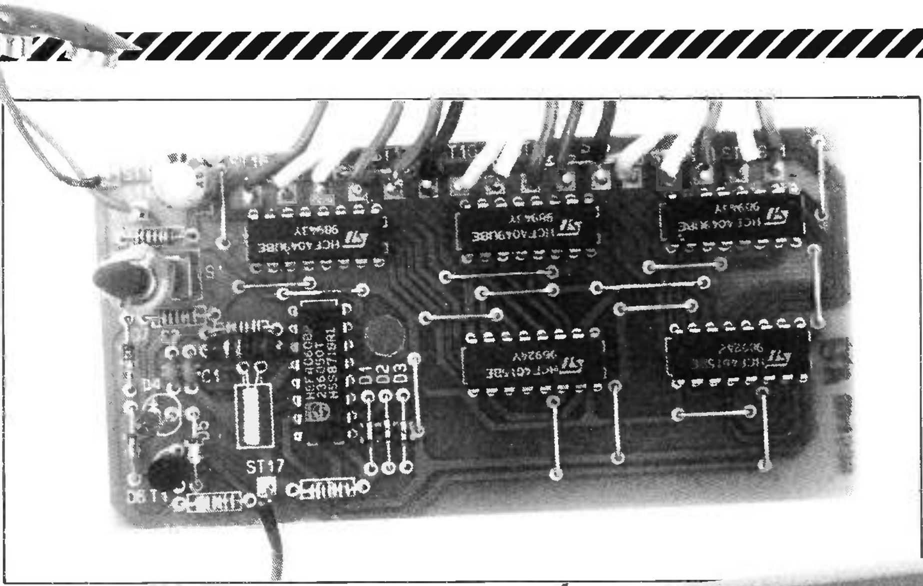


Figure 4. Printed circuit board for the transmitter.

Encoding the Cable

Figure 3 shows two timing diagrams for the transmitter and receiver. It can be seen that while the output of IC4 ST1 of the transmitter is low for all 16 clock cycles, each successive output goes low one cycle later, until IC6 ST16 is the last to go low for only one clock cycle. Hence each wire in a cable loom is identified by the duration of an active low pulse. Left to its own devices, i.e. with ST3 open circuit, the receiver idles at the same frequency but is not locked to the transmitter, and the counters are reset to zero by the reset pulse from IC2 Q10 after every 32 clock cycles. The display shows '00' (open circuit or



'nothing') while IC3a output is low.

When the receiver is connected to one of the wires to test, the transmitted active low pulse, if present, first synchronises the receiver by the high to low leading edge resetting both its timebase and display counters via IC3d, before enabling the counters to count the timebase clock cycles with IC3a. The number of these depends on the length of the transmitted pulse and, because both the transmitter and receiver timebases are crystal controlled, the counts are very accurate. If the test pulse is the longest (16 clock cycles) then the receiver will be able to count a full sixteen of its own clock pulses before 'reset' transfers the result to the display. If however the test pulse is shorter, then the receiver is only allowed to count a correspondingly fewer number of cycles.

Note that ST1 – ST16 *do not* correspond to the front panel numbers on the transmitter, which are the reverse way round. Hence ST1 outputs the *longest* pulse allowing the maximum of 16 counts (for wire 16), while ST16 has the *shortest* allowing only one count made by the receiver (for wire 1). Hopefully this will avoid some confusion while testing the instrument.

The input of IC3d is protected by R4 in series with clamping diodes D2 and D3, the latter being a Zener type to limit positive going inputs, as D2 alone would not provide sufficient protection against

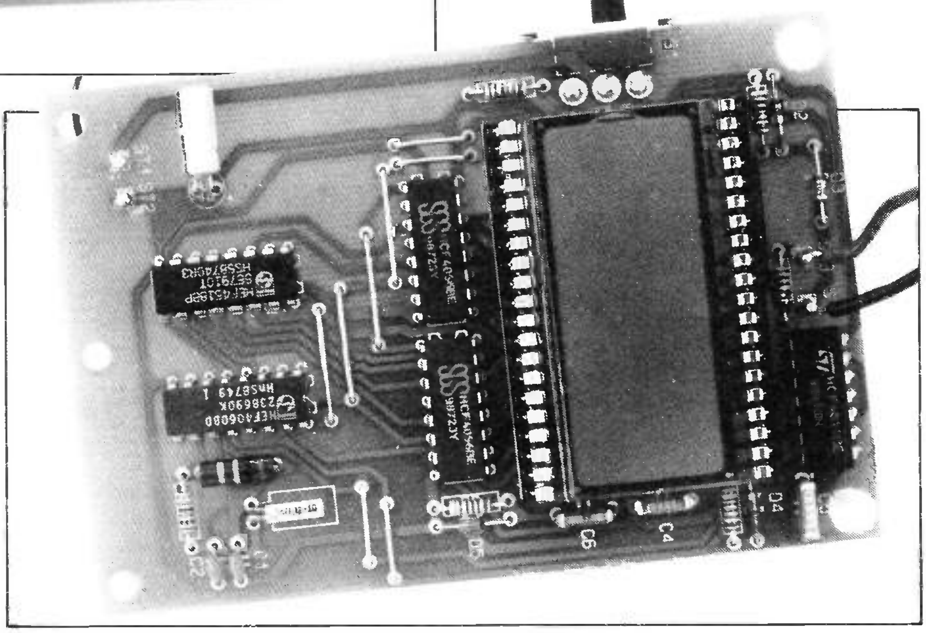


Photo 3. Transmitter and receiver assembled PCBs.

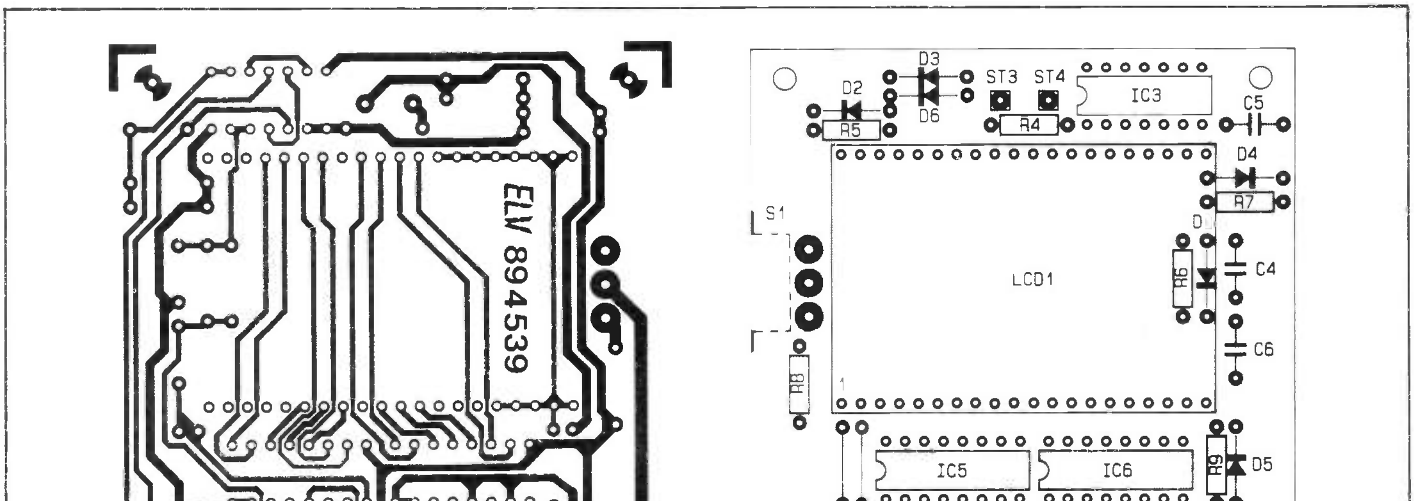


Figure 5. Printed circuit board for the receiver.

serious input overload conditions, although it serves to prevent the inputs of IC3a exceeding the chip's supply potential.

General PCB Assembly

For those readers with little experience in project building, a 'Constructors' Guide' (stock code XH79L) is available to help with component identification. This helpful booklet also contains hints and tips on soldering and constructional techniques. Please note that, unlike most other Maplin kits, this guide is *not* included in this kit.

If errors are made during assembly of the PCB, the removal of a misplaced component may be difficult without causing too much damage, so *please* double-check each component type, value and its polarity where appropriate, before soldering! Each printed circuit board (PCB) has a printed legend to assist in positioning each item correctly, see Figures 4 and 5 for the transmitter and receiver respectively, which also show the track layouts.

In each case install, solder and trim the leads from all the components ensuring than no wires stand proud of the board by more than two or three millimetres. Commence with resistors and capacitors first, and diodes last. Only after all other components have been fitted would you then carefully insert the relevant ICs into their places, making sure to correctly align the pin number 1 marker at one end of each DIL package with the legend. All the ICs in this design are CMOS types which can be at risk from static electric charge during handling, so do not remove them from their protective packaging until they are needed, and handle them carefully when you do so. All ICs have to be soldered in position, which should be done carefully with pauses of several seconds between soldering each pin. To ensure that the package lies flat on the PCB, solder two diagonally opposite pins at two corners first while pressing the device to the PCB.

Make sure that electrolytic capacitors are fitted the correct way round. The negative lead, indicated by a dark stripe and minus (−) sign on the body of the capacitor (or light stripe on a dark background), must be inserted in the hole opposite that marked as positive (+) on the PCB legend.

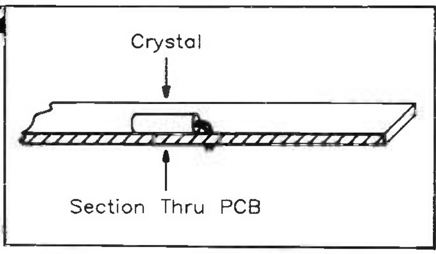


Figure 6. Mounting the crystal Q1.

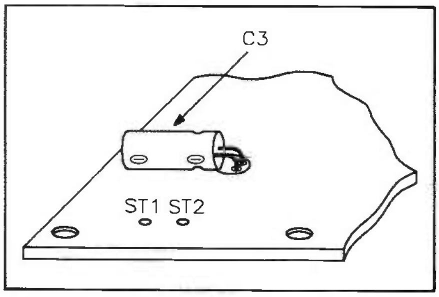


Figure 7. Mounting capacitor C3.

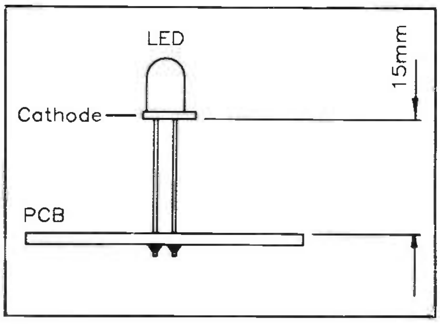


Figure 8. Positioning the transmitter power-on LED.

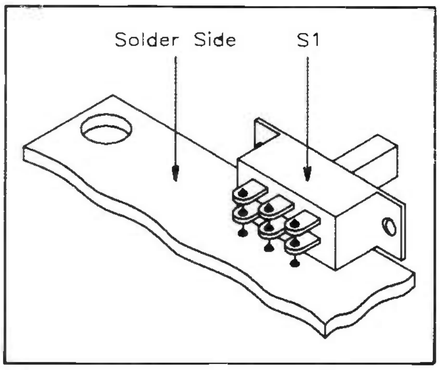


Figure 9. Mounting the receiver's on/off switch.

Transmitter Construction

The transmitter is built on a single printed-circuit board. Construction is quite straightforward with reference to the transmitter parts list and the legend in Figure 4. Begin by fitting the wire links and resistors, then the capacitors. Fit the diodes and transistor next, *but not the ICs just yet*. Crystal Q1 should be mounted flat on the PCB as shown in Figure 6, similarly so should C3 as in Figure 7.

Push the terminals of the miniature toggle switch, S1, as far as possible into its allocated holes, then solder them at the track side. Fit the LED D4 so that the lower side of its plastic body is about 15mm above the board surface, as shown in Figure 8. It may help to cut a 15mm wide strip of card for insertion between the pins to accurately position this item.

Connect the battery clip wires to solder points ST18 (+, red wire) and ST19 (−, black wire). ICs 1 to 6 can then be installed with regard to the precautions mentioned earlier.

Seventeen crocodile clips and flexible leads are provided with the kit for the transmitter. The leads should be arranged into a regular colour distribution, with either black or white for the individual 'REFERENCE' connection. Insert the free end of each lead into its respective hole in the side of the top half of the transmitter case. Make a knot in each lead on the inside to provide a strain-relief and a free length of about 10mm. Connect all 16 signal input leads, and the single reference lead, to their respective points on the PCB, bearing in mind that, as mentioned earlier, wires numbered 1, 2 and so on go to ST16, 15 etc., up to wire 16 at ST1, in 'reverse order'. Otherwise the PCB will be connected to the case top half back to front! Finally attach the chosen 'REFERENCE' wire to ST17.

Carefully fit the completed PCB into the lower half of the enclosure, and install

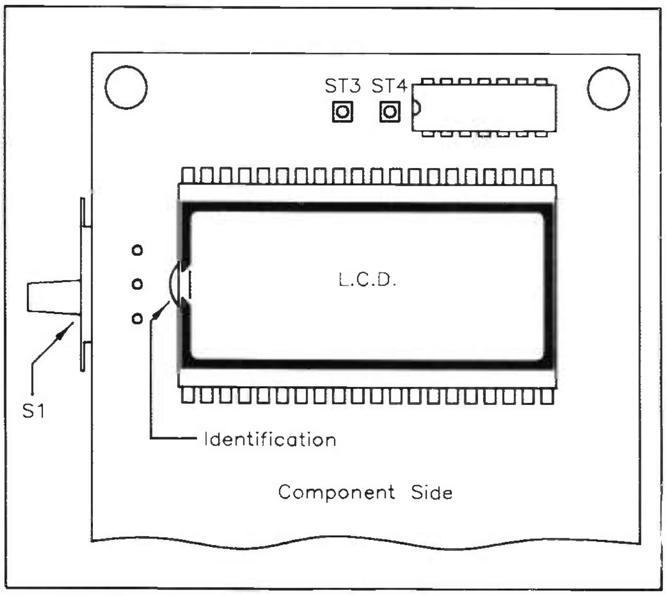


Figure 10. Orientation of the LCD.

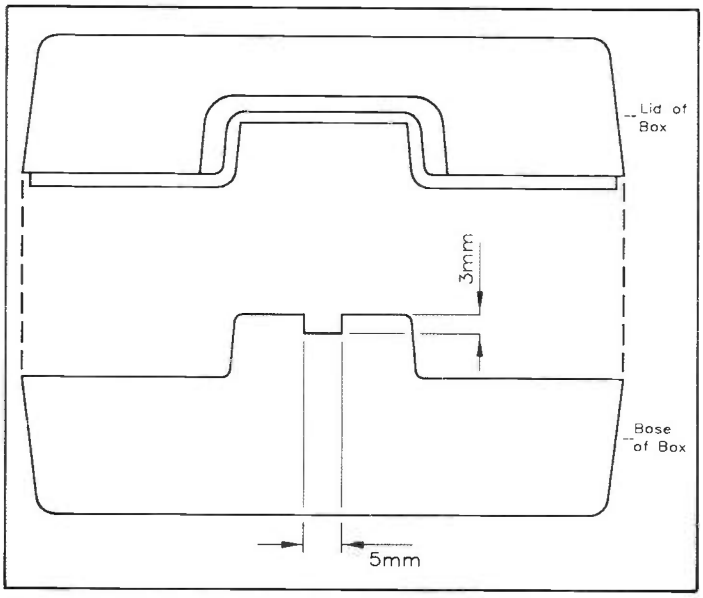


Figure 11. Receiver box cut-out details.

and connect the battery. Remove the nuts from the switch's threaded boss and place the top half of the enclosure onto the lower half, while carefully drawing out all 17 leads up to their strain-relief knots. Also make sure that the top of the LED is about level with the front panel surface. Then the top and the bottom halves of the case can be secured with the self-tapping screw provided.

Receiver Construction

The construction of the receiver is also straightforward but a few special points should be noted.

The LC display is not soldered directly onto the board but instead plugs into the pair of 20-way contact strips, which are soldered in place first. These contact strips raise the LC display a little so that its face is at the correct height for the front panel of the enclosure, but especially to prevent heating of its pins by a soldering iron splitting the glass! Do not insert the display at this stage yet.

As with the transmitter, fit the wire links and resistors followed by the capacitors and diodes. Again fit capacitor C3 and the crystal Q1 flat on the board. To fit S1, cut off three 10mm long pieces of the wire supplied in the kit and solder these at one end into the three holes for the slide switch S1. Make sure they remain vertical. Next, slide the solder terminals of S1 over the wires until S1 is flush on the board, and solder in position, but without also melting and moving the PCB solder joints on the PCB! See Figure 9 for an illustration.

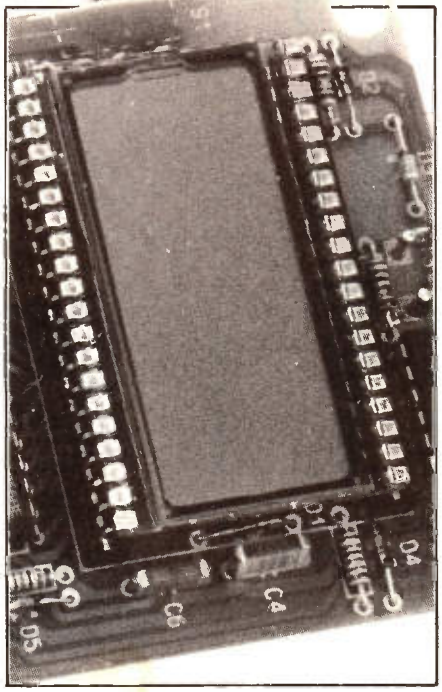


Photo 4. How the contact strips are used for the LCD.

Lastly install ICs 2 to 6 (there does not seem to be an IC1 for some reason) with the same care as for the transmitter. *Carefully* insert LCD1 into its two rows of pin connectors making sure it is the right way round according to the alignment identification illustrated in Figure 10. The result should be as shown in Photo 4. With this the PCB is practically complete. The receiver's pair of input leads are threaded through their holes and tied with a strain relief knot in the same manner as those of the transmitter. The red wire goes to ST3, the black (or white) to ST4. The battery clip red wire goes to ST1 (+), and the black wire to ST2 (−).

Turn the receiver's case front or top half front-side down, and install the PCB in it with the LC display facing down behind the window aperture. Push the PCB down until the surface of the LCD is about level with the inner front panel surface. Don't forget that these LCDs often have a thin, protective plastic film on the front glass surface which should be peeled off. The PCB is secured with two self-tapping screws at the side of the battery compartment. Apply glue beside the input terminals to secure the PCB in this area.

Remove the battery cover and assemble the two halves of the case. At the same time, as with the transmitter, draw out the two input wires and guide the battery clip wires to the battery compartment, through the slot provided. If necessary adjust the position of the battery clip in the compartment.

Join the two case halves with the screws provided, and install the battery. The wiring allocation tester is now ready for use. No alignment is required, but proper operation can be verified by directly examining each of the transmitter's outputs in turn with the receiver.

RECEIVER PARTS LIST

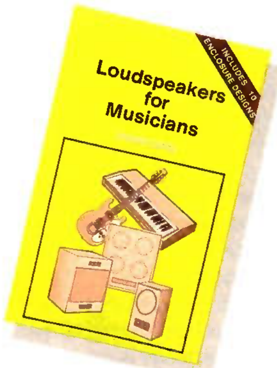
RESISTORS		
R1	20M	1
R2	33k	1
R4	10k	1
R5,R8	100k	2
R6,R7	22k	2
R9	82k	1
CAPACITORS		
C1,C2	33pF	2
C3	1µF 16V	1
C4,C5	10nF	2
C6	1nF	1
SEMICONDUCTORS		
IC2	C4060BE	1
IC3	C4011BE	1
IC4	C4518BE	1
IC5,IC6	C4056BE	1
D3	ZPD 8V2 Zener	1
D1-D5	1N4148	5
MISCELLANEOUS		
Q1	32·758kHz Miniature Quartz Crystal	1
LCD1	3½ Digit Display	1
S1	SPDT Slide Switch	1
	PP3 Battery Clip	1
	40-Way IC Contacts	1 Stp
	Test Lead with Crocodile Clip	2
	Silvered Wire	39cm

TRANSMITTER PARTS LIST

RESISTORS:		
R1	20M	1
R2	33k	1
R3	100k	1
R4,R6	10k	2
R5	68Ω	1
CAPACITORS		
C1,C2	33pF	2
C3	100µF 16V	1
SEMICONDUCTORS		
IC1	C4060BE	1
IC2,IC3	C4015BE	2
IC4-6	C4049UBE	3
T1	BC548	1
D5	ZPD 4V7 Zener	1
D1-3,D6,D7	1N4148	5
D4	3mm LED Red	1
MISCELLANEOUS		
Q1	32·768kHz Miniature Quartz Crystal	1
S1	SPDT Min Toggle	1
	PP3 Battery Clip	1
	Test Lead with Crocodile Clip	17
	Silvered Wire	39cm
	Instruction leaflet	1

The above items are available as a kit only:
Order As LP61R (Wire Alloc Tester Kit) Price £49.95

NEW BOOKS



Loudspeakers for Musicians

by Vivian Capel

Few musicians can claim also to be sound technicians. Their scene is making music, not delving into the technicalities of the complex equipment that nowadays is needed to produce it. Yet the high cost of equipment makes the prospect of constructing your own very attractive.

With electronic equipment there is little that can be done in the way of DIY unless you are one of the knowledgeable few. It is a different story with loudspeakers, however. Great savings can be had from building your own, and you do not need to be an electronics expert. Ten designs are included at the end of this book which should give results equally as good as commercial ones at a fraction of the cost.

Much of the problem in understanding technical things is that the languages of music and technology are so different. While the musician talks about semitones, tones and octaves, the technician knows them as frequencies and wavelengths. The musician listens to the timbre and tone quality of a sound, the technician measures its harmonic content.

This book looks at the subject from the musician's point of view, and although some technical terms must of necessity be used, they are explained to make them clear to a non-technical reader. It explores the nature of sound, examines different driver designs and types of cabinets, and explains why wadding is used. This is a loudspeaker book written especially for working musicians.

1991. 178 x 111mm. 170 pages, illustrated.

Order As WT47B (Speakers for Muscns) Price £3.95 NV

The Satellite Book

A Complete Guide to Satellite TV Theory and Practice

by John Breeds

The nature and extent of advances in satellite technology are remarkable. No one would question that the electronics industry is changing rapidly. Between now and the turn of the century we are likely to see new developments in satellite technology which will affect our whole way of life.

Satellite television will continue to expand and stimulate the television industry, increasing the demand and creating new markets. By 1996 a total of 46 million homes across Europe are expected to have satellite TV via cable, SMATV and direct-to-home, which represents a 40% penetration.

This book provides a broad yet fairly in-depth introduction to satellite related subjects for both technicians and enthusiasts. The chapters are organised into two broad sections; practical, and theoretical. The topic for each chapter was carefully chosen, and the text written by a recognised expert in this particular field. The result is a handbook that is both comprehensive and authoritative. Contains lots of really interesting information about the satellites, signal protocols, scrambling, signal distribution and much more.

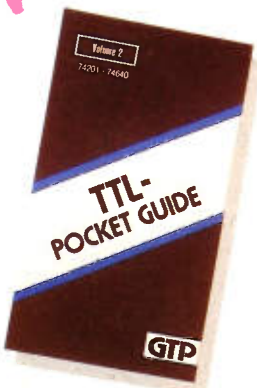
1991. 295 x 210mm. 289 pages, illustrated.

Order As WT46A (The Satellite Book) Price £27.95 NV

TTL Pocket Guide

Volume 2: 74201 to 74640

This is the second volume of the TTL pocket guide providing a comprehensive listing of all commonly used TTL integrated circuits, including products from all major manufacturers.



All the current families are covered, i.e. standard, low power, Schottky, low power Schottky, advanced Schottky, advanced low power Schottky, high speed and fast Schottky. The guide is easy to use in both format and content. Each page describes one component only and is divided into eight sections. The first illustrates the device with a schematic pin-out diagram with, where possible, a clear and simple logic diagram of the internal structure. Next, there follows a brief description of the device, providing a quick reference to the internal structure.

The next section provides details on how to use and operate the device, describing the logic levels and transitions of inputs and outputs on all the pins, plus, where required in rare instances, the connection of any additional external components that may be necessary.

The fourth section lists the major applications followed by a summary of essential data, and then a table indicating the TTL families in which the device is available. The device type number and general reference description are at the end to help make finding the required device(s) easier. There is a manufacturers' index at the back of the book, showing in tabular form which companies manufacture each device. The guide extracts all the essential data from the manufacturers' own data books and presents it in a clear and concise format.

This volume complements the TTL pocket guide part 1 and the CMOS devices pocket guide, which have already been introduced in recent issues of 'Electronics'. These brilliant little books will replace all your loose, vagrant, dog-eared data sheets, and are as crucial to logic circuit design as they are for identifying unknown devices and describing what they are doing in a circuit. We here at the editorial office have quickly established them as 'The Word' for concise, logic IC info. Why haven't you?

English translation of the German original. 1991. 185 x 105mm. 348 pages, illustrated.

Order As WT49D (TTL Pocket Guide 2) Price £11.95 NV

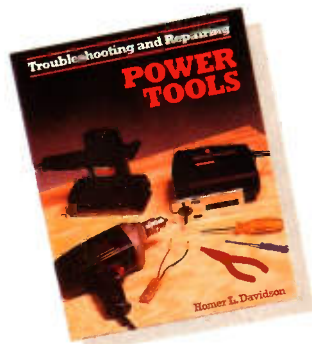
Troubleshooting and Repairing Power Tools

by Homer L. Davidson

Whether you are a woodworker, metalworker, machinist or general DIY'er, you need this time and money-saving guide to the repair of power tools, which will help you diagnose and repair virtually any tool in your workshop, from small hand-held drills, sanders, power screwdrivers to bench-top saws, grinders, routers and lathes.

The only repair manual aimed specifically at domestic power tool users, this book covers everything you need to know to keep your tools in good working condition. The main subjects deal with the proper care and maintenance of power tools, including cleanliness, lubrication, rust prevention and keeping cutting edges sharp; power tool components with emphasis on universal, split-phase, capacitor and DC motors; common easy repairs requiring only basic skills and tools; advanced troubleshooting and repair procedures, illustrated step-by-step with photographs for specific power-tool problems. Special safety considerations are also dealt with while tackling the repair of each tool.

A complete glossary of terms is included, and techniques are described for overhauling and renewing cheap second-hand power tools. Also described are two simple electronic projects for a universal power tool speed controller and a ni-Cad battery charger. The book is a must for anyone who owns even only a small selection of power tools. The advice given will ensure that they last a lifetime.



__WARNING:__ this is an American book and there are repeated references to the US 120V mains standard. You should of course read these as 240V for appliances in the UK, and have a correspondingly greater respect for the higher voltage level.

American book. 1990. 235 x 187mm. 260 pages, illustrated.

Order As WT51F (Power Tools) Price £14.95 NV

The PC Music Handbook

by Brian Heywood and Roger Evan

Since the IBM Personal Computer (or PC) was introduced in August 1981, it has become one of the most popular business and personal computers ever designed. This proliferation of personal computing power has brought the possibilities of computer music within the budget of most amateur and professional musicians. Power that, less than a generation ago, was confined to universities and the rich.

This book takes you through the creative possibilities of the PC and is a guide through the twin minefields of choosing software and hardware for making music. It will be of interest to the professional musician, the gifted amateur or the just plain curious. It explains the possibilities of computer music and covers what is currently available in both software and hardware. It advises which pitfalls to avoid, and suggests a number of possible music systems that could bring out the best in your musical skills or creativity.

Contents include: music as text; the MIDI connection; MIDI sequencing on the PC; using the PC for remote control; the PC as a sound source; bits and the PC; and MIDI specifications and on-line communications among the appendices.
1991. 216 x 138mm. 160 pages, illustrated.

Order As WT53H (PC Music Handbook) Price £8.95 NV

A Concise Introduction to Microsoft Works

by N. Kantaris and P.R.M. Oliver

'Microsoft Works' is an easy to use, integrated package for a PC which incorporates four modules: word processing, spreadsheet with graphics, database, and communications. The modules are downward compatible with earlier versions (version 2.0 is dealt with in this book). The package comes with its own front-end graphic interface and full documentation.

This book was written to help the beginner, and the material is presented on a 'what you need to know first appears first' basis, although the underlying structure is such that you don't need to start at the beginning. Experienced users can go to any of the self contained sections for reference.

'Microsoft Works' is operated by selecting commands from menus or by writing special 'macros' which chain together menu commands. Each method for accessing the package is discussed separately, but the emphasis is mostly in the area of the menu-driven command selection. Using a mouse is not essential but certainly saves time.

The power and versatility of 'Microsoft Works' is evident in its integration which allows data from any module to be quickly and easily transferred into any of the other modules. The word processor includes a spell checker and a thesaurus.
1991. 198 x 130mm. 130 pages, illustrated.

Order As WT42V (Microsoft Works) Price £4.95 NV

Advanced MIDI User's Guide

by R.A. Penfold

Although still regarded by many as nothing more than a means of getting one instrument to follow the playing of another, MIDI actually has capabilities that go well beyond this simple slaving arrangement. MIDI can be used as a means of storing and replaying pieces of music, for the control of sophisticated systems having more than a dozen instruments, and can even be used to control ancillary equipment such as mixers and effects units.

There seem to be few gadgets associated with electronic music which do not sport a set of MIDI sockets these days. MIDI has 'come of age', and it is crucial to much of today's electronic music making.

This book is for those who wish to go beyond the very basic slaving and sequencer set-ups, and who wish to exploit MIDI to the full. The topics covered include: MIDI modes and codes; MIDI signal routing and patch bays; System exclusive messages and their practical uses; MIDI trouble-shooting including, using a computer as a diagnostic tool; MIDI gadgets, channelisers, filters, merge units, pedals etc.; synchronisation using MIDI time code, SMPTE etc.; the basics of MIDI programming; and MIDI hardware specification. Anything within reason can be accomplished with MIDI – this book shows you how.
1991. 216 x 138mm. 192 pages, illustrated.

Order As WT52G (Adv MIDI User Guide) Price £9.95 NV

The Morse Code for Radio Amateurs

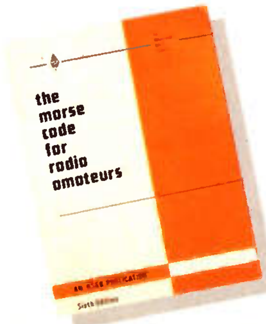
Sixth Edition

by Margaret Mills G3ACC

From time to time the cry is heard that the telegraphic method of communication is nearly dead and that in the near future all communications will be by means of telephony. Nothing could be further from the truth – telegraphy is still the backbone of maritime communication.

In the field of Amateur radio, a vast number of operators continue to use telegraphy. In fact many of them regard it as the most reliable method of communication. Expeditions in remote parts of the world still maintain contact with civilisation by means of the Morse Code. Much of the 'rare' DX heard on the amateur bands emanates from telegraphy stations.

It is an international requirement that every person holding a radio amateur licence shall have satisfied the licence-issuing authority of their country that they have a sound knowledge of the Morse Code. Slow morse practice



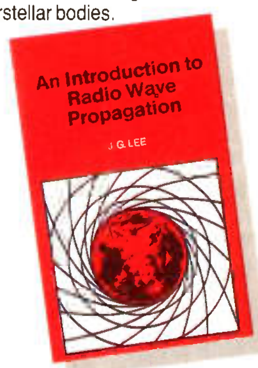
transmissions organised by the Radio Society of Great Britain are radiated daily on frequencies in the amateur bands. Constant practice is essential if a good speed is to be achieved. The book shows the morse alphabet, procedures and includes seven lessons.
1987. 248 x 186mm. 20 pages, illustrated.

Order As WT36P (Morse Code Am Radio) Price £3.95 NV

An Introduction to Radio Wave Propagation

by J.G. Lee

Radio wave propagation is one of the more important discoveries made in the early 20th century. Although technology lagged behind, early experimenters pursued this newly discovered phenomenon eagerly. In understanding the physics of propagation, they were discovering more about our Universe and its workings. The worlds around us have always been fascinating, and here was a means of spanning not only our own Earth, but of reaching out to other interstellar bodies.



Radio wave propagation has its origins in the world of solar physics. The Sun's radiation provides the mechanism for the formation of the ionosphere. How this is done and how it provides long distance communication is carefully explained. Non-ionospheric propagation, including 'moonbounce' or satellite communications is covered as well.

This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find the explanations of the propagation phenomena which both experience in their pursuit of communications enjoyment.
1991. 178 x 111mm. 124 pages, illustrated.

Order As WT48C (Intro Radio Wave Prp) Price £3.95 NV

Square One

A First Course in the Theory and Practice of Electronics

Part 9 by Graham Dixey C.Eng., M.I.E.E.

RC Phase-Shift Oscillators

It was established in the last article that, for a circuit to oscillate, it is necessary to satisfy two requirements, those for the *loop gain* and *loop phase shift*.

The *loop gain* is the product of amplifier gain and feedback circuit loss, and which must equal *unity*.

The *loop phase shift* is the sum of amplifier phase shift and feedback circuit phase shift and must equal 360°.

The other consideration is that there must be some way in which the frequency of the oscillations can be predicted (and controlled). In the case of the LC oscillator, oscillations take place at the natural resonant frequency of the LC tuned circuit, and frequency can be controlled by varying either L or C.

We now come to an important class of oscillators for which the same basic principles hold (of course), but the way in which they are applied is different. They are know generically as RC oscillators and they rely upon the gain/frequency and phase/frequency behaviour of particular combinations of resistance R and capacitance C. There are several different circuits of this type, all capable of generating a sinewave output, even though the resonance phenomenon is absent. In these circuits we shall still be able to identify the amplifying section and the feedback section, the latter also determining the frequency of oscillation.

Phase-Shifting Networks

Figure 1 shows two 'inverted L' RC networks, each of which produces a progressive change in phase with a variation in frequency. In the case of Figure 1(a), the phase shift between the input voltage V_1 and the output voltage V_2 has a 'leading angle' that *increases* with *decreasing* frequency. This phase angle approaches a limit of 90° as the frequency approaches a value of zero. By contrast, the circuit of Figure 1(b) has a 'lagging angle' which *increases* with *increasing* frequency. This also has a limiting value of 90°, which occurs at the theoretical limit of infinite frequency but is closely approached at a value much less than that!

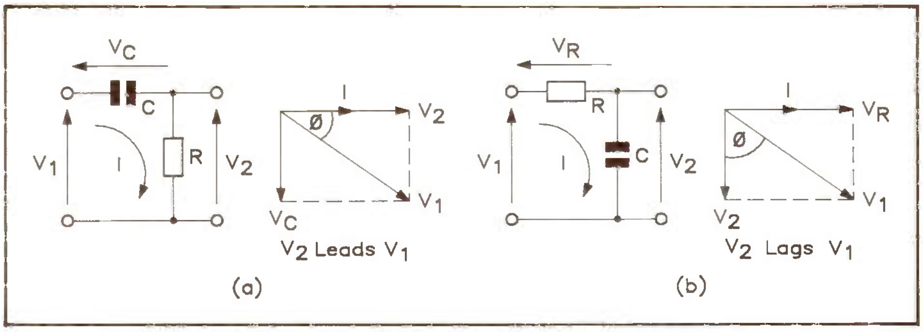


Figure 1. Two inverted-L phase shift networks.

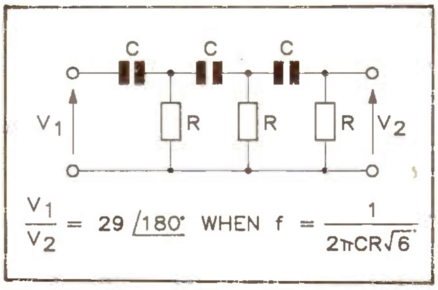


Figure 2. A three-section ladder network.

Since the maximum theoretical phase shift that a single circuit of either of the above types is capable of producing is only 90°, it is necessary to 'cascade' (connect in series) several of these circuits in order to produce phase shifts in excess of this figure. We must ask, 'what is the phase shift required if the circuit is to be used as part of an oscillator, and how many RC sections will then be needed?' In an oscillator, as stated above, the total loop phase shift has to be 360°. If a transistor, in the common emitter mode, is used as the amplifying device, this will provide a phase shift of 180°, leaving the RC circuit to provide the remaining 180°.

Two RC circuits would be insufficient since their limiting phase shift of 90° each is more theoretical than practical. Three sections would be feasible since each can be expected to have to contribute only 60° or so of phase shift each. Note the 'or so' qualification in the last sentence. When several sections are series connected, following sections load previous ones to some extent so that the actual phase shift per section is not exactly equal, though the difference may often be academic. Be that as it may, there will always be some frequency at which the *total* phase shift has the required value of 180°.

Figure 2 shows what is known, for fairly obvious reasons, as a three-section 'ladder network', of the type commonly used in phase-shift oscillators. The one illustrated here uses the option of series capacitors and shunt resistors, based on the single section of Figure 1(a). As an alternative, the ladder could have been constructed by cascading the sections of Figure 1(b). It is possible to show that the latter type is more suitable for use with BJTs and the former type with FETs. Notwithstanding, circuits using the former arrangement operate quite satisfactorily with modern BJTs, and the configuration is actually more convenient. Figure 3 shows a complete ladder network phase-shift oscillator.

The Ladder Network Oscillator

The ladder components may not appear to be arranged exactly as in Figure 2 but can be identified as follows: ladder capacitors are C1, C2 and C3; ladder resistors are R2, R3 and R4. However, R2 is actually shunted by the resistor R1 and the input impedance of the transistor, which

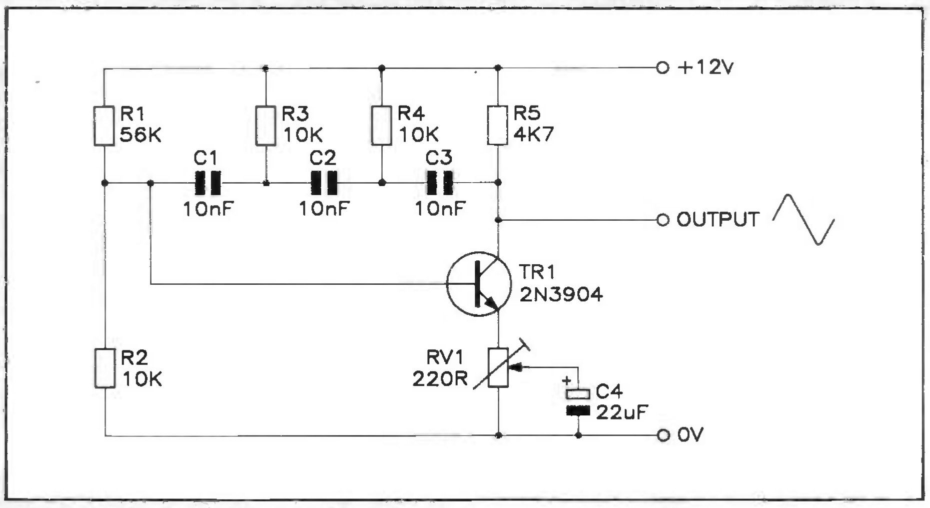


Figure 3. A ladder network oscillator.

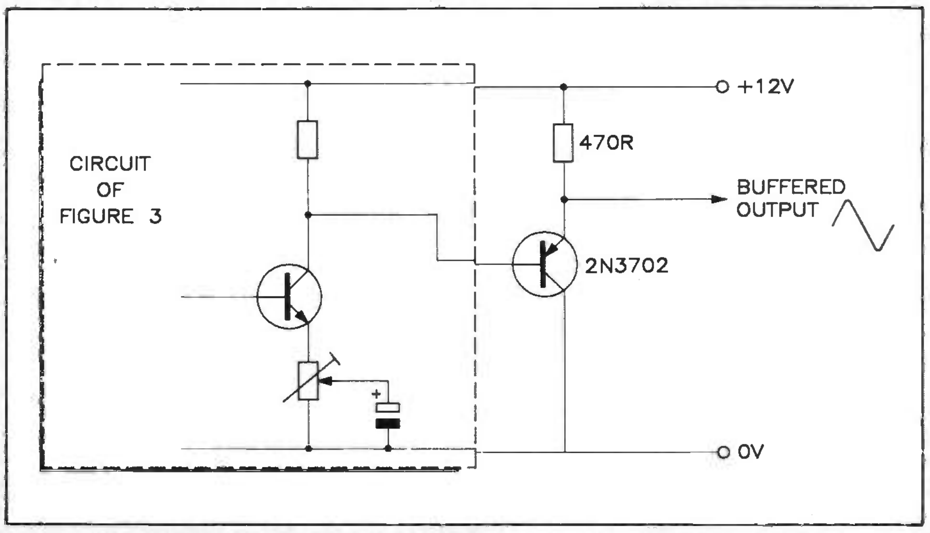


Figure 4. The circuit of Figure 3 with a 'buffered' output to drive low impedance loads.

reduces its effective value somewhat. The effect of this is to give a shift in the value of the frequency obtained compared with the expected value. The approximate value of the latter can be predicted from the formula:

$$f = 1 \div (2 \times \pi \times C \times R \times \sqrt{6})$$

As stated in Figure 3, the assumption is made that the three resistors are equal (each of value R) and all three capacitors are equal (each of value C).

It is possible to trim the frequency slightly by making R4 variable, e.g. a 10k preset resistor in series with a 4k7 fixed resistor.

The parallel combination of preset resistor RV1 and capacitor C4 governs the gain of the amplifier by controlling the amount of negative feedback applied. Thus, the circuit has both 'positive' feedback (through the ladder, from collector to base) and 'negative' feedback. Adjustment of the latter, by means of RV1, allows the loop gain to be controlled. When the loop gain equals unity, the circuit oscillates and develops a clean sinewave. If the loop gain exceeds unity, distortion results, and if the loop gain is less than unity, then of course, the circuit doesn't oscillate at all. If the circuit has been built correctly but doesn't oscillate as soon as the power is applied, rotation of RV1 should cause it to spring into life. A 2N3904 transistor has been specified but, in practice, the choice is not critical provided that the transistor chosen has adequate gain. Other BJTs such as BC108, BC182 should be equally suitable.

The loss of the ladder feedback network is 29:1 in voltage terms. This means that, if the loop gain is to be unity, the voltage gain of the amplifier must be 29. Since voltage gain is proportional to the value of the collector load resistor, the latter has to be of reasonably high value. In this case it is 4·7k. However, if the output of the oscillator is to drive another circuit (as is bound to be required in a practical situation), then the input impedance of the driven circuit will appear in parallel with the 4·7k resistor. This will decrease its effective value and reduce the voltage gain. While this may be compensated to some extent by readjustment of RV1, there will be a limit to this (reached when the wiper is at the top of the track). Therefore, if this situation arises, it will be necessary to insert a 'buffer' stage, such as an emitter follower between the oscillator and the driven stage. Figure 4 shows the circuit of Figure 3 with a 'buffered' output, obtained with a PNP emitter follower, that is directly coupled (no coupling capacitor used) from the oscillator output. This will now drive low impedance loads directly without affecting the oscillator's performance.

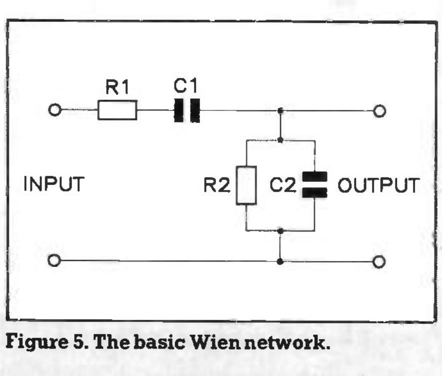


Figure 5. The basic Wien network.

The Wien Network

While the ladder network oscillator has the merit of simplicity, it has the distinct disadvantage that it is awkward to vary frequency very much. In fact, for practical purposes, it is virtually impossible to make other than nominal variations in the oscillator frequency by the method described earlier. Therefore, if a variable frequency audio oscillator is required, we must look elsewhere for inspiration. It is found in the Wien network, which is then developed, as we shall shortly see, into the Wien bridge.

The Wien network is shown in Figure 5, and is seen to consist of a series RC combination (R1C1) itself in series with a parallel RC combination (R2C2); the output from the network is taken from the junction of these two RC combinations.

Assume for the moment that R1 does not equal R2 and C1 does not equal C2. Now, if a constant amplitude, variable frequency voltage is applied to the input and the amplitude and phase of the output are monitored, it will be found that there is one particular frequency at which input and output are exactly in phase. At this frequency, the loss of the network is just 3:1. Or, put another way, the gain is ⅓. The frequency in question is given by the formula:

$$f = 1 \div (2 \times \pi \times \sqrt{R1 \times R2 \times C1 \times C2})$$

If, as is quite usual, R1 = R2 (=R) and C1 = C2 (=C), then the formula simplifies to:

$$f = 1 \div (2 \times \pi \times R \times C)$$

The Wien Bridge Oscillator

On the face of it, and in the light of previous discussion, the Wien network, with its gain of ⅓ and zero degrees phase shift, can be used to produce oscillations if it is used as the *feedback* network between output and input of an amplifier of gain ×3 and zero phase angle. This would give the required loop gain of unity ($\frac{1}{3} \times 3 = 1$) and zero loop phase shift. Since a single common emitter stage has a phase shift of 180°, two such stages will be required to satisfy the phase angle criterion – 180° + 180° = 360° (0°). The gain would then certainly be much greater than the required value of 3, probably in the hundreds. Rather than throw the excess gain away, it can be put to good use. The usual approach is to combine the positive feedback that is required for self-oscillations together with large amounts of negative feedback, the balance between these opposing forces acting, as we shall see, to hold the oscillations at constant amplitude; a generally desirable characteristic in oscillators.

The way in which this balancing act is managed is by including the Wien network in a bridge, which is completed by two resistive components R3 and R4 in Figure 6. In the manner of all bridges, an energising voltage (E_b) is applied across the two vertical 'nodes' (points A and B) and the imbalance voltage, 'e', that may result, appears between the horizontal pair of nodes (points C and D). To produce oscillations, a high gain amplifier is used (Figure 7), usually of the Op-amp type. The input of this amplifier is the imbalance voltage, 'e', and the output is used as the bridge energising voltage E_b. In this way a loop of dependence is set up.

Obviously there must be an imbalance of voltage from the bridge for the amplifier to amplify in order to develop the output which is the energising voltage for the bridge. This is the loop of dependence mentioned above. The amplifier input is the difference between the voltages at nodes C and D.

The voltage at node C is the output of the Wien network of Figure 6. This is a positive feedback voltage.

The voltage at node D depends upon the relative values of R3 and R4, these forming a potential divider across the amplifier output. If R3 = 2k and R4 = 1k then the proportion of E_b appearing across resistor R4 is equal to R4 ÷ (R3 + R4). Putting in the values of these two resistors gives a result of ⅓. It is a fact that the ratio of these two resistors defines the gain of the amplifier shown in Figure 7, the gain value being the reciprocal of this ratio. Since the ratio in this instance is ⅓, this gives a gain value of 1 ÷ (⅓) which is, of course, simply 3! Does this value seem familiar? It should do since it is the value of gain that we said earlier was needed in order to produce a loop gain of unity. This figure of 3 for the amplifier gain is properly referred to as the 'closed loop gain', since the internal gain of the amplifier on its own cannot be altered by external components but remains at its very high value, perhaps as high as 10^5. This latter value of amplifier gain is know as the 'open loop gain'.

Because the amplifier has such high open loop gain it only requires a very small input to develop a substantial output voltage. The input is, as we have seen, the bridge imbalance voltage, 'e'.

To take some real figures, if the output of the amplifier is to be 2V RMS and the amplifier gain is 10^5, then the imbalanced voltage has only to be 2 ÷ 10^5 = 20 microvolts.

This means that the imbalanced voltage is very sensitive to changes in the values of either R3 or R4. This naturally leads on to the next consideration, namely how to ensure that the amplitude of the oscillation is constant. What is needed is some form of automatic control over the amplitude of the output. The principle is as follows.

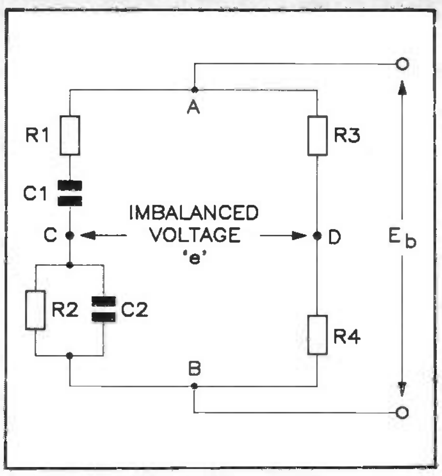


Figure 6. The Wien 'bridge' network.

Either R3 or R4 can be made a particular resistive element (not a resistor as such) whose resistance depends upon the current flowing in it. This is in contrast to a normal resistor, in which the resistance value is independent of the current. There are two choices.

If the choice falls on R3, then the resistance of this element must *decrease* with an *increase* in current. It is then said to have a 'negative temperature coefficient of resistance' (written as NTC for short). Examples of such devices include certain types of thermistor and semiconductor diodes.

If instead R4 is chosen, then the resistance of this element must *increase* with *increase* in current. It is said, therefore, to have a 'positive temperature coefficient of resistance' (PTC). An example of such a device is a filament lamp.

The auto-stabilising action works as follows. Suppose that R3 is a NTC device. If the value of the output voltage tends to increase (for whatever reason), the current flowing in the path through R3 and R4 also tends to increase since the output voltage is across these two resistors in series. As a result, the resistance of R3 reduces (the NTC action), the ratio R3/R4 thus reduces and the voltage at the node D increases. Since this is a negative feedback voltage, the amplifier closed loop gain drops slightly, just enough to cause the amplifier output to return to its original level. A similar compensating action takes place if the output voltage tends to fall. In this case, the current through R3 and R4 reduces, the value of R3 rises, the ratio R3/R4 increases and the amount of negative feedback is reduced. As as result, the closed loop gain of the amplifier increases and the output is restored to its correct value.

In fact the compensating action is more effective than the above explanation implies. In this discussion it appears that changes in the output voltage actually occur and are then corrected. What really happens is explained by the word 'tends', used in the above description. Any attempt on the part of the output voltage to change its value is countered by the controlling action before it has a chance to happen. The exception is where changes at the output happen too quickly for the 'current sensitive element' (e.g. the thermistor) to be able to follow them. The latter has a certain amount of 'thermal inertia' which has to be overcome before its resistance follows the current variations. Thermistors used for this particular function are of special construction and quite expensive.

It is now worth returning to the terms positive and negative feedback, whose significance in this particular circuit may not have been fully appreciated. First, the terms themselves, taking positive feedback to begin with.

When a signal is fed back from the output of an amplifier to its input, such that after further amplification it reappears at the output in the same phase as when it started, then the feedback is said to be positive. Clearly the fact that the amplified feedback signal is in the same phase as the output voltage means that it is assisting it. This happens deliberately in oscillators, as we have seen. The loop phase shift in such a case is 0° (360°).

If, however, the signal fed back is of such a phase that, after being amplified, it opposes the output, then the feedback is negative. This type of feedback is used in certain amplifier designs because of the benefits that it confers.

Note, that in both of the above explanations I have spoken of the amplified signal opposing the 'output' of the amplifier. This is a viewpoint which is

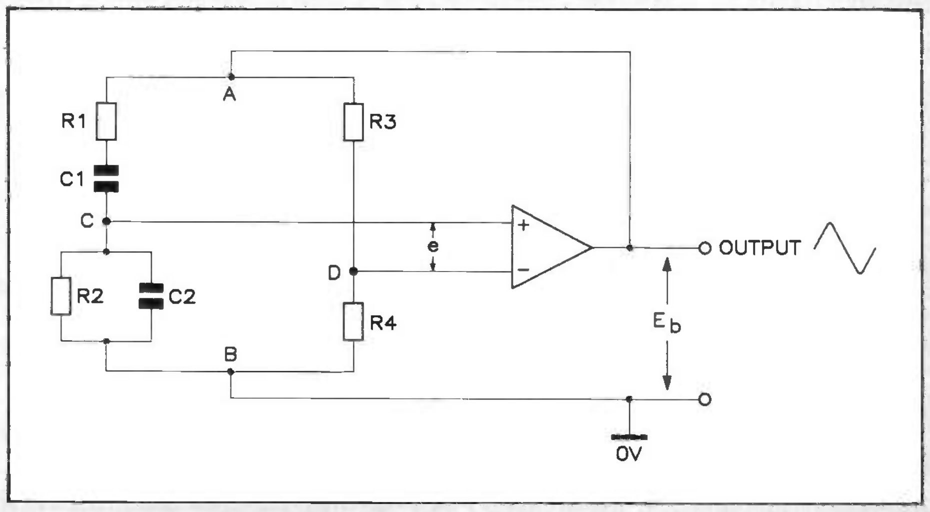


Figure 7. Basic Wien bridge oscillator.

consistent with the current theme, that is the oscillator. An alternative approach is to consider that the fed back signal opposes the 'input' to the amplifier; this approach is, however, more consistent with the subject of feedback amplifiers where an external input signal can be identified. In the case of an oscillator, there is no external input, once oscillations start they sustain themselves by means of the positive feedback loop described.

Now that the terms are understood, refer to Figure 8. The output of the amplifier feeds a signal back to both of its inputs. These are marked with + and – signs, and are known as 'non-inverting' and 'inverting' inputs, respectively. The phase shifts between input and output are 0° for the '+' input and 180° for the '–' input. The '+' input is fed from the output of the Wien network while the '–' input is fed from the junction of R3 and R4.

It should now be obvious that the voltage fed back to the '+' input produces positive feedback:- zero phase shift through the Wien network and zero phase shift through the amplifier, giving zero loop phase shift. This occurs only at the frequency at which the phase shift of the Wien network is zero, which is why the circuit oscillates at this frequency.

In contrast, the voltage fed back to the '–' input produces negative feedback, since R3 and R4 produce no phase shift but the amplifier produces 180° of phase shift, giving a total loop phase shift of 180°.

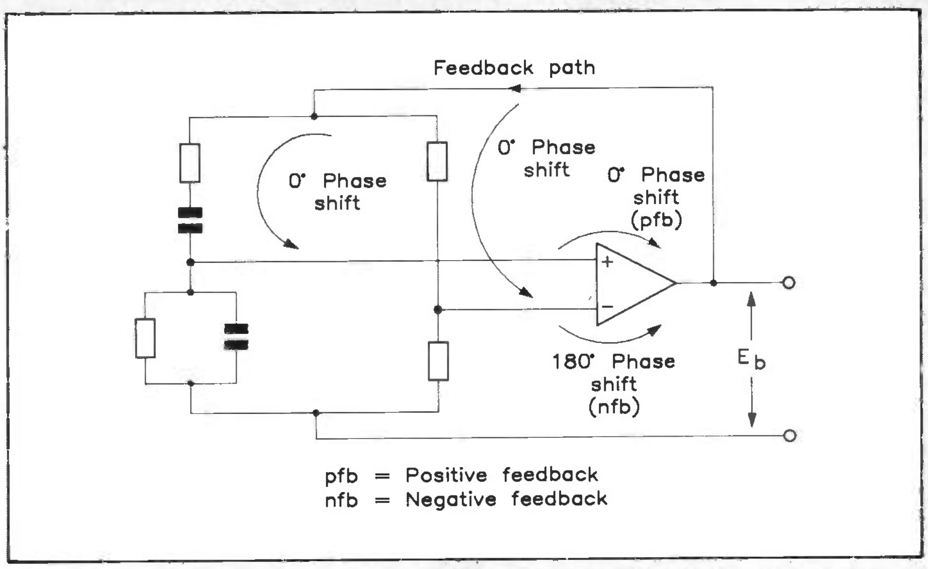


Figure 8. Positive and negative feedback in the Wien bridge oscillator.

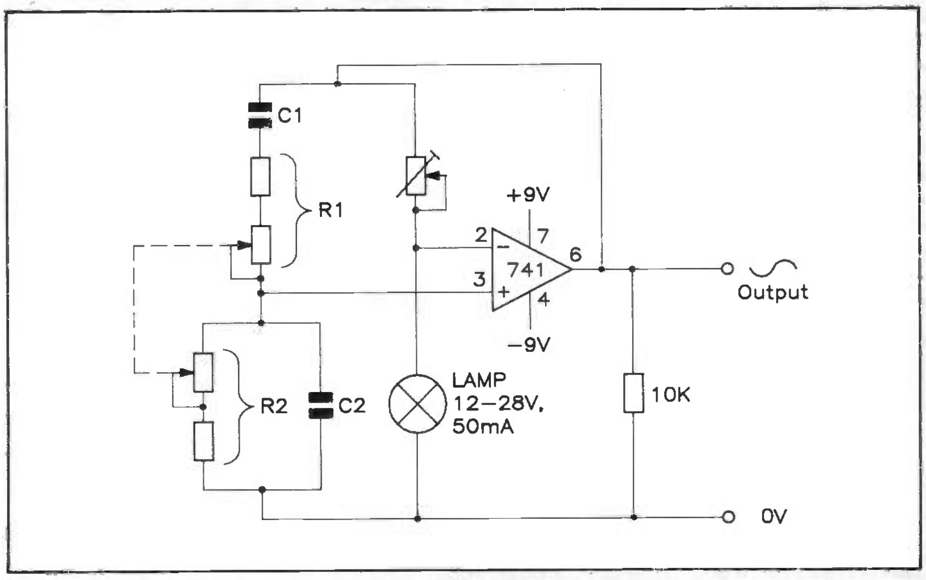


Figure 9. Practical Wien bridge oscillator; Circuit 1: lamp stabilised.

How do the Oscillations Start?

The self-sustaining oscillator may seem somewhat like a 'chicken and egg' situation. When it is oscillating, the output is fed back to be re-amplified to sustain it, i.e. it supplies its own input once it is going. But how does it get going in the first place? No output, no input; no input, no output!

In the case of LC oscillators, the answer may seem obvious. We have really explained it already. The LC circuit, as soon as it is supplied with energy (by the capacitor acquiring a charge from the d.c. supply) starts to resonate, or oscillate, at its natural frequency. This is fed back and the cycle starts. But what about RC oscillators, where the phenomenon of resonance is absent?

The explanation for the ability of an oscillator of this type, or indeed any type, to be self-starting, can be explained by what may seem a somewhat obscure idea. It is based upon what is known as 'noise'. This is present in all electronic components and conductors and is assumed to be a small, random voltage signal that is so complex that it contains components at all frequencies from zero to infinity! The theory is that, no matter how small this voltage, when the oscillator circuit is first switched on, some noise will be present at the input of the amplifier. A component of this noise will exist at the desired frequency of operation, which will then be amplified. When the signal has such a small value the loop gain is greater than unity and the oscillations increase rapidly (virtually instantaneously) in amplitude. As they do so the loop gain falls until, when the oscillations are of full amplitude, the loop gain has fallen to unity. The circuit then oscillates with constant amplitude. This behaviour, whereby the initial value of the loop gain is very large and reduces as the signal builds up, is a common and necessary feature of oscillators in order to stabilise the amplitude of the oscillations. Naturally the reason that the circuit oscillates at the required frequency is because of the frequency selective nature of the RC network which favours the build-up of oscillations only at that frequency for which the phase shift has the desired value.

Practical Sinewave RC Oscillators

Figures 9 to 13 show theory put into practice, offering several variations on the basic circuit and ending with a simple test oscillator that will provide a variable amplitude sinewave output with a choice of four spot audio frequencies.

Figure 9 shows one of the ways mentioned earlier in which amplitude stabilisation can be obtained. The non-linear component in this case is a small filament lamp (positive temperature coefficient) and its rating is important. It must be a very low current type, less than 50mA, with a voltage rating in the range 12 – 28V. It is placed in the lower arm of the bridge. If you can track one of these lamps down, this circuit works extremely well and has been used as a BTEC OND project with excellent results. In order to set the correct amount of negative feedback for oscillations to occur, the upper arm of the bridge is a preset variable resistor. This should be rotated until the circuit oscillates and develops a clean output waveform.

The frequency variation is obtained by an inexpensive, linear two-gang potentiometer and a wider frequency range is possible by switching banks of capacitors, as shown in Figure 12, giving several overlapping frequency bands. It is quite easy to cover the range from 10Hz – 100kHz, or wider if desired, in this way. The fixed resistors, in series with each of the potentiometer sections, are each part of the total frequency-determining resistance. They are included so that, when the potentiometer is at the end of the track giving zero resistance, there is still some resistance in circuit. Not only does this stop the oscillator frequency from rising rapidly towards, infinity at this end of the track (resulting in oscillations dying) but it determines the maximum frequency required.

An alternative method, easier and slightly cheaper to implement, is the diode stabilised circuit of Figure 10. Semiconductor diodes have a negative temperature coefficient and must, therefore, be placed in the upper arm of the bridge. Two are used in an inverse-parallel (known as back-to-back) arrangement. The preset resistor is, in this instance, placed in parallel with them, the lower arm being a fixed resistor. In other respects the circuit functions similarly to that of Figure 9.

The final variant of the Wien bridge oscillator is the thermistor stabilised circuit of Figure 11. Thermistors are often thought of as fairly cheap devices but the one required for this circuit certainly doesn't fall into that category! The type required is a very low power device with the type number R53. At the time of writing it costs £5.95. It is, however, a very effective stabiliser, suitable for professional equipment. The previous types of circuit do offer very good performance so the greatly increased expense of this device is probably not really justified for the average experimenter.

Returning now to Figure 12, this is probably more or less self explanatory. As mentioned earlier, frequency can be varied by varying either R or C in the Wien network. Why not vary both in the manner shown? Since two-gang potentiometers are readily available and fairly cheap, one can be used to give continuous frequency variation between some specified minimum and maximum values. These limits can be changed by simultaneous switching of both capacitors in the Wien network, providing a number of different bands. Switched and continuous frequency variation obtained in this way is often referred to as 'coarse' and 'fine' control respectively. This figure includes full details of the component values required to give four nominal frequency ranges in the audio-frequency spectrum.

Finally, Figure 13 shows the circuit of a simple piece of test gear using a sinewave oscillator. In order to avoid the complications of Op-amps and their dual supply rails, but still provide a useful circuit, the ladder network oscillator, plus an emitter follower output stage to boost the power level somewhat, is used. Four spot frequencies are provided: 10Hz, 100Hz, 1kHz and 10kHz, a useful enough range to provide test signals for experimenting on audio circuits. The output level is variable between zero and maximum, using a simple potentiometer. The construction should be straight-forward, on a small piece of stripboard.

In the next installment we move away from sinewaves and look at some of the circuits that can be used for generating other types of waveforms.

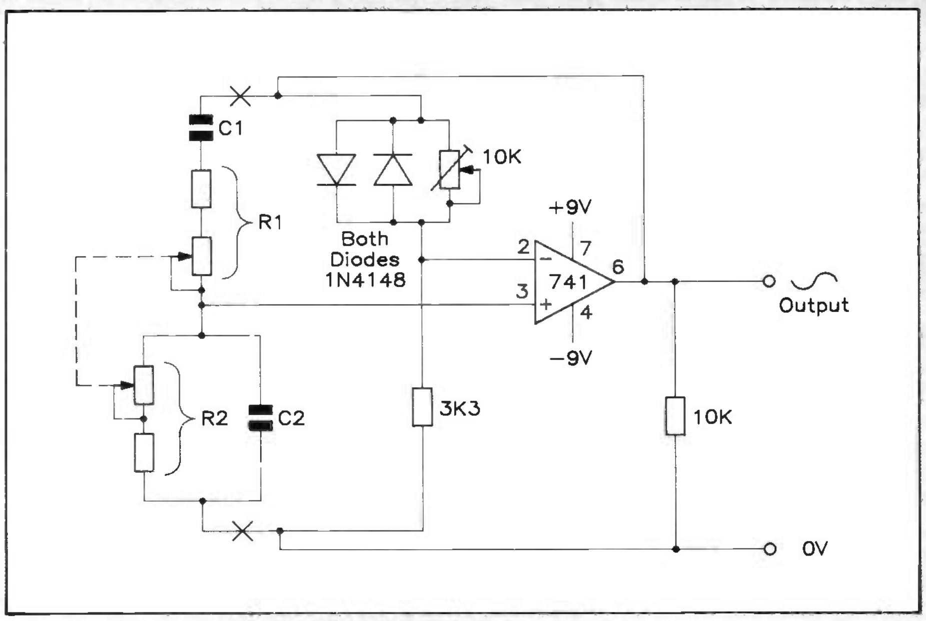


Figure 10. Practical Wien bridge oscillator; Circuit 2: diode stabilised.

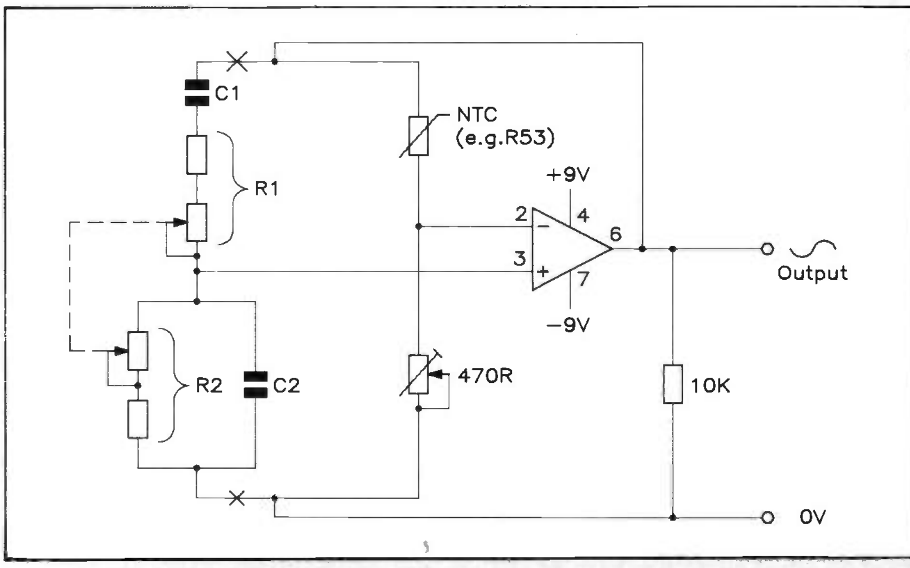
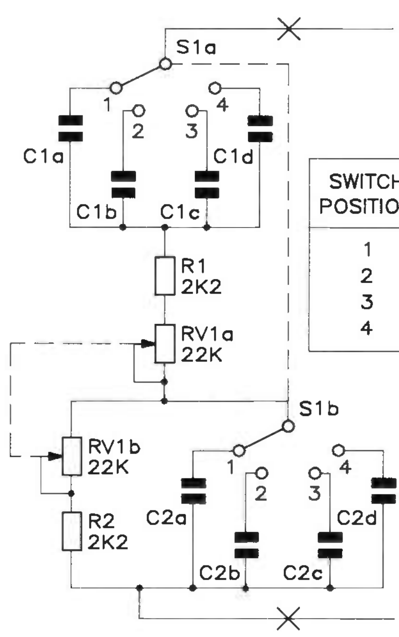


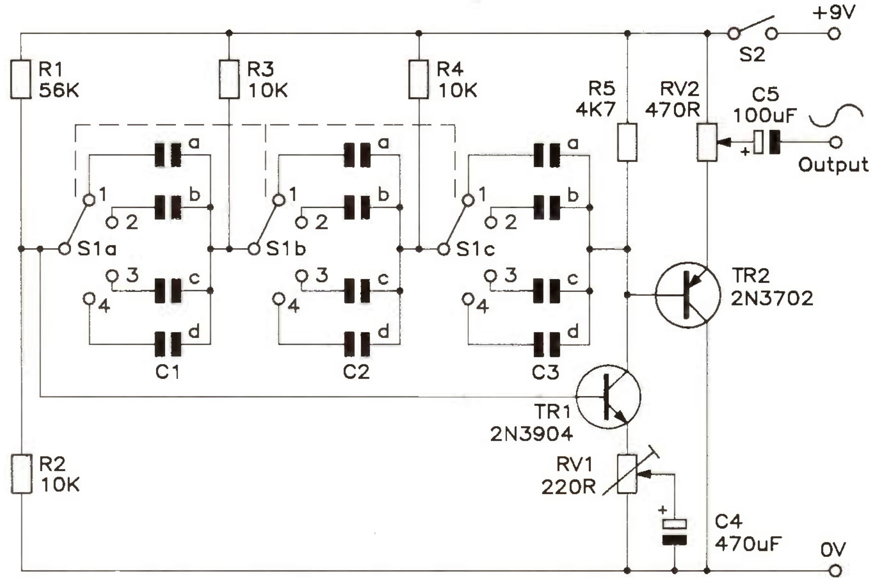
Figure 11. Practical Wien bridge oscillator; Circuit 3: thermistor stabilised.



SWITCH POSITION	FREQUENCY RANGE	CAPACITORS SELECTED	CAPACITOR VALUES
1	1–10Hz	C1a/C2a	6.8uF
2	10–100Hz	C1b/C2b	680nF
3	100Hz–1kHz	C1c/C2c	68nF
4	1kHz–10Hz	C1d/C2d	6.8nF

N.B. Frequency ranges given are nominal. Actual ranges overlap slightly.

Figure 12. Frequency variation in the Wien bridge circuit, using band switching and continuous control.



SWITCH S1 POSITION	FREQUENCY	CAPACITOR REFERENCE AND VALUE
1	10Hz	(a) 680nF
2	100Hz	(b) 68nF
3	1kHz	(c) 6.8nF
4	10kHz	(d) 680pF

Figure 13. A simple 'four tone' test generator using the ladder network oscillator.

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3.	(7)		PWM Motor Driver	LK54J	£10.15	Best of Book	3	(XC03D)
4.	(8)		TDA7052 Kit	LP16S	£ 4.03	Magazine	37	(XA37S)
5.	(5)		Car Battery Monitor	LK42V	£ 9.13	Magazine	37	(XA37S)
6.	(12)		8W Amplifier	LW36P	£ 7.09	Catalogue	'91	(CA08J)
7.	(15)		U/Sonic Car Alarm	LK75S	£20.35	Projects	15	(XA15R)
8.	(6)		Partylite	LW93B	£10.15	Catalogue	'91	(CA08J)
9.	(3)		1/300 Timer	LP30H	£ 5.05	Magazine	38	(XA38R)
10.	(9)		Mini Metal Detector	LM35Q	£ 5.35	Magazine	25	(XA25C)
11.	(10)		I/R Prox. Detector	LM13P	£10.15	Projects	20	(XA20W)
12.	(20)		15W Amplifier	YQ43W	£ 7.09	Catalogue	'91	(CA08J)
13.	(17)		LM386 Amplifier	LM76H	£ 3.82	Magazine	29	(XA29G)
14.	(19)		TDA2822 Amplifier	LP03D	£ 7.09	Magazine	34	(XA34M)
15.	(-)	RE ENTRY	Digital Playback	LM85G	£15.25	Magazine	31	(XA31J)
16.	(-)	RE ENTRY	TDA7000 Radio MK2	LM55K	£22.39	Magazine	27	(XA27E)
17.	(14)		Siren Sound Generator	LM42V	£ 4.33	Magazine	26	(XA26D)
18.	(-)	NEW ENTRY	TDA1514 Power Amplifier	LP43W	£16.27	Magazine	40	(XA40T)
19.	(11)		Watt Watcher	LM57M	£ 5.35	Magazine	27	(XA27E)
20.	(-)	NEW ENTRY	3 Gun Sound Generator	LP11M	£ 4.33	Magazine	36	(XA36P)

Over 150 other kits also available. All kits supplied with instructions.

The descriptions are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate project book, magazine or catalogue mentioned in the list above.

DATA FILE

ZN419/409 PRECISION SERVO

FEATURES

★ HIGH OUTPUT DRIVE CAPABILITY ★

★ LOW COMPONENT COUNT ★

APPLICATIONS ★ Motor Speed Control ★ Servo Control ★

Introduction

The ZN419 precision servo IC (also supplied as the ZN409) is specifically designed for use with pulse width operated servo mechanisms, used in a variety of control applications. A low external component count and relatively low power consumption make the device ideal for use in model boats, aircraft and cars where battery life, space and weight are of prime consideration.

In addition to the role of a servo driver, it is also possible to use the IC in motor speed control applications. The device is supplied in a 14 pin DIL package. Figure 1 shows the IC pinout and Table 1 shows some typical electrical characteristics for the device.

General Description

A typical control system is that based on the operation of a joy-stick to vary the pulse width of a timing circuit. Large numbers of pulses are multiplexed by time division and are used to modulate a radio control transmitter. At the receiver, the received signal is demodulated and a train of pulses is produced to control a servo. The servo consists of a motor driven reduction gearbox which has a potentiometer coupled to the output shaft. The servo potentiometer produces an output which corresponds to the position of the output shaft. The output from the potentiometer is used to control the pulse width of a timing

Parameter	Conditions	Min	Typ	Max
Supply voltage		3·5V	5V	6·5V
Supply current	Quiescent	4·6mA	6·7mA	10mA
Input resistance		20k	27k	35k
Input current		350μA	500μA	650μA
Lower input threshold	(Pin 14)	1·15V	1·25V	1·35V
Upper input threshold	(Pin 14)	1·4V	1·5V	1·6V
Minimum output pulse		2·5ms	3·5ms	4·5ms
Output saturation voltage	Load current = 400mA		300mV	400mV

Table 1. ZN419 typical electrical characteristics.

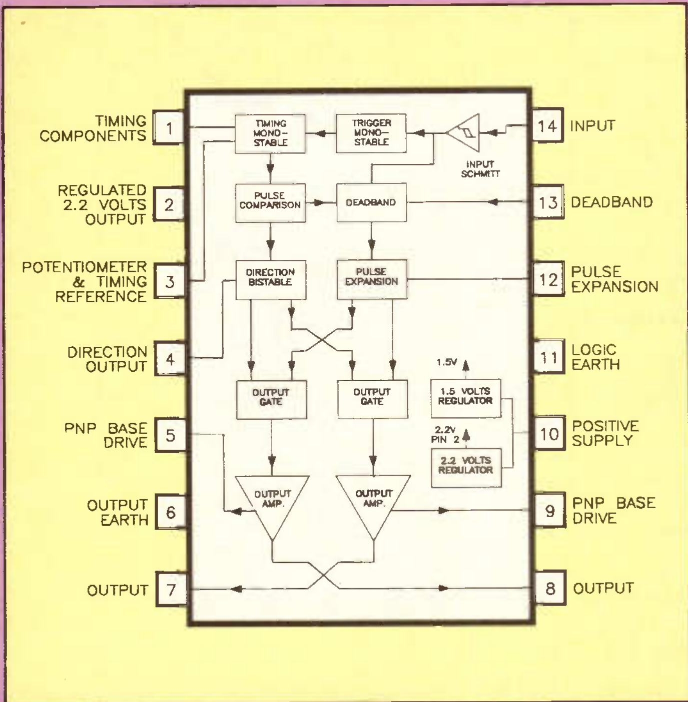

Figure 1. IC pinout.

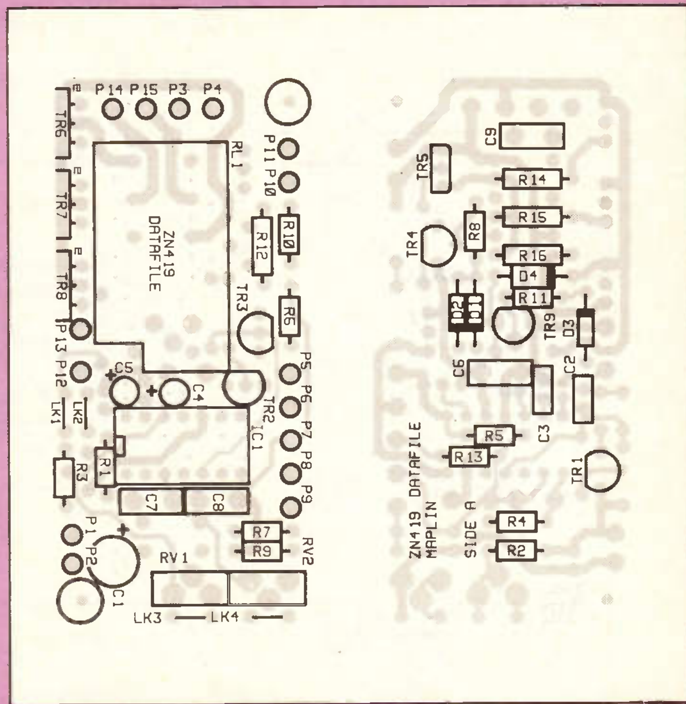

Figure 3. Legend on both sides of PCB.

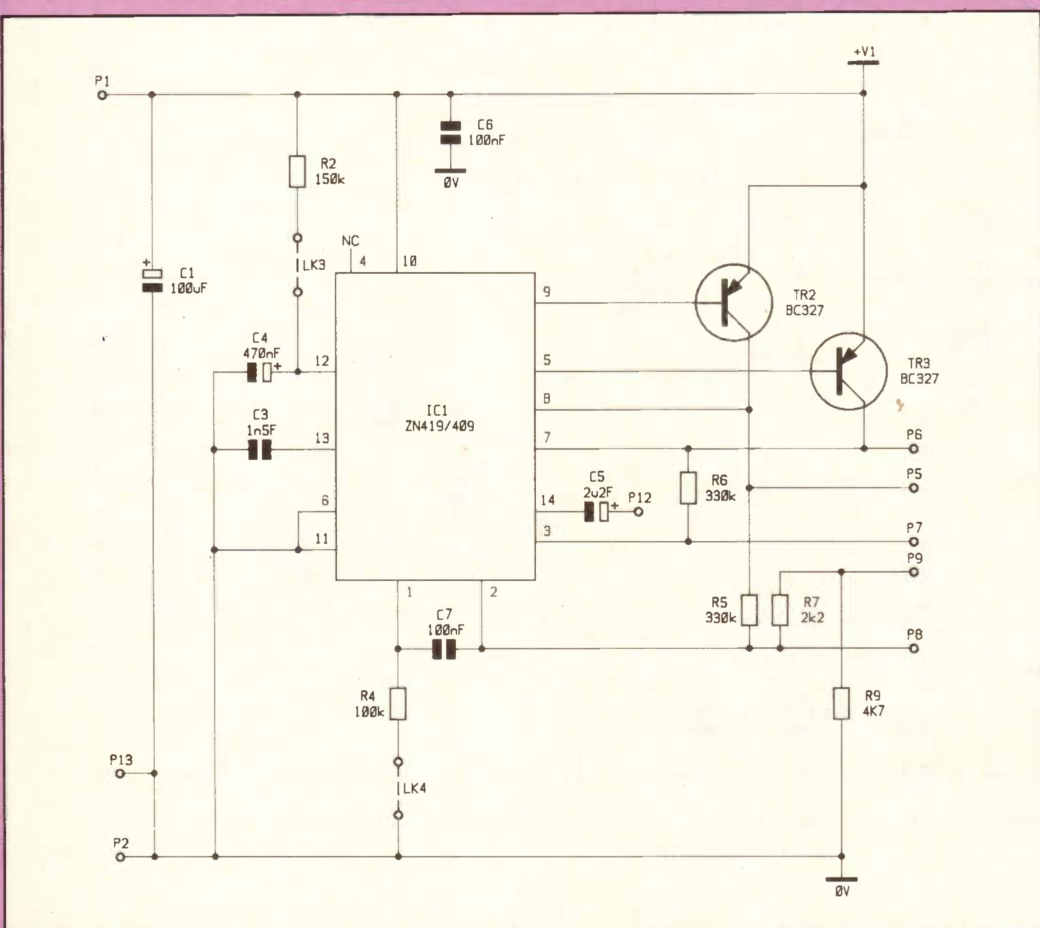

Figure 4. Circuit diagram of servo application.

monostable which forms part of the ZN419 IC. An internal pulse comparison stage compares the input pulse width with that of the monostable pulse and produces an output which determines the correct phase of the on-chip power amplifier. Another output from the pulse comparison circuit drives a pulse expansion circuit which expands the difference between the input and monostable pulses. The difference pulse is used to drive the motor in such a direction as to reduce the difference so that the servo takes up a position which corresponds to that of the controller joy-stick.

In addition to driving servo motors, the ZN419 can also be used for motor speed control. In this application the IC acts as a linear pulse width amplifier. The motor is driven with a train of pulses which have a variable pulse width such that the speed of the motor can be controlled between zero and maximum. The ZN419 uses fixed timing components and a fixed resistor is used in place of the servo potentiometer. The centre of the range monostable period represents zero motor speed, and pulses less than or greater than this drive the motor in the forward or reverse direction respectively. A direction output is produced on pin 4 of the IC and this may be used to control a relay to determine the motor direction. The pulse expansion components should be chosen to provide a suitable relation between the controller joy-stick position and the speed of the motor.

A 'deadband' is required around the centre of this range, between the minimum forward and reverse positions, where no power is applied to the motor. The IC contains an internal deadband control circuit and the size of the deadband is adjustable to suit different requirements.

Because of the high current consumption of many motors, using the device in motor speed control applications usually requires a separate high current power supply to increase the operating time between recharging the batteries.

IC Power Supply

The IC requires a 4V to 6·5V (absolute maximum) single rail power supply which is capable of supplying a current of up to 10mA. As the device is primarily

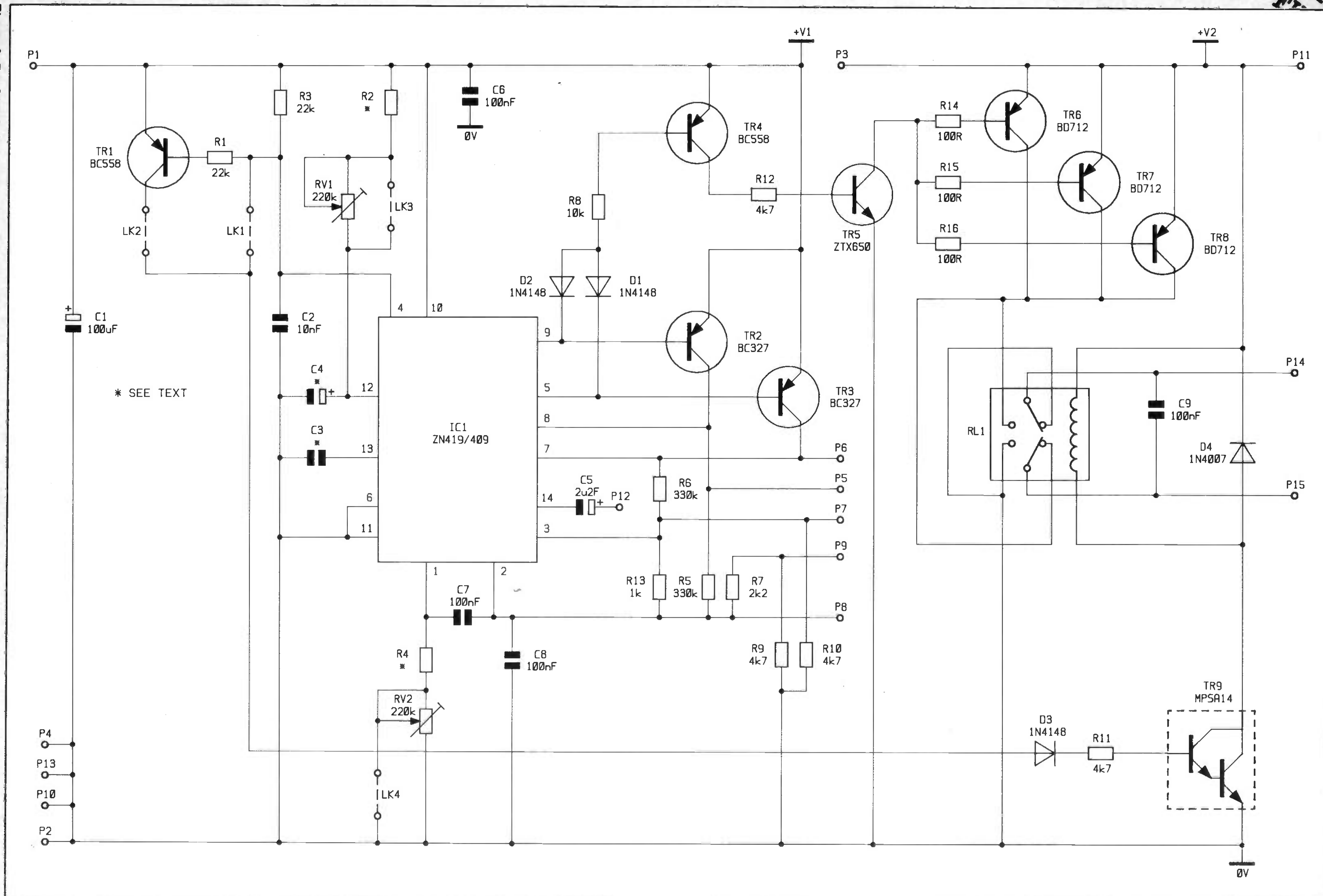

Figure 2. Combined circuit diagram of module.

DATA FILE

designed for use in radio controlled models the supply is usually derived from a battery. For reliable operation it is recommended that high frequency supply decoupling is used close to the IC to prevent high frequency voltage spikes on the supply rail.

PCB Available

A high quality, double sided, fibreglass PCB with screen printed legend is available as an aid to constructors wishing to use the ZN419 IC. The PCB may be utilised in the construction of either a servo driver or a motor speed control circuit. Figure 2 shows the combined circuit diagrams for both the speed controller and servo driver options. The PCB legend is shown in Figure 3.

In order to make the PCB as small as possible, components are mounted on both sides of the board. The PCB is marked "side A" and "side B" for ease of identification. When constructing either circuit, the components mounted on side A should be fitted first, followed by the components on side B. It is necessary to solder some components on the same side of the PCB as they are mounted, instead of the normal 'other side'. This is particularly the case with R5, R8, R11, R13, R14, R15, R16 and D4. Protruding component leads should be cut as close to the PCB as possible so that they do not obstruct components on the other side of the board.

Servo Driver Option

Figure 4 shows the circuit diagram of the servo driver application. If building this circuit, reference should be made to the servo driver parts list only and *not* to the motor speed controller parts list which shows a different set of component values. Figure 5 shows the wiring diagram for the module when used as a servo driver.

The circuit is primarily designed to operate from a 6V battery but may be powered from any supply voltage between 4V and 6V. Power supply connections are made to P1(+V) and P2(0V). A pulse width modulated input is required to drive the module, with a variable pulse width between 0·2ms and 2·5ms as illustrated in Figure 6 and Figure 7. A typical test circuit is shown in Figure 8. Please note: LK1 and LK2 are *not* fitted for the servo driver application, but *both* LK3 and LK4 should be fitted.

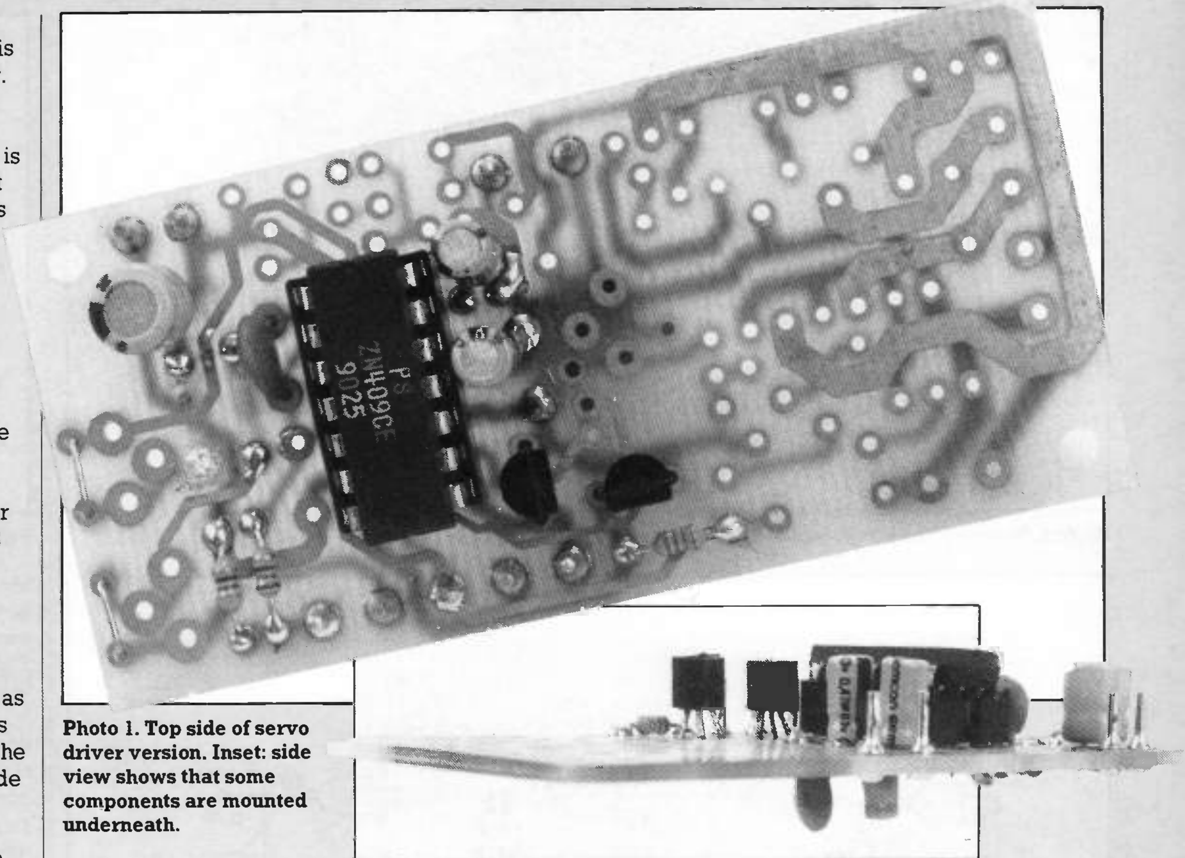

Photo 1. Top side of servo driver version. Inset: side view shows that some components are mounted underneath.

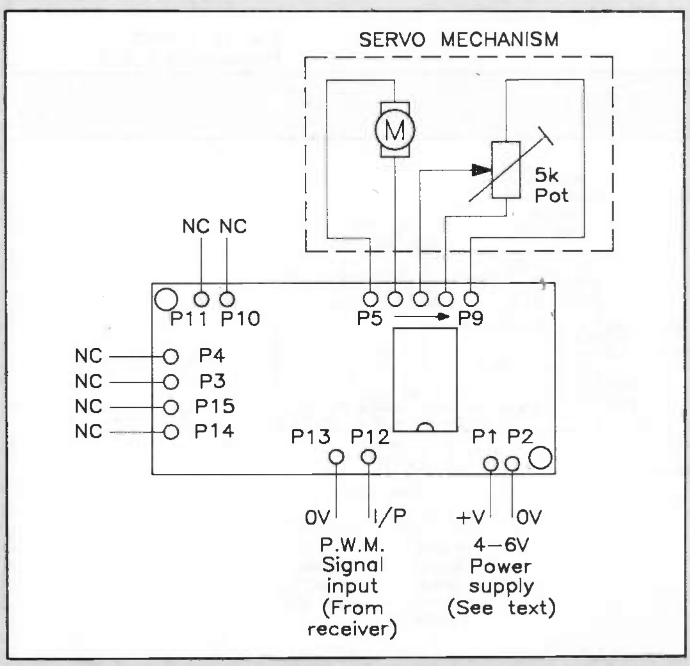

Figure 5. Servo driver wiring diagram.

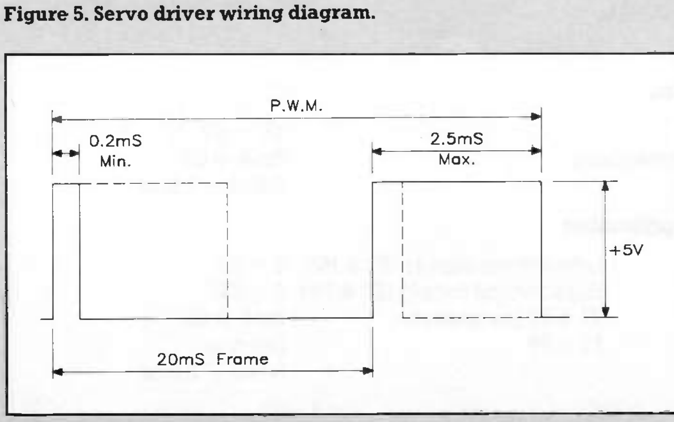

Figure 6. Control signal.

Motor Speed Control Option

Figure 9 shows the diagram of the motor speed control circuit. When building this circuit reference should be made to the motor speed control parts list only and *not* to the servo driver parts list which shows a different set of component values. Figure 10 shows the wiring diagram for the module when used as a motor speed control circuit.

The circuit has two separate power supply rails. A 4 to 6V power supply is used for IC1 and associated components, and the connections from this supply are made to P1(+V) and P2(0V). An additional supply (usually provided by a rechargeable Ni-Cd pack) is required for the motor drive circuitry and connections from this supply are made to P3(+V) and P4(0V). The supply voltage for the motor may be between approximately 6V and 8V at continuous currents up to 5A using the components specified; however, higher voltages and currents can be accommodated using different component values. In particular, the power handling capability of relay RL1 and resistors R14 – R16

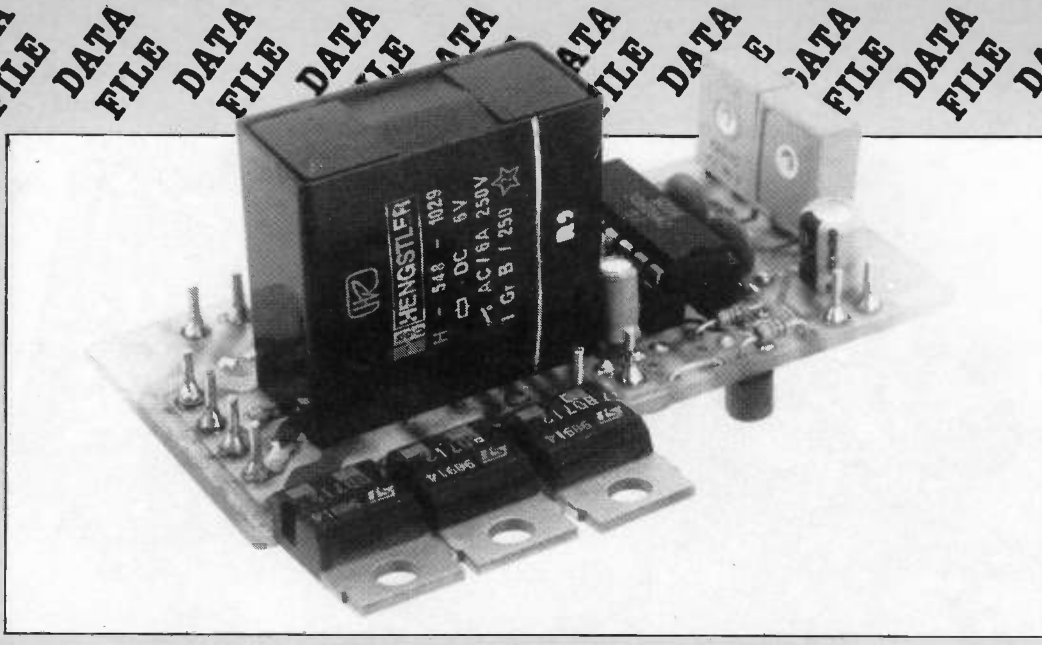

Photo 2. Note how the power transistors are mounted on the motor driver option.

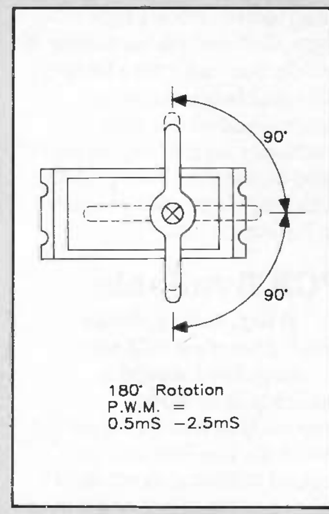

Figure 7. Servo operation.

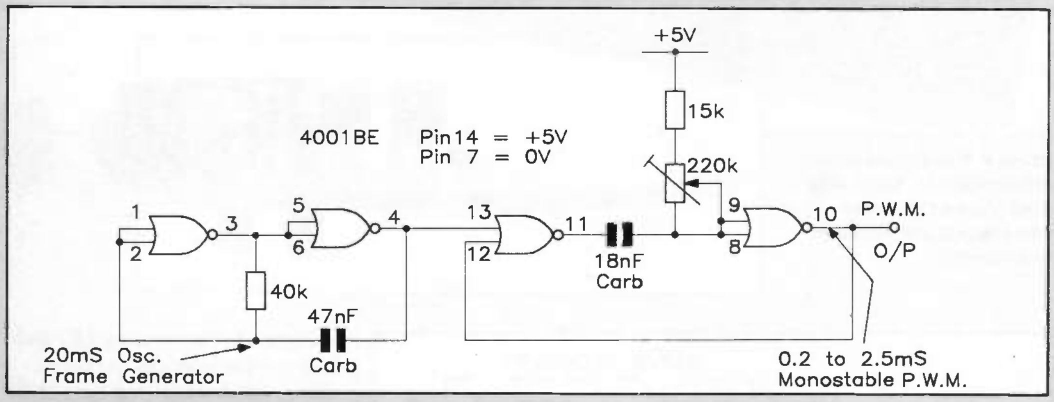

Figure 8. Typical test circuit.

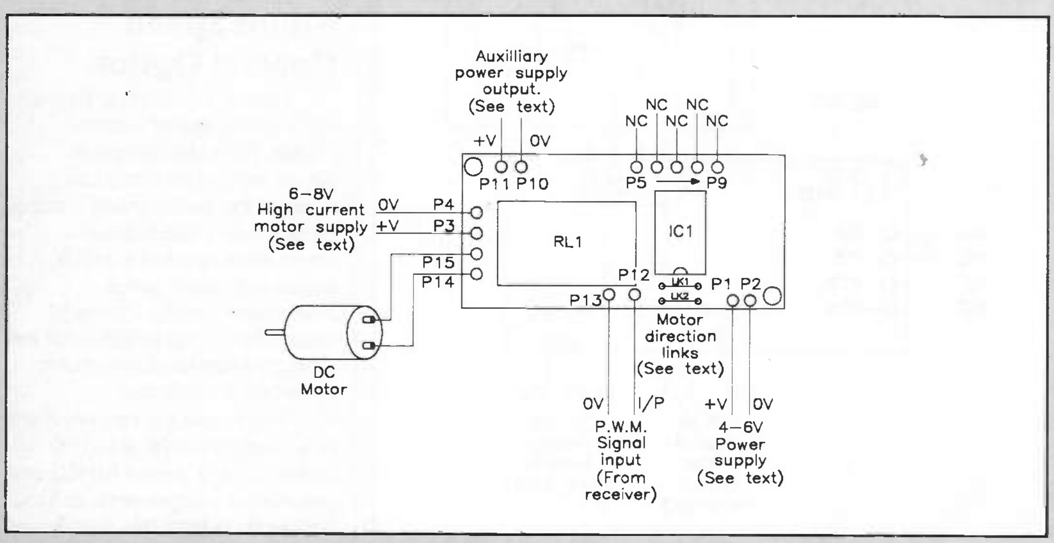

Figure 10. Motor speed control wiring diagram.

Servo Driver Application		
Power Supply Voltage		4V – 6V
Power Supply Current (quiescent)		8mA at 6V
Input Pulse Width		0·2ms – 2·5ms
Motor Speed Control Application		
Power Supply Voltage	Low current supply (P1 & P2)	4 – 6V
	High current supply (P3 & P4)	6 – 8V
Power Supply Current	P1 & P2 (quiescent)	8mA at 6V
	P3 & P4	See text
Input Pulse Width		0·2ms – 2·5ms

Table 2. Specification of prototype.

should be taken into consideration as well as the power dissipation of transistors TR5 – TR8. A suitable 12V relay to use in place of RL1 is FJ43W.

Power transistors TR6 – TR8 are positioned close to the edge of the PCB (see photo 2), to allow the installation of heatsinks as required. There is a small 'e' on the legend denoting the emitter of the transistor for reference purposes. If and to what extent a heatsink is required is really determined by the power consumption of the motor being driven; higher power motors will obviously require additional heatsinking. If the model has a metal chassis, it is often possible to use this as a heatsink for the motor drive transistors. It should be remembered though that the transistor heatsink tags are at collector potential and if necessary should be insulated from the heatsink using a suitable bush and insulating washer such as stock code WR23A.

The direction of rotation of the motor is set by fitting either wire link LK1 or LK2. Please note LK1 and LK2 *should never be used together at the same time!* LK3 and LK4 are not used in the motor speed control application.

Two preset resistors are used to align the module. The relationship between the control stick and the speed of the motor is set using RV1. Because both forward and reverse motor drive are required, a "no drive" or zero position is needed; this is determined by adjusting RV2. Some experimentation is necessary to optimise the parameters of the module for individual applications.

Finally, Table 2 shows the specifications for both the servo driver and speed control options from the prototype module.

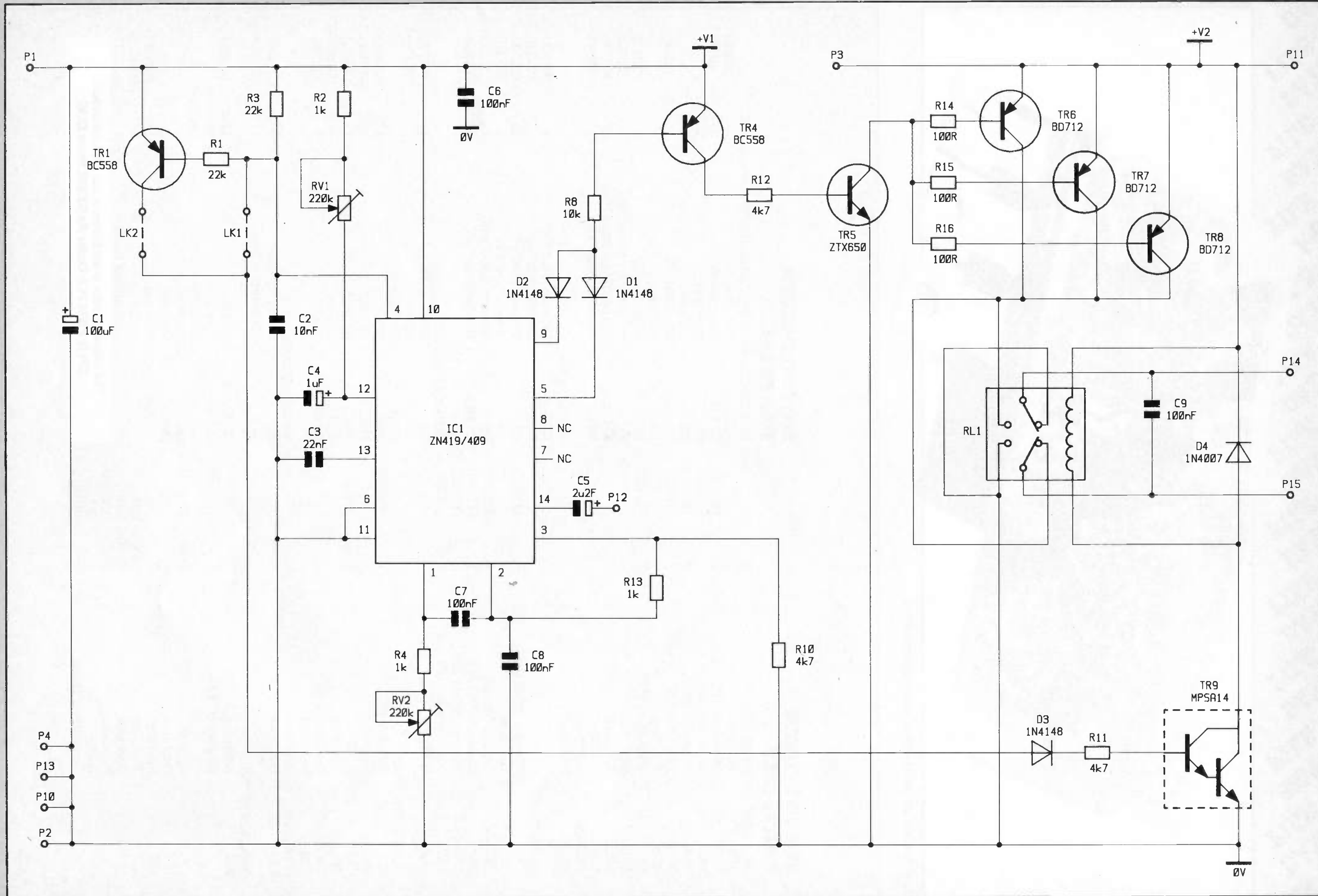

Figure 9. Circuit diagram of motor speed control application.

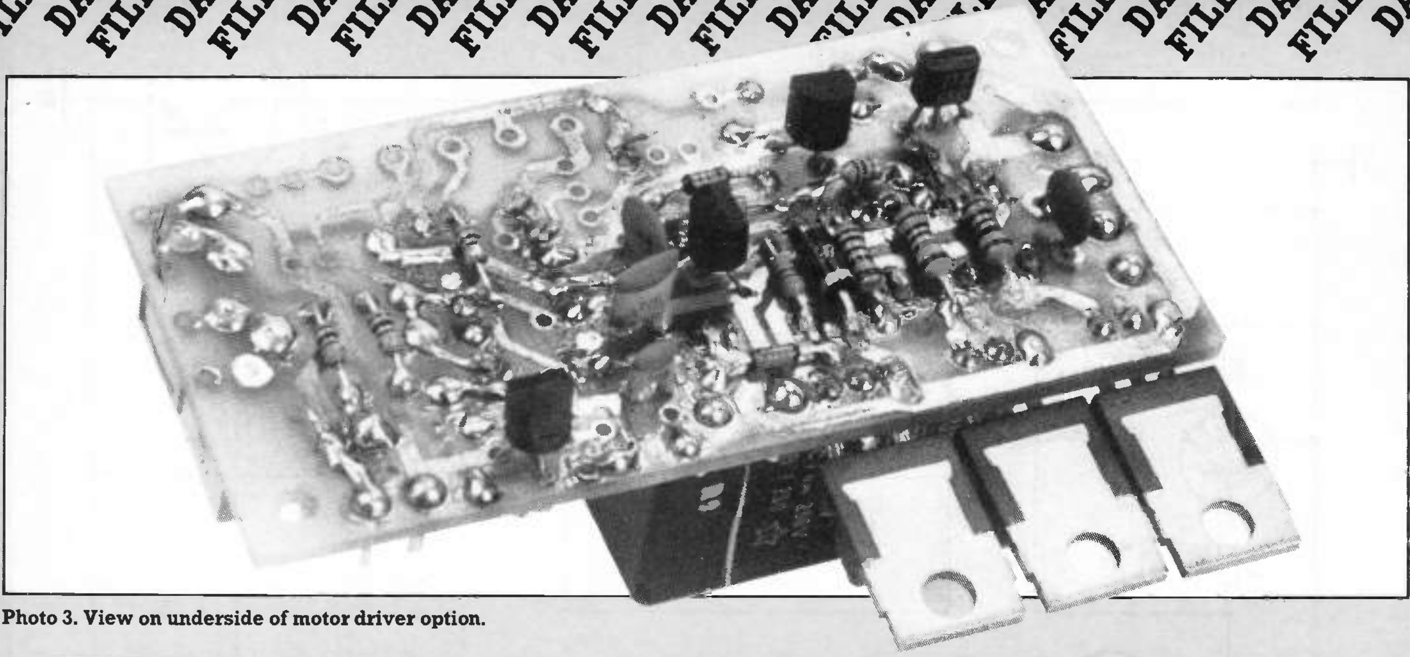

Photo 3. View on underside of motor driver option.

SERVO DRIVER PARTS LIST

RESISTORS: All ⅛W 5% Carbon Film

R1,3	Not Fitted	–	
R2	Micro Res 150k	1	(U150K)
R4	Micro Res 100k	1	(U100K)
R5,6	Micro Res 330k	2	(U330K)
R7	Micro Res 2k2	1	(U2K2)
R8	Not Fitted	–	
R9	Micro Res 4k7	1	(U4K7)
R10,11	Not Fitted	–	
R12	Not Fitted	–	
R13	Not Fitted	–	
R14,15,16	Not Fitted	–	
RV1,2	Not Fitted	–	

CAPACITORS

C1	Minelect 100µF 10V	1	(RK50E)
C2	Not Fitted	–	
C3	Ceramic 1500pF	1	(WX70M)
C4	Minelect 470nF 63V	1	(YY30H)
C5	Minelect 2200nF 63V	1	(YY32K)
C6,7	Minidisc 100nF 16V	2	(YR75S)
C8,9	Not Fitted	–	

SEMICONDUCTORS

IC1	ZN419/409CE	1	(YH92A)
TR1,4	Not Fitted	–	
TR2,3	BC327	2	(QB66W)
TR5	Not Fitted	–	
TR6,7,8	Not Fitted	–	
TR9	Not Fitted	–	
D1,2,3	Not Fitted	–	
D4	Not Fitted	–	

MISCELLANEOUS

RL1	Not Fitted	–	
	DIL Socket 14 Pin	1	(BL18U)
P1,2,5,6,7,8, 9,12,13	Pin 2145	1 Pkt	(FL24B)
LK1	Not Fitted	–	
LK2	Not Fitted	–	
LK3	Wire Link	Fit Wire Link	
LK4	Wire Link	Fit Wire Link	
	PC Board	1	(GE83E)
	Leaflet	1	(XK49D)
	Constructors' Guide	1	(XH79L)

MOTOR DRIVER PARTS LIST

RESISTORS: All ⅛W 5% Carbon Film (unless specified)

R1,3	Micro Res 22k	2	(U22K)
R2,4,13	Micro Res 1k	3	(U1K)
R5,6	Not Fitted	–	
R7	Not Fitted	–	
R8	Micro Res 10k	1	(U10K)
R9	Not Fitted	–	
R10,11	Micro Res 4k7	2	(U4K7)
R12	4k7 (0·6W 1% Metal Film)	1	(M4K7)
R14,15,16	100Ω (0·6W 1% Metal Film)	3	(M100R)
RV1,2	Vert Encl Preset 220k	2	(UH20W)

CAPACITORS

C1	Minelect 100µF 10V	1	(RK50E)
C2	Ceramic 10,000pF	1	(WX77J)
C3	Ceramic 22,000pF	1	(WX78K)
C4	Minelect 1µF 63V	1	(YY31J)
C5	Minelect 2200nF 63V	1	(YY32K)
C6,7,8,9	Minidisc 100nF 16V	4	(YR75S)

SEMICONDUCTORS

IC1	ZN419/409CE	1	(YH92A)
TR1,4	BC558	2	(QQ17T)
TR2,3	Not Fitted	–	
TR5	ZTX650	1	(UH46A)
TR6,7,8	BD712	3	(WH16S)
TR9	MPSA14	1	(QH60Q)
D1,2,3	1N4148	3	(QL80B)
D4	1N4007	1	(QL79L)

MISCELLANEOUS

RL1	Min 6V 6A Relay	1	(FJ42V)
	DIL Socket 14 Pin	1	(BL18U)
P1,2,3,4,10,11, 12,13,14,15	Pin 2145	1 Pkt	(FL24B)
LK1	Wire Link	See Text	
LK2	Wire Link	See Text	
LK3	Not Fitted	–	
LK4	Not Fitted	–	
	PC Board	1	(GE83E)
	Leaflet	1	(XK49D)
	Constructors' Guide	1	(XH79L)

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No Strings Attached

by Alan Simpson

If rubber happens to be your personal turn-on, then lose no time. Make tracks for the new Spitting Image Rubberworks, in spitting distance from London's Covent Garden underground station. As the promotion puts it, 'The Spitting Image Rubberworks is the most fun you can have with rubber (unless you are a Tory MP or a High Court judge). It's London's newest and most hilarious live robotic attraction'.

If you want to see your heroes (or villains) as 'real-life' as possible, then an alternative visit to the redoubtable Madame Tussauds Waxworks, or even the Rock Circus, will be more rewarding. But if you want to see them on display, warts and all, grossly exaggerated and wickedly caricatured, then hasten to The Spitting Image Rubberworks in Cubitts Yard. In fact, any connection between a standard-issue waxworks and the Rubberworks is out of sight and out of mind.

Also any connection with the infamous television Spitting Image programme, which delights and disgusts viewers in equal measure, is also out of focus. Those two-dimensional screen puppets have been elbowed out by animated caricatures, with associated full frontal blows being complemented by back-stabbing and all-round aggro.

The Rubberworks lurks in an old warehouse amid a den of rubber iniquity. Here the famous, and infamous, compressed-air driven marionettes come alive in a typical Spitting Image fashion, playing host to some 1,500 visitors a day. Actually the event extends to the Covent Garden Piazza, where, most days, the spectre of ex-President Reagan in a bath chair haunts the area, barking up business for the Spitting Image Rubberworks.

Have Fun with Rubber

Visitors to the event are greeted in the open courtyard by 'The Roboids', or more specifically Prince Charles standing at a lectern, plus a seated M. Thatcher. The animation is controlled by three specially designed playback computers, located in Reagan's motorised bath chair, the lectern, and the seat. Inside the workshop, incidentally, President Bush's computer is located in his golf-bag.

Having made your way into the workshop, the first stop is the studio presentation. Here is staged 'Lickety-Lick', a 'live' TV panel game hosted by the noted Royal fancier, Sir Alastair Burnet. The guests are The Queen, Prince Philip, a certain retired housewife who lives in Dulwich, M. Thatcher, and what at first sight appears to be a Prince Charles look-a-like, but turns out to be the Labour Party leader, Neil Kinnock. (It was the nose which caused the confusion.) However, there was no disguising the frosty atmosphere between The Queen and M. Thatcher.

Total Package

Instead of the traditional hand-operated puppets seen in the TV Spitting Image programmes, the 'Lickety-Lick' caricatures are entirely automated: they are powered by compressed air and controlled by a specially-designed computer system. The fifteen minute show is a total package including the five animated caricatures, stage-set, lighting, programming and a customised script which is constantly updated. Behind the scenes, there is an eight-track, reel to reel machine which incorporates the sound-track and time code, which is read by a playback computer which initiates another EPROM based system to control movement.

To make the show even more realistic, the presentation is set in a game-show studio set, with practical

OUT AND ABOUT

Main picture: The Spitting Image creator Peter Fluck and two other less well-known personalities.
Bottom left: John Major passing comment on the replacement for the 'Poll Tax'.
Bottom right: Ideas come to life in the Spitting Image workshop.

robot cameras and monitors, cables, bright lights – all the usual razzmatazz. The voice of the director (Sir Richard Attenborough in this case) comes through loud and clear: "Okay, loveys, darlings. Gorgeous, loverly, wonderful. Good luck everybody". So realistic in fact that one young visitor, Michael Pratt from North London, produced an autograph album before being led away by an attendant.

Inside the workshop proper you can see what really goes on behind the scenes at Spitting Image. On show are puppets in the process of being created, designed and built, and if you really want to enter into the party spirit, you can even be photographed with a famous Spitting Image puppet.

Spitting Image Productions

It was back in 1987, when one of the creators of Spitting Image, Peter Fluck, started up Spitting Image Engineering, while his partner Roger Law continued in TV production. The new company concentrated on developing techniques for making the famous caricature puppets move and speak independently of human operators. By mid-1989, the first fully working animated figure had been built. Last year saw the arrival of Peter Fluck's new company, Spitting Image Projects, whose first venture is The Rubberworks. Meanwhile Spitting Image Productions was responsible for the creation of the puppet-based Genesis video, and the Ronnie Reagan caricature copier poster campaign.

The Flexator

While it takes at least three people to work each traditional hand operated puppet – one human arm operating the head, and one human for each arm, plus a fourth arm if an additional effect such as tears was required (it must be very crowded under that table) – the Rubberworks variety are motivated by means of a process known as 'The Flexator'. The system, which is computer based, drives compressed air into inflatable sacs, made from fireman's hose, which act like muscles by stimulating body movement.

Depending on requirements, any part of the individually-built model can be made to move. This is largely determined by the representation re-

quired. While the body is normally fixed, shoulders shrug, arms can move and the life-like model can appear to breathe. Maggie Thatcher, for example, sticks her head forward. Incidentally, Spitting Image have, over the years, made some ten different Maggies (how they must regret her absence), and have now got the measure of John Major.

An Open and Shut Case

It is at a workshop in Whitechapel, East London, where the specially designed programming computer is used. Developed by electronics consultant Steve Rutherford, it incorporates both digital and analogue channels which control the flexators. According to Anton Boniface, who is responsible for the electronic engineering in the workshop, getting a smooth movement is easy. Motive power is by means of compressed air, controlled through solenoid valves. Once everyone is happy with the program, an EPROM 'hard copy' board is produced which is transferred to the playback computer. The sound-track is produced in a recording studio from a script written by the Spitting Image team.

Certainly there is no shortage of work for Anton and the workshop team. Already there is a new Rubberworks exhibition now open in Newcastle, and there are plans for future 'live' attractions – both in the UK and in mainland Europe – well in advance. The models also make personal appearances at various exhibitions, or to address conference delegates, but just in case you were thinking about commissioning a real, life-sized caricature of your boss, think again. Each model can cost up to £30,000. Other notable roles for the Flexator include TV commercials.

The World has certainly come a long way since clockwork-driven mechanisms. Animation is now very much a growth industry, and without doubt, one of the best places to see state-of-the-art model automation, as at the highly innovative Spitting Image Rubberworks. Open every day from 11am to 7pm, admission £2.90, or £1.90 for senior citizens and children under ten, with special terms for parties and tours. For further details contact Spitting Image Rubberworks, Cubitts Yard, James Street, Covent Garden, London WC2.

Competition

This is your chance to rub shoulders with the high and mighty, plus a few down and outs. The first six all correct entries drawn out of our old editor's hat (the hat is old I mean, not the editor) wins two double tickets to The Spitting Image Rubberworks. As ever, zap your answers on a post card (or back of envelope) to 'Rubberworks Contest', The Editor, Electronics – The Maplin Magazine, P.O. Box 3, Rayleigh Essex, SS6 8LR (or by fax to 0702 553935). Don't delay. The contest closes on 31st August 1991. **Please note**: employees of Maplin Electronics and family members of same are not eligible to enter. In addition multiple entries will be disqualified.

1. Spot the odd one out.
a) Prince Charles
b) Laurel and Hardy
c) The Muppets

2. Where can you expect to find The Spitting Image programme?
a) BBC1
b) BBC2
c) ITV
d) Channel Four

3. Is the regular TV audience for Spitting Image:
a) Two million, three hundred thousand;
b) Thirty seven million;
c) Ten million?

4. Is the host of the Lickety-Lick game show, Sir Alistair Burnet:
a) a chat show host;
b) a TV news-reader;
c) The Bishop of Salisbury?

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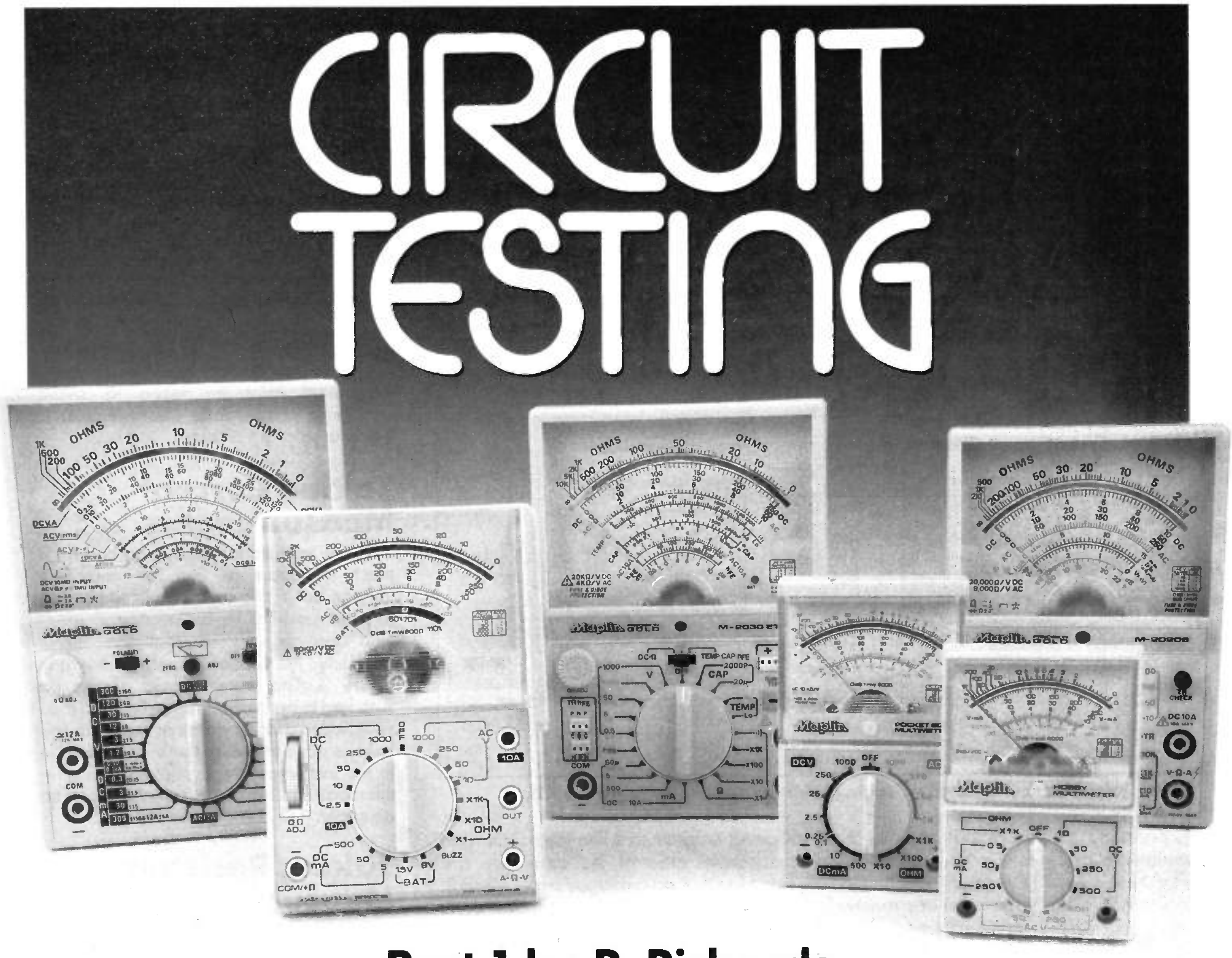
Beginner's Guide to CIRCUIT TESTING



Part 1 by R. Richards

In an ideal world you should be able to build a circuit and expect it to operate as it was intended. However Murphy's law says that mistakes in both design and construction are often the norm, not the exception, and if it can go wrong, it will. Such mistakes can be no more than overlooking some small detail, or not anticipating something quite obvious at the design level, probably because it *is* so obvious (the moral being don't assume anything).

For instance it is almost universally assumed, by those yet to learn otherwise through hard experience, and even without the evidence of the increasing sophistication of modern electronic devices, that electronics is a precise science. It is nothing of the sort.

When a circuit is not working as it is meant to, it helps a lot to remember that the motive power, electricity, has just one goal – to complete a circuit between the supply terminals any way it can. The fact that it is not doing it in the way you would like is neither here nor there as far as it is concerned.

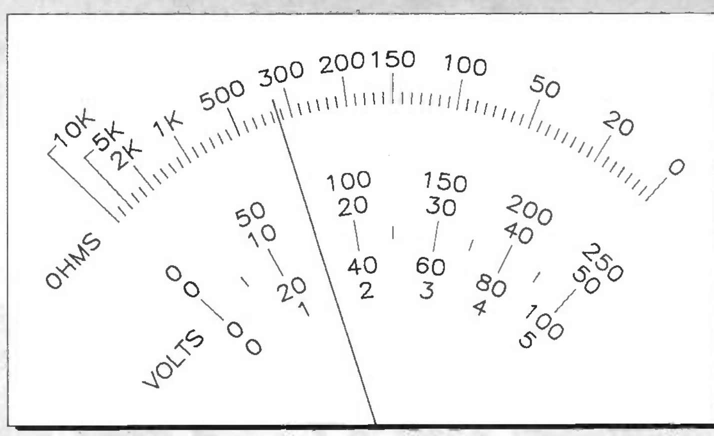
There is no easy way of learning how to find faults in a circuit. Many might think that it requires a large amount of technical knowledge and background theory. This is almost always a fallacy; you *don't* need a university degree in order to be able to solve circuit problems. In fact, electronic circuit theory is usually no help whatsoever – all you will learn is what is supposed to happen, and not what can go wrong! Stories about university graduates who have designed circuits which don't work are usually the most popular to circulate around the hobbyist fraternity. This would indicate that the best teacher is practical experience – actually building things and making them work.

Neither do you need a mass of expensive electronic test equipment. The bare minimum is a multimeter of some description, and while even a modest oscilloscope will give rather more insight into how the circuit is behaving, and is nice to have if you've got one, it is not absolutely essential for the purposes of this discussion. Using a multimeter only, the following ground rules should help the beginner to understand the first basic steps to circuit testing, and point them in the right direction to solving problems in faulty circuits.

Basic Test Gear

The most common test instrument is the multimeter, so it is important to be fully conversant with the working principles of the meter for measuring voltage, current and resistance, together with the correct interpretation of the different scales as illustrated in Figure 1. Read the instructions supplied with the meter and make yourself familiar with all its workings. Actually a multimeter is the bare minimum required – you are not going to be able to measure any form of electrical quantity at all otherwise, since mother nature has not endowed you with the necessary sensory organs to examine electron flow in any small detail. As with anything else, multimeters come in varying qualities, and it is probably better to choose a 'reasonable' one with a good variety of different ranges than a small 'hobby type'. A genuinely high quality, expensive, high precision digital multimeter will possibly be disconcerting to use at first, due to it constantly showing how inaccurate everything else is – a 12V supply rail is not exactly 12V, a 4k7Ω resistor is not in reality exactly 4,700Ω in spite of being 1% tolerance – do you see what I mean about electronics not being a precise science?

The following outline the basic procedures for examining the three essential electrical quantities of voltage, current and resistance using a mulitimeter.



Range	Reading	Range	Reading	Range	Reading
0 to 5 Volts	1.5V	R x 1	340 Ω	0 to 100mA	30mA
0 to 50 Volts	15V	R x 100	34K Ω	0 to 200mA	60mA
0 to 100 Volts	30V	R x 1000	340K Ω	0 to 500mA	150mA
0 to 250 Volts	75V				

Figure 1. Taking readings and what the pointer indicates on the different scales.

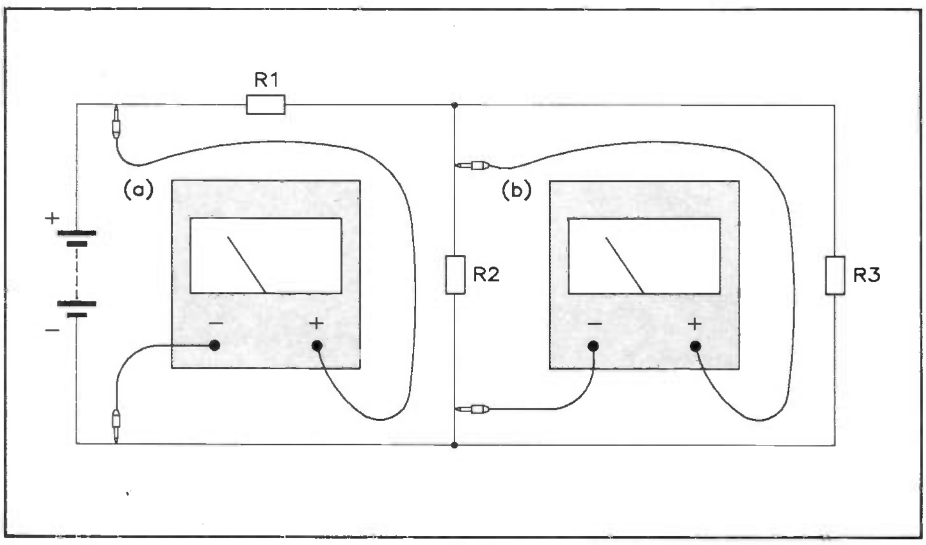


Figure 2. (a) Measuring total voltage. (b) Measuring voltage across R2.

Taking Voltage Measurements

The multimeter should be set-up somewhere out of the way of the work area but where it can be easily seen for taking the correct readings. *Important* – always select the *highest voltage range* to start with, and then you can connect the black probe to a common or earth of the circuit under test, and take readings by touching the various test points with the positive probe, see Figure 2. Choosing the highest range first is a precaution to protect the instrument – when it is established that this is too high a suitable lower range can now be chosen for the required reading without overloading the meter. The best reading is obtained when the pointer is in the central area of the scale (we are assuming that an analogue meter is used). When measuring high voltages it is advisable to use one hand only holding the positive probe, and keep the other hand in your pocket, or at least away from any other part of the circuit or indeed the meter! It must be remembered that voltages greater than approximately 100V are potentially *dangerous* and every precaution must be taken to avoid accidents. In this mode the multimeter is being used as a *voltmeter.*

Taking Current Measurements

The method for measuring current is much the same as that for measuring voltage but in this case the circuit must be *'broken'* and the meter inserted *in series* with the 'break', so that the meter completes the broken circuit, as shown in Figure 3. The meter should *always* be switched to the highest range first and then switched to a lower range as required. This must be done to ensure there is no damage to the instrument through overloading. In this mode of operation, the multimeter is an *ammeter.*

Taking Resistance Measurements

Firstly always ensure that the power to the circuit is *switched off.* The ohmmeter part of the instrument has its own battery supply and readings will be seriously offset, and the meter possibly damaged, by

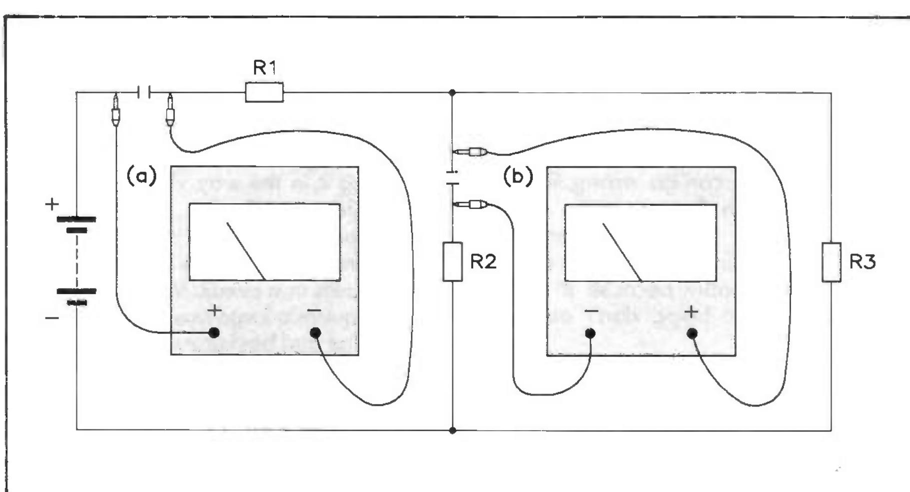


Figure 3. (a) Measuring total current. (b) Measuring current through R2.

external voltages applied to the probes. For example, it is unusual for the internal battery to attempt to wrap the pointer needle backwards around the left hand scale stop – obviously current is flowing *into* the instrument from somewhere else, and not out!

Again place the meter in a safe place where it can be easily read. Start by selecting the lowest resistance range, then apply the probes across the resistance to be measured. This will indicate a suitable range; if the reading is too high then switch up to the next highest range(s) until the needle is nearer the centre of the scale. The graduations marked on the resistance scale are not linear, hence the greatest accuracy will occur near the spaced out right hand end, and the most ambiguous readings will occur at the cramped left hand end. *Important* – before taking the final reading the meter *must* be calibrated to read zero for zero resistance by placing the ends of the probes together and adjusting the zero control until the pointer is on the zero mark.

This check should always be carried out to make sure that the meter is at zero before the proper reading is taken. Each range is different and each needs to be set at zero individually before any semblance of accuracy is possible! It is important to note while checking resistors that allowance be made for the manufactured tolerance of the resistor. For example a 2000 ohm resistor with a tolerance of ±20% can be anything from 1960Ω to 2400Ω. Such a resistor can be regarded as in error if its measured value lies outside of this margin – but always double check the accuracy of the meter with a zero check!

Resistors are manufactured with tolerances between ±1 and 20% (though nowadays anything over 5% is rare and probably old), and it is also worth noting that your *fingers* should be kept clear of the ends of the test probes as well, to avoid your body becoming part of the circuit and measured in parallel with the test resistance! This is not a problem with very low resistances, but introduces a profound error when measuring high resistances. When used for these sorts of tests the instrument is an *ohmmeter*.

To begin with it is probably easier to use an analogue multimeter as opposed to a digital type, because it is easier to gauge a quantity from the position of a needle on a scale than it is to decipher a constantly changing, flickering mass of seven segment digits. After some experience, and perhaps for specific purposes where a digital display shows better resolution to tenths or hundredths of a unit, you could move up to a better quality digital multimeter – by better quality I mean having more ranges and accuracy than your current analogue instrument. This is, of course, dictated by how much money you have to spend – from Maplin's current range of test gear you couldn't do much better than choose one of the three truly incredible American Fluke digital multimeters – but unfortunately the prices are in proportion, around £100 upwards.

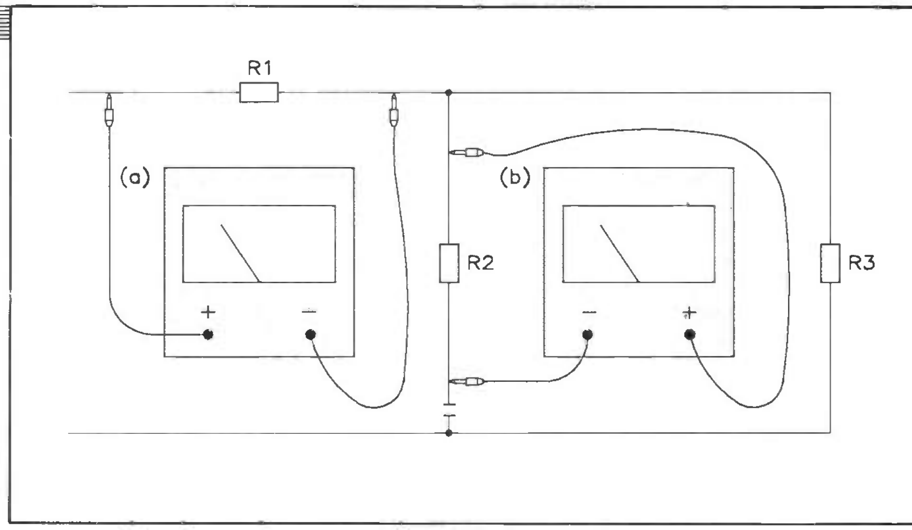


Figure 4. (a) Measuring resistance of R1. (b) Measuring resistance of R2 (one end disconnected).

For 'serious' fault finding try to steer clear of the 'pocket' and 'hobby' type instruments. While these are very useful for lots of general purpose tests, they are normally only provided with a crudely minimum number of ranges. Not only this, but invariably their *impedances* do not follow a recognised standard.

Ohms per Volt

What does this mean? Well very simply that it must follow that if you poke two probes attached to a multimeter into a circuit, current is going to be drawn from the circuit to power the meter movement (move the needle). This is a power loss, and if the source impedance (from whence the current comes) is high, then the actual voltage the meter will register will be *lower than it would be if the meter were not connected.* In other words, the voltage you are reading is not actually correct. It is very nearly correct if the source impedance is substantially lower than the meter's input impedance; somewhat less than it really would be without the meter connected if it's a higher source impedance, and definitely misleading if the source impedance approaches or surpasses that of the meter impedance.

For a long time there has been an industry standard which provides a means for taking this into account, and it hinges on the idea that the meter impedance is a constant. The industry standard constant is 20,000Ω per volt DC and 8,000Ω per volt AC. As a result it is possible to quote the voltage levels at various test points in a circuit which should be present, as part of specification or servicing data for the circuit, because it is assumed that the instrument doing the testing follows the standard. The fact is that the small 'hobby' type instrument often does not comply.

The 20,000Ω per volt standard follows from the fact that the meter movement is rated at 50μA for f.s.d. (full scale deflection). This means that, to produce a 10V DC range say, extra resistance is added to the movement for a current flow of 50μA at 10V, giving a total impedance of 200,000Ω, hence, 20,000Ω per volt! This ratio follows through all the other ranges; it must be so

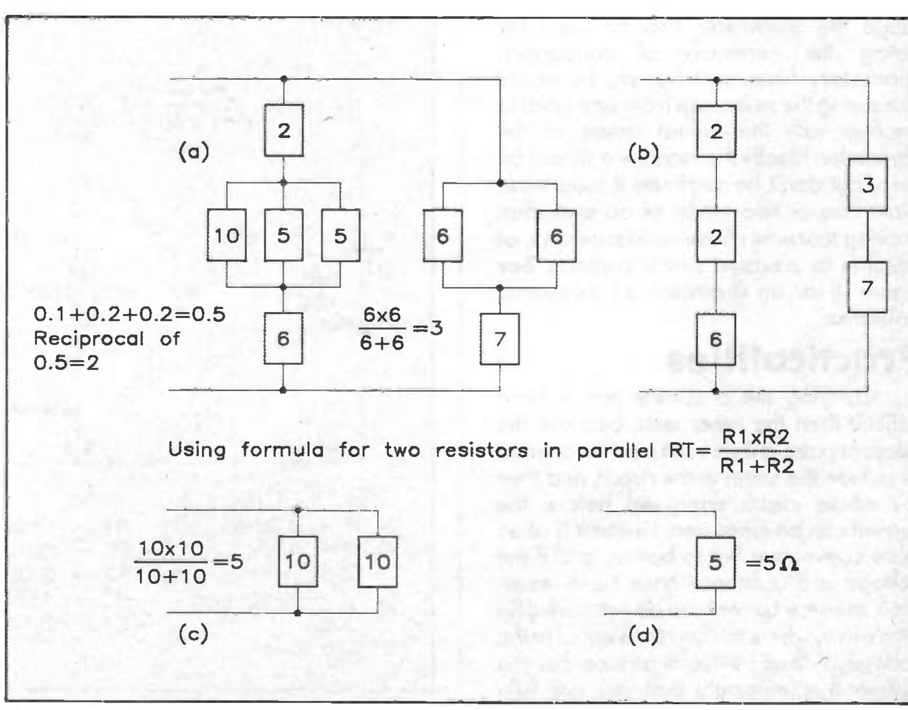


Figure 5. Solving parallel resistance by easy stages.

to achieve the 50μA f.s.d. at the maximum of each range.

The AC voltage standard is 8,000Ω per volt, based on the fact that the AC waveform is always assumed to be a sinewave, and hence its power factor is only some 70% of its peak level *because* it is not a constant DC voltage. In other words the same mean average current flow can be obtained from DC at a level some 30% *below* this peak level, and not at the same level. Moreover, inside the instrument the current is only halfwave rectified, meaning that the meter movement only receives the mean average current of one half cycle, and so to get adequate deflection of the pointer the impedance must be 8,000Ω per volt, quite a bit lower than the DC impedance. The overriding implication of this is that such an AC voltmeter is useless for measuring anything other than pure sinusoidal waveforms, and then only at low frequencies, i.e. in the range of those most often used for AC power transmission and exchange.

However a decibels scale is often provided allowing dB measurements of electronic sine signals using AC voltage ranges, although in practice the facility is limited. AC electronic signals are best examined with more specialised equipment such as a VVM or AC millivoltmeter – but again provided that the signal remains sinusoidal – or an oscilloscope.

Of the analogue multimeters currently available from Maplin, three affordable examples which fit the above criteria and are excellent instruments for this subject are the M-102BZ, M-2020S and the M-2030 ET. All have DC voltage ranges up to 1,000V, and the M-2020S has a 0·1V range for truly millivolt measurements. All have DC current ranges up to 10A and the M-2030 ET includes four AC current ranges.

Continuity

As an ohmmeter switched to a low range the multimeter can be used for testing the continuity of conductors, connectors, fuses, switches etc. by simply measuring the resistance from one point to another with the lowest range of the ohmmeter. Ideally the resistance should be zero, but don't be surprised if long wires show one or two tenths of an ohm, thus proving that wires have resistance also, as do dirty or oxidised switch contacts. See Figure 4 for an illustration of measuring resistance.

Practicalities

Carrying out a current test is more difficult than the other tests, because the relevant point in the circuit must be opened to include the meter in the circuit, and then the whole circuit energised before the current can be measured. Hence it is often more convenient not to bother, and if the voltage and resistance have been measured, then the current can be calculated by Ohms law, where the current is equal to the voltage divided by the resistance. For this reason it is important that you are fully conversant with Ohms law and be able to

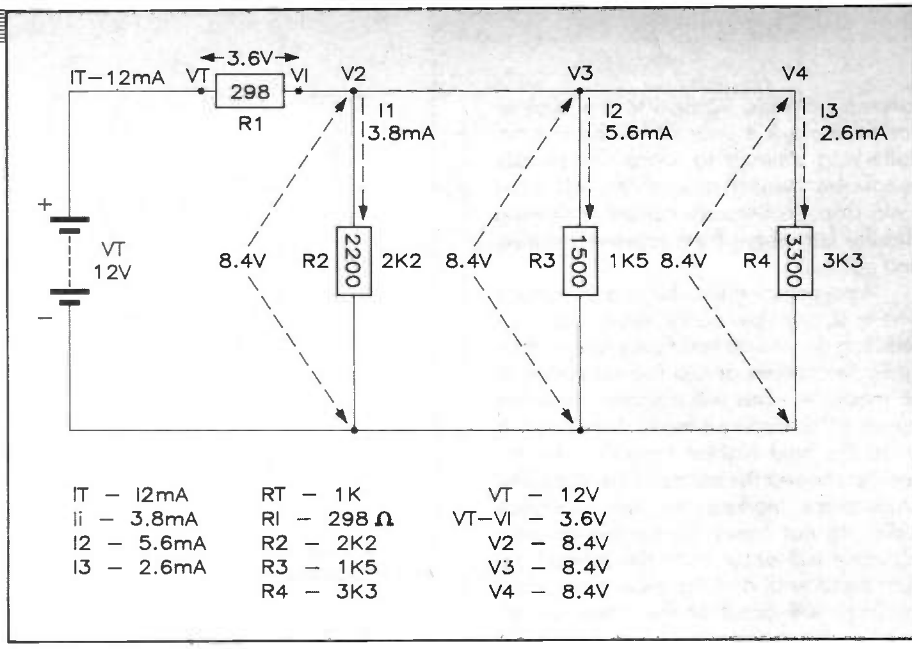


Figure 6. Meter readings taken under normal conditions.

calculate voltage, current, resistance and power in a circuit. However, current measurements are necessary to ascertain the power consumption of a complete circuit with the meter in series with the supply line. This is because deriving resistance with an ohmmeter only works with a true resistance, and attempting the same with a complete circuit will give untrue readings where the circuit has several 'active devices' (transistors and diodes). The current consumption of such a circuit cannot be deduced from such a test.

However, performing a resistance test upon a whole circuit like this can show up faults of the short or open circuit variety, and is a useful check prior to powering the circuit for the first time to see if there are any serious faults. Note however that, in the vast majority of multimeters, the black negative lead is *positive* when the ohms ranges are selected, and the red positive lead is *negative*. This is because of the way the internal battery is polarised to drive the meter movement in the proper direction – the '+' side of the movement receives current flow in the conventional direction (from '+') for both voltage and current ranges via the red probe. Therefore, to receive positive current flow from a resistor under test, the *other* end of the resistor, at the negative probe, must be connected to a positive supply – the battery '+' side! This is why, where polarity is important, the black probe must go to the plus side of a circuit and the red probe to the negative side during resistance tests.

Short Diversion

Where several interconnected resistances are involved, it is necessary to be aware of and fully understand the effects of resistances connected in series or in parallel where applicable. The calculation of resistance in series is a simple addition of all the separate values. For example RT = R1 + R2 + R3 + R4 etc, but the formula for resistance connected in parallel is not quite so simple, because the current splits up into

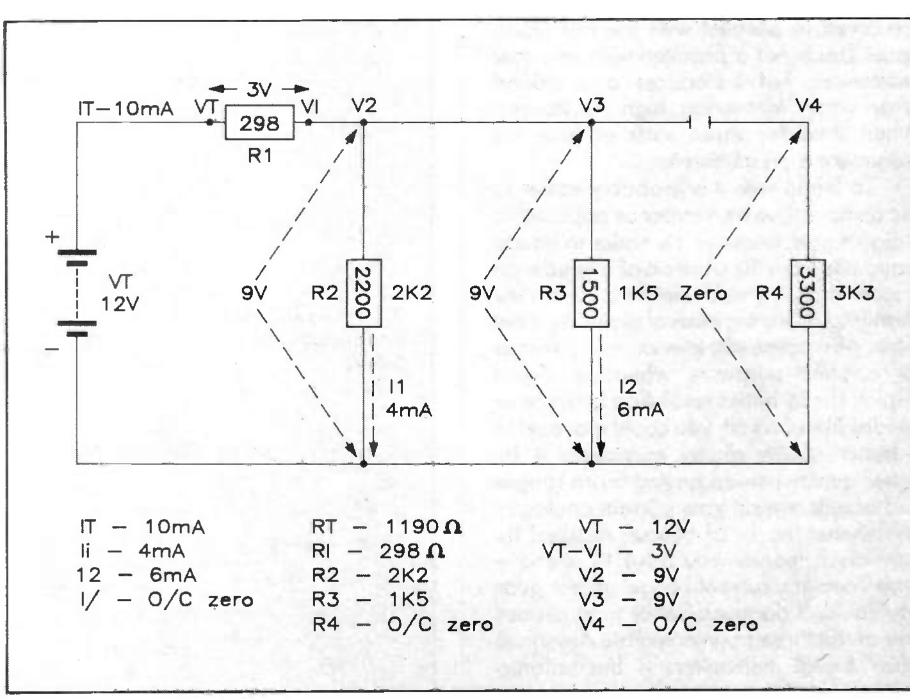


Figure 7. Meter readings taken with R4 open circuit.

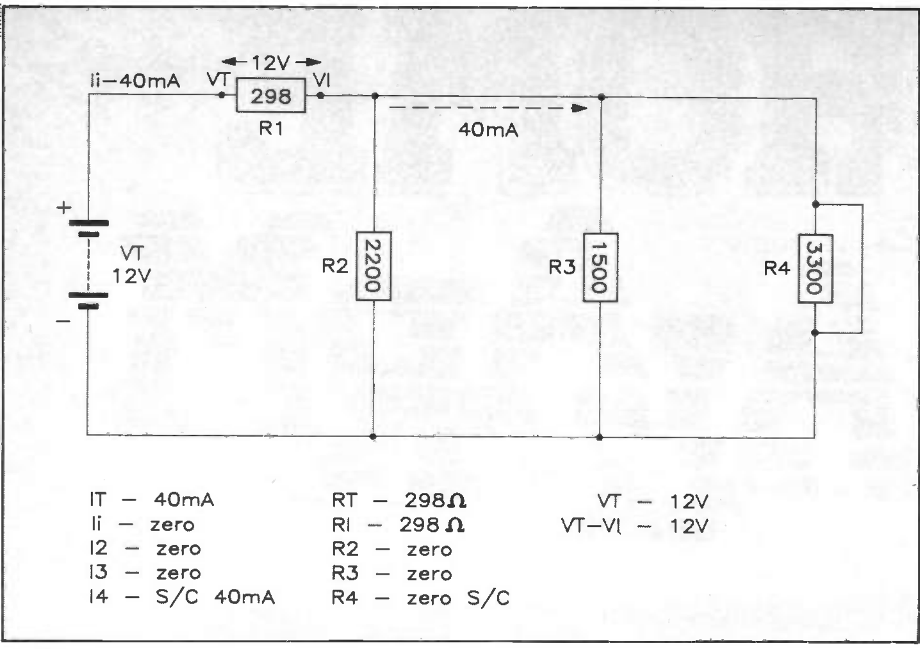


Figure 8. Meter readings taken with R4 short circuit.

several paths which lowers the total resistance. In fact it is as if the cross sectional area of a single conductor is multiplied by the number of paths. If the resistance of these paths differ in value, then the total resistance is the reciprocal of the sum of the reciprocals. Sounds complicated, but you get used to it after a while (honest!). For example:

$$\frac{1}{R_T} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \frac{1}{R4}$$

where
R1 = 20Ω, R2 = 30Ω, R3 = 40Ω, R4 = 60Ω

therefore the total resistance will be equal to $\frac{1}{20} + \frac{1}{30} + \frac{1}{40} + \frac{1}{60} = \frac{15}{120} = \frac{1}{8}$, and the reciprocal of $\frac{1}{8}$ equals 8Ω. See also Figure 5, which illustrates resistances connected in parallel, and how the total resistance is solved by tackling the problem in easy stages as shown in (b) and (c), in order to produce the answer which is given in (d).

Figure 6 illustrates a series parallel circuit showing how the voltage, current and resistance is measured and recorded, but in this case the voltage, current and resistance have been calculated by the use of Ohms law. Figure 7 shows the same circuit and how an open circuit can alter the voltage, current and resistance readings. Observing that the main current I_T is decreased from 12mA to 10mA, then the voltage at V2 and V3 has increased from 8·4 to 9 volts and the total resistance R_T increased from 1000 to 1190Ω.

Figure 8 illustrates the same circuit with a short circuit across R4. Note how the total resistance R_T is reduced to 298Ω. The short circuit across R4 has reduced the three parallel resistors to zero, leaving the 298 resistor in series, which increases the main current I_T to 40mA while the voltages at V2 and V3 are reduced to zero.

These examples show how Ohms law can be applied to a circuit and used to calculate the sum value of resistors connected in series and in parallel, but most importantly, how the parameters change under fault conditions and how the parameters can provide information that will assist in making logical deductions as to the nature of the fault and its whereabouts. Through this method you will also be able to recognise a problem in a localised area by discovering what the result should be, and then testing the actual area to verify this – if correct, then the problem is somewhere else.

To summarise so far then, while voltage drop can be measured with the meter in *parallel* to or *across* the source or component, and does not require the circuit to be broken, current on the other hand is measured with the meter in *series* with the source or component, and a break is required in which to insert the instrument. Both types of measurement have to be made with the circuit energised. Resistance measurements may or may not require a disconnection, but in either case the power must be switched off. With this in mind we can look at a procedure for examining a real circuit.

Preliminary Checks

The first thing to do before testing a circuit is to make a close physical inspection of it, using your natural senses of vision and smell, looking for signs of overheating which is indicated by a discolouring of the components or melted lumps of wax from capacitors. Look for open circuits such as loose connections, blown fuses, cracked PCB tracks and badly soldered joints. The latter two are actually more difficult to spot than you might imagine, and one last resort might be to effectively resolder each joint. Cracked tracks can be really elusive, tending to be 'intermittent' (conductive some of the time, resistive the rest of the time and rarely truly open circuit). A continuity test of each track is called for with some simultaneous 'excitation', i.e. flexing the PCB to aggravate the fault. Easiest cure is to bridge the crack with a wire link.

The next stage is to measure the supply voltage to the circuit. If the fuse has blown then the circuit was drawing excessive current, and it is obvious that there is a short circuit somewhere and it is not simply a question of replacing the fuse – they usually blow for some very good reason! Under these conditions the fuse will have to be left out while the short circuit is located by means of a resistance test.

This is done by connecting the meter across the circuit while switched to a suitable resistance range and in the right polarity as explained earlier, and noting the reading. Then, by making a disconnection at some point midway along the supply line and observing the meter reading, logical deduction should lead you to that half of the circuit which is faulty, and by subdividing the faulty half of the circuit in a similar manner the faulty item is isolated.

Alternatively an unusually high resistance might be encountered instead, indicating a broken PCB track or component, a 'dry' joint or a failed semiconductor. This sort of test is however ambiguous; if the fault directly involves the supply line then it is not too difficult to find, but if it is local to a specific stage its effect may be too small to be noticed by this test.

For the simple reason that less 'surgery' is involved, the voltage test is the most popular method of detecting faults in electronic circuits if power can be safely applied. In fact voltage testing is so convenient that it is nearly always used for preliminary investigation. It discovers open circuits without any trouble by giving too high readings, and reveals shorts and partial shorts by giving low readings. When the voltage level is incorrect and there is no obvious reading, then the circuit can be interrupted to make current and resistance tests.

More Detailed Tests

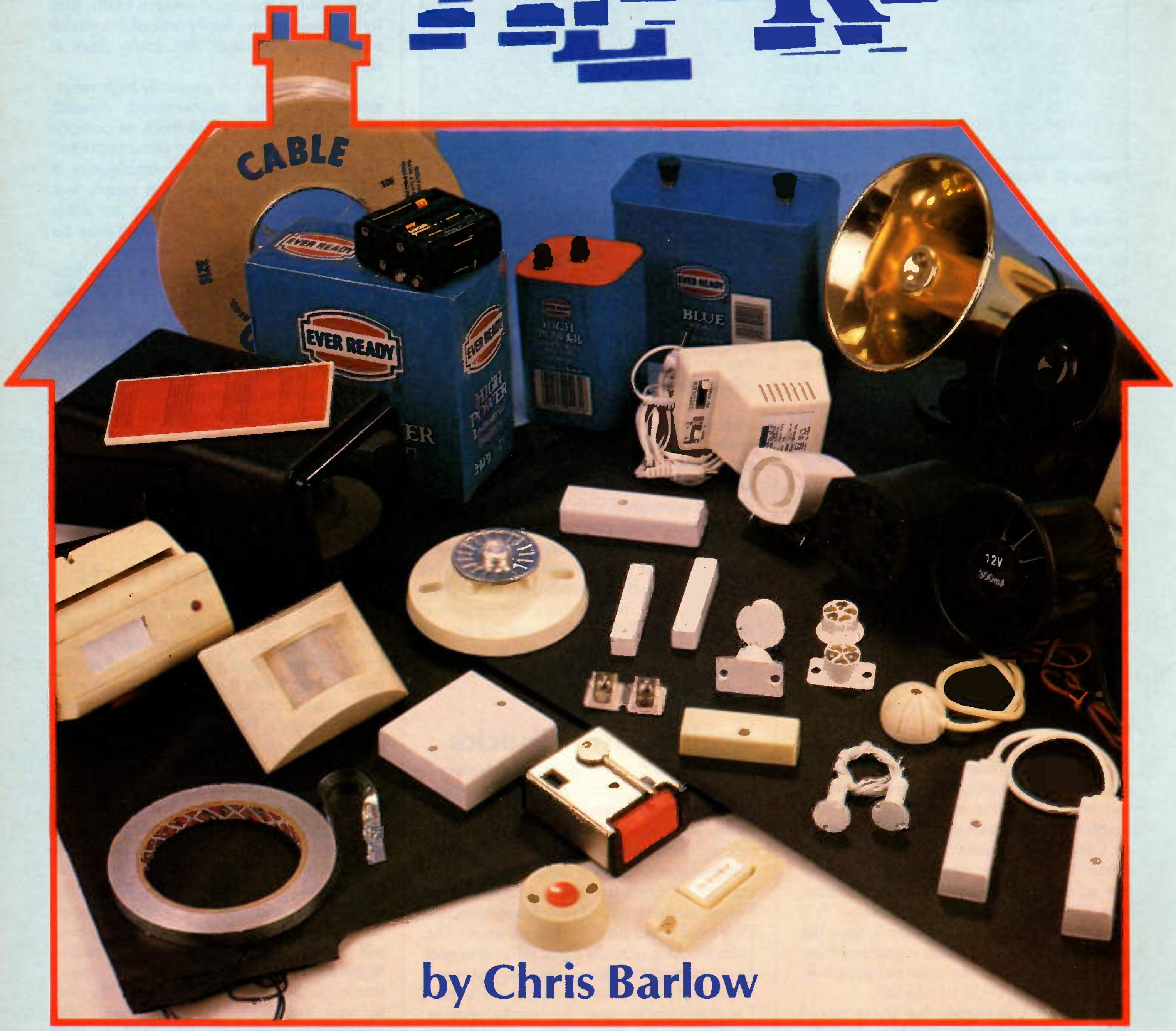
It is advisable to record your findings to compare them with specifications data, if available, so have pencil and paper handy. If such data and a circuit diagram are not available it can make things very difficult because you don't know what you are looking at. Then you will have to rely on your own experience, and logical deduction without a diagram is much more difficult and can be very time consuming.

Nevertheless it is quite possible to trace a small, simple circuit through and draw a diagram on paper according to what connects to what, which doubtless will need to be redrawn a few times until everything falls into its proper place. However this is very time consuming and will certainly be an almost impossible nightmare with complex circuits using unidentifiable ICs and complex PCBs, and so you will have to be content with examining individual components and connections. Most faults are mainly due to open or short circuits or to faulty components. Next time we will take a look at testing some of the most popular components found in electronic circuits.

Don't Miss Part 2 in the next super issue! ON SALE 6th September.

LOW COST

HOME ALARM



by Chris Barlow

FEATURES

- ★ Low Cost
- ★ Normally Open and Closed Security Loops
- ★ Arm Key Switch
- ★ Adjustable Exit/Entry Delay
- ★ Tamper and Panic Button Loops
- ★ Audio/Visual Status Indicators
- ★ Extremely Low Standby Current

Specifications of Prototype

Power supply input voltage:	6V to 12VDC
Current at 12V:	Standby = 1·3μA
	Active = 3mA
	Intruder = 7·5mA
	Help = 4·5mA
Siren Switching Current:	1A Maximum
Exit/Entry Delay Time:	1 to 60 seconds
Security Loops:	Normally Open and Normally Closed
Tamper Loop:	Normally Closed
Panic Button Loop:	Normally Open

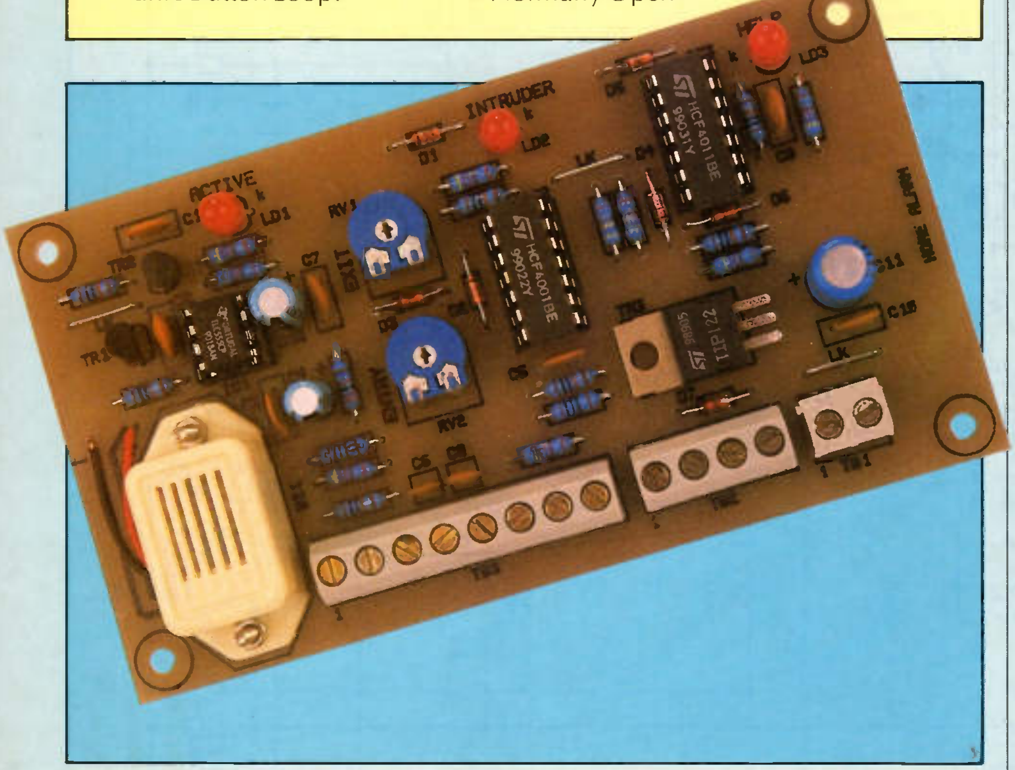


Photo 1. Completed PCB.

Introduction

The need for an inexpensive but effective home alarm is becoming of greater importance as time passes. This simple unit has several features which are normally found on more expensive alarms now available.

No alarm can offer complete protection against the determined professional burglar, but it will act as a strong deterrent to the small-time thief. This alarm can be triggered from a wide range of security sensors, such as a reed switch, pressure mat, window foil, etc. It can be expanded further to include heat, vibration and infra-red detectors. This system flexibility ensures that the potential thief never knows just what to expect from house to house.

The operating principle is that when the arm key is turned on, you then have up to 60 seconds to secure the building; during this exit time a buzzer will be sounding. After this delay the alarm is active and ready to be triggered by any of the sensors in the security loops. If you are still inside the building a red indicator acts as a reminder that the system is active. When one or more of the sensors is disturbed the alarm is triggered, lighting the intruder indicator and sounding the buzzer. You now have up to 60 seconds of entry delay to deactivate the alarm before the main siren goes off.

The alarm is equipped with two additional security loops which are permanently active and immediately trigger the main siren when disturbed. The first of these is a 'tamper-proof' loop which when broken sounds the siren until it is re-connected. The second loop is used for manually operated panic buttons, and if either loop is triggered, the help indicator will light up until the alarm is reset by the key switch being turned from the standby to the armed condition.

Circuit Description

A circuit diagram detailing the complete unit is shown in Figure 1. The timing and control of the sequence of events is governed by the logical function of the following Integrated Circuits (IC) and Transistors (TR):

IC1 TLC555 timer, 1 to 60 seconds exit/entry delay.

IC2a,b 4001BE latch, alarm active and exit/entry delay select.

IC2c,d 4001BE latch, security loop trigger.

IC3a,b 4011BE gate, siren entry delay.

IC3c,d 4011BE latch, tamper and panic loop trigger.

TR1 BC548 timer entry re-trigger.

TR2 BC548 exit/entry buzzer switch.

TR3 TIP122 siren switch.

PCB Construction

All information required about soldering and assembly techniques can be found in the 'constructors guide' included in the kit (stock code XH79L). Removal of a misplaced component will be fairly difficult so please double-check each component type, value, and its polarity where appropriate, before soldering! The Printed Circuit Board (PCB) has a legend to help you correctly position each item, see Figure 2. Install all the components including the buzzer which is secured to the board using the 8BA screws and nuts. When mounting the red Light Emitting Diodes (LEDs) you must ensure that their polarity and positioning is correct. The cathode (K) is denoted by the shorter of the two leads and by a flat on the bottom edge of the package as shown in Figure 3.

When the assembly of the circuit board is complete you should check your work very carefully, making sure that all solder joints are sound. It is also very important that the solder (track) side of the PCB does not have any trimmed component leads standing proud by more than 2mm, as they may cause short circuits. The completed PCB assembly is shown in Photo 1.

Testing

All the tests can be made with the minimum of equipment. You will need a regulated 12V DC power supply, or 12V battery, capable of providing the current required by the siren you have chosen to use, but which must not draw more than 1A, and some hook-up wire. The following quoted meter 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 you use.

Before you commence testing the unit, set the two presets, RV1 and RV2, fully counter-clockwise (CCW). Next, fit two wire links to Terminal Block 3 (TB3) as follows:

Terminal 3 to 4 (normally closed security loop), see Figure 4.

Terminal 7 to 8 (normally closed tamper loop).

Prepare the key switch S1 and siren SR1, then connect them to TB2 as follows:

S1 to terminals 1 and 2 (set key switch to its clockwise ON position).

SR1 red lead (+V) to terminal 3 and black (−V) to 4.

Do not connect any power to TB1 until it is called for during the testing procedure!

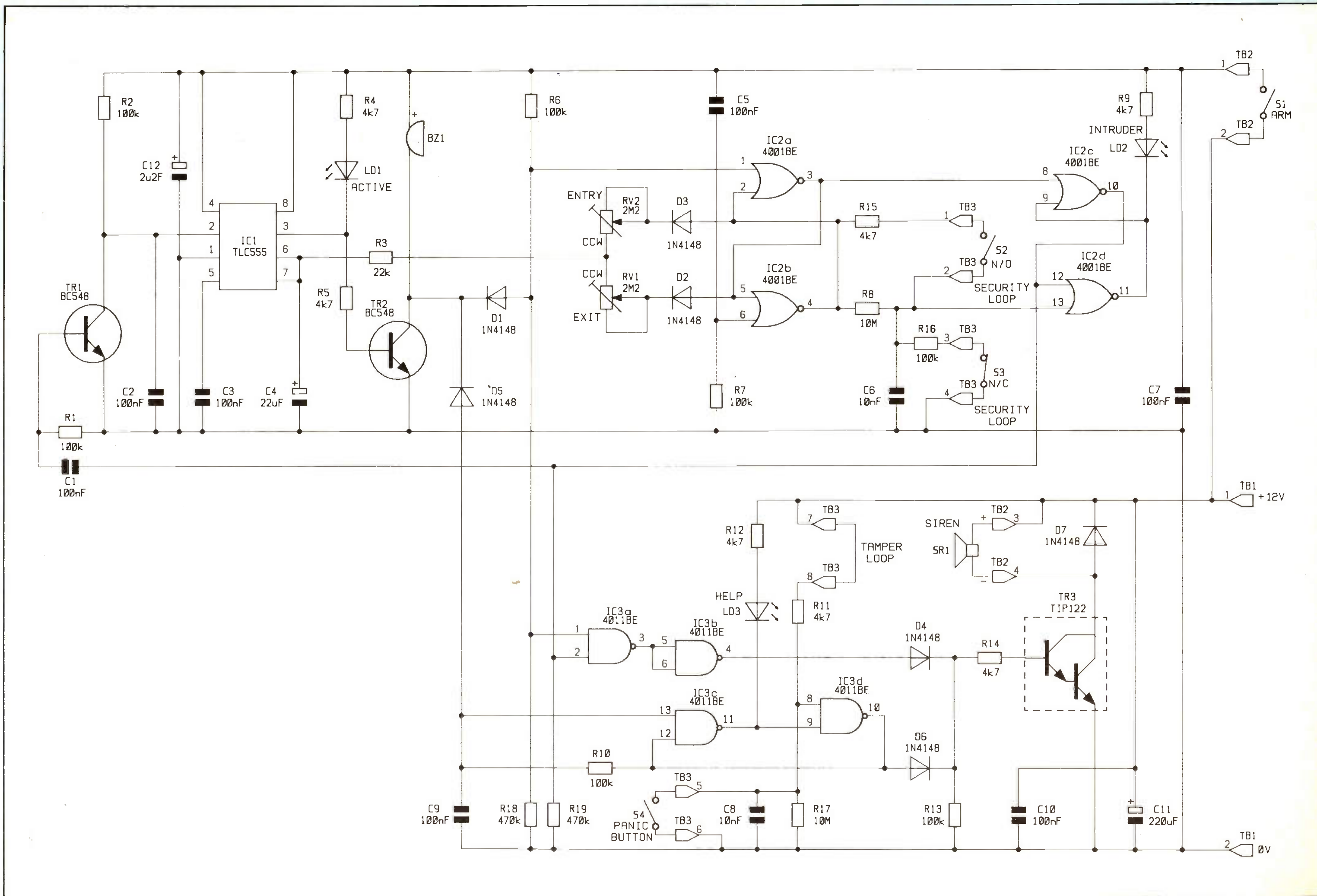


Figure 1. Circuit diagram.

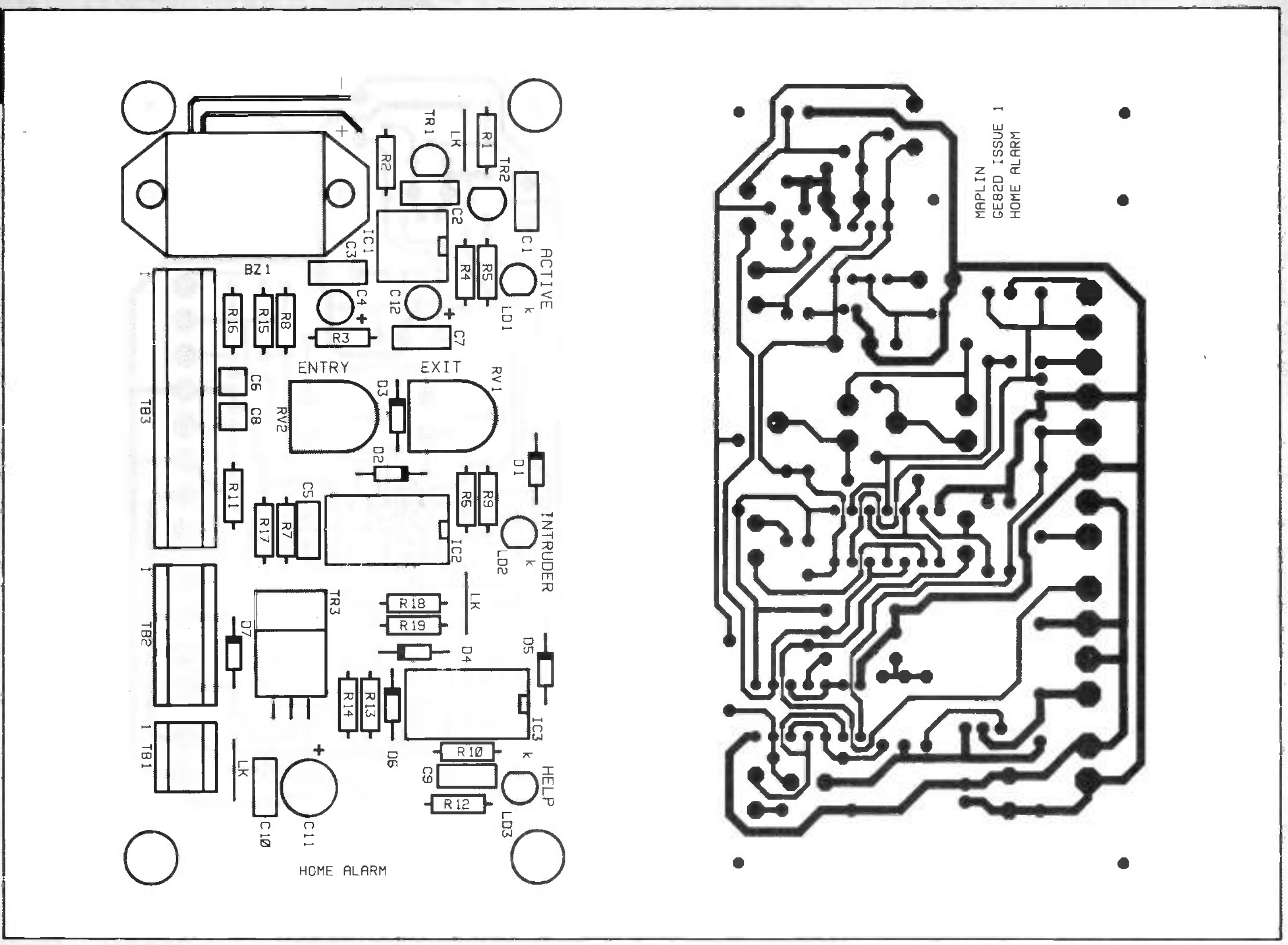


Figure 2. PCB legend.

The first test is to ensure that there are no short circuits before you connect the power supply. Set your multimeter to read OHMS (Ω) on its 20kΩ or equivalent resistance range, and connect the test probes to terminals 1 and 2 of TB1. With the probes either way round a reading greater than 1kΩ should be obtained.

Before testing the current consumption of the unit, set S1 to its counter-clockwise OFF position. It is also recommended that the output of the siren is muffled to reduce its sound intensity! Now set your meter to read DC mA and place it in series with the positive line of the power supply to TB1 terminal 1. When the negative power line is connected to TB1 terminal 2 the following should be observed:

1. None of the LED's should light.
2. Buzzer should not sound.
3. Siren should not sound.
4. A current reading of approximately $1 \cdot 3\mu A$ should be obtained.

Next, turn the key switch clockwise to its ON position, which should arm the alarm system. At the same time the buzzer should sound for approximately one second, and at the end of this time the active indicator, LD1, should light. Repeat this procedure whilst advancing the position of RV1 in small steps. Each time the setting is increased, the exit delay should also increase until, when RV1 is fully clockwise, a maximum delay of approximately 60 seconds is reached. During the exit delay a current reading of approximately 35mA should be observed, dropping down to 3mA when the system is active.

To test the alarm trigger function, each security loop on TB3 must be individually opened or closed. Set RV1 and RV2 fully counter-clockwise. Then turn the key switch S1 to its ON position (system armed) and perform the following tests:

1a. Link terminals 1 and 2 (normally open security loop).

Result: Active indicator LD1 goes out. Intruder indicator LD2 lights up. Buzzer sounds for a one second entry delay.

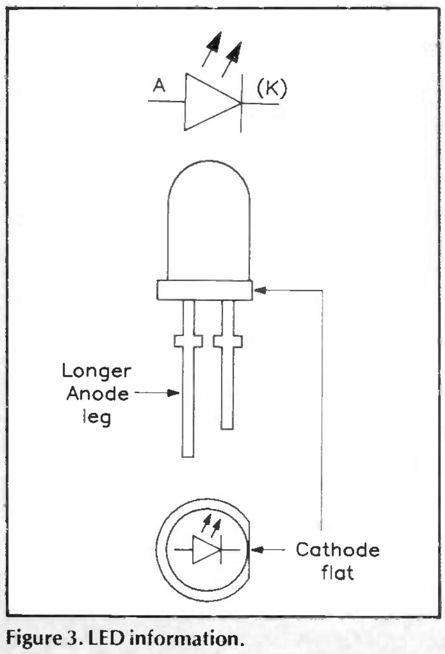


Figure 3. LED information.

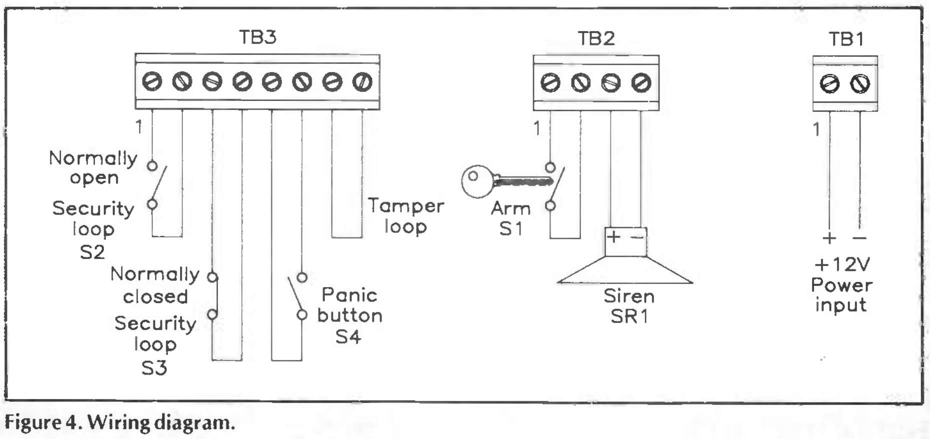


Figure 4. Wiring diagram.

Photo 2. Batteries and AC adaptor (FK64U, RK44X, YJ19V, YJ22Y, YB23A).

Photo 3. Sirens (JK42V, JK43W, YK60Q, YP11M, XG14Q, YN59P, YZ03D).

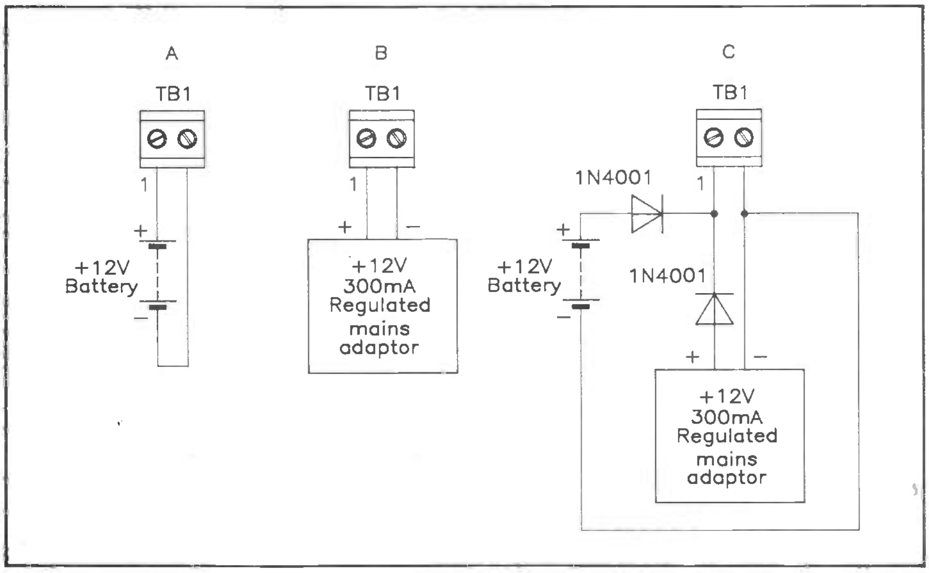


Figure 5. Power supplies.

Active indicator LD1 lights up.
Siren SR1 sounds.
Supply current reading increases by that demanded by your siren.

1b. Reset the alarm by turning the key switch off (system standby).

Result: All indicators go out.
Siren stops sounding.
Current reading drops back to 1·3μA.
Remove the link from terminals 1 and 2.

2a. Re-arm the system.
Remove the link from terminals 3 and 4 (normally closed security loop).

Result: Same as test 1a.

2b. Reset the alarm (system standby).

Result: Same as test 1b.
Refit the link at terminals 3 and 4.

3a. Link terminals 5 and 6 (normally open panic loop).

Result: Help/tamper indicator LD3 lights up.
Siren sounds immediately.

3b. Remove the link from terminals 5 and 6.
Arm the system.

Result: Help/tamper indicator LD3 goes out.
Siren stops sounding.
Reset the alarm (system standby).

4a. Remove the link from terminals 7 and 8 (normally closed tamper loop).

Result: Same as test 3a.

4b. Refit the link at terminals 7 and 8.
Arm the system.

Result: Same as test 3b.
Reset the alarm (system standby).

This completes the testing of the alarm. Now disconnect the power, test links and your multimeter from the unit.

Using the Alarm

Before the completed module can be used in a practical working environment the following operating conditions should be considered.

Power Supply: as can be seen from Figure 5, there are three basic power supply options. The simplest is shown in 'A' where a 12V battery supplies all the power to the alarm system. It must be remembered that the capacity of the battery will determine the effective operational life of the unit, which is in turn governed by the sequence of events. In its standby condition the alarm draws very little current (1·3μA), so even small capacity batteries will last for a relatively long period. However, when armed the supply current increases to 3mA and once triggered the current drawn by the siren can go up to 1A depending upon the type you have selected. For this reason it is advantageous to use a battery with a high capacity to ensure good long term operation, as illustrated in Photo 2.

The second option, 'B', uses a 12V regulated mains adaptor which must have sufficient current capacity to drive the siren. The prototype used a siren which drew less than 300mA, so only a small mains adaptor (YB23A) was necessary. Although this option gives a virtually un-interrupted supply you must take into account the fact that should the 240V AC mains fail, then the alarm system is left inoperable. For this reason a secondary battery back-up supply is advantageous, as indicated in option 'C' of Figure 5. Combining both supplies requires two 1N4001 1A rectifier diodes (QL73Q) connected as shown which effectively isolate the supplies from each other.

Siren: as can be seen from Photo 3 there is a wide range of sirens available from Maplin, and their current consumption starts as low as 30mA (YP11M), extending up to 600mA (YN59P). Since the alarm has a switching capacity of 1A it is permissible to use more than one siren as long as the total current demand is less than 1A and within the capacity of the power supply, in other words the following combinations are possible:

Where all sirens are wired in parallel:
Up to 33 30mA piezo electronic sirens (YP11M), total current 990mA.
Up to 6 150mA micro sirens (JK42V), total current 900mA.

Up to 3 300mA miniature piezo sirens (JK43W), total current 900mA.
Up to 3 300mA low cost electronic sirens (YK60Q), total current 900mA.
Up to 3 300mA staccato electronic sounders (YZ03D), total current 900mA.
Up to 2 500mA electronic sirens (XG14Q), total current 1A.
1 600mA metal horn siren (YN59P).
Or any combination of these totalling 1A.

The siren chosen for testing the prototype was the micro siren (JK42V) drawing only 150mA but producing a very loud output. All the sirens are loud and there must be careful consideration when choosing where to install them as you could very easily upset the neighbours!

Box: it's good practice to build as much as possible into the box, because the more wiring there is outside the easier it is to tamper with. The choice of box will depend upon the following design criteria:

1. Size of assembled alarm PCB.
2. Size of batteries.
3. Size of mains power supply. Can be external if battery back-up fitted.
4. Size of siren. Additional sirens can be outside the box.
5. Box material plastic or metal.
6. Free-standing or wall mounted.
7. Front panel layout and markings.

A comprehensive range of boxes is available from Maplin which can be found in the current catalogue.

Security Sensors: as can be seen from Photo 4 shows a wide range of sensors and your selection will depend on your requirements. Here is a list to help you select those most suitable for your needs.

Photo 4. Security loop sensors (YW46A, FK77J, JU65V, YW47B, FK46A, FP12N, YZ67X, YB91Y, FK79L, YW50E, YW51F, FP11M, YU81C, JG24B, YM87U, FK47B, FK78K, YW48C, YW49D, FK76H, PA77J).

Reed switches

Recessed door or window	YW46A
Recessed five terminal door or window	FK77J
Recessed panel pin fixing, five terminal door or window	JU65V
Surface mounting, door or window	YW47B

Panic buttons

Round panic button	FK46A
Help button	FP12N
Metal panic button	YZ67X

Pressure mats

Standard carpet	YB91Y
Stair carpet	FK79L

Window protection

Window foil	YW50E
Foil terminals	YW51F
Glass break detector	FP11M

Infra-red

Photo relay system	YU81C
Indoor pulsed infra-red movement detector	JG24B
Indoor passive infra-red movement detector	YM87U

Miscellaneous

Heat detector	FK47B
Vibration detector	FK78K
Door junction box	YW48C
5-Way junction box	YW49D
8-Way junction box	FK76H
4-Core burglar alarm cable (1 metre)	XR89W
(100 metres)	PA77J

LOW COST HOME ALARM PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,2,6,7,10,13,16 100k		7	(M100K)
R3	22k	1	(M22K)
R4,5,9,11,12,14,15 4k7		7	(M4K7)
R8,17	10M	2	(M10M)
R18,19	470k	2	(M470K)
RV1,2	Hor Encl Preset 2M2	2	(UH10L)
CAPACITORS			
C1,2,3,5,7,9,10	Disc Ceramic 100nF	7	(YR75S)
C4	PC Electrolytic 22µF 25V	1	(FF06G)
C6,8	Disc Ceramic 10nF	2	(BX00A)
C11	PC Electrolytic 220µF 16V	1	(FF13P)
C12	PC Electrolytic 2µ2F 100V	1	(FF02C)
SEMICONDUCTORS			
D1,2,3,4,5,6,7	1N4148	7	(QL80B)
LD1,2,3	LED Red 5mm 2mA	3	(UK48C)
TR1,2	BC548	2	(QB73Q)
TR3	TIP122	1	(WQ73Q)
IC1	TLC555CP	1	(RA76H)
IC2	4001BE	1	(QX01B)
IC3	4011BE	1	(QX05F)
MISCELLANEOUS			
	DIL Socket 8-Pin	1	(BL17T)
	DIL Socket 14-Pin	2	(BL18U)
	Low Cost Alarm PCB	1	(GE82D)
TB1	2-Way PC Terminal	1	(FT38R)
TB2	4-Way PC Terminal	1	(RK73Q)
TB3	8-Way PC Terminal	1	(RK38R)
S1	Plas Key Switch	1	(FV42V)
BZ1	Buzzer 12V	1	(FL40T)
	Bolt 8BA ½in.	1 Pkt	(BF09K)
	Nut 8BA	1 Pkt	(BF19V)
	Constructor's Guide	1	(XH79L)
	Home Alarm Leaflet	1	(XT03D)
OPTIONAL			
SR1	Micro Piezo Siren	1	(JK42V)
S4	Help Button	As Reqd	(FP12N)
Security Loop Switches:			
S2	Std Pressure Mat	As Reqd	(YB91Y)
S3	Surface BA Reed	As Reqd	(YW47B)
	Window Foil	As Reqd	(YW50E)
	Foil Terms	As Reqd	(YW51F)
	4-Wire Burglar Cable	As Reqd	(XR89W)
Batteries:			
	Alkaline KAA	8	(FK64U)
	12V Battery Box	1	(RK44K)
	PP3 Clip	1	(HF28F)
	Gen Purpose 991	2	(YJ19V)
	Gen Purpose HP992	2	(YJ23A)
	Gen Purpose HP1	1	(YJ22Y)
	AC Adaptor Regulated	1	(YB23A)
	Rectifier Diode 1N4001	2	(QL73Q)

The above parts, not including Optional items, are available as a kit:
Order As LP72P (Low Cost Home Alarm Kit) Price £12.95
The following item is also available separately although not shown in the 1991 Maplin catalogue:
Low Cost Alarm PCB **Order As GE82D Price £3.95**

A readers forum for your views and comments. If you want to contribute, write to: **The Editor, 'Electronics – The Maplin Magazine' P.O. Box 3, Rayleigh, Essex, SS6 8LR.**

AIR YOUR VIEWS

Dear Editor

Talking Keyboards and IBMs

Dear Sir,
First let me thank you for your quick response in forwarding my missing copy (No. 41) of the Maplin magazine. I would like to write in full support of J. Gall, Godalming in respect of his request for MIDI projects and also a possible article about compatibility between devices, keyboard to expander and what language is used, i.e. how does a microcomputer talk (and listen) to an organ for instance? I would also like to see an article on the construction of a MIDI keyboard, with a possible option of touch sensitivity to be able to interact with a commercial voice expander, rhythm unit etc.
As far as I can see in respect of add-in boards and other computer projects, the IBM appears to be a neglected species by most writers on the subject. Do they assume that anyone with an IBM, no matter how second hand, can just go out and buy what they want? So how about including some articles and information about the IBM and its compatibles to include an expansion bus so that the suggested boards can be plugged in. I have yet to come across a 'pin out' of the expansion bus for this machine although there seems to be one for most other computers, even Mr Penfold seems to overlook this machine (I have four of his books). On the subject of beginners projects I must accept your invitation to Air My Views on the subject. In the first instance I saw nothing in J. Clarke's letter that was in any way abusive, and would largely back his views. However it does call for a lot of initiative on the part of the beginner to seek information and the general tone of the anti-help lobby would appear to be leave them to get on with it. I do not know to what extent beginners have been requesting help from your goodselves, but would anticipate a helpful and encouraging response, while not necessarily spoonfeeding, i.e. give information where appropriate or a pointer to where further information can be found.
R.W. Harrison, Somerset.

With regard to MIDI and how MIDI devices communicate with one-another, it is worth looking at Issue 22 of 'Electronics – The Maplin Magazine', available as a back issue (XA22Y) price 85p. The article entitled 'MIDI Interfacing Techniques' deals with the basics of what MIDI is and how it works. There are also a number of good books around on the subject, see our current catalogue and try the local library. However, that said, MIDI is on the editorial 'ideas for features and projects' list.
Regarding the highly topical area of beginners, we do not in any way support the anti-help lobby, in fact we try to do everything possible to help our customers. We provide a technical help line by telephone and letter, and a 'get you working service' if constructors get totally stuck. All that we are really saying is tell us the problems, rather than just moaning "it doesn't work!" After all it is a bit like going to a doctor and saying "I'm ill" and not telling the doctor the symptoms! For the beginner who wants a really step by step way of getting started then there is the 'Watch as you build' Kit, order as SK00A price £12.21.

S·T·A·R L·E·T·T·E·R

This issue, Eric Smith from Crowborough, East Sussex receives the Star Letter Award of a £5 Maplin Gift Token for his letter on the Maplin Catalogue.

Catalogue should be Read and Not Red

Dear Sir,
In the present issue of the Maplin Magazine, you ask for readers to write to you on this subject.
I must say that I agree with Mr Tyson's views. The problem with the red printing is that the colour does not exactly stand out against the greyish background of the paper used in the catalogue. In the daytime it is not too bad, but under normal artificial light, the contrast is decreased because of the considerable lack of 'blue' in incandescent lighting. Added to this, I have been told that statistically, a considerable number of the population probably suffer from a very mild form of colour-blindness without being unduly aware of it. I cannot remember the percentage figure, but I was surprised at the time as to how high it was. This is another factor which can possibly reduce the perceived contrast. I am aware that superficially, the colour does separate the text from the ordering information, but in my opinion your previous black heavy print between two lines did this even better.
So my vote is for a return to the black printing.

We have been taking note of readers comments on the use of red print for the order codes and pricing in the Maplin catalogue. It has been suggested that blue may be preferable, so please write in with your comments, both for and against the use of blue print instead of red print.

PCB Has Got the Runs

Dear Ed,
I noticed some of the tracks on your PCB track layouts 'run' together where they should not and have spent, and I suspect some others too, a fair amount of money to make use of PCB track layouts. Is it possible to rectify this? Otherwise your magazine is a godsend. Lastly to the veteran hobbyist L. Nash of Cornwall (issue 42), never say die, may you 'solder' on forever.
P. Maudsley, Salford.
P.S. Thanks for the excellent mail order and shop service over the past few years.

The track layouts that have 'run' together is due to an excess of ink on the printing rollers, this happens quite rarely and is 'not our fault' - we have checked our artworks and film-sets and in each, the PCB track work is perfectly legible. We will contact our printers and ask them to closely monitor ink flow.

More MIDI Please

Dear Sir,
I was pleased to read the letter on the subject of MIDI, from J. Gall of Surrey, in issue 42 of 'Electronics'. In the past two years there appears to have been a great upsurge in the sale of MIDI compatible keyboards, aided no doubt by TV programmes explaining the basics of synthesisers. Being myself, since my retirement four years ago, a convert to the world of music and the owner of a Yamaha keyboard, I am greatly interested in MIDI add-ons for my keyboard, and in particular some means of good quality digital recording on a multi-track system. I think such a unit is known commercially as a 'sequencer'. I am sure a project to build a home constructed 'sequencer' would go down well with many of your readers, it most certainly would with me.
A. McGeachie, Glasgow.

We are hoping to include some MIDI projects in the future, but we feel that a dedicated sequencer is not really a practical project for two main reasons. Firstly; simple sequencers are available both new and second-hand for reasonable prices and it would be doubtful if we could offer a unit to match the price/performance ratio of the industry 'big names'. Secondly; by far the more versatile method of sequencing is to use a computer, the Atari ST series of machines springs to mind as these are the 'industry standard' in the music business. However, it is possible to use a Commodore Amiga, PC compatible or other machines with a suitable interface and software. Public domain software for the Atari is available for little more than the price of a disk and even these offer more facilities than many dedicated sequencers! STs can be bought quite cheaply second-hand and the machine can also be used for many other serious applications.

Article Ideas

Dear Sir,
Would it be possible for you to have an article in the magazine on speed control of single phase a.c. motors with thyristors. Also perhaps something on the method of mixing the sampling and audio signal in digital recordings. This is dealt with from a mathematical viewpoint in Sony's book, but it is not readily followed.
G. C. Walker, Camberley, Surrey.

We will see what we can come up with!

Deplorable

Dear Sir,
I too, deplore the use of red print for the designation of the order codes and prices in the 1991 Maplin Catalogue.
A. S. Ball, London.

AIR YOUR VIEWS

Naff N.A.B. and Speakers

Dear Sir,
In the Dec '90 – Jan '91 issue 41, Taped on page 64 – I got a twitch when I saw what was reckoned to be a practical N.A.B. pre-amplifier. Figure 10b on page 67 is not a practical circuit. With the resistors R1 and R2 being the value they are the DC voltage gain of this circuit will be around 63dB. For no significant output offset voltage to appear the input offset voltage should be in the lower end of the microvolt region, say less than 20μV. Can you find a pre-amp with these characteristics – easily and cheaply – as in practical terms? Not from Maplins that's for sure. The closest chip that probably could, may be the LT1028, a very nice beasty but have you seen the price! Also the actual resistance values that would give an amplifier this gain are somewhat high. Any designer worth his salt would want to keep resistances as low as possible when designing high gain circuits which involve amplifiers similar to – if not really an op-amp. Having high resistance in feed-back loops usually results in poor stability, higher noise and poor immunity to stray signals. I'm not saying make R2 10Ω, such an act would also be worth a snigger. For a start you will affect the open loop gain if an op-amp was used. And in general you will encounter the problems encountered when an amp of this type has too large a load. Remember the inverting input is a virtual earth.
I know that I'm nit-picking, but I feel I had to write in since I had just finished building myself a tape pre-amp. And it's a pre-amp and a half! It uses two whole LM837's, the best value for money chip for this job that Maplin sells, I reckon. I've assigned four op-amps for each channel, the first along the chain compensates for the high frequency drop of the head, the next two along are in straight forward non-inverting mode. Configured for minimal gain and hopefully minimal noise, after which the actual N.A.B. stage comes. I needed four stages so that I could get the best from the op-amp in each stage, but with an overall high gain. I found also that with each stage having a low gain (x6), I could couple directly without capacitors since I have a preference for split supply and the offset voltage was a fraction of a volt.
Lastly, why are the circuits in the amplifier section of the catalogue still using single supply rails. If you're going to spend that much money on your "system" why not spend just as much on a split rails power supply? I think big beefy electrolytics should only be used on power supplies, not for coupling some amplifier to some sound transducer. It's like putting Formula One racing tyres on a Skoda. Besides I thought Skodas went on tank tracks, it certainly moves like it!
Last but not least what happened to the beefy high compliance speakers Maplin had, what's with the new range of high quality mid-range speakers? It's only the 18" one that's worth a look, you'd have a job on your hands designing cabinets for these, just use your next door neighbours wall as the baffle, but make sure he's deaf and brainless.
V. White, Co. Durham.

Mike Holmes replies:
A valid point concerning Figure 10b on page 67. Our fault for assuming one or two things that we thought would be obvious requirements, like for instance the op-amp needing plus and minus supply rails and output decoupling, also not shown. Obviously an amplifier with this much DC gain is ridiculous, and so R1 should be decoupled to ground with, given the low value, something in the region of 220μF for a frequency response which is flat down to >10Hz, and reducing DC gain to unity. Similarly the input coupling capacitor, shown with no value, can be selected for the required low frequency roll-off, e.g. 1μF giving 20Hz. However the values for the important bits, namely feedback network and components at the input, are given. In this respect the example is 'practical' (and directly from a working circuit) – without these values it remains very much hypothetical!
We are also somewhat confused that you feel you should need four op-amps to produce one tape playback preamplifier – Figure 10b can produce 100 – 150mV r.m.s. output on its own, perhaps more depending on the sensitivity of the play-back head. With the addition of a further 30dB of 'straight' amplification as a first stage it can produce up to 0dB, and in fact all this is provided by the brilliant TDA3410 IC, purpose designed for ultra low noise, high quality stereo tape playback. Why not ask for a data sheet along with your next order?
As for the large number of power amp ICs shown in the catalogue with single ended supplies, it should be pointed out that most are specifically arranged internally for single ended operation and are not designed to be used any other way. While this requires large coupling capacitors between output and speaker, which admittedly seems 'old hat' in this day and age, something slightly provided by combining the reservoir capacitors with speaker coupling, by using two reservoir caps in series (between the supply rails), with the speaker connected directly between the common junction and the output. This is a time honoured method of eliminating switch-on 'thump' with this sort of design – but be careful, many of these ICs are very fussy about how you wire them up!
As for the speakers themselves, there are several answers to your last question. Either the manufacturers don't exist anymore, the models have been phased out, better quality items are now available for the same price or more cheaply, and not least, speaker design has moved on apace and is no longer 20 years behind the times. Although genuinely good speakers were always around they weren't easy to get hold of, leaving just the general purpose 'P.A.' variety. Modern consumer demand now calls for good quality sound from small boxes that don't clutter up the lounge, instead of folded bass reflexes the size of wardrobes. This has forced changes in driver design to comply, resulting in the increased availability of such drivers (the 'mid-range' ones you mention), and the other type of speakers to which you refer are 'no longer good enough'.
To cite a real example – fairly expensive (>£50 each in 1985) French Audax bass drivers (not sold by Maplin incidentally) in 19 litre infinite baffle (not ported) enclosures, verified by computer aided design using Thiele/Small data. –3dB @ 60Hz. Lovely smooth bass response down to the nether regions with no loss of sensitivity or clarity at very low power levels. Not perfect of course (what is?), but against which, as I consequently discovered, the older so-called high compliance driver cannot hold a candle... Nuff said.

Give Me (Field) Strength

Dear Sir,
With increasing public interest in TV picture/sound quality, it has long been my intention to propose a signal strength meter for a magazine project allowing constructors to ensure the best results from whatever aerial. Scanning past issues I find this proposal has already been made by Mr M. Ashby of Luton in the 'Air Your Views' of the Dec '89/Jan '90 issue. Since many installers do not possess a meter and either point the aerial roughly in the same direction as others on adjacent property, or by visual judgement of picture quality from an assistant on the ground, this project should appeal to many readers.
It could of course be argued that existing projects for the NICAM stereo tuner and surround sound processor appear premature without means of ensuring optimum signal strength on which they and the visual picture quality depend.
H. Maynard, North Humberside.

Ferret Finder

Dear Sir,
I am in the process of reading the first issue of my first subscription to 'Electronics' and immediately I am impressed. However, on turning to page 77 'Air your Views' I was a little surprised and cynically amused at the acrimonious note struck by some of your contributions. Not being unfamiliar with electronics professionally as a subject, I have only recently entered the 'hobbyist level'. I have also been approached by a young friend who asked me if I could build him a 'Ferret Locator' or similar radio tracking devices for a college project he has undertaken, not being technically qualified enough to work up from first principles, or sufficiently au fait with component supplies to achieve the required miniaturisation. May I, through your column ask you and/or your readers, for any advice or circuits or publications which will assist me in building and operating radio tracking and similar devices.
Paul Anderson, Ludlow, Shropshire.

If any readers can help Mr Anderson, please write in and we will pass your letters on.

Serial Robotics

Dear sir,
Your new series "Practical Robotic Techniques" prompted me to write in with two project ideas. Many computers such as the Commodore Amiga have no user port as such but do have a serial port very easily controlled both from BASIC and DOS. Why not produce a pair of kits: a simple serial to parallel converter along the lines of the one which appeared in "Bob's Mini- Circuits" June-August 1988, plus a parallel to serial converter, maybe including an analogue to digital converter for use with LDRs, etc? I am sure that many people will find them most useful, not least for robotics.
R. A. Skeen, Herts.

P.S. I favour the use of red ink in the catalogue but would prefer it to be just a little darker.

Thank you for the ideas, they have been passed onto the lab.

MULTI-FUNCTION

by Tony Bricknell

LOW COST 10MHz COUNTER

F E A T U R E S

- ★ *Functions as a frequency counter/period counter/unit counter*
- ★ *Three internal gate times in frequency counter mode*
- ★ *10 cycle, 100 cycle and 1000 cycle gate times in period mode*
- ★ *Leading zero blanking and automatic decimal point shifting*
- ★ *Reverse polarity protection* ★ *Reset switch for added flexibility*
- ★ *8 Segment multiplexed LED display* ★ *Low cost design*
- ★ *Minimal wiring required*

This project is the first in a suite of low cost test equipment for the hobbyist. During this series the construction of several useful items of test equipment will be covered.

1.2.3.4.5.

There are many multifunction counters available but, unfortunately, most are priced way out of the range of the home hobbyist. This project aims to fill the gap in the lower end of the market by offering a counter, packed with features normally found on its more expensive counterparts (no pun intended).

The design is based on the Intersil ICM7216A, giving measurements of frequency, periodic time or totalising counter (event counter). The counter input has a maximum frequency of 10MHz in frequency and unit counter modes, and 2MHz in periodic time mode. For period measurement the unit gives a 0·1μs resolution. In the frequency mode, the user can select input gating periods of 0·1, 1 or 10 seconds. With a 10 second gate time, the frequency can be displayed to an accuracy of 0·1Hz in the least significant digit. There is a delay of 0·2 seconds between each measurement for all ranges, and the ICM7216A allows leading zero blanking and automatic decimal point positioning, according to range to be incorporated. The reading is displayed in kilohertz in the frequency mode, and in micro-seconds for the time measurement mode. Four 0·56in. high contrast, double digit displays are used, which are multiplexed at 500Hz with a 12·5% duty cycle for each digit. A full specification of the prototype can be found in Table 1.

Input Amplifier

With reference to Figure 1, it can be seen that the signal input on P1 (signal) and P2 (ground) is immediately capacitively coupled to remove any DC bias. The signal, clamped by D1 and D2, enters a wide band discrete amplifier. To achieve a high input impedance an FET is used for TR1. The output signal from the drain of TR1 is fed into TR2, to provide a clean switching waveform to drive the A input of IC1.

Logic and Display

IC1 handles the range and function switching, display buffering and multiplexing, and the internal and external oscillators. Its block diagram can be found in Figure 2. The output from the collector of TR2 enters IC1 on pin 28. The internal crystal frequency is determined by the setting of VC1. IC1 provides the digit and segment drive for the 8-digit, 7-segment display. The function and range inputs are time multiplexed to select the input function desired. This is achieved by connecting the appropriate digit driver output to the inputs. Noise on the multiplex inputs can cause improper operation, which is particularly

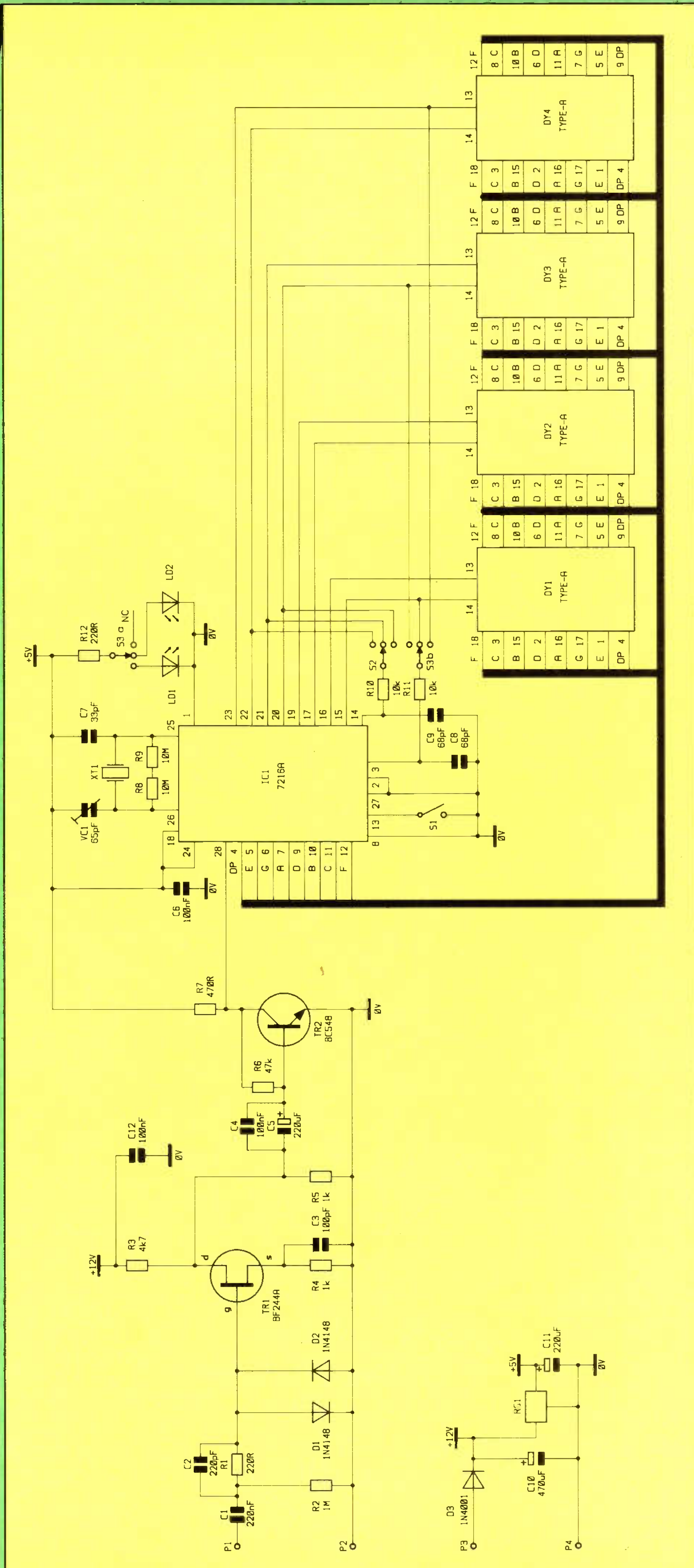


Figure 1. Circuit diagram.

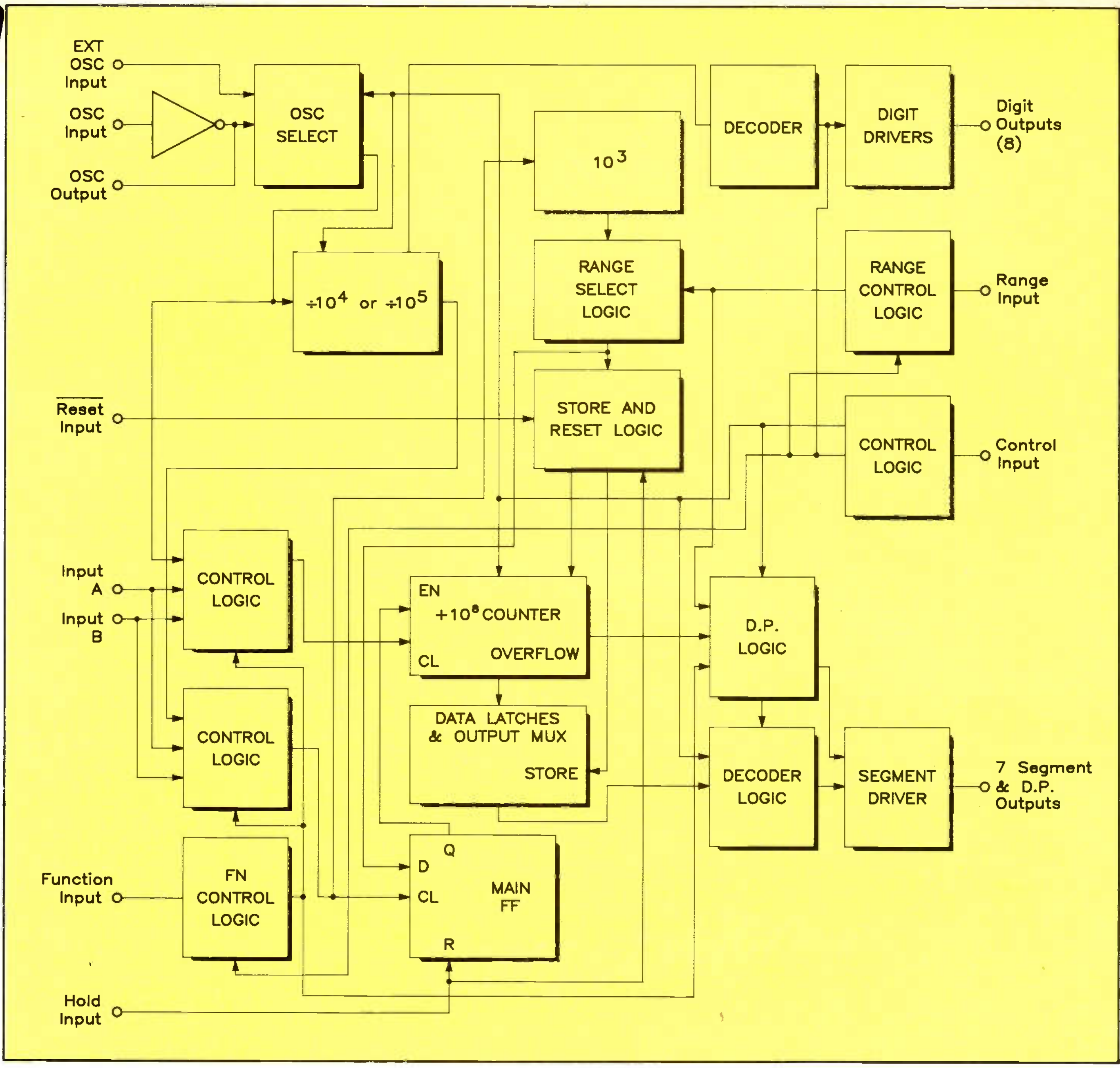


Figure 2. Block diagram of the ICM7216A.

Supply voltage	10V–15V
Average supply current @ 12V	110mA
Nominal input impedance	1MΩ
Input signal frequency range	10Hz–10MHz
Input signal amplitude (p.d.) 10kHz – 1MHz input frequency, 1MHz – 5MHz input frequency, 5MHz – 10MHz input frequency,	 30mV 45mV 90mV
Functions	Frequency, Periodic time, Unit counter
Gate times	0.1, 1, 10 seconds (Frequency mode) 10, 100, 1000 cycles (Period mode)
Best resolution	0.1Hz (Frequency mode) 0.1µs (Period mode)
Indicators	8 seven-segment displays, 2 range LED's, Over-range
Timebase	10MHz high-stability crystal

Table 1. Specification of prototype.

true when the unit counter mode is selected, since voltage changes on the digit drivers can be capacitively coupled through the LEDs to the multiplex inputs. For maximum noise immunity, a low pass filter consisting of a 10kΩ resistor and 68pF capacitor is placed in series with the multiplexed inputs.

Power Supply

A 12V regulated input is required which can be supplied from an AC adapter. D3 ensures that no damage will be done to the circuit if the power supply is connected with incorrect polarity. This 12V line powers the front-end amplifier directly, while a regulated 5V line is taken from this supply to drive all the additional circuitry including the LED display.

Construction

The Low-Cost Counter is constructed on a single-sided glass fibre PCB, chosen for maximum reliability and stability.

Figure 3 shows the PCB, with printed legend, to help you correctly locate each item. The order in which the components are fitted is not critical, however the following instructions will make the assembly task as straightforward as possible. For general information on soldering and assembly techniques, refer to the Constructors' Guide in the kit.

From the short length of 22 s.w.g. TC wire included in the kit, cut and fit the 39 links. Next, fit the four PCB pins. After insertion, use a hot soldering iron to press the pins into position. If sufficient heat is used, it should not be necessary to use a great amount of force. Once in place, the pins may be soldered.

Now fit the remaining components, starting with the small resistors and diodes, working upwards in size until the switches are fitted last. The IC socket should be fitted before any other high profile components, as it must be kept flush with the PCB. Ensure that the notch at the end of the socket aligns with the white block on the legend. *Do not* insert the IC until it is called for during the test procedure!

Special precautions are needed when fitting the semiconductors (diodes and transistors). In particular, take care not to overheat them during soldering. All the silicon diodes have a band identifying one end, be sure to position these adjacent to the white blocks marked on the legend.

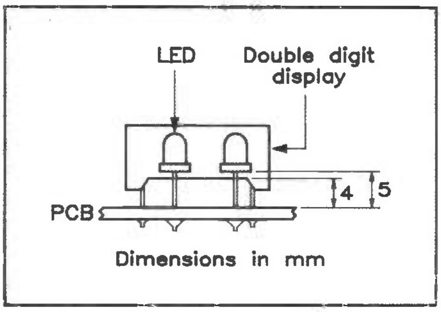


Figure 4. Inserting LD1, LD2 and DY1-4.

When installing the transistors, match the shape of each case to its outline on the legend. Take care with the polarity of the electrolytic capacitors, which is indicated by a full-length negative (−) stripe, the lead *nearest* this symbol goes into the hole *opposite* to that marked with a positive (+) symbol on the legend.

Install LD1 and LD2 at a height of 5mm above the PCB, matching the flat side of the package with that shown on the legend. The double-digit displays DY1 – 4 are installed next, and must be raised off the PCB to a height of 4mm, as shown in Figure 4.

Before continuing further it is recommended that you take several minutes to double-check your work to make sure that there are no dry joints, or stray strands of solder that could cause a short circuit. 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 3mm, as this may cause a short circuit.

No specific box has been designated for the project, however, the single board prototype fitted nicely into an ABS box with

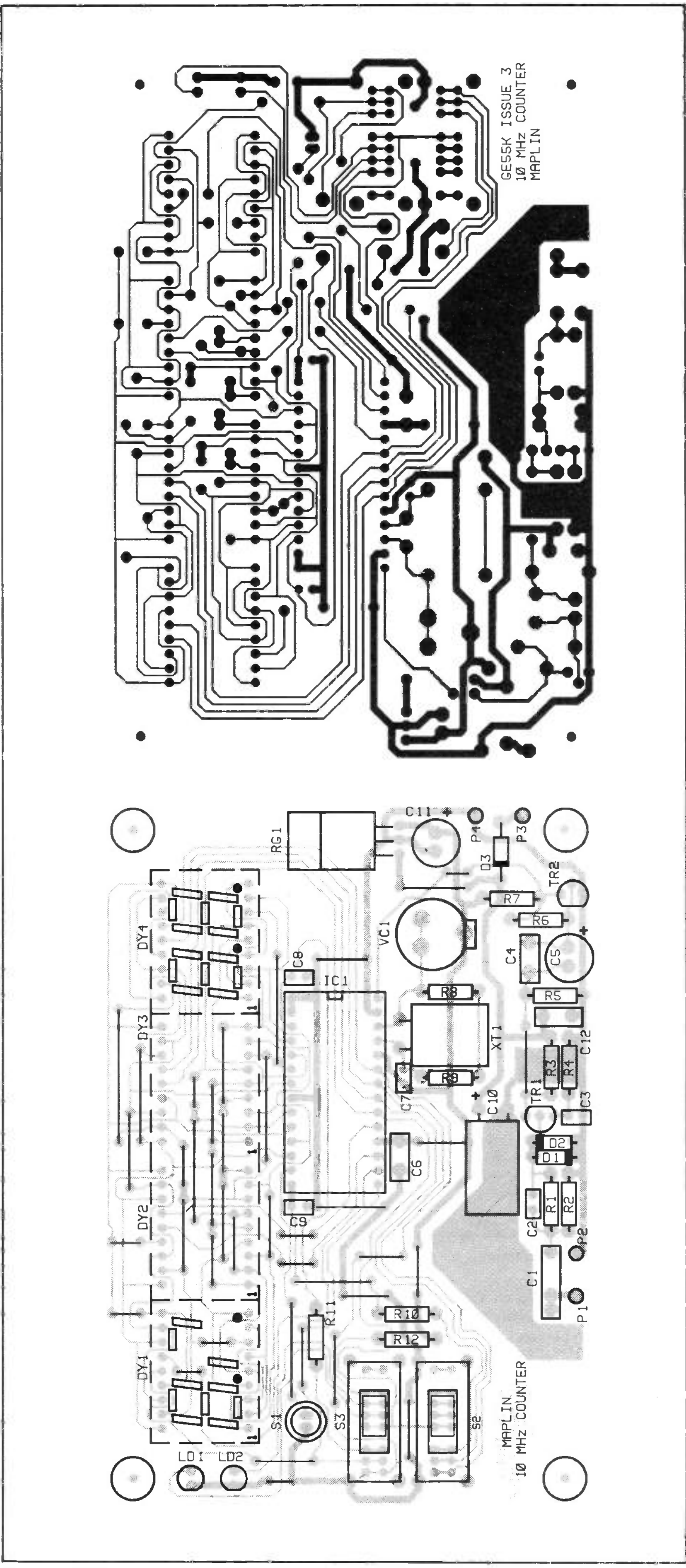


Figure 3. PCB with legend.

metal front panel type M4005 (stock code WY02C), see Figure 5 for box drilling details.

The choice of connectors for the power and input leads is entirely up to you. However, it is good practice not to use the same type of connector for different functions.

When installing the complete PCB assembly remember to use some form of spacer between its solder side and the inside surface of the case, particularly vital if you are using a metal case or chassis.

Setting Up and Testing

Apply power to the PCB (+12V to P3, 0V to P4) and check the voltage present across pin 18 (+V) and pin 8 (0V) of the socket for IC1 using a multimeter. A reading no greater than 5·5V and no less than 4·5V should be present. If there is zero volts present then you may have the power supply polarity incorrectly connected. By moving S2, LD1 and LD2 may be made to illuminate. If everything is satisfactory, remove the power supply and insert IC2. Be careful not to bend the pins which are easily damaged. Temporarily short together P1 and P2, and re-connect power. The format of the display will differ depending which mode you are in. Switch through the ranges with S2 and check that the display varies as shown in Figure 6. The multifunction counter is now fully working.

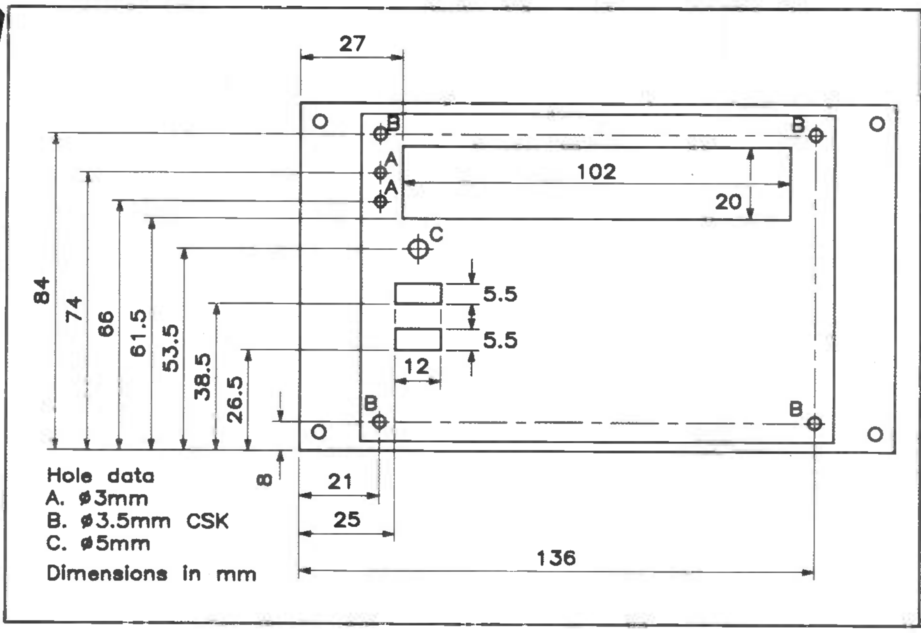


Figure 5. Box drilling details.

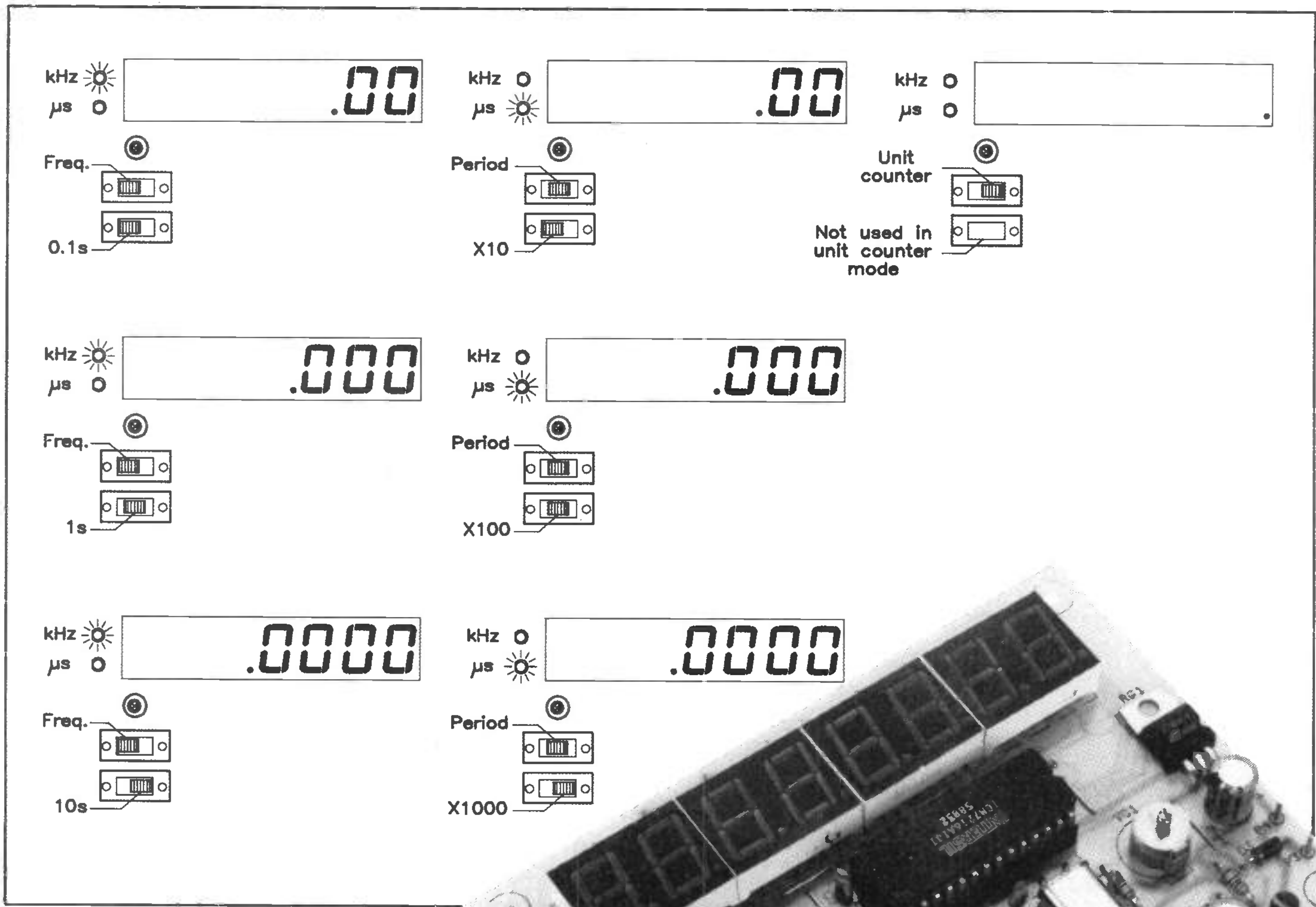
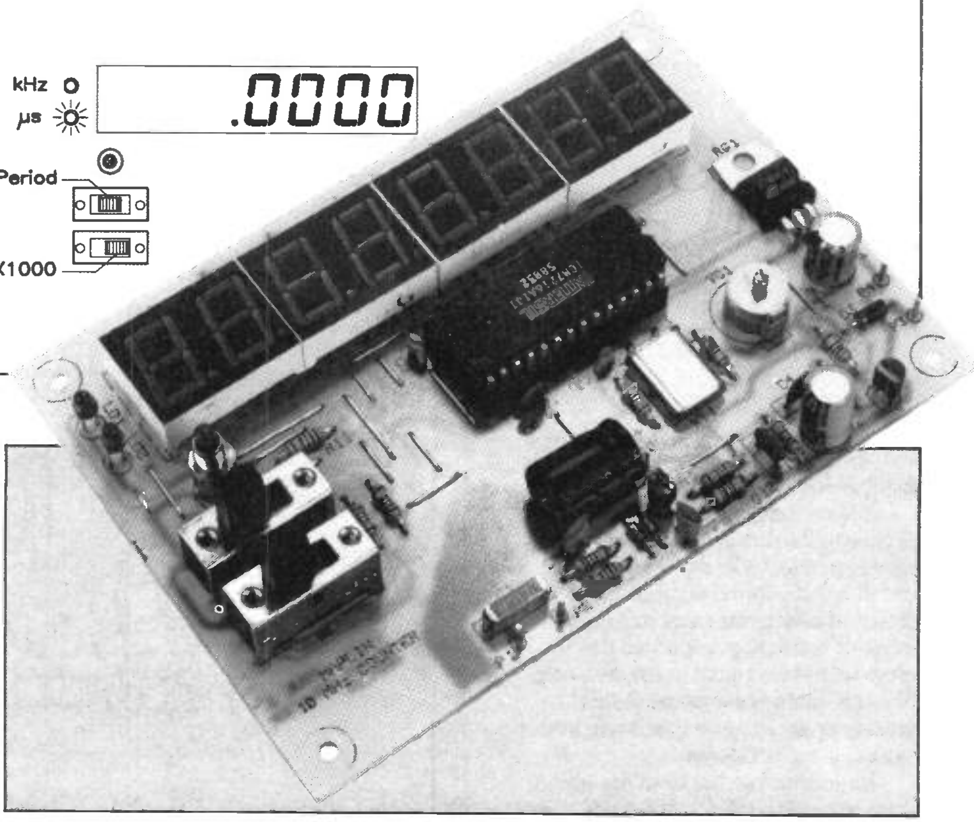


Figure 6. Display conditions.


The completed PCB. A project you can count on!

Mode	Main Counter	Reference Counter
Frequency	Input A	100Hz (Oscillator – 10^5)
Period	Oscillator	Input A
Unit counter	Input A	Not Applicable

Table 2. Internal counters.

Calibration and Accuracy

The unit is calibrated by applying a signal of known frequency and accuracy to the input, and then adjusting VC1 until the correct frequency is displayed. The setting of VC1 will determine the accuracy of the unit, and care should be taken in making this adjustment. However, if a reference signal is not available, set VC1 to its mid-point. It was found that, on the prototype, this procedure produced a small, but acceptable error equating to 0·002%, with an input frequency of 10MHz.

In a universal counter such as this, it must be realised that there can be crystal drift and quantisation errors. In frequency and period modes, a signal derived from the oscillator is used by either the reference counter or the main counter. Therefore, in these modes an error in the oscillator frequency will cause an identical error in the measurement. For instance, an oscillator temperature coefficient of 20ppm/°C will cause a measurement error of 20ppm/°C.

In addition, there is a quantisation error inherent in any digital measurement of ±1 count. Clearly this error is reduced by displaying more digits. In the frequency mode the maximum accuracy is obtained with high frequency inputs, and in period mode maximum accuracy is obtained with low frequency inputs.

In Use

The selected mode of operation decides which signal is counted into the main counter, and which signal is counted by the reference counter, as shown in Table 2.

Reset switch S1 — When the reset switch is depressed, any measurement in progress is stopped, the main counter is reset, and the chip is held ready to initiate a new measurement. The latches which hold the main counter data remain enabled, resulting in an output of all zeros. When the Reset switch is released, a new measurement is initiated.

Function switch S2 — Changing the function with S2 will stop the measurement in progress without updating the display, and then initiate a new measurement. This prevents an erroneous first reading after the function switch is moved.

Gate switch S3 — In frequency counter mode this switch selects a 0·1s, 1s or 10s gate time. In period mode the switch selects 10 cycle, 100 cycle or 1000 cycle gate times.

In every range, any overflow is shown by the decimal point in the most significant (left-hand) digit being illuminated.

LOW COST 10MHz COUNTER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1,12	220Ω	2	(M220R)
R2	1M	1	(M1M)
R3	4k7	1	(M4K7)
R4,5	1k	2	(M1K)
R6	47k	1	(M47K)
R7	470Ω	1	(M470R)
R8,9	10M	2	(M10M)
R10,11	10k	2	(M10K)
CAPACITORS			
C1	220nF Poly Layer	1	(WW45Y)
C2	220pF Ceramic	1	(WX60Q)
C3	100pF Ceramic	1	(WX56L)
C4,6,12	100nF 16V Minidisc Ceramic	3	(YR75S)
C5	220μF 16V PC Electrolytic	1	(FF13P)
C7	33pF Ceramic	1	(WX50E)
C8,9	68pF Ceramic	2	(WX54J)
C10	470μF 16V PC Electrolytic	1	(FF15R)
C11	220μF 10V Minelectrolytic	1	(JL06G)
VC1	65pF Trimmer	1	(WL72P)
SEMICONDUCTORS			
D1,2	1N4148	2	(QL80B)
D3	1N4001	1	(QL73Q)

TR1	BF244A	1	(QF16S)
TR2	BC548	1	(QB73Q)
IC1	7216A	1	(UL64U)
RG1	μA7805UC	1	(QL31J)
LD1,2	Mini LED Red	2	(WL32K)
DY1,2,3,4	DD Display Type A	4	(BY66W)
MISCELLANEOUS			
S1	Sub Min Push Switch	1	(JM47B)
S2,3	4 Pole Slide Switch	2	(FH38R)
XT1	FS Crystal 10MHz	1	(FY78K)
P1-4	Pin 2145	1 Pkt	(FL24B)
	DIL Socket 28-Pin	1	(BL21X)
	LC 10MHz Counter PCB	1	(GE55K)
	Constructors' Guide	1	(XH79L)
	LC 10MHz Counter Leaflet	1	(XK31J)
OPTIONAL			
	Box M4005	1	(WY02C)
	Red Display Filter	1	(FR34M)
	Regulated Adaptor	1	(YB23A)

The above parts, excluding Optional items, are available as a kit:
Order As LP37S (LC 10MHz Counter Kit) Price £49.95
The following is also available separately although not shown in our 1991 catalogue:
LC 10MHz Counter PCB **Order As GE55K Price £3.95**

Take the Sensible Route!

BoardMaker is a powerful software tool which provides a convenient and fast method of designing printed circuit boards. Engineers worldwide have discovered that it provides an unparalleled price performance advantage over other PC-based and dedicated design systems by integrating sophisticated graphical editors and CAM outputs at an affordable price.

NEW VERSION

In the new version V2.40, full consideration has been given to allow designers to continue using their existing schematic capture package as a front end to BoardMaker. Even powerful facilities such as Top Down Modification, Component renumber and Back Annotation have been accomodated to provide overall design integrity between your schematic package and BoardMaker. Equally, powerful features are included to ensure that users who do not have schematic capture software can still take full advantage of BoardMaker's net capabilities.

BoardMaker V2.40 is a remarkable £295.00 (ex. carriage & VAT) and includes 3 months FREE software updates and full telephone technical support.

AUTOROUTER

BoardRouter is a new integrated gridless autoroute module which overcomes the limitations normally associated with autorouting. **YOU** specify the track width, via size and design rules for individual nets, BoardRouter then routes the board based on these settings in the same way you would route it yourself manually.

This ability allows you to autoroute mixed technology designs (SMD, analogue, digital, power switching etc)in **ONE PASS** while respecting **ALL** design rules.

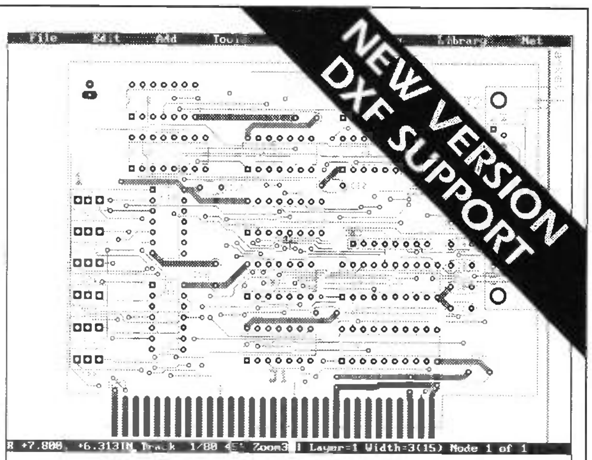
GRIDLESS ROUTING

No worrying about whether tracks will fit between pins. If the track widths and clearances allow, BoardRouter will automatically place 1, 2 or even 3 tracks between pins.

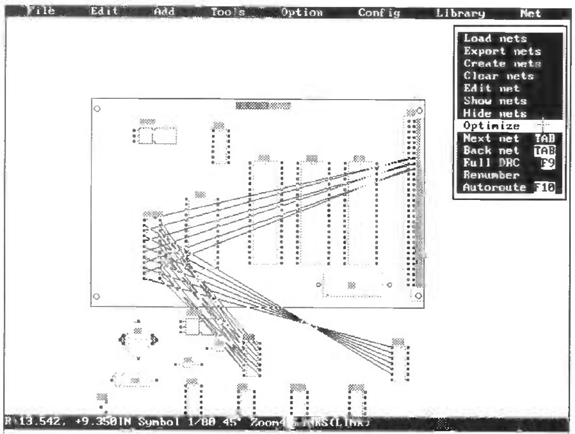
FULLY RE-ENTRANT

You can freely pre-route any tracks manually using BoardMaker prior to autorouting. Whilst autorouting you can pan and zoom to inspect the routes placed, interrupt it, manually modify the layout and resume autorouting.

BoardRouter is priced at £295.00, which includes 3 months FREE software updates and full telephone technical support. BoardMaker and BoardRouter can be bought together for only £495.00. (ex. carriage & VAT)



Full analogue, digital and SM support - ground and power planes - 45 degree, arced and any angle tracks with full net-based Design Rule Checking.



Optimized placement by displaying ratsnest per component. Lines indicate the unrouted nets.

HIGHLIGHTS

- Net list import from OrCAD, Schema etc.
- Graphical and manual netlist entry
- Top down modification for ECOs
- Forward and back annotation
- Component renumber
- Effortless manual routing
- Fully re-entrant gridless autorouting
- Simultaneously routes up to eight layers
- Powerful component placement tools
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fast food counter

If you have a microwave oven, how well do you understand it? Possibly not as well as you think you do. Although these so called ovens have been available for use in the home since 1947, the microwave concept is still vague and confusing to most people who use them. It would be a poor show if that included any reader of this magazine, so read on, to make sure you have your facts straight. Have no fear, this is not a cookery lesson.

Basically, the microwave oven is a metal box containing radio frequency energy at around 2,450MHz. That is the frequency which provides optimum speed and penetration of foodstuffs. Deviant frequencies give more of one and less of the other. The wattage rating of the oven is the amount of energy fed into the box. This causes the molecules of the 'load' (mainly its moisture, fat and sugar) to change direction twice per cycle. That causes a rapid temperature rise, and a flywheel effect which sustains the temperature for an appreciable period after the microwave energy stops. That's it in a nutshell, bringing us to our main concern, which is the way the energy behaves. Its unique characteristics are quite remarkable.

The effect of microwave energy is determined by three primary factors:

1. Wattage (power level);
2. Load Size (food quantity);
3. Time.

This effect will change if just one of these factors is altered, but it need not change if two are altered. Here's an example. A pot of water boils in two minutes at power level X. Alter the power *or* the size of the pot, and the boiling time will be different. Alter the power *and* the size of the pot (in direct proportions) and the boiling time need not change. In practice, a large cup of water at high power, and a small cup of water at low power, could take the same time to boil. This may be purely academic with water, but vital with some foods, which can be spoiled if cooked too slow or too fast.

"Rupert Besley cartoon"

Food Quality

The duration or speed of cooking has a marked effect on the quality of the result, and as you can see, it is influenced by food quantity and power level together. Cookbook recommendations usually give a power level for each purpose, and ignore food quantity. This leaves the time factor to take care of itself. Curiously, cooking in a shorter time is not always seen as cooking faster.

Another important point now emerges. If water can be boiled at low power then power levels cannot be related to temperatures, as is widely believed. Potency of microwave energy shows up in rate of temperature rise, not in maximum temperature reached. It is inversely proportional to load size.

There you have the true essence of the culinary microwave. While it would be useless putting it in those terms to the average person, there are other ways of explaining it, and almost anyone can understand the principle. The reason that so few people do, is that the public have been guided by cookery experts, and cooks are not in the habit of thinking along those lines. They have been perfectly happy to adapt their conventional cookery notions, and leave the technicians to pursue the technicalities.

If you use a microwave oven, you will see that many common practices cannot be reconciled with this concept. For example, power levels are often presented as having individual characteristics. In the early days, this was purely a beginners' guide, with a few levels being ascribed the effect they had with average amounts of food. The system has remained in use, but some of the original quantities are no longer typical. Consequently, their respective levels are now, on average, wrong instead of right.

The Timer Myth

Probably the greatest microwave misconception is timing. It is usually accepted that a time must be known before the oven can go into action. Obviously, it could do its job just as well if it had an ordinary on/off switch. The main difference would be that someone would have to keep an eye on it – as with most other cookers. Of course, used intelligently, the timer is helpful, and it can guard against the oven being left to dehydrate or burn its contents – and subsequently damage itself. Microwave energy must change to heat somewhere, it cannot, just do nothing.

If people were forced to watch their

Continued on page 60

GALACTIC TIMER UNIT
PART TWO: THE RELAY CARD

by Tony Bricknell

Features
- ★ Drives loads up to 110V AC/24V DC at 10A
- ★ Normally closed and normally open contacts available
- ★ Interfaces directly with the Galactic Timer
- ★ Four switched outputs

Last Issue

In the last edition of *'Electronics'*, the construction of the Galactic Timer, was described, a timer that will control four outputs by time of day or week. The timer operates its outputs from switch-times which are entered through a keyboard and stored in battery backed-up memory. There are 28 switching times available to each output on a weekly basis and four on a daily basis.

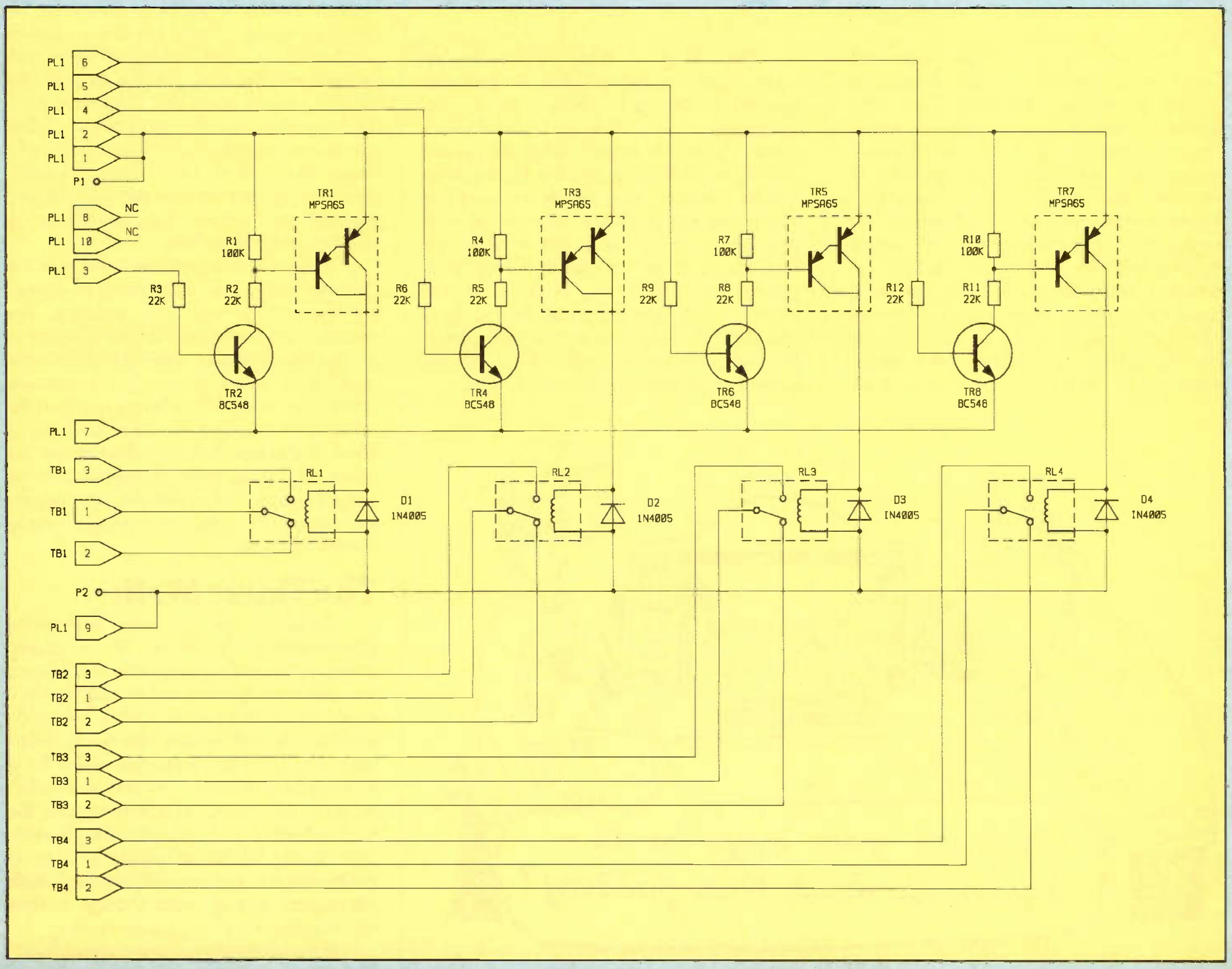

Figure 1. Circuit diagram.

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★ 110 degree detection angle

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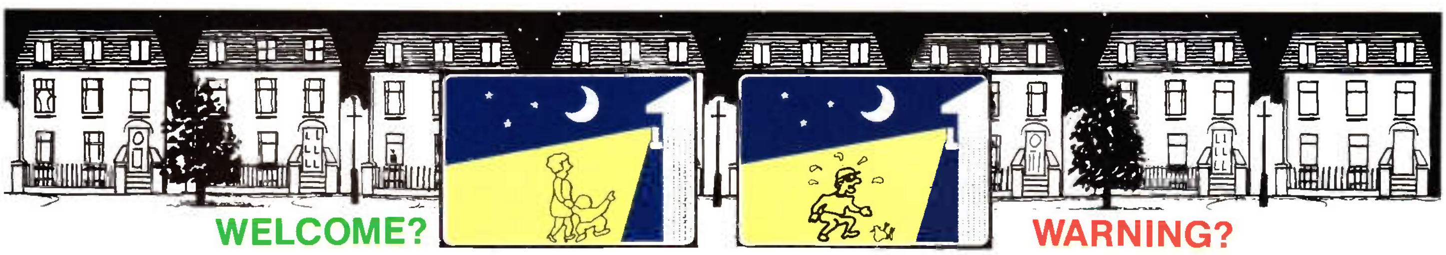
HOMEBASE	•	•	•	•	•	•	£7.99	£69.95
TEXAS	•	•	•	•	•	•	£5.99	£59.99
ARGOS	•	•	•	•	•	•	Not supplied	£46.99
PAYLESS	•	•	•	•	•	•	£7.59	£74.99
B&Q	•	•	•	•	•	•	£3.95	£79.99
MAPLIN	•	•	•	•	•		£3.75	£29.95

(Survey conducted on 21st February 1991)



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