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SOFTWARE COMPETITION

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HARMONIC DISTORTION METER

SYMMETRICAL POWER SUPPLY

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£ 25,000 software design competition
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straightforward complex

YOUNG RADIO AMATEUR OF THE YEAR AWARD 1996

The Radiocommunications Agency, an Executive Agency of DTI, in conjunction with the Radio Society of Great Britain (RSGB) has announced the Young Radio Amateur of the Year Award 1996. The competition, which is for the most outstanding achievement by a young amateur radio enthusiast, is open to anyone under 18 who has an interest in radio. Candidates do not have to be licence holders to apply, but the following areas of activity will be taken into account when applications are assessed.

- DIY radio construction;
- operation of radio;
- community service (e.g., helping the disabled or assisting in emergency communications;
- encouraging others (e.g., through the novice licence scheme; and
- school projects.

The idea behind the scheme is to generate interest in amateur radio and to encourage people to become involved for themselves.

The prize for the most outstanding achievement between August 1995 and 31 July 1996 will be awarded by the Radiocommunications Agency and presented at the RSGB's HF Convention in October 1996. All entrants will receive a copy of the RSGB's amateur radio log book, while the winner will receive a £ 300 cash prize, and the runner-up a £ 50 cash prize, from the Agency. Both winner and runner-up will also be invited to visit the Agency's Radio Monitoring Station at Baldock, Hertfordshire. In the past, the radiocommunications industry has also been very supportive of this award and has provided additional prizes for both the winner and runner-up.

The closing data for applications is 31 July 1996. The award is open to any resident of the UK, the Channel Islands or the Isle of Man, who has not reached his/her 18th birthday by the closing date. Entrants must be nominated by an adult sponsor.

Applications should be sent to: Young Amateur of the Year Award, Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE. Telephone 01707 659 015.

INTERNET USERS

Various surveys have tried to establish how many people in Britain are using the Internet. Best estimates suggest that throughout the country about 3 million people have at least some experience of it. Statistics also show that many more people are planning to use the global network this year. Interestingly, almost twice as many Britons have heard of the Internet than have heard of digital television.

Barclays Merchant Services, the credit card division of Barclays Bank in Britain, has set up an on-line shopping centre which, it claims, will lead the way for secure financial transactions via the Internet. Called BarclaySquare, it features many of Britain's top retailers and is the first big on-line centre in the country. The site uses a new secure method of transferring credit card details and takes advantage of Netscape's SSL built-in security layer.

With the opening of the Cafe Internet, close to Buckingham Palace and Victoria Station, London now has its second Internet venue. It is already attracting a wide audience: business people, students, tourists, and a curious general public. In particular, foreign students are finding the Cafe an ideal location for temporary e-mail addresses and business people are lining up for training sessions. The cafe, which also serves wines and beer, can be e-mailed on cafe@cafeinternet.co.uk

Overseas companies wishing to expand operations to Britain may find the Commission for New Towns guide useful. It lists development sites around the country with details on spare capacity. Access by Internet is: http://www.cnt.org.uk

RAPID PROTOTYPING OF EDM ELECTRODES

Engineers can now view a physical model within hours of completing a design, thanks to rapid prototyping (RP) technology which enables the production of 3-dimensional models from CAD (computer-aided design) data.

The benefit of rapid prototyping is that the model is produced exactly as the designer intended without any artistic interpretation from a modelmaker or pattern maker. This model can be used for touch, feel, fit and function but more importantly as a master pattern for tooling. Various tooling technologies are being researched and developed at present.

Reducing costs

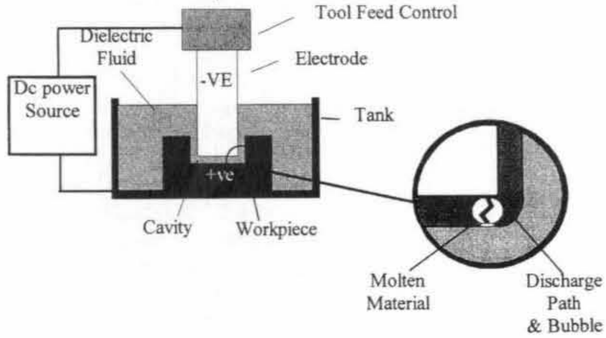
These technologies are challenging the role of traditional tooling owing to lower volume requirements and lower cost. As a result, the rapid prototyping systems and the models or master patterns they produce are capable of compressing the time between design and manufacture, lowering the cost of tooling, thereby increasing profitability, quality and competitiveness.

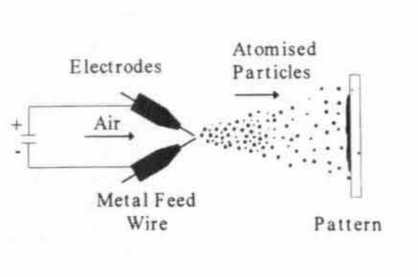
Electrical discharge machining (EDM) has been used since World War II to produce cavities that would otherwise be difficult or near impossible to machine. A requirement of both the tool and work piece is that they are both electrically conductive. The process generates a series of sparks between the tool and work piece while submerged in a non-conductive fluid. Both the work piece and tool melt locally around the site of the spark, eroding both surfaces, the debris is then flushed away from the work area. Wear of the work piece is significantly greater than the tool.

The tool is fed in a controlled manner toward the work piece until a cavity of similar shape to the electrode is formed in the surface of the work piece. The process is relatively slow in comparison to traditional CNC machining techniques. Recent advances in EDM machinery and its ability to machine unattended throughout the night have seen a steady increase in its use by toolmakers.

Drawback

However, its main drawback is that an electrode has to be generated, usually in copper or graphite, using traditional machining techniques before die-sinking can begin. Faster approaches for the genera-





In brief

FLAG ashore

The British end of a 16,000 mile long cable was brought ashore at the Cornish village of Porthcurno and there linked to the British domestic telecommunications network on 13 May.

The cable – FLAG for Fibre-optic Link Around the Globe – is the longest man-made structure in the world and will link three continents and 12 countries.

Good for Scotland

American electronics corporation National Semiconductor has announced a £ 33 million expansion of its plant at Greenock in Strathclyde. It is the first phase of a £ 180 million investment in the factory.

Telekinesis: a first step?

A method of using human brain waves to switch on electrical or electronic appliances has been demonstrated at Sydney University of Technology. A scientist with two electrodes attached to his head lighted desk-lamps and turned a toy robot on and off. The electrodes capture the minute voltage pulse resulting from a switch between different states of mind. The finding may help develop fatigue warning devices for drivers and pilots.

New distributors for Stag Programmers

Europe's largest manufacturers of silicon device programmers, Stag Programmers, has appointed RS Components•, Europe's leading distributor of electronic components and test/instrumentation, as its main catalogue distributor in Germany. Also, Brighton-based Amplicon Liveline has been appointed distributor for the UK, Ireland and the Netherlands.

•Phone 06105 40 1234/1262 Fax 06105 40 1265/1269.

tion of EDM electrodes must be found if they are to be truly competitive with other machining techniques.

By using plated electrodes, a rapid prototype model can be plated directly or a more suitable epoxy-resin master pattern cloned from it. This master pattern is placed within the electroplating and a layer of 2–3 mm is applied. The finished copper shell is suitably mounted and can be used as an electrode.

The process produces high-quality electrodes, but is only suitable for the generation of very large electrodes or very complicated geometries. Work on the plating of rapid prototype patterns for use as electrodes has been under way for some time at both the University of Warwick and the University of Nottingham.

Thermal spray equipment, using metal sprayed electrodes, has been available for some time in the following forms: arc spraying, plasma-arc spray, transferred plasma-arc spray, and high-velocity oxygen fuel (HVOF). In each process, the material is melted, atomized and carried at speed on to a substrate, where bonding of the particles occurs. By successive deposition, a metal shell of a few millimetres thickness can be generated in a few hours.

Commercial use

It is possible to apply a thin layer of copper to a thermally stable pattern cloned from an RP model. This process is fast (a matter of minutes), but unfortunately the copper shell is relatively weak owing to porosity/oxidation and erodes very quickly. Recent research within the Warwick Manufacturing Group (WMG) has resolved this problem. Further development should see the commercial use of these techniques.

What is particularly encouraging is that the capital cost of arc-spray equipment is relatively low, potentially giving small companies the opportunity to manufacture electrodes. Electrode casting is advantageous in the production of complex electrodes. These are ideally suited to investment casting, which is of the oldest known routes for the production of metal components. Investment casting involves the creation of a ceramic shell around an RP pattern. The pattern is then burnt from the shell during a firing process. Copper can then be cast in to the cavity and when the metal has solidified the shell is removed from the cast electrode.

When more than one electrode is required, the RP pattern can be used to construct a simple resin tool into which wax can be poured or injected. The wax patterns produced from this tool can be used to investment-cast many electrodes. Work within the WMG has shown that casting is a perfectly acceptable route producing reliable electrodes in as little as one to two weeks.

Keltool Inc. in the USA manufactures electrodes by a powder metallurgy process (sintered electrodes). An over-size master model is required to produce an epoxy mould. The mould is then filled with a metal powder mix of tungsten and copper and closed under pressure to produce a green compact. The compact is then infiltrated with copper to give a 100% dense electrode.

Multiple electrodes

Keltool claims the electrodes can be manufactured accurately and out-perform an equivalent machined graphite electrode. Because the electrodes are moulded, the process can be used to generate multiple electrodes.

The Danish Technical Institute, reporting work on the rapid production of EDM electrodes, states the electrode it had manufactured performed satisfactorily.

Warwick University will be investigating sintered electrodes in the immediate future, with a view to assessing their potential. The time requirement for the manufacture of an electrode using this method is one week from receipt of the master model.

Rapid prototyping is a relatively new technique that is set to change the face of engineering. Some of the techniques described have not been tested fully and require further development, but it is clear that there will come a time when they will be used actively. It is unlikely that any one technique will become a clear winner as each technique has specific advantages and limitations.

POWER PROTECTORS

At any one time, 2000 thunderstorms of varying severity are raging throughout the world. And each year in the USA alone there are 40 million ground strikes by lightning. Their current flow frequently exceeds 10,000 amperes and the temperature at the core of the flash reaches 50,000 °C. The tremendous power unleashed can cause severe damage to trees, structures, communications and power lines.

Against this background of high risk, it is clear that microprocessing equipment, with its miniscule circuits and sensitive software, can be severely damaged – or even annihilated, not just by a surge of immense power but by power failures resulting from these storms.

And thunderstorms are not the only predators stalking the highly-sensitive electronic systems that now abound across the planet. Hurricanes and heavy snowfall frequently bring down power lines, also causing power failures.

Even in the urban environment, human error can cause equally catastrophic failures. Abrupt switching of power circuits or construction workers damaging cables are typical daily occurrences.

Failure of supply takes several forms. 'Blackouts' produce a total loss of power, while so-called 'brownouts' are a momentary loss in voltage that may cause potential failure. Then there are 'spikes', caused locally as an effect of lightning or switching large equipment, such as electric motors or welding equipment, on or off.

'Surges' occur when demand on the mains supply system rises suddenly. Typical of this peak demand phenomenon is after a televised major sporting event when millions of lights and electric kettles are turned on. Power outages are even caused by small wildlife, such as mice, gnawing into transformers or switchgear and forming a bridge short-circuit. They usually do this only once!

Natural disaster

The extent to which natural disasters can strike at power supplies is demonstrated by statistics for the UK electricity supply industry for 1987–88. In the southeast of England, the total number of hours' supply lost from all causes in the previous year was 94 minutes. In 1987–88, during which a hurricane swept across the region, that total had risen to more than 1266.

To protect against these phenomena, uninterruptible power supplies have been developed. In simple terms, a UPS is a buffer battery located between the power socket and the computer or other equipment. It converts the alternating mains voltage into a direct voltage to charge the batteries, and then reconverts this to alternating voltage to supply the load.

A newly-formed British company unites the technological expertise of two firms already well established in the field, providing a unique protection service against potential power failure. Established since 1984, Universal Power Systems (UPS) based in Loughborough expanded its activities earlier this year through a merger with Savin UK of nearby Burton-on-Trent, formed in 1990 and specializing in protecting microprocessor equipment.

Protection systems

The company already has among its clients Buckingham Palace and Windsor Castle to guard emergency lighting circuits, as well as major financial institutions and information houses in the City of London. UPS equipment also protects key Ministry of Defence communications installations, hospitals, water companies, airports, railways, shopping centres, and information storage systems at London's Victoria and Albert Museum, and at the British Library technical publications section.

The company also protects the mainframe systems at the English east coast port of Felixstowe, which handles around 16 ships a day and more than a million containers a year. Their systems guard against power-outs that could cause immense disruption, not only of highly expensive shipping movements, but the port's allied services, such as HM Customs, Port Health Authority, shipping agents, and port police.

Agony aunts

UPS supplies solutions to power problems in a range from 250 VA to 500 kVA in both a.c. and d.c. applications.

Uninterruptible power supplies take several forms, the simplest being the off-line system that switches across to back up the system with only a microsecond break in power which can be safely absorbed.

Synchronization circuits within the UPS can also achieve what is know as active standby to ensure minimal phase shift in transfer. The line-interactive system is also off-line, with power supply from the mains, but ensures maintenance of acceptable voltage levels.

On-line, or continuous operation, technology takes in power and converts the current to d.c. and back again to a.c., thus guaranteeing a constant level of quality regardless of disturbance on the mains power source. Batteries are only used in the event of a complete outage.

A recent innovation at UPS is low-cost full- or short-term hire, which provides full power protection while avoiding major capital outlay.

SILICONE DIGESTANTS

Cured and uncured silicone elastomers, resins, oils and greases can be depolymerized and dissolved by a range of safe and environment-friendly silicone digestants, solvents and cleaners• are available from BDH Laboratory Supplies, Poole, Dorset, England BH15 1TD. Telephone 01202 660444; fax 01202 666856.

• Digesil FS, Digesil 1000 and 2000 and Di-Aqua.

NEW AUTOROUTER

MultiRouter from Number One Systems is a low cost, but fast and powerful multi-pass autorouter that combines the latest routeing technologies to ensure that tracks do get through where other autorouters would fail.

Gridless routeing handles difficult components like D connectors and surface-mount packages, making them maximum use of the available space. The routeing algorithm is shape based, taking the design rule clearances and track width limit as the only constraints on routeing. As each net is routed, existing tracks are **Shoved aside** to make room and if all routes appear to be blocked, MultiRouter will **Rip up** and **Retry** problem areas until a solution is found.

MultiRouter does not stop when all nets are routed. Smoothing passes fatten the tracks, mitre corners and eliminate unnecessary track segment and vias. The final result is optimized for manufacture and it looks good as well.

See also advert on p. 6.

NEW TEXT-LINKING FACILITIES

Computer scientists at the University of Southampton have developed powerful new text-linking facilities which could radically alter the way academics find and use information on the World Wide Web. Current hypertext links allow a reader to follow a chain of links from document to document, possibly straying from an area of interest and finishing at a dead end. The new system allows not just links to be added to papers added at the end of a document, but to absolutely anything within a document. The first project using the new system is *Development*, the monthly journal for research biologists. Already more than 2000 pages are available through the projects site http://journals.ecs.soton.ac.uk

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Events

June

10–11 Integrating Standards for Seamless Mobile Services Conference at the Royal Lancaster Hotel, London

July

2 Portable appliance maintenance (IEEIE
3–5 Fighting Mobile Fraud (1996 Update) Conference in London
5 Specification and instruction writing (IEEIE)
5–7 Emerging broadcast technology (IEE)
5–7 24th history of electrical engineering weekend (IEE)
9 Inspection and testing of electrical installations (IEEIE)
12 EU Directives: requirements for product compliance (IEEIE)
15–17 Telecomms networks - the next generation (IEE)
14–19 Satellite communication systems
19 Visit to the Electronics Museum, HMS Collingwood (under the auspices of CHiDE—Centre for the History of Defence Electronics, Bournemouth)

August

14–16 CAD/CAM, robotics and factories of the future (Imperial College)
20–23 Human computer interaction (IEEIE)

September

11–13 The Asia Pacific Digital Cellular Mobile Communications Conference at the Shangri-la Hotel, Singapore

October

8–10: The ***Euro-EMC*** *exhibition at Sandown, UK.*
18–27: The ***Connect 96*** *consumer electronics show at the NEC, Birmingham.*

November

12–15: The ***Electronics 96*** *exhibition in Munich, Germany.*
26–28: The ***Manufacturing Week*** *Exhibition at the NEC, Birmingham.*

symmetrical power supply

Electronic circuits that draw a current of more than a few milliamperes should preferably not be powered by a battery: most are, therefore, powered by an integral power supply or have provision for connection to a mains adaptor. In fact, a mains adaptor is the most often used power source. On such a unit all that needs to be done is for the wanted voltage level and polarity to be selected with a switch.

A mains adaptor may even be used as a small power supply for experimental purposes, but this poses a few difficulties. Many adaptors consist of nothing more than a small mains transformer, a rectifier and a smoothing capacitor (whose value is frequently too low). Moreover, its output voltage to small loads is often much higher than the selected level, which, of course, may not do the circuit it is powering much good.

Design by L. Pijpers

The present power supply is rather more sophisticated in that it uses a voltage regulator IC. Such a device effectively suppresses the ripple on the output voltage to a large extent, which results in a constant output.

Also, a regulator makes possible a continuously variable output voltage. In many cases, however, a continuously variable output is not needed (but two or three fixed outputs at different levels are frequently needed). Moreover, unless the supply unit is fitted with a voltmeter, the output voltage must always be checked with a multimeter.

These considerations gave rise to the present design, in which three output voltage levels are available: 5 V, 9 V and 12 V. These levels are selected with a simple switch. Since many circuits contain operational amplifiers (op amps), which require a symmetrical power supply, the present unit provides two different output voltages. When these outputs are connected in series, a symmetrical power source is obtained. The duality of the design also makes it possible for two different circuits requiring dissimilar supply voltages to be powered simultaneously.

Voltage regulator

Since it must be possible to set the output voltage to three different levels, the voltage regulator used is a type whose output can be set with a couple of resistors—see **Figure 1**. The output voltage is calculated with the formula

$$U_{out} = 1.25(1+R_2/R_1) + I_{adj}\,R_2,$$

in which 1.25 represents the reference voltage of the IC, and I_{adj} is the current flowing from the 'adj(ust)' pin of the IC to ground.

The reference voltage, U_{ref}, is shown in the block diagram in **Figure 2**. Here, the comparator continuously compares part of the output voltage, set by resistive divider R_1/R_2, with the reference voltage. If U_{out} is too low, the output of the comparator increases which makes the transistor conduct harder. This reduces the collector-emitter resistance, resulting in an increase of U_{out}. This arrangement ensures a virtually constant U_{out}.

In practice, the value of I_{adj} lies between 50 μA and 100 μA. Because of

1

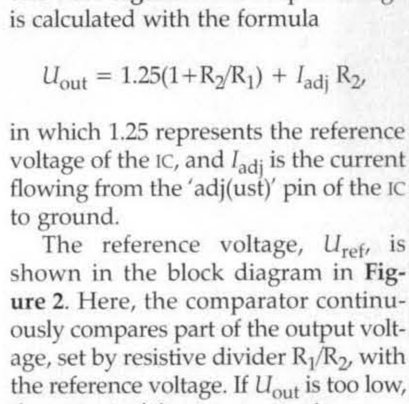

Figure 1. General view of an LM317.

this low value, the factor I_{adj} R_2 may often be omitted from the formula. Thus, the simplified formula

$$U_{out} = 1.25(1+R_2/R_1)$$

gives a reasonably correct answer for most applications.

Although the regulator in the present design is used in this manner, the way the output voltage levels are switched is described with reference to **Figure 4**. Resistor R_1 in the formula is the total resistance between the output pin and adj pin of the regulator, while R_2 is the total resistance between the adj pin and ground.

With switch S_1 in position 12 V, $R_1 = R_a$ and $R_2 = (R_c+R_d)$. Resistor R_b is short-circuited. Then,

$$U_{out} = 1.25[1+(1270+1280)/280] = 12.19 \text{ V.}$$

When the switch is set to 9 V, all resistors R_a–R_d are used in the calculation. Resistor R_1 then has a value $R_a+R_b = 280+118 = 398\ \Omega$ and $R_b = R_c+R_d = 1270+1180 = 2450\ \Omega$. The output voltage is then

$$U_{out} = 1.25[1+2450/398] = 8.94 \text{ V.}$$

With the switch in position 5 V, R_1 is the sum of R_a and R_b, and $R_b = R_d$. The output voltage is then

$$U_{out} = 1.25[1+1180/398] = 4.96 \text{ V.}$$

Small deviations of the practical voltages from these computed values are, of course, of no consequence.

Circuit description

The circuit diagram in **Figure 5** consists of two similar halves. Capacitors C_3 and C_6 across the outputs of the regulators suppress any tendency of the IC to oscillate.

The alternating voltages are applied to terminal blocks K_2 and K_3 respectively, and rectified by diodes D_2–D_4 and D_5–D_8 respectively. Note that the circuit may be used with a PCB type mains transformer, Tr_1, whose secondaries are connected to K_2 and K_3 via terminal blocks K_6 and K_7 respectively. The transformer may, of course, be replaced by a suitable mains adaptor. It should be borne in mind, however, that the source supplying the input alternating voltages must have an output that is at least 3 V higher than the desired output voltage of the supply. Diode D_9 is a 'supply on' indicator.

Construction

The power supply is best constructed on the printed-circuit board shown in **Figure 6**. The ICs are all located at the edge of the board, so that the regulators may be provided with a heat sink if necessary.

Note that the rating of the electrolytic capacitors is based on an input

Choice of mains transformer or adaptor

Each voltage regulator can provide a current of up to 1.5 A. The voltage drop across the regulator, U_{in}–U_{out}, may be 3–40 V.

The rule of thumb for determining the value of the smoothing (electrolytic capacitor is that for each ampere of direct output current, the capacitance must be not less than 2200 µF.

The specified transformer provides an effective alternating voltage of 2×12 V and is rated at 3.3 VA. The output alternating current is, therefore, 138 mA. This is, of course, not equal to the maximum direct output current, but to 1.4–1.5 times this current. Thus, the maximum direct output current of each supply half is about 100 mA. This means that the smoothing capacitors need to have a value of not less than 220 µF: the specified value of 470 µF is thus more than enough for effective ripple suppression.

It should also be borne in mind that the voltage across an electrolytic capacitor must never exceed its rated maximum. Therefore, it needs to be ascertained what the worst case input voltage is. The maximum rectified voltage is equal to the peak value of the output alternating voltage, and this is $\sqrt{2}\times12$ V ≈ 17 V. However, practice shows that the voltage is heavily dependent on the current drawn and can be up to 40 per cent higher than the value just calculated, that is, 23.8 V. This means that the electrolytic capacitors should have a working voltage rating of not less than 25 V.

Cooling of the regulators is not always necessary. Their heat dissipation depends on the product of the voltage drop across them and the output current. In general, the ICs need a heat sink when they get so hot that you cannot touch them without burning your fingers

2

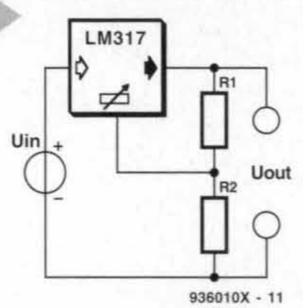

Figure 2. The output voltage of an LM317 can be fixed with the aid of two resistors.

3

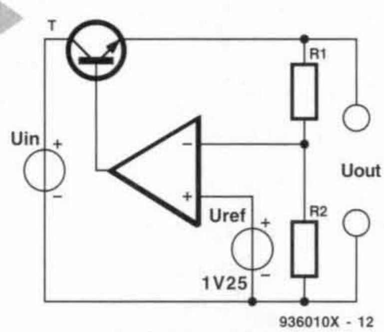

Figure 3. Basic functional innards of a voltage regulator.

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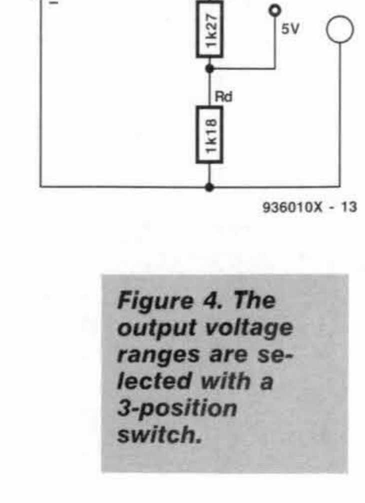

Figure 4. The output voltage ranges are selected with a 3-position switch.

5

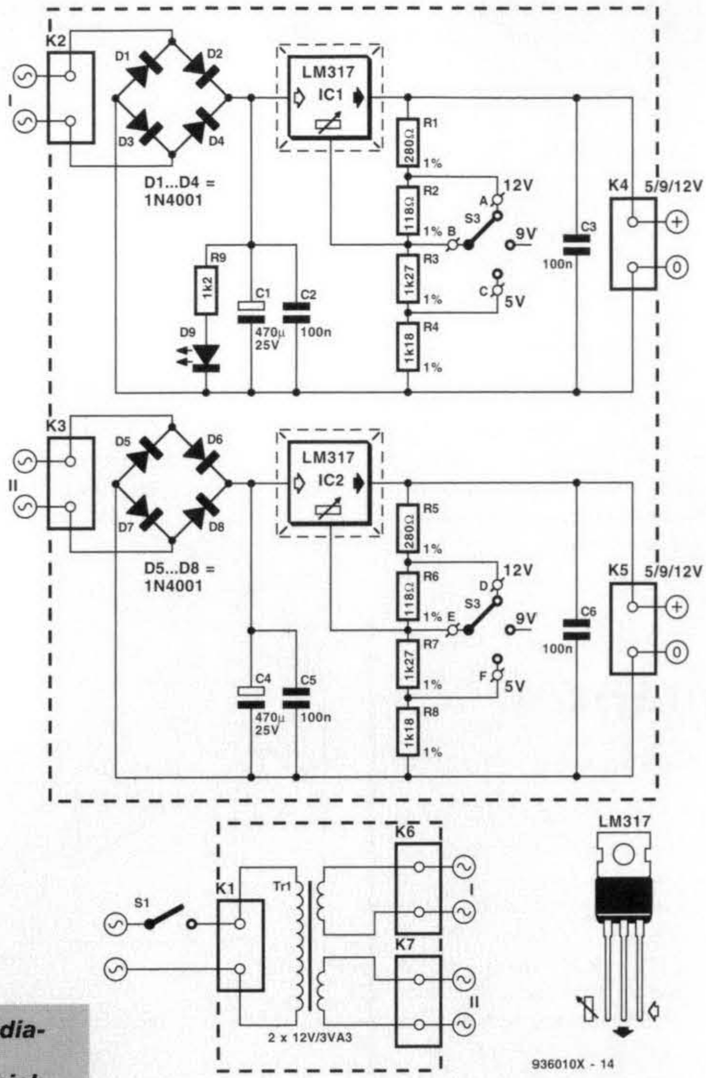

Figure 5. Circuit diagram of the dual power supply, which is converted to a symmetrical supply by linking K_4 0 to K_5+.

6

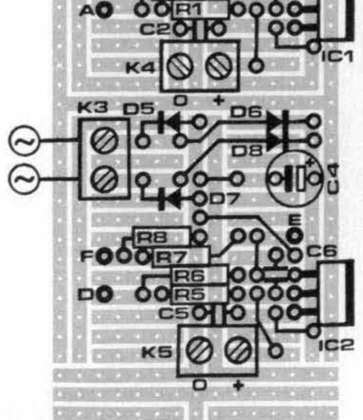

Figure 6. Printed-circuit board for the power supply.

7

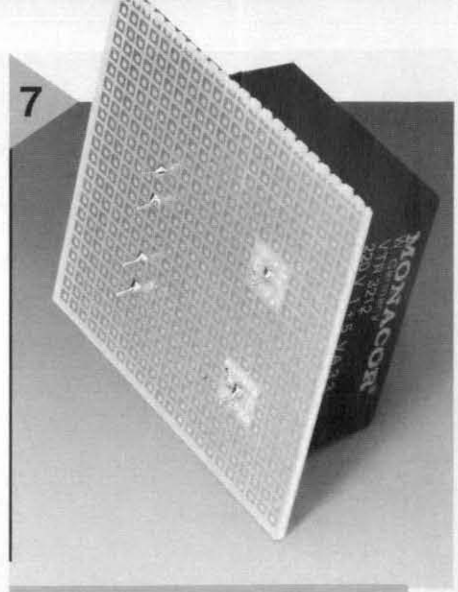

Figure 7. Arranging a minimum spacing of 6 mm around two solder pads.

PARTS LIST

Resistors:
R_1, R_5 = 280 Ω, 1%
R_2, R_6 = 118 Ω, 1%
R_3, R_7 = 1.27 kΩ, 1%
R_4, R_8 = 1.18 kΩ, 1%
R_9 = 1.2 kΩ

Capacitors:
C_1, C_4 = 470 µF, 25 V
C_2, C_5, C_6 = 100 nF, pitch 5 mm
C_3 = 100 nF, pitch 7.5 mm

Semiconductors:
D_1–D_8 = 1N4001
D_9 = LED, red, 3 mm

Integrated circuits:
IC_1, IC_2 = LM317

Miscellaneous:
K_1 = 2-way terminal block, pitch 7.5 mm
K_2–K_7 = 2-way terminal block, pitch 5 mm
S_1 = switch, make contact, 240 V, 2 A
S_2, S_3 = 3-position change-over

some definitions

Comparator. *This is a voltage comparing circuit, normally in the shape of an op amp without feedback. When the potential at the non-inverting (+) input of the op amp is greater than that at the inverting (–) input, the output voltage cannot rise above the positive supply line. In the reverse situation, the output voltage cannot drop below the common supply line. The operation of a comparator depends on the op amp amplifying the potential difference between the two inputs by a very large factor.*

Reference source. *This is a source with a very stable voltage, current or frequency output, which is used in comparator circuits for measuring, setting up or calibrating.*

Ripple voltage. *A direct voltage obtained by rectifying an alternating voltage and smoothing the rectified voltage with the aid of a capacitance cannot be a pure direct voltage. Depending on the load, practice shows that there is always some residual alternating voltage, called the ripple voltage, superimposed on the direct voltage.*

Voltage source. *This is a circuit that provides a constant voltage which is independent of the loading of the circuit. Typical of such a circuit is its very low internal resistance.*

Symmetrical supply. *A power supply that provides, with reference to ground, a positive as well as a negative potential, for instance, ±15 V. The total potential difference between the +ve and –ve terminal is then 30 V.*

8

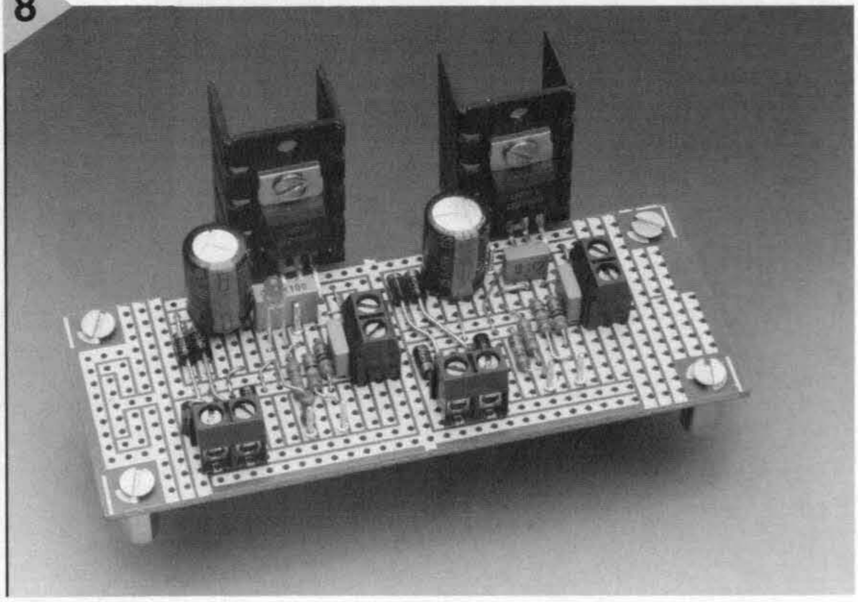

Figure 8. Completed prototype board.

switch
Tr_1 = mains transformer, output 2×12 V, 3.3 VA (if used, see text)
Heat sink for IC_1, IC_2 (if necessary) Type KL90
Enclosure, metal, 143×167×51 mm (5⁵/₈×6⁹/₁₆×2 in) (D×W×H), e.g. ESM Type EB16/05FA
4 off insulated terminals

alternating voltage of 12 V. If this voltage is higher, the rating of the capacitors must be increased accordingly.

If a PCB mains transformer is used, the distance between adjacent solder

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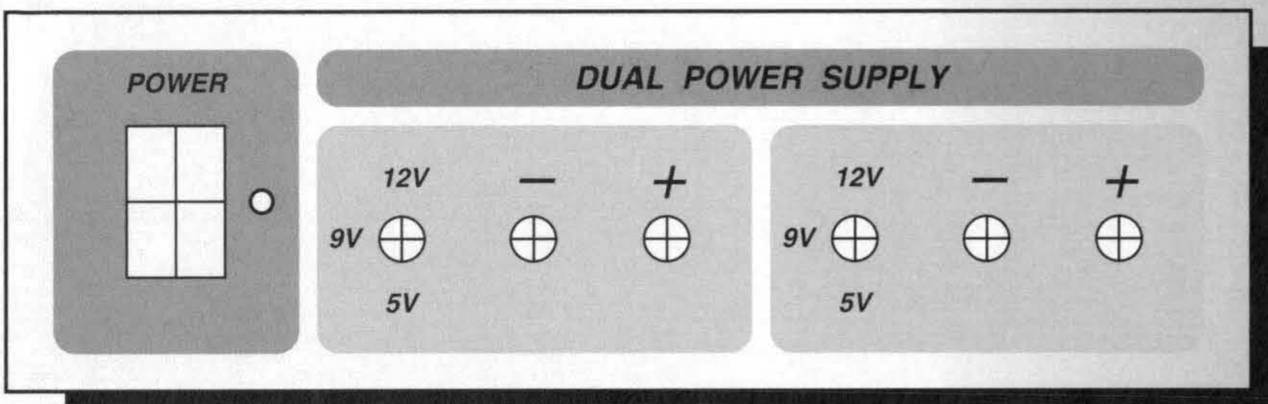


Figure 9. Suggested front panel layout.

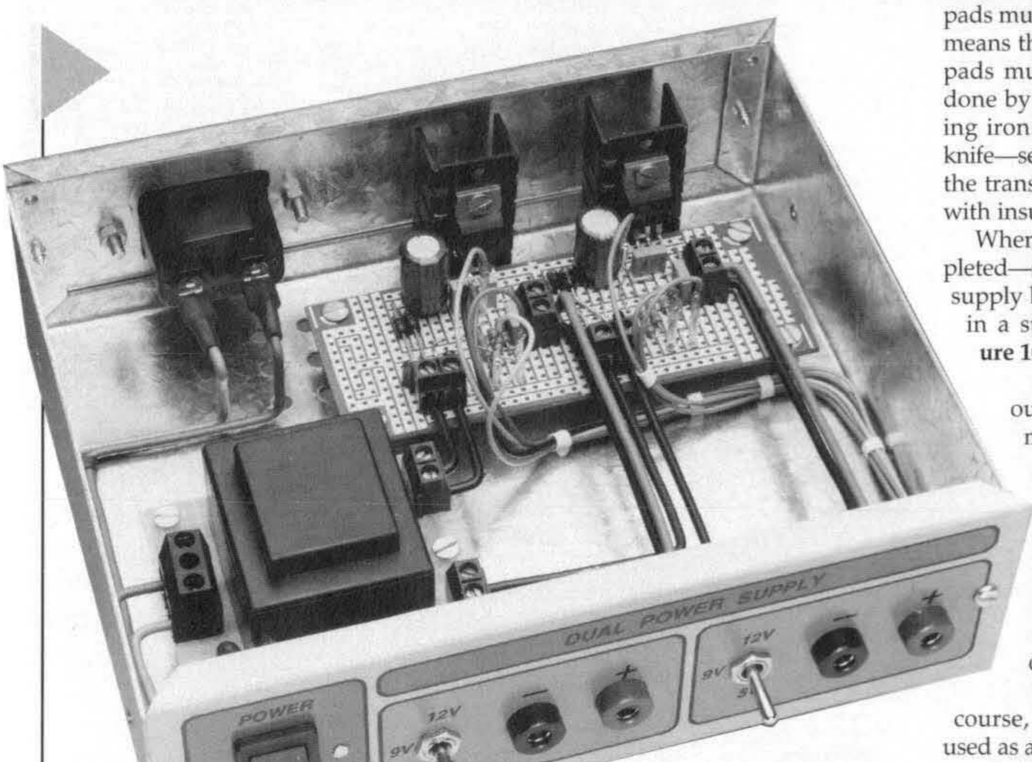


Figure 10. Completed prototype power supply unit.

pads must be not less than 6 mm. This means that in some places the copper pads must be removed. This is best done by heating them with a soldering iron and removing them with a knife—see **Figure 7**. All connections on the transformer board must be made with insulated stranded circuit wire.

When both boards have been completed—see **Figure 8** for the prototype supply board—they must be housed in a suitable metal case—see **Figure 10**.

The output voltages are led out via four insulated chassis-mounting terminals on the front panel.

The mains input cable should be fitted with a strain relief. See also the safety guidelines elsewhere in this issue.

A suggested front panel layout is shown in **Figure 9**.

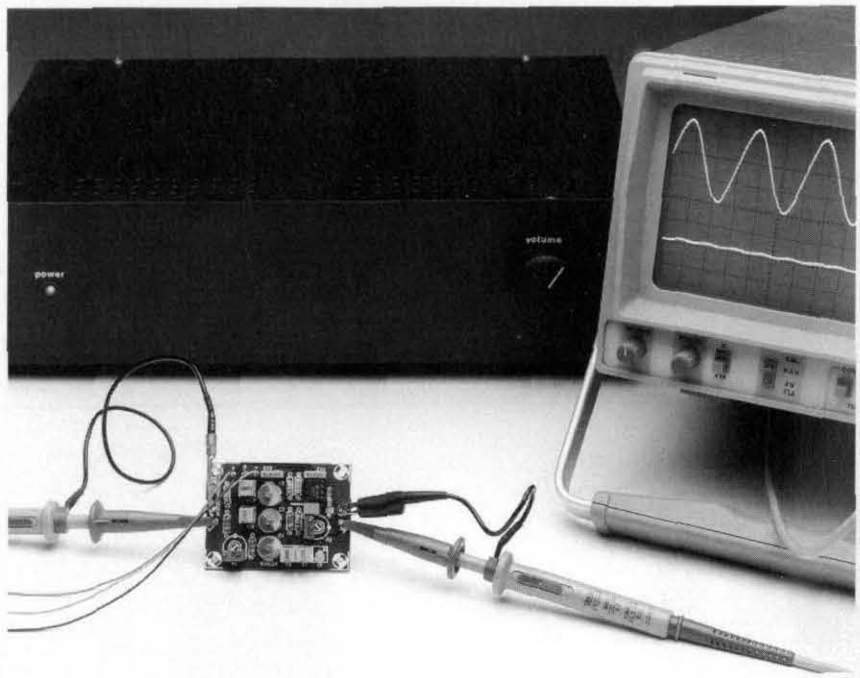
The supply as shown is, of course, a dual version. If it is to be used as a symmetrical supply, the +ve terminal of one must be linked to the –ve terminal of the other; this junction becomes the common line, while the two remaining terminals become the positive and negative lead-outs. [936010]

harmonic distortion meter

(for use with an oscilloscope)

Most measurements of electrical quantities, such as voltage, current, resistance, or frequency, can be carried out on a multimeter or an oscilloscope. Unfortunately, measuring (harmonic) distortion in a.f. amplifiers requires rather more sophisticated, and thus more expensive, equipment. However, the adaptor presented here makes it possible for the harmonic distortion to be viewed and analysed on an oscilloscope.

Design by T. Giesberts



Experimenters and constructors of a.f. equipment frequently need to measure impedances, output power, signal-to-noise ratios, sensitivity and ... harmonic distortion. For non-professional constructors, the latter quantity is probably the most problematical. The problem lies not so much in the actual measuring as in the cost of suitable instruments. Moreover, some constructors, especially newcomers, do not quite know what is meant by harmonic distortion.

The present circuit enables the distortion of a signal to be viewed on even a simple oscilloscope. It does not show the distortion to within a few per cent, but it does enable a reasonable assessment to be made of the total harmonic distortion—THD.

The adaptor is also suitable for checking whether certain modi-fications in, say, an a.f. amplifier increase or reduce the distortion.

IS IT AUDIBLE?

Of course, every designer of a.f. equipment strives to keep distortion as low as possible. The question is, however, whether an amplifier with, say, 0.5 per cent distortion provides less listening pleasure than one with 0.01 per cent.

On paper, of course, the percentage distortion enables the quality of an equipment to be judged or compared with that of another apparatus. To be able to judge the importance of such figures, it is necessary to know what exactly harmonic distortion is, how it comes about and how it can be measured.

HARMONICS

To understand what distortion is, it is necessary to know the composition of audio signals. The best known a.f. signals are undoubtedly the sine wave and the rectangular wave. Fourier showed that any signal, other than a pure sine wave, consists of a number of sinusoidal signals of different frequency.

A rectangular signal as in **Figure 1** is shown by Fourier analysis to consist of a large number of sine waves. The frequency of the original signal is called the fundamental frequency, of which all the others, called har-monics, are multiples. For instance, a 1 kHz rectangular signal consists of harmonics

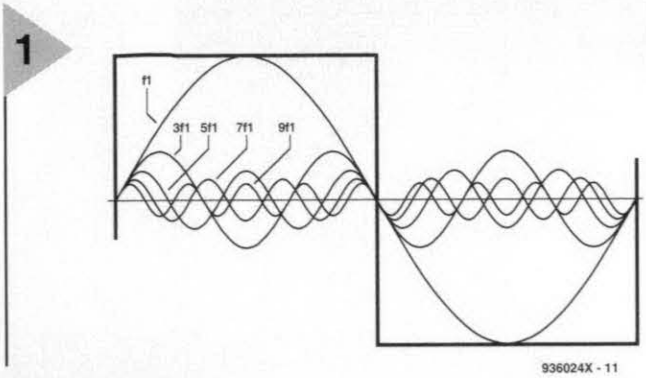


Figure 1. A signal, other than a pure sinusoidal one, is composed of the sum of a number of sine waves with different frequencies. A rectangular signal consists of a particularly large number of such sine waves, normally called harmonics.

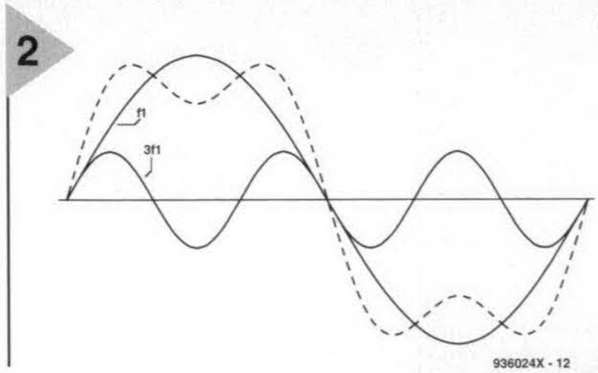


Figure 2. Adding the third harmonic of a rectangular signal to the fundamental frequency results in an approximation of the original rectangular signal. Summing all harmonics and the fundamental reproduces the original rectangular signal.

of 3 kHz, 5 kHz, ..., 21 kHz, and so on. In the case of a rectangular signal, the harmonics are odd-numbered (3, 5, 7 ... and so on). The peak value of the harmonics is inversely proportional to their frequency, that is, the higher the frequency, the lower the peak value.

The sum of the fundamental and third harmonic already shows an outline of a square wave as illustrated in **Figure 2**.

A sine wave representation of a given signal as in Figure 1 is, of course, not very useful. It is much better to show it as a bar graph as in **Figure 3**. The tallest bar represents the fundamental frequency, and the others, from left to right, in ascending order, the harmonics. The height of the bars is the peak value of the harmonic relative to that of the fundamental. For instance, the peak value of the 5th harmonic is 20 per cent ($^1/_5$) of that of the fundamental.

MEASURING DISTORTION

As stated earlier, a pure sinusoidal signal has no harmonics—see **Figure 4**. If such a signal is applied to an ideal amplifier, the (amplified) output signal should still be a sine wave. Unfortunately, such amplifiers do not exist – all practical power amplifiers introduce some measure of distortion, that is, the output contains some harmonics. These harmonics cannot be seen on an oscilloscope, since they are submerged in the overall signal. To make them visible, it is necessary to remove the fundamental from the signal.

FILTERING

The fundamental frequency is removed by a narrow-band-stop filter with a characteristic as shown in **Figure 5**. It will be seen that the harmonics are not affected by the filter. Applying the remnant of the signal to an oscilloscope gives a view of the total harmonic content.

A filter eminently suitable for the present purpose is a double-T type as shown in **Figure 6**. Its shape explains its name. In theory, such a network can suppress a certain frequency or narrow band of frequencies, but in a practical design this suppression is not total. The main reason for this is the tolerance of the constituent components, although the op amp is, of course, also not perfect. A typical practical pass- band characteristic of such a section is shown in **Figure 7**. The suppression is greatest at the central frequency, f_0. The quality of the filter is reflected by the narrowness of the characteristic and the suppression of f_0.

It stands to reason that the design of a double-T filter is bound by certain strict rules. For instance, the various components must have a certain mutual relationship as shown in **Figure 8**. Also, the source impedance must be as low as feasible, which means that the source must be able at all times to provide current to the section. On the other hand, the terminating impedance of the filter must be as high as feasible.

An op amp has a low output impedance and is, therefore, eminently suitable for driving a double-T network. As it happens, an op amp also has a very high input impedance, so that the output of the filter can be coupled to an op amp.

Since the filter characteristic is very narrow, a variation as small as 0.5 per cent from a component's value can cause the attenuation to be reduced from near-infinity to –25 dB. Since the aim is to suppress the fundamental entirely, the component values need to be as close to the computed theoretical values as possible.

CIRCUIT DESCRIPTION

The circuit in **Figure 9** shows how any variations of the component values may be compensated: each component is made variable by the addition of a trimmer capacitor or preset potentiometer. This has the advantage that expensive, high-tolerance components are not required.

Enhanced filter properties are obtained by placing the filter in the feedback loop of the op amp. In this (active) way, the Q(uality) factor of the network is determined by the ratio R_5:R_6. The higher the Q-factor, the narrower the filter characteristic. In the present design, the Q-factor has been

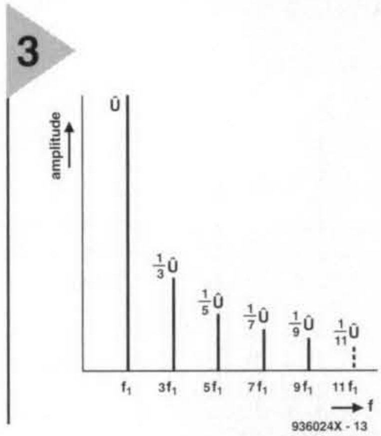


Figure 3. A frequency spectrum gives a good idea of the harmonics present in a signal.

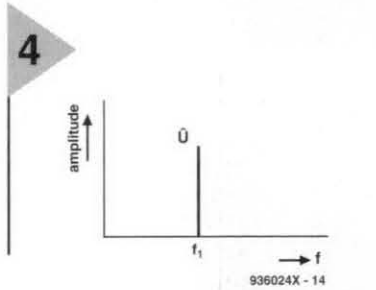


Figure 4. Drawing the spectrum of a pure sine wave is simple, since it consists of the fundamental frequency only.

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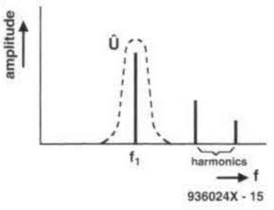

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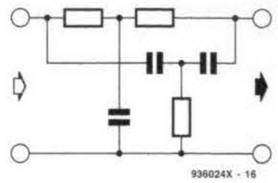

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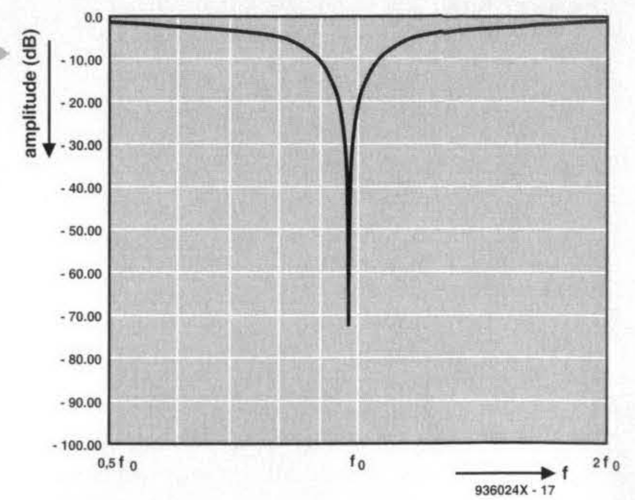

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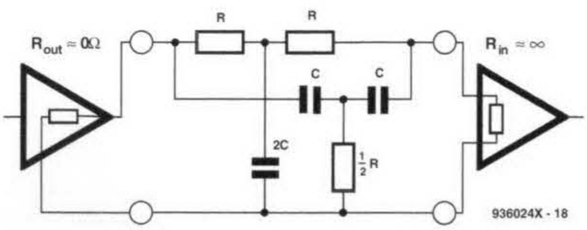

Figure 5. A suitable filter can remove the fundamental frequency from the spectrum so that only the harmonics remain.

Figure 6. The two T-shaped RC networks explain why such a filter is called a double-T filter.

Figure 7. Results of measurements on a double-T filter. The central frequency, f_o, is largely suppressed, while the harmonics are virtually unaffected.

Figure 8. In the design of a double-T filter, it is important that the values of the components used are as close as possible to the computed values. Such a filter has a low-impedance input and a high-impedance output.

chosen to allow even the 2nd harmonic to be passed unattenuated. The prototype filter, on switch-on, gives an initial attenuation of 100 dB at f_o (which means that the centre frequency is reduced by a factor of 10^5). However, after the filter has been on for about fifteen minutes, the attenuation drops to about 70 dB (still a reduction by a factor of 3.2×10^3).

For the present purposes, an attenuation of 70 dB is more than enough (see Figure 7). This means that if the spectrum of the earlier discussed square wave is applied to the filter, the fundamental frequency is reduced to $1/3200$ of its nominal value. The peak value of the 11th harmonic in the spectrum is $1/11$ of that of the fundamental frequency, so that the peak value of the suppressed fundamental frequency is only $1/290$ of that of the 11th harmonic, which is negligible for all practical purposes.

Any (high-frequency) noise on the output of the filter is removed by low-pass section R_7-C_{10}.

CONSTRUCTION

The adaptor is best built on the printed-circuit board shown in **Figure 10**. Start by laying the wire bridges and inserting PCB pins at lead-in and lead-out points. Place the IC in a suitable socket.

The presets should preferably be multi-turn types, since single-turn versions provide too small a setting range. Nevertheless, the board can be used with either type.

The capacitors should preferably be polystyrene types. If (metallized) polyester types are used, the quality of the filter will be degraded.

The frequency-determining resistors must be 1% metal film types, which are readily available almost anywhere.

It is advisable to house the adaptor in a metal case that complies with current EMC regulations.

SETTING UP

Connect the adaptor to a suitable, symmetrical ±15 V power supply. Connect an AC voltmeter or oscilloscope to the output terminals of the adaptor (see **Figure 12**). Using a sine wave generator, inject a 1 kHz signal at a peak level of 13 V into the adaptor. If a lower level is used, the output may be so low that measurements become difficult. Owing to the setting facilities of the adaptor, the signal need not be exactly 1 kHz, but it should be stable.

Set the trimmer capacitors and preset potentiometers to the centre of their travel. Adjust the frequency of the sine wave generator for minimum output. Adjust first P_1 and C_1, then C_2 and C_3, and finally P_2, for minimum output. Repeat the adjustment of all five components in the same order.

As a final test, connect the adaptor to a low-distortion sine wave generator, suitable power supply, and oscilloscope, as shown in **Figure 13**. In normal use, the amplifier hardly distorts the signal—see **Figure 14**. If, however, the peak value of the input signal is increased, the output signal becomes distorted, until at large input levels it begins to be clipped—see **Figure 15**.

The adaptor has no facility for reading the distortion in per cent. Never-

Figure 9. The adaptor is based on a single op amp. Since the double-T filter is located in the feedback loop of the op amp, design considerations are met, and an excellent filter is obtained. As the frequency-determining components are variable, the filter can be adjusted optimally.

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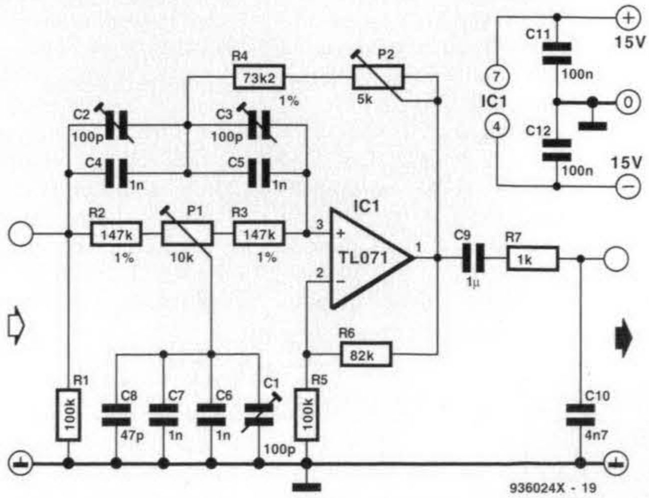

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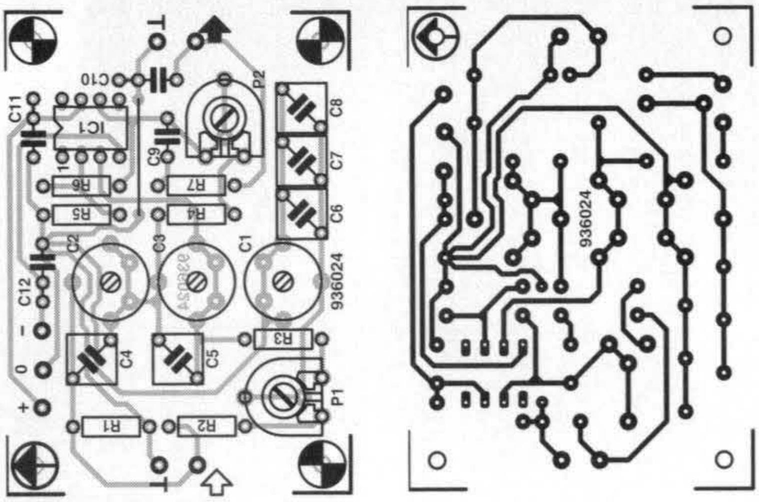

Figure 10. The printed-circuit board is available ready-made (see Readers' Services).

Parts list

Resistors:
R_1, R_5 = 100 kΩ
R_2, R_3 = 147 kΩ, 1%
R_4 = 73.2 kΩ, 1%
R_6 = 82 kΩ
R_7 = 1 kΩ
P_1 = 10 kΩ multi-turn, vertical preset potentiometer (e.g. Bourns 3296Y)
P_2 = 5 kΩ multi-turn, vertical preset potentiometer (e.g. Bourns 3296Y)

Capacitors:
C_1–C_3 = 100 pF trimmer
C_4–C_7 = 1 nF polystyrene
C_8 = 47 pF polystyrene
C_9 = 1 μF
C_{10} = 4.7 nF
C_{11}, C_{12} = 100 nF

Integrated circuits:
IC_1 = TL071

Some definitions

Central frequency
The frequency in the centre of the pass-band of a band-pass filter.

Double-T filter
A filter consisting of three resistors and three capacitors. These components are arranged as two T-shaped RC networks in parallel. The filter has the property of suppressing one particular frequency or band of frequencies and is therefore a band-stop filter. It may also be used as a band-pass filter by placing it in the feedback loop of an op amp. This type of filter is used frequently in a.f. applications, particularly in equalizers.

Fourier, Jean Baptiste Joseph (1768–1830)
A French mathematician who developed a method of arithmetical analysis that is used in many disciplines. In electronics, the analysis shows that any signal can be reduced to the sum of a number of sine waves.

Fundamental frequency
Also called the first harmonic frequency. It is the sinusoidal constituent of a signal with the same frequency as that signal.

Harmonic frequencies
Normally called harmonics. Many oscillators produce, apart from the fundamental frequency, a number of harmonics whose frequencies are a multiple of the fundamental frequency. This property is used in some applications, but normally it is an undesired (spurious) effect, which is audible and called harmonic distortion.

Operational amplifier
Normally called by its abbreviated name op amp. It consists of one or more complete analogue amplifiers which are integrated on to one integrated circuit—IC. Typical properties of an op amp are the differential input and the very high amplification factor.

Figure 11. The completed printed-circuit board.

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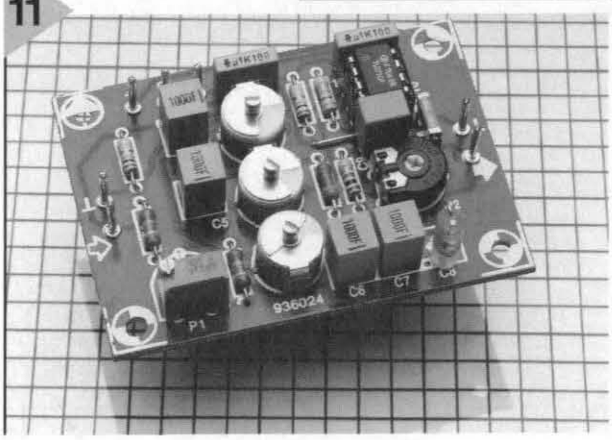

Figure 12. Set-up for adjusting the various trimmers and presets.

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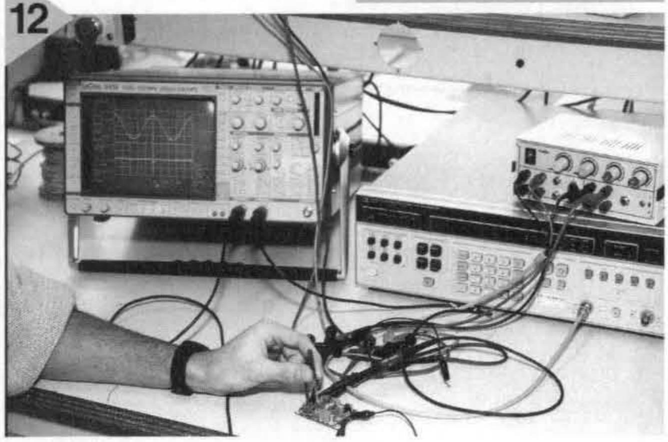

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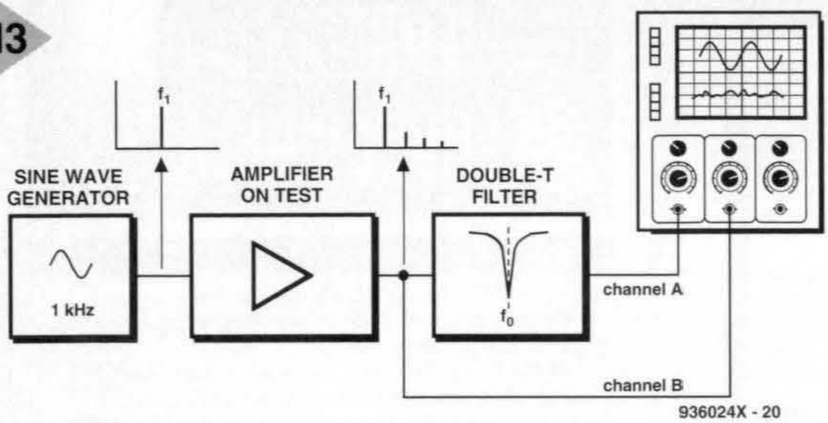

theless, the percentage can be estimated roughly from the picture on the oscilloscope. If, for instance, the level of the input signal is 1 V and the total harmonic distortion is not greater than 1 mV (peak), the percentage distortion is about 0.1.

If a true-RMS meter is available, the percentage distortion can be determined fairly accurately by dividing the output of the filter by the input to the adaptor.

[936024]

Figure 13. Set-up for determining how much distortion is caused by an op amp. Although a dual-channel oscilloscope is shown, a simple version will do just as well, since all that is needed is a display of the total harmonic distortion.

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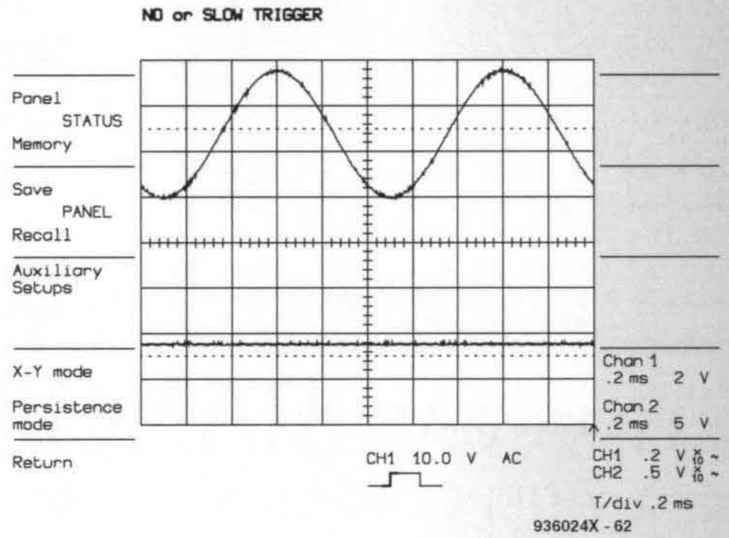

Figure 14. When the op amp is driven by a pure sine wave at not too large a level, the output shows no or hardly any distortion.

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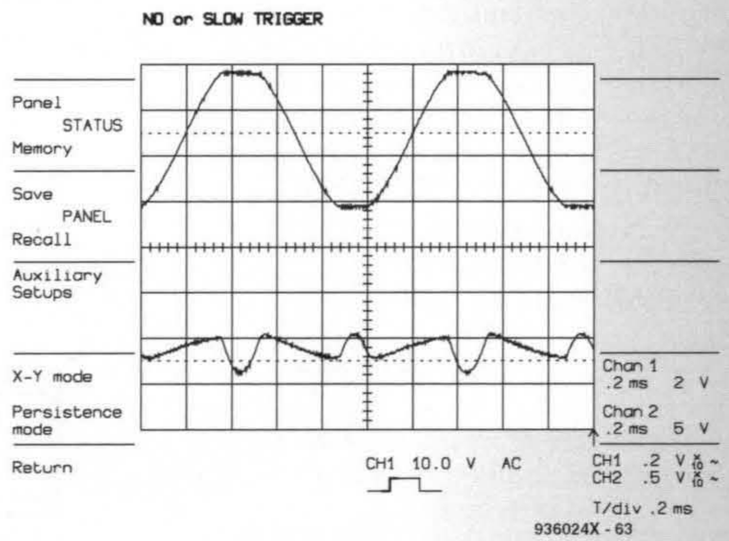
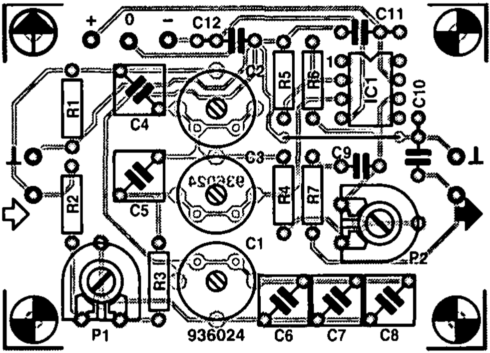


Figure 15. When the input to the op amp is large, the distortion rises appreciably.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C11
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IC1
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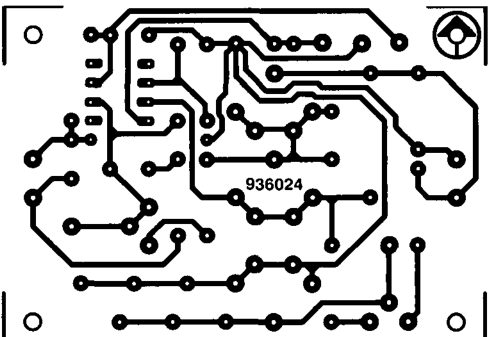
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grid dipper

at home in every radio shack

Only a handful of components are needed to build an instrument which is indispensable in any RF workshop: the grid dip meter or 'dipper'. The main function of this clever piece of test equipment is to determine the resonance frequency of unknown tuned circuits within a certain range (here, 1.5 to 80 MHz). Apart from this, the dipper doubles as an RF signal generator and an absorption frequency meter. Some amateurs even use it to repair radios or tune short-wave antennas!

The operation of the grid dip meter is based on the principle of energy absorption. An oscillator produces RF energy through an inductor. When this inductor is brought in the vicinity of another inductor with the same resonance frequency, the latter 'draws' energy via inductive coupling. Because the oscillator is equipped with an RF output level indicator, the energy loss is easily detected as a 'dip' when the instrument is tuned, and hits upon the resonance frequency of the unknown inductor. The name 'grid dipper' is historic, and a remnant of the days when this instrument was built using valves (electrically, the nearest equivalent of valve grid is the gate of a FET).

The oscillator in the grid dipper may be modulated with a fixed tone to make its signal easily identifiable on a short-wave tuning scale (where chaos may reign).

Design by L. Lemmens

Colpitts oscillator

The circuit diagram of the grid dipper is given **Figure 1**. The heart of the circuit is an RF oscillator built around transistor T2. The oscillator is a Colpitts design, which is marked by a tap on the capacitive element in the tuned circuit. In other words, the tuned circuit has a capacitive tap. Other oscillators, for example, the Hartley oscillator, use a tap on the inductive element. A capacitive tap is made by connecting two capacitors in series, and then in parallel with an inductor. The junction of the two capacitors forms the capacitive tap.

In the circuit of Figure 1, the capacitive part of the tuned circuit is formed by two series-connected halves of variable-capacitance diode ('varicap') D3, a KV1236Z from Toko. The inductor that belongs with this capacitance is not shown because it is one of six plug-in coils which you should make yourself. Each coil gives a different frequency range, and is plugged into socket K2. The tuning in each range is accomplished by varicap D3.

The adjustable voltage required for the tuning of the varicap is supplied by potentiometer P2. So, turning this pot tunes the grid dipper across the relevant frequency range.

The energy which is needed to maintain resonance in the tuned circuit formed by the varicap and the plug-in coil is supplied by transistor T2. Its emitter-collector circuit is connected to the top capacitor of the tuned circuit, and the transistor pumps a tiny amount of current into it just at the right moment. The tuned circuit, in turn, provides the drive signal for the transistor, the lower capacitive half of the circuit being connected to the base of T2 via C1 and C2/R2.

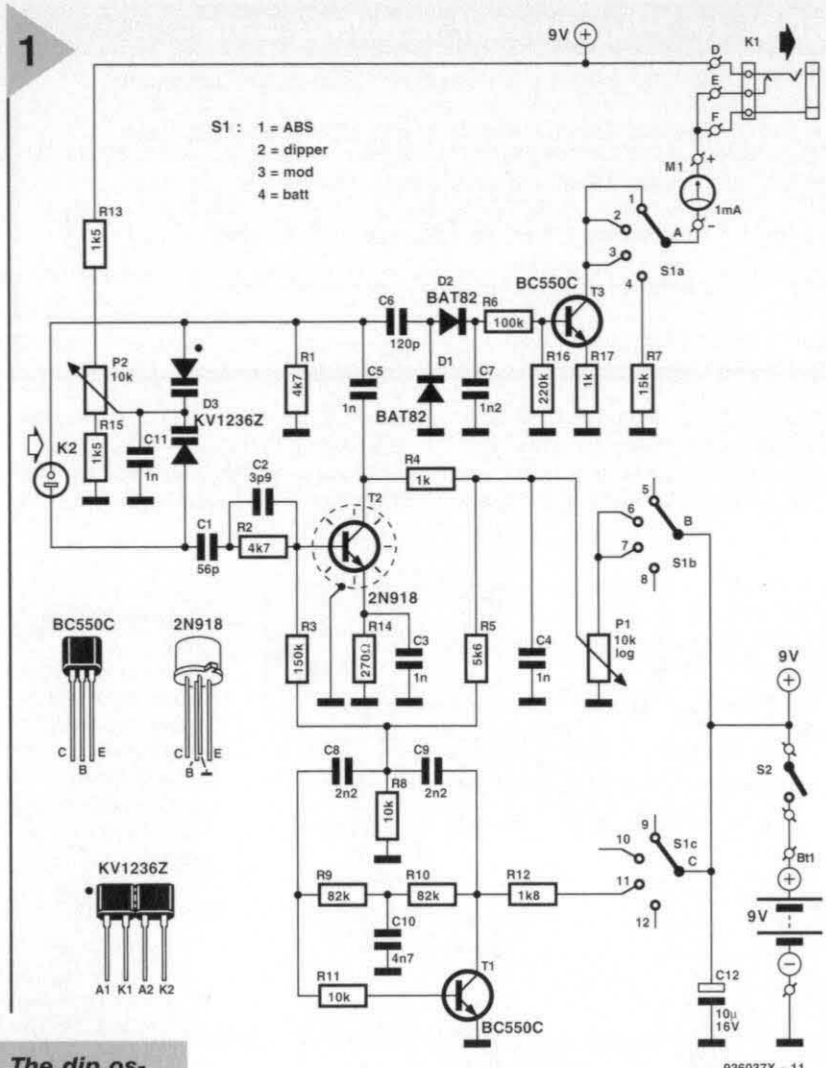

Figure 1. The dip oscillator built around transistor T2 is tuned by a dual varicap. The coils that create the various frequency ranges of the instrument are plugged into socket K2.

Meter circuit

The level of the RF voltage produced by the oscillator is controlled with the aid of potentiometer P1. In fact, it controls the direct voltage for the base as well as the collector circuit of T2. The relative level of the signal generated by the oscillator is indicated on a moving-coil meter, M1. The meter is inserted in the collector circuit of T3, and actually measures the collector current of this transistor. T3, in turn, is driven with the rectified RF signal produced by the oscillator, T2. The voltage-doubling rectifier is formed by components C6, C7, D1 and D2. The resulting rectified RF voltage is limited with the aid of R6, and converted into a base current for T3. The amount of base current is directly proportional to the RF voltage. Any change in the level of this voltage is therefore reflected by the meter indication. Such changes may occur as a result of P1 being turned, or energy being absorbed from the oscillator coil by a resonating tuned circuit.

Modulation

The RF signal produced by the grid dipper may be amplitude modulated with a 1-KHz tone. This is achieved by superimposing a 1-kHz waveform on to the varicap control voltage. The audio signal is supplied by a simple oscillator built around T1. This transistor is switched on when rotary switch S1 is set to the 'mod' (modulation) position. A double-T network consisting of capacitors C8, C9, C10 and resistors R8, R9 and R10 is connected between the base and the collector of T1. The network provides feedback from the collector to the base, which is necessary to make the transistor oscillate. For the same purpose it also causes a phase shift of 180 degrees.

Other applications

Apart from applications like finding the resonance frequency of unknown tuned circuits, and fault-finding by signal injection in RF circuits, the instrument may also be used as an absorption frequency meter. By setting S1 to the 'abs' (absorption) position, the dipper may be used as a multi-purpose detector/receiver. The RF oscillator, T2, and AF oscillator, T1, are switched off in this mode. The coil inserted into K2 is held close to an external RF signal source, enabling it to absorb energy when the tuning of the dipper 'hits upon' the signal frequency. This is indicated by a quick needle movement on the meter. The frequency supplied by the source under test may then be read from the scale.

A wire link in series with the moving coil meter circuit allows a pair of headphones to be connected. The headphones enable you to listen to the signal produced by the signal source under test. Actually, you are listening to the output of an AM (amplitude modulation) detector consisting of C6/C7/D1/D2. By purposely detuning the dipper a little, you may hear FM (frequency modulation) signals, too. This method is called edge detection.

The fourth position of the mode switch allows you to check the battery condition. Some battery current is applied to the meter via limiter resistor R7. The deflection of the meter needle then provides a relative indication of the battery condition.

Construction and test

The track layouts and component mounting plan of the printed circuit board designed for the dipper are shown in **Figure 2**. The double-sided board is available ready-made through our Readers Services. The photograph in **Figure 3** shows the completed prototype.

Stuffing the board is not difficult if you work neatly and stick to the parts list and the component mounting plan. Where a wire is inserted into a hole that has copper pads at both sides of the board, it has to be soldered at both sides to effect the through-contact.

For a first test, connect all pots, switches, and the moving-coil meter to the board. Make an experimental plug-in coil from about 20 turns of 1-mm dia enamelled copper wire (SWG20) on a former with a diameter of about 1 cm. Switch on the power supply. Turn P1 and P2 to see if the moving coil meter shows activity. If the oscillator works properly, the meter needle will move

Table 1. Plug-in coil winding data

Coil A:	*50 turns 0.2mm e.c.w. on plastic PCB spacer dia. 6mm*
Coil B:	*20 turns 0.2mm e.c.w. on plastic PCB spacer dia. 6mm*
Coil C:	*10 turns 0.2mm e.c.w. on plastic PCB spacer dia. 6mm*
Coil D:	*6 turns 1mm e.c.w., no core, internal dia. 8mm*
Coil E:	*3 turns 1mm e.c.w., no core, internal dia. 8mm*
e.c.w. = enamelled copper wire	

from zero to a position close to full-scale deflection. If that is okay, you may start testing the other functions of the grid dipper. An AM receiver may be used, for example, to check if the modulator, T1, works properly.

If you like, you may have the grid dipper pick up a small signal from an

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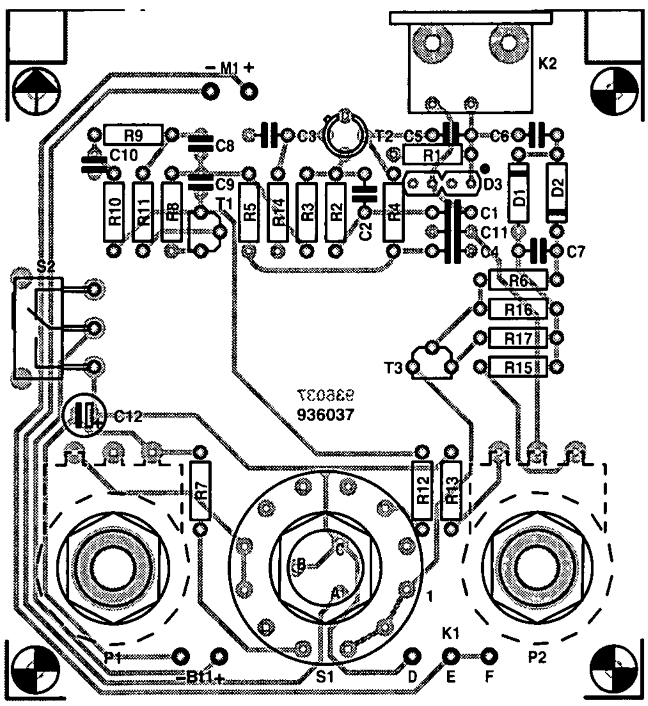


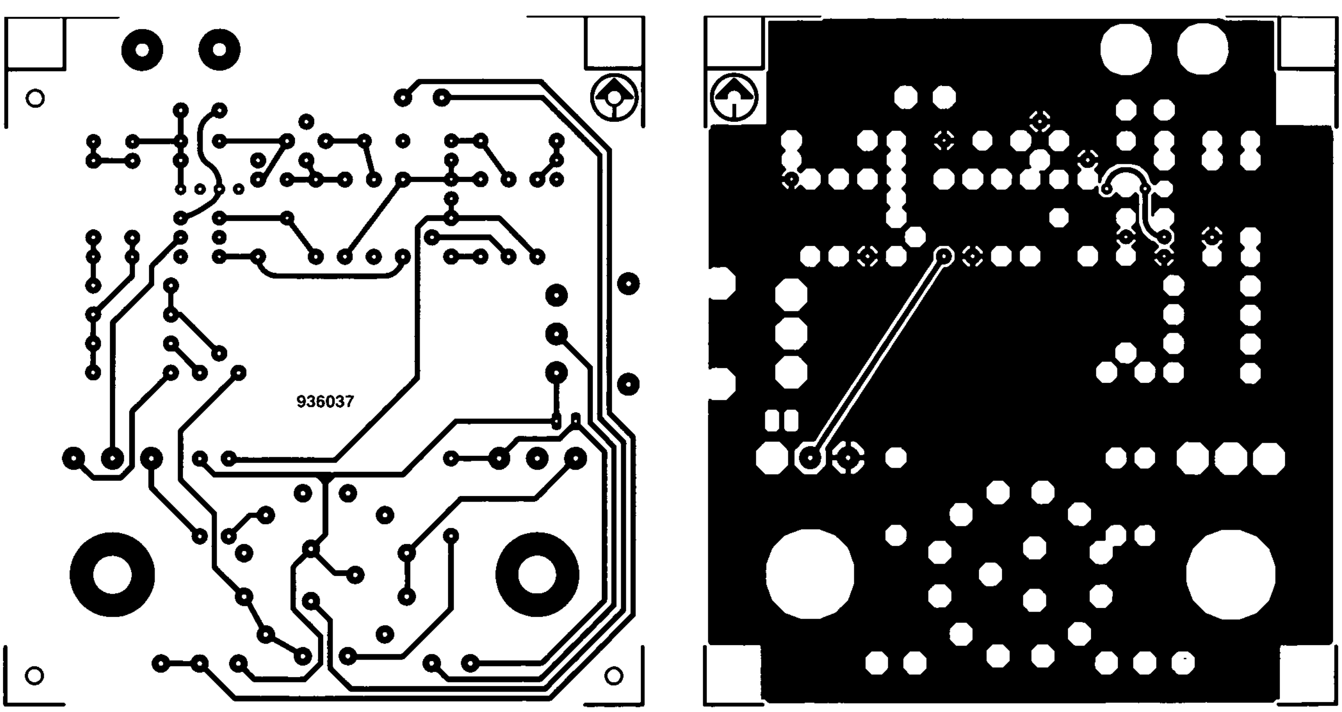


Figure 2. Copper layouts and component stuffing plan (board available ready-made, see Readers Services page).

COMPONENTS LIST

Resistors:
R1,R2 = 4kΩ7
R3 = 150kΩ
R4 = 2kΩ2
R5 = 5kΩ6
R6 = 100kΩ
R7 = 15kΩ
R8,R11 = 10kΩ
R9,R10 = 82kΩ
R12 = 1kΩ8
R13,R15 = 1kΩ5
R14 = 270Ω
R16 = 220kΩ
R17 = 1kΩ
P1 = 10kΩ logarithmic potentiometer
P2 = 10kΩ linear potentiometer

Capacitors:
C1 = 56pF
C2 = 3nF9
C3,C4,C5,C11 = 1nF
C6 = 120pF
C7 = 1nF2
C8,C9 = 2nF2
C10 = 4nF7
C12 = 10µF 16V radial

Semiconductors:
D1,D2 = BAT82
D3 = KV1236Z (Toko)
T1,T3 = BC550C
T2 = 2N918

Miscellaneous:
K1 = jack receptacle, PCB mount
K2 = 2-pin DIN connector, PCB mount
S1 = 3-pole, 4-position switch, PCB mount
S2 = slide switch, PCB mount, angled pins
M1 = 1mA moving coil meter
Bt1 = 9V battery with clip
Case: Hammond type 1590C
Printed circuit board, order code 936037

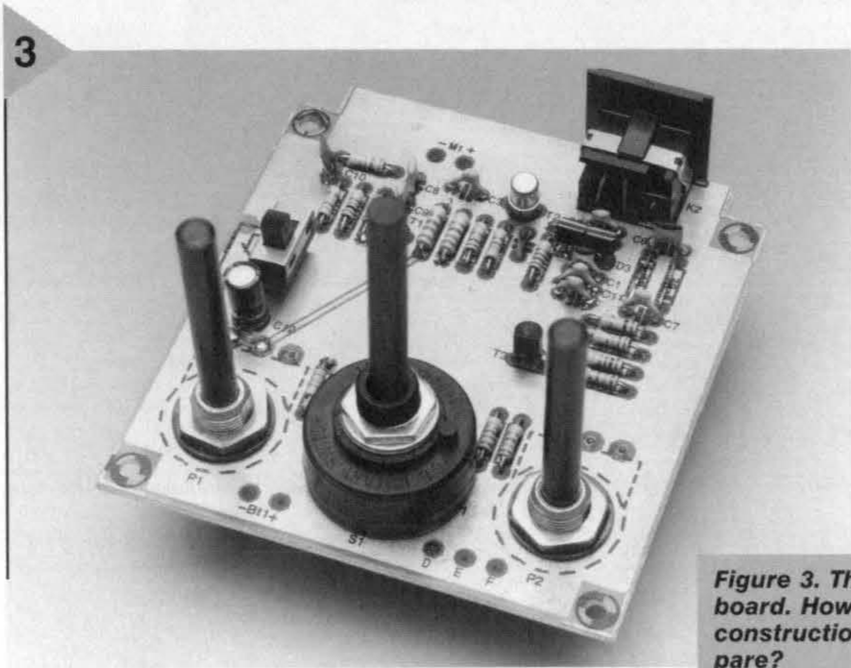


Figure 3. The finished board. How does your construction compare?

external source. Tune the dipper, and use the headphones to listen to the received signal, which should also be indicated on the meter. If you switch on the dipper's oscillator (without the modulation signal), the two RF signals should produce a beat frequency in the headphones, provided, of course, they are nearly equal!

Finally, run a quick test on the battery condition meter. The meter needle should almost reach the full-deflection stop.

If everything appears to work so far, the completed circuit board may be installed in a suitable case. The connection to the plug-in coils must as short as possible. That is why the PCB-mount DIN style socket mentioned in the parts list must be used.

The wiring to the other connectors, the pots and the meter is not critical because it does not carry RF signals.

Making the inductors

Data for winding the set of plug-in coils is presented in **Table 1**. Note that the number of turns for each coil is guidance only, because it is hard to predict the exact stray capacitance that lurks in your particular construction of the oscillator. For the same reason, the frequency scale shown in **Figure 4** is given as guidance only. The idea is to first make your set of plug-in coils, and then check the dipper's output frequencies using a frequency meter or a calibrated receiver. This will enable you to place the markings on the scale at the appropriate points. The scales should have some overlap. The home-drawn frequency scale may then be copied together with the design shown in Figure 4, and secured on to the front panel of the grid dipper.

(936037X)

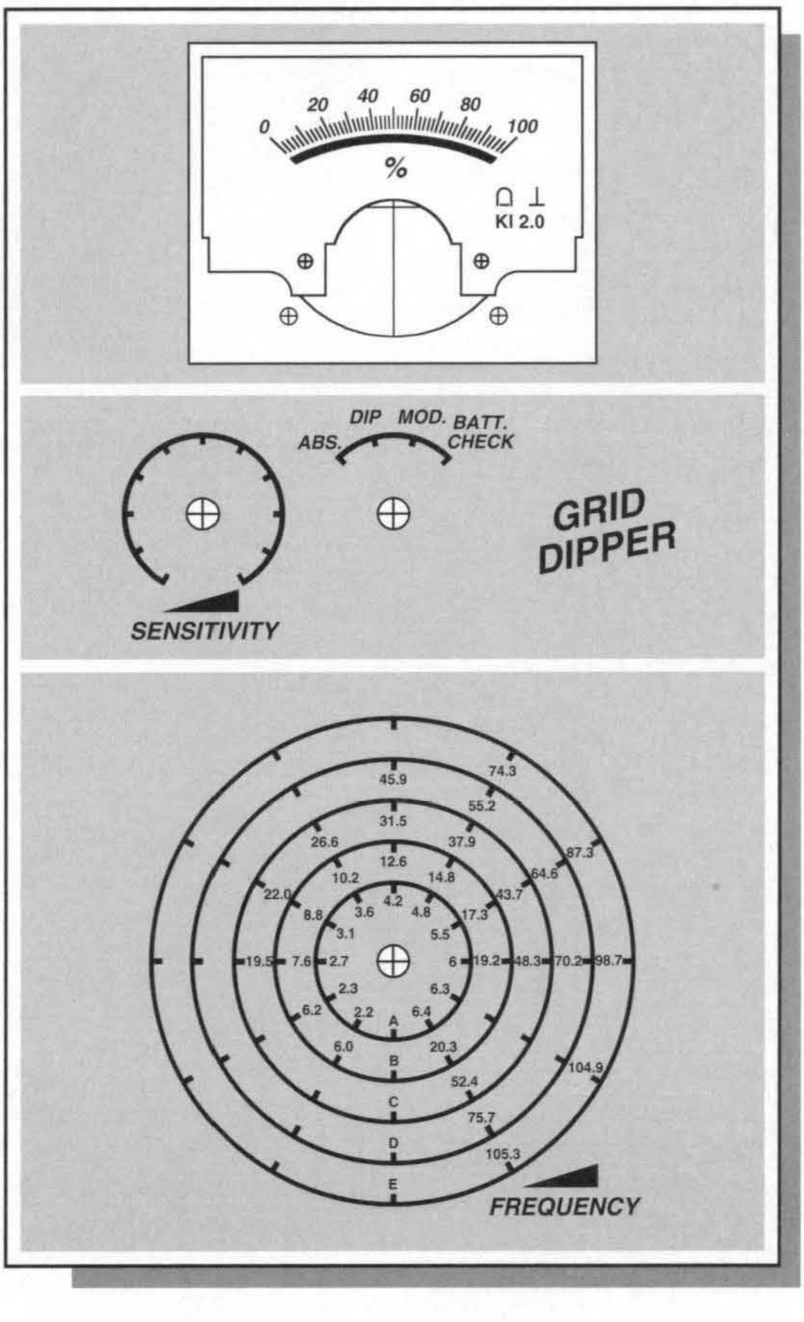
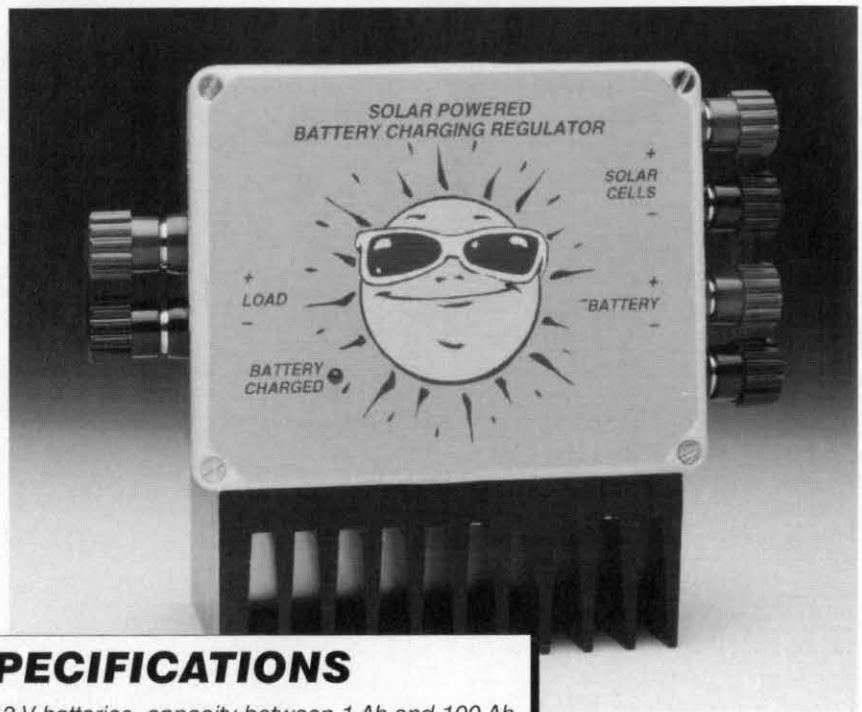


Figure 4. Suggestion for the front panel design. The exact markings on the frequency scale will depend on the tolerance of the home-made plug-in coils for the instrument.

solar-charging regulator

indispensable link between solar panel and battery

Considering the deteriorating state of our environment and the decreasing resources of organic fuel, it is not difficult to predict a much more prominent role for solar energy as an alternative energy source in years to come. For individuals, too, it is becoming more and more interesting to employ the sun as an electricity supplier that doesn't send bills. Apart from lots of sunshine, the only components you need to get started with solar energy are a solar panel, a battery and a properly designed charge controller like the one described here.



MAIN SPECIFICATIONS

- *suitable for 12-V batteries, capacity between 1 Ah and 100 Ah*
- *max. charging current 10 A*
- *high efficiency*
- *low internal current (1.7 mA typ.)*
- *parallel regulation of charging current*
- *overcharging protection with charge voltage limiter*
- *deep discharging protection*
- *electronic fuse*
- *polarity reversal protection for solar panel and battery*
- *charging indication*

Design by K. Walraven

Although solar panels are still rather expensive, prices are coming down slowly, and particularly the smaller types are now offered at reasonable prices. The environmentally aware among you may, therefore, get started with their own solar-powered energy supply system, without breaking the bank.

The main components in such a system are, of course, the solar panel and the (12-V) battery. The latter acts as an energy storage device. Low-voltage lighting and the like may be powered directly from the battery, while a power inverter may be used to turn the direct battery voltage into 240 V a.c. However, these applications are not the subject of the present article, which concentrates on connecting a battery to a solar panel.

Wonderfully simple as it would be, it's not possible to connect a battery to a solar panel just like that. A suitable charge controller is essential between these elements. The main function of the charge controller is to reduce the charging current when the solar panel supplies more current than the battery can accept. This is necessary because overcharging can cause serious damage to the battery, and is sure to reduce the battery's lifetime. Without a charge controller, the risk of overcharging is always imminent, because the current output of a solar panel is strongly dependent on the degree of irradiation, or the amount of incident sunlight.

Basically, there are two ways of controlling the charging current: using a series regulator or a parallel regulator. A series regulator is inserted in the link between the solar panel and the battery. The parallel (or 'shunt') regulator is connected in parallel with the two elements. The regulator described in this article is a parallel type. The main advantage of a shunt regulator is that it does not consume appreciable energy unless the battery is fully charged. In practice, its own current consumption is negligible. When the battery is full, however, the 'surplus' energy is converted into heat. Particularly in larger solar systems, that heat calls for a fairly 'heavy' design of the regulator.

In addition to its actual function, a good charge controller also offers protection in a number of ways, including a deep-discharging protection for the battery, an electronic fuse and a reliable protection against polarity reversal on the battery or the solar panel.

Because the entire circuit is powered by the battery via a polarity reversal protection diode, D1, the solar-charging regulator retains its function when the solar panel does not supply current. The circuit uses the unregulated battery voltage (junction D2-R4) as well as a highly accurate reference voltage of 2.5 V, which is created with the aid of zener diode D5. The control terminal of this reference diode is not used.

Because the charging regulator itself works happily with a current of less than 2 mA, the battery is hardly loaded during the hours of darkness, or when the sky is overcast. The low current consumption is achieved through the use of power MOSFETs type BUZ11, T2 and T3, which are driven with a voltage only, i.e., they work at virtually zero drive power.

Returning to the voltage regulator, tracks the battery voltage and controls the degree of conduction of transistor T1. The higher the battery voltage, the greater the current through T1. Consequently, the voltage drop across R19 increases. This voltage is the gate voltage for MOSFET T2. As the MOSFET conducts harder, its drain-to-source resistance drops, in other words, the adjustable power resistor is set to a smaller value. The result of the increased battery voltage is that the load on the solar panel increases also.

Schottky diode D7 prevents damage caused by accidental reversal of the + and – terminals of the solar panel. The same diode also prevents a current flow from the battery into the solar panel in case the panel voltage drops below the battery voltage. This function can not be carried out by T1 because such a current finds its way much easier through the diode which is present across the drain-source junction in the MOSFET, T2. A type BYV32-50 is used in position D7 because this diode is marked by a low voltage drop at relatively high forward currents.

Components IC1b and D3 provide a visible 'battery charging' indication. The LED lights as soon as the battery voltage exceeds 13.1 V, and the battery is being charged. Because of the LED current, the current consumption of the charging regulator then rises from

1

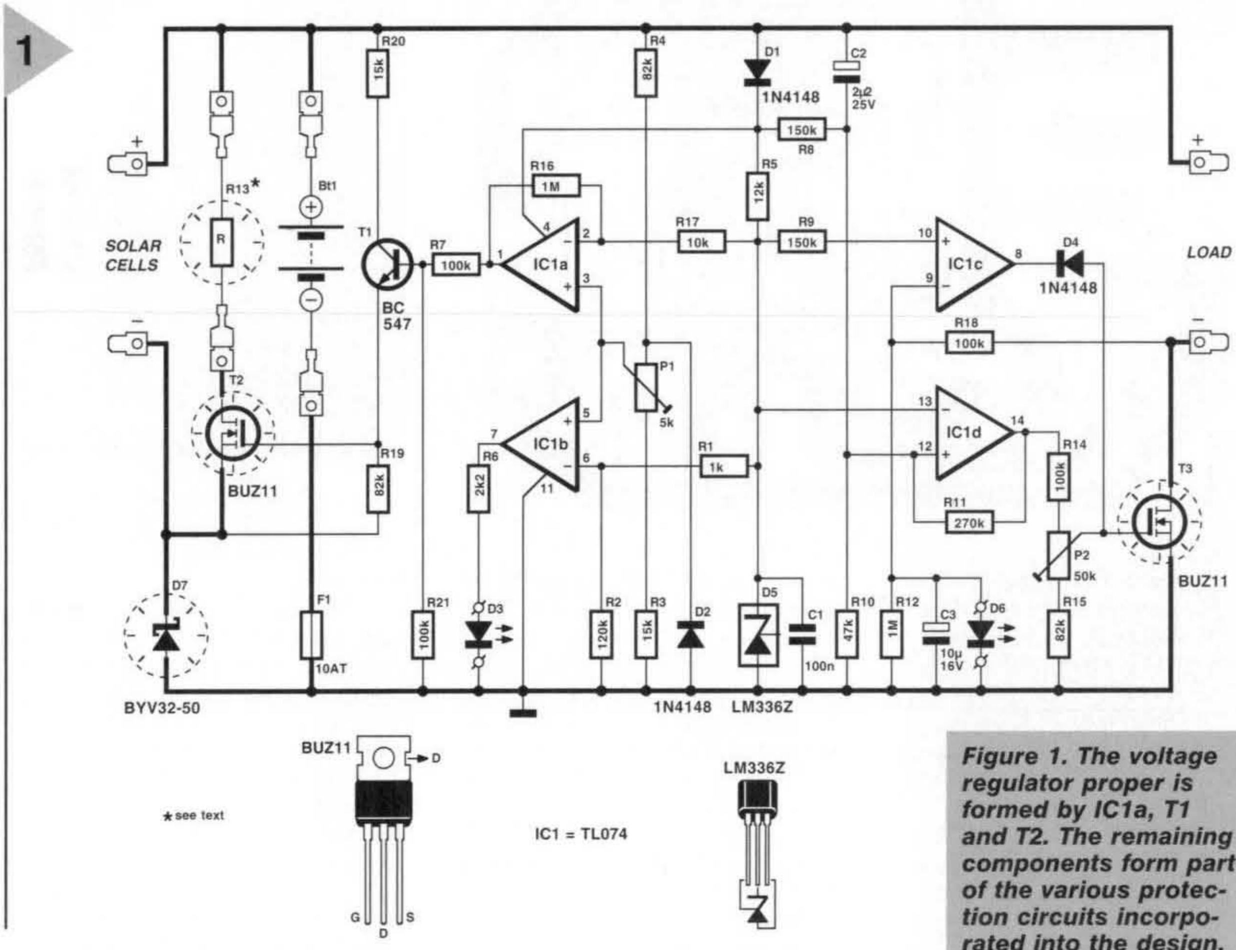


Figure 1. The voltage regulator proper is formed by IC1a, T1 and T2. The remaining components form part of the various protection circuits incorporated into the design.

VOLTAGE REGULATION

The circuit diagram of the solar-charging regulator is shown in **Figure 1**. As you can see, the main components are two 'heavy' MOSFETs and a quadruple operational amplifier. The latter (IC1) has a key function in this circuit.

Functionally, the circuit may be divided into three parts: the voltage regulator around IC1a, the discharging limiter around IC1d and the electronic short-circuit protection built around IC1c.

IC1 is the controlling element, while T2 is used as an adjustable power resistor which, together with R13, acts as a kind of active load on the output of the solar panel. The operation of the regulator is fairly basic. An adjustable part of the battery voltage is fed to the non-inverting input of control amplifier IC1a via voltage divider R4-P1-R3. The previously mentioned 2.5-V reference voltage is applied to the inverting input of the amplifier.

The behaviour of the regulation is proportional. The output of IC1a

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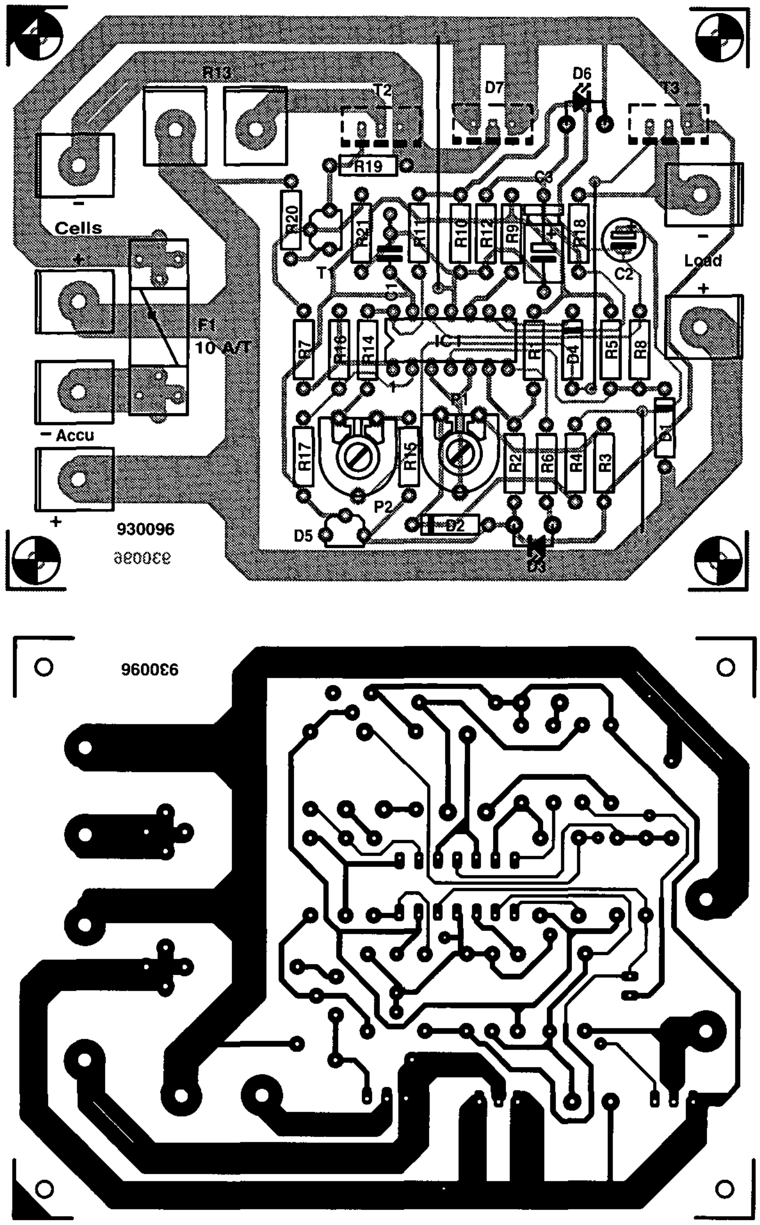

COMPONENTS LIST

Resistors:
R1 = 1kΩ
R2 = 120kΩ
R3,R20 = 15kΩ
R4,R15,R19 = 82kΩ
R5 = 12kΩ
R6 = 2kΩ2
R7,R14,R18,R21 = 100kΩ
R8,R9 = 150kΩ
R10 = 47kΩ
R11 = 270kΩ
R12,R16 = 1MΩ
R13 = see text
R17 = 10kΩ
P1 = 5kΩ preset
P2 = 50kΩ preset

Capacitors:
C1 = 100nF
C2 = 2µF2 25V radial
C3 = 10µF 16V

Semiconductors:
D1,D2,D4 = 1N4148
D3,D6 = LED red
D5 = LM336Z-2.5
D7 = BYV32-50
T1 = BC547
T2,T3 = BUZ11
IC1 = TL074

Miscellaneous:
F1 = fuse 10 A (T) with PCB mount holder
Waterproof case, e.g., Hammond 1590C
8 spade terminals for screw mounting
Heatsink 1.25K/W (e.g. SK71-75 from Fischer, Dau Components)
Printed circuit board, order code 930096, see Readers Services page

Figure 2. The printed circuit board has a neat and compact layout. Components T2, T3 and D7 are purposely arranged at one side of the board, allowing them to be bolted on to a common heat-sink.

1.7 mA to about 7 mA. Although the LED can draw this extra current from the solar panel – saving the precious energy stored in the battery for 'useful' loads – thrifty users may none the less think of the LED as a waste of energy. Well, they may consider omitting the LED, and instead mount an ammeter with a centre indication, as used in cars, for example.

Protection circuits

The deep-discharging protection is realized with the aid of opamp IC1d which is wired as a comparator, and MOSFET T3. The battery voltage is first scaled down to about a quarter of the nominal value by potential divider R8/R10, and then compared with a reference voltage of 2.5 V supplied by D5. The comparison is performed by IC1d. The values of the resistors in the potential divider are such that the output of IC1d drops low when the battery voltage drops below a level of approximately 9 V. MOSFET T3 then blocks and interrupts the ground connection between the battery and the load. Because of the hysteresis created with feedback resistor R11, the comparator does not change state until a battery voltage of 12 V is measured again. Electrolytic capacitor C2 prevents the deep-discharging protection from being actuated by voltage dips caused by, for instance, the switching on of large loads.

The short-circuit protection built into the circuit acts as an electronic fuse. In the event of a short-circuit, it disconnects the load from the battery. This is also done with the aid of T3, only then the MOSFET has a double function. Not only does the device act as a circuit breaker, its drain-to-source junction also behaves like a measuring resistor. The voltage drop across this resistor is scaled down by R12/R18 and then applied to the inverting input of comparator IC1c. Here, too, the accurate voltage supplied by D5 is used as a reference.

As long as the short-circuit protection is not active, the output of IC1c supplies a 'high' level. Diode D4 then blocks, and the output of IC1d alone determines the gate voltage of T3. A gate voltage range of about 4 V to 6 V is achieved with the aid of potential divider R14/P2/R15, allowing a well-defined voltage drop to be set across the drain-to-source junction of T3. When the load current reaches its maximum level, the voltage drop increases rapidly until the level is reached at which IC1c toggles and pulls its output low. Diode D4 then conducts, causing the gate of T3 to be pulled to ground. The result is that the MOSFET blocks, interrupting the current flow.

R-C network R12/C3 determines the response time of the electronic fuse. A fairly slow response is chosen to prevent erroneous triggering of the protection by sudden peaks in the load current (as with the deep-discharging protection). LED D6, incidentally, is used as a 1.6-V reference, ensuring that C3 can not be charged beyond this voltage. Once the short-circuit has been eliminated and the load disconnected from the battery, C3 is slowly discharged across the LED (this will take about seven seconds).

The fact that the electronic fuse has a fairly slow response does not mean that the load current is allowed to reach too high values. Before the electronic fuse is actually actuated, the gate voltage of T3 causes the MOSFET to limit the output current to the level set with preset P2. Just to make sure nothing goes up in smoke, the circuit also includes a normal fuse, F1, which is connected in series with the battery, and offers peace of mind that a possible malfunction in the circuit does not cause instant disasters. As a last protective measure, D2 has been added to the circuit. This diode protects the inputs of IC1a and IC1b against damage caused by a reverse-connected battery.

LARGE OR SMALL

The choice of a suitable solar panel is, of course, strongly dependent on the capacity of the battery you wish to use. The solar-charging regulator is, in principle, intended for solar panels with a nominal output voltage of 15 to 18 volts and a power of 10 to 40 watts. Such panels are normally combined with batteries having a capacity between 36 and 100 Ah. However, because the solar-charging regulator allows a maximum current flow of 10 A, solar panels with a power rating of up to 150 watts may be used.

The solar-charging regulator may, of course, also be used in wind power systems and with other voltage sources, as long as the input voltage is in the 15-18 V range.

The largest amount of heat is dissipated by the active load, T2/R13. Obviously, the MOSFET must be properly cooled, and R13 must be capable of tolerating quite high temperatures. The power rating of R13 should remain in step with the power that can be supplied by the solar panel. In the (extreme) case of a solar panel being used with a no-load output voltage of 21 V and a short-circuit current of 10 A, then T2 and R13 dissipate a power which equals the voltage difference between the battery and the solar panel (approx. 7 V) multiplied by the short-circuit current (10 A), or about 70 watts! This may actually happen when the battery is fully charged. Most power is dissipated by R13, because the MOSFET then presents an extremely low resistance. The value of the resistor is easily calculated using Ohm's law:

$$R13 = P/I^2 = 70/10^2 = 0.7\ \Omega$$

Such a high solar-panel power should be rare, though. In the prototype of the solar-charging regulator, a resistance of 0.25 Ω/40 W is used which consists of four parallel-connected resistors of 1 Ω/10 W.

The required cooling for T3 is computed in a similar way. Assuming that the maximum output current is 10 A (which corresponds to a voltage drop of about 2.5 V across the drain-source junction), then a maximum dissipation of about 27 W should be taken into account. To ensure sufficient cooling of T3 even at high ambient temperatures (e.g., 50 °C), the heat-sink should have a thermal resistance of 3.5 K/W or less.

Components T2, T3 and D7 are arranged at one side of the board, allowing them to be mounted on to a common heat-sink (using isolation materials). The dissipation of these three semiconductors should, therefore, be added, and you then need a heat-sink with a thermal specification of 1.5 K/W or better. The type mentioned in the components list satisfies this requirement.

CONSTRUCTION

The printed circuit board designed for the solar-charging regulator is shown in **Figure 2**. Populating the board should not present undue difficulties if you follow the component overlay and the component list. The board is available ready-made through our Readers Services. The battery, solar panel and load are connected via robust, screw-type spade terminals as used in car electrical systems. Power resistor R13 is also connected to the board in this way.

The nearly finished board is shown in the photograph in **Figure 3**. The introductory photo provides a useful suggestion how the circuit may be built into a water-proof enclosure (we used a diecast type from Hammond). The heat-sink is simply secured to one side of the case by a set of screws. The power semiconductors, T2, T3 and D7, are then mounted on to the bottom panel of the case using isolating washers, bushes and bolts, not forgetting a fair amount of heat conducting paste.

Although banana sockets are used in the prototype, you may want to feed the (heavy-duty) input and output cables directly through grommets in the sides of the case, connecting them straight to the spade terminals on the board.

ADJUSTMENT

Fortunately, the circuit is relatively simple to adjust. The job does, however, require two (regulated) power supplies. One of these is set to an output voltage of 14.1 V, and connected to the battery terminals (marked 'accu') on the board. The other should have a current limiter. This supply is set to the open-circuit voltage of the solar panel used (for example, 21 V as in the above mentioned situation), and connected to the spade terminals marked 'cells'. When P1 is properly adjusted, the voltage will drop to 14.1 V. You need not worry about this, because the current limiter and D7 ensure that nothing can go wrong!

For proper adjustment of P2 it is necessary to use a load which is slightly higher than the heaviest anticipated load. If you want to squeeze the most out of this system, select a load current of 10 A. That can be achieved by means of a load resistor of 1 Ω/120 W, consisting of, for example, ten resistors of 10 Ω/10 W in parallel. Preset P2 is initially turned to 'maximum' (wiper against R14). Next, the load is connected to the terminals marked 'load' on the board. Carefully adjust P2 until you reach the point where T3 switches off and disconnects the load.

After removing the load resistors, the 'load' terminals may be short-circuited briefly to check that the electronic fuse works properly. (930096)

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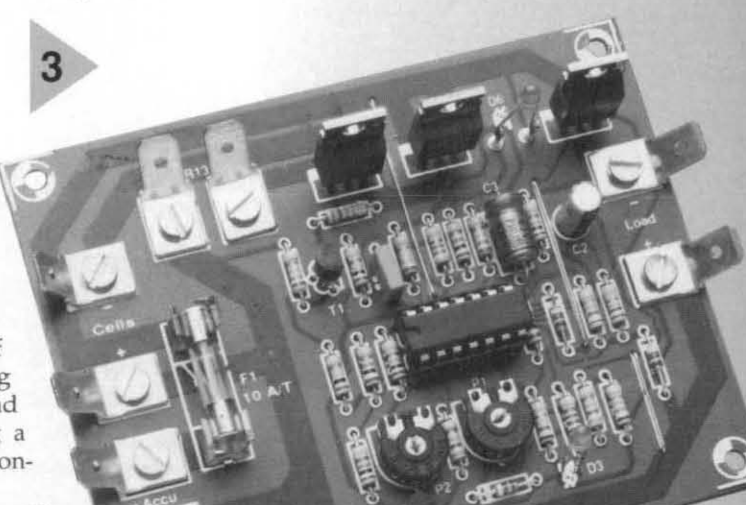

Figure 3. Nearly finished prototype of the solar-charging system. The missing parts are power resistor R13 and the heat-sink.

Comparator/DAC combinations solve data-acquisition problems

This report examines an overlooked option for many existing A/D converter (ADC) applications: the A/D conversion is sometimes better implemented with a discrete comparator and D/A converter (DAC). This substitution generally entails a different measurement approach, but the advantages can include lower cost, higher speed, more flexibility, and lower power consumption.

Current trends, though, are in the other direction—designers who must implement A/D conversion usually specify a packaged ADC for the job. Most engineers are not aware of an alternative, and the price/performance ratios for ADCs are falling all the time. Yet, an analogue comparator plus DAC, along with digital processing capability, form the core of a successive-approximation ADC.

The discrete comparator/DAC approach is already common in certain fields. Automatic test equipment, nuclear pulse-height discriminators, and automated time-domain reflectometers often use the technique whereby one comparator input is driven by the DAC, and the other is driven by the signal to be monitored. Following is a selection of general measurement problems and specific applications in which a comparator/DAC combination is actually more appropriate than an off-the-shelf ADC.

A MAxim Report

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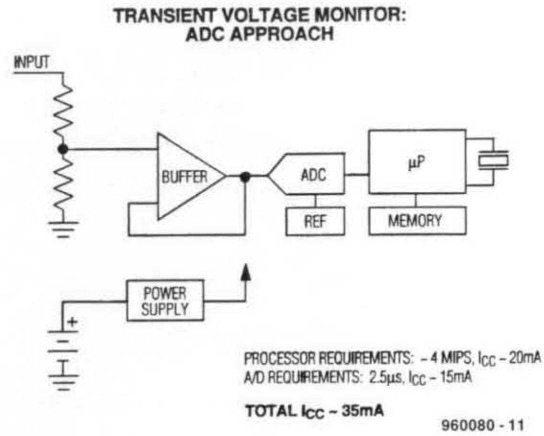

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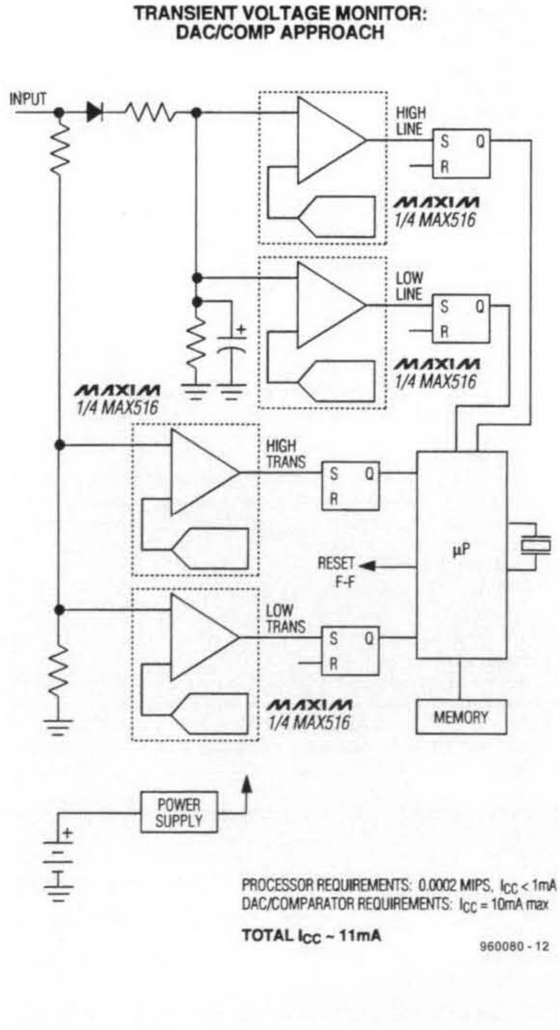

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TRANSIENT VOLTAGE ANALYSIS

A brute-force technique for capturing fast-changing amplitude events (transients) is simply to digitize them with a high-speed ADC supported by a processor and fast RAM (**Figure 1**). Single-shot events may compel the use of this approach, as may the need to discern fine detail in the transients. Otherwise, if the transients are repetitive, you can measure their peak amplitude and other features with the DAC/comparator approach (**Figure 2**).

The DAC sets a trial level at one input of the comparator while the transient signal is applied to the other input. You then determine peak transient amplitudes by adjusting the DAC output, using a digital latch to capture the comparator's output response when its threshold is exceeded. Only the comparator input need sustain the full bandwidth of the transient, and the DAC output can exhibit arbitrarily long settling times without affecting the measurement accuracy. Thus, sensing in the analogue domain lets you replace an expensive ADC with a low-cost DAC and comparator.

A related problem is monitoring an analogue voltage with respect to tolerance limits. Many self-diagnostic instruments monitor system voltages, temperatures, and other analogue quantities, against limit values set in software. However, if the comparisons are made by a comparator whose set-point value is provided by a DAC, you can reduce the processor's overhead because it need only read a single bit representing the out-of-limit condition.

This technique (analogue-domain comparison) is just as accurate as the ADC technique (digital-domain comparison), so why digitize the whole value when you can simply compare it against a setpoint? One case should be mentioned: if the value must be compared against several setpoints, such as a low and high warning level and a low and high shutdown level, an ADC may be preferable to the four DACs and four comparators otherwise required.

DERIVE A SIMPLE DC FROM AN EXISTING DAC

In portable instruments constrained by cost and size, an existing DAC can sometimes be persuaded to perform A/D conversions as well. Cellular phones and medical electronics, for example, often include a DAC for adjusting the contrast voltage in an LCD (**Figure 3**). In some cases, you can also monitor a temperature or battery voltage (as described above) simply by adding a comparator and switches. The existing DAC then does double duty, with the display blanked while the DAC participates in analogue-to-digital conversions. As an alternative to blanking, a simple sample&hold consisting of an analogue switch and capacitor (**Figure 4**) can maintain the LCD contrast voltage during an A/D conversion.

Another alternative is to substitute a low-cost dual DAC for the existing single DAC. One half of the dual DAC produces a full-time LCD-contrast voltage, while the other half helps form a full-time ADC. Whether single or dual, the DAC and comparator require support from a fast, simple software routine that drives the DAC and samples the comparator to implement successive approximation (see Box).

DESIGN CONSIDERATIONS

Combining a DAC and comparator is simple. A signal is applied to the comparator's non-inverting input, and the DAC provides a digitally programmable threshold at the inverting input. The comparator then produces a logic-high output whenever the signal is more positive than its threshold. But, you must apply care in several areas.

To ensure accurate threshold levels, the DAC's d.c. output resistance should be low with respect to the comparator's input bias current and scaling network. The concern arises mainly in very-low-power circuits, for which the DAC's output resistance can be as high as 10 kΩ.

Another DAC requirement is low a.c. output impedance. Otherwise, the comparator's output fast digital slew rate can couple through parasitic layout capacitance, producing input transients that degrade accuracy by causing oscillations. If some settling time can be sacrificed, you can lower the DAC's a.c. output impedance by adding a bypass capacitor at the comparator input. Instability and oscillation can re-

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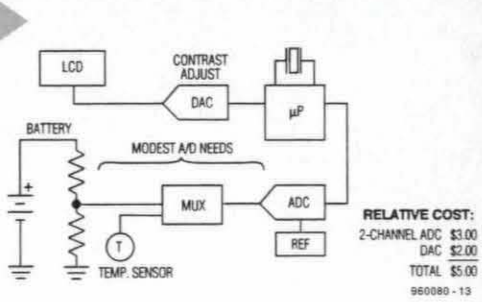

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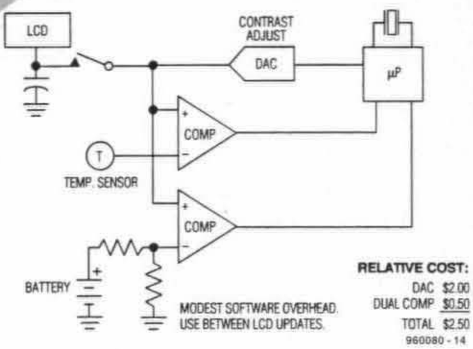
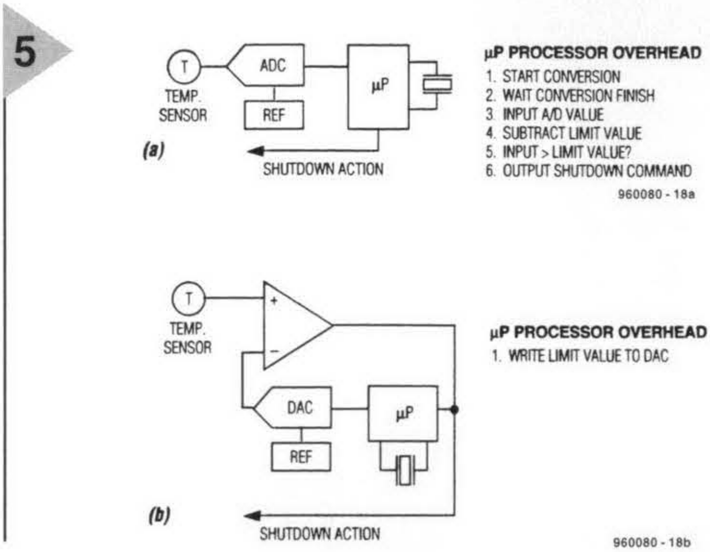


Successive approximation

Successive approximation is easily illustrated by the procedure that uses a balance and a set of binary trial weights (a series of weights whose relative values are 1, 2, 4, 8, 16, ...) to determine an object's weight. To determine the unknown weight by the quickest method (successive approximation), first balance the unknown against the largest trial weight. According to the balance indication, either remove that weight or add the next largest, and continue that process down to the smallest trial weight. The resulting best estimate of the object's weight is the sum of trial weights remaining in the balance pan.

In successive-approximation ADCs, the bits of the internal DAC are analogous to the set of binary weights, and the comparator output is analogous to the balance indication. Logic for driving the bit-trial procedure can reside either in the successive-approximation register (SAR) of a packaged ADC, or in a software routine associated with the processor that controls a DAC/comparator circuit. The 'pseudo-code' shown in the table represents such a routine. For most processors, this routine can be realized with fewer than 20 lines of code.

Begin	/Comments
Mask = 80h	/Shifting weight value—start high
Value = 80h	/Value = output (initially half scale)
Loop:	
Output DAC (value)	/Output current value to DAC
Delay (settling time)	/Wait for DAC output to settle
If input (comp. output) = high	/Check comparator output bit
Value = value and not (mask)	/Clear mask bit (set by default)
Shift mask right:	
Value = value or mask	/Next trial weight
Loop until mask = 0	/Loop until all bit weights are tried
End: value contains the final result of the successive approximation.	



sult from too much capacitive load on the DAC's output amplifier, but that problem is easily fixed by adding a resistor in series with the DAC output.

The main issue for comparators is hysteresis. Most comparator circuits include hysteresis to prevent noise and oscillation, but hysteresis should be used sparingly—it also causes the threshold value to change with output state. That behaviour is acceptable if the system can compensate for state-dependent hysteresis; otherwise hysteresis should be avoided.

If the comparator to be used has internal hysteresis that cannot be disabled, you can eliminate any negative effect by ensuring that the DAC output always approaches the comparator threshold from the same direction. That action is easily established by setting the DAC to zero after each bit test; that is, by adding one line to the pseudo-code listing in the box on p.43.

As another option, you can often eliminate the need for hysteresis by adding a small amount of capacitive feedback, which provides speed-up in the comparator's linear-transition region. Or, you can add an output bistable or latch to capture the comparator's output state at a given instant of time.

APPLICATIONS

This section presents a number of situations in which a DAC/comparator approach offers advantages over the ADC approach. The application circuits discussed are neither unusual nor esoteric, but address common problems that arise frequently.

First, consider the need for a low-cost method to detect and log the sags, surges, and transients, that occur on a power line. An ideal design would be a wall-cube device that detects power-line abnormalities and logs the time of each occurrence to RAM. (Sags and surges can last from milliseconds to hours; transients are as short as 10 microseconds). The monitor must log the duration of complete failures in line power, so the monitor power should come from a battery.

The conventional solution to this problem is a controller and ADC. As the converter continually samples the line voltage, the controller compares each value to user-settable limits stored in software, and logs any out-of-spec condition to RAM. Because the system must be capable of tracking transients as brief as 10 μs, the ADC sample interval must be considerably shorter—perhaps 2.5 μs maximum as a conservative estimate. The controller must therefore process the samples at $1/2.5\,\mu s = 400$ ksps.

If software comparisons can be coded efficiently and the ADC requires no processor intervention, the system can operate with as few as ten instructions per sample, requiring processor performance in the 4 MIPS range. Such performance is substantial, and is not readily compatible with battery operation (Figure 1). You might then consider an analogue method that responds to the derivative of an input transient instead of tracking it, but that approach appears untenable.

The alternate DAC/comparator approach in this case offers several significant advantages. It requires four DACs and four comparators (or a single MAX516), followed by a quad set/reset bistable. One DAC/comparator/bistable combination monitors high transients, one monitors low transients, one is for sags, and one is for surges (Figure 2). Transient voltages couple directly to the comparators, but the input to the sag and surge comparators is first rectified and filtered to obtain the average value of line voltage. Appropriate r.m.s. adjustments can be made in software.

The system operates by sampling and resetting the bistables every T seconds, where T is the time resolution required in the transient log (perhaps 60 seconds). DACs for the high and low transient levels are set to the desired high and low threshold values. The sag and surge DACs are adjusted after each T-second interval, using a successive-approximation technique to generate high-line and low-line limits that track the current average value.

Assuming a very conservative 1000-instruction routine to perform this successive approximation and the other housekeeping chores, the average CPU performance for $T = 60$ s is 17 instructions per second. The resulting execution rate is 0.00002 MIPS—quite suitable for low-power systems, and far below the 4 MIPS required with an ADC approach. For further power savings, the controller can 'sleep' most of the time, waking only to process an abnormal line condition. The circuit thus reduces power, complexity, and cost, by offloading the voltage comparison from software to analogue hardware.

LOW-MAINTENANCE FAULT DETECTION AND DIAGNOSTICS

Printer-head control, carriage control, and many other electromechanical applications, monitor critical internal voltages and temperatures to determine when to modify their operating mode. In extreme cases, this feedback enables the system to avoid self-destruction by shutting down altogether. For example, a stepper-motor controller must adjust gate drive to the output MOSFETs when necessary to avoid the excessive power dissipation associated with linear operation.

Again, the conventional solution to these monitoring problems is an ADC (**Figure 5a**). The processor directs the ADC to make periodic measurements consistent with the time constant of the process under control. It then scales the resulting digitized values and compares them with limits in software. If they go out of bounds, it can trigger corrective action or shut down the system completely.

An alternate approach uses the DAC/comparator combination (**Figure 5b**). The static DAC output establishes a shutdown limit or trip value for the comparator. When a temperature change causes the comparator to trip, the comparator sends an interrupt to the processor that initiates corrective action. If necessary, the processor can also determine the absolute temperature value by initiating a software-based successive-approximation routine.

On the other hand, to support an ADC, the processor must poll the ADC, input the sample value, and compare it with the setpoint before jumping to the shutdown routine. Thus, a DAC/

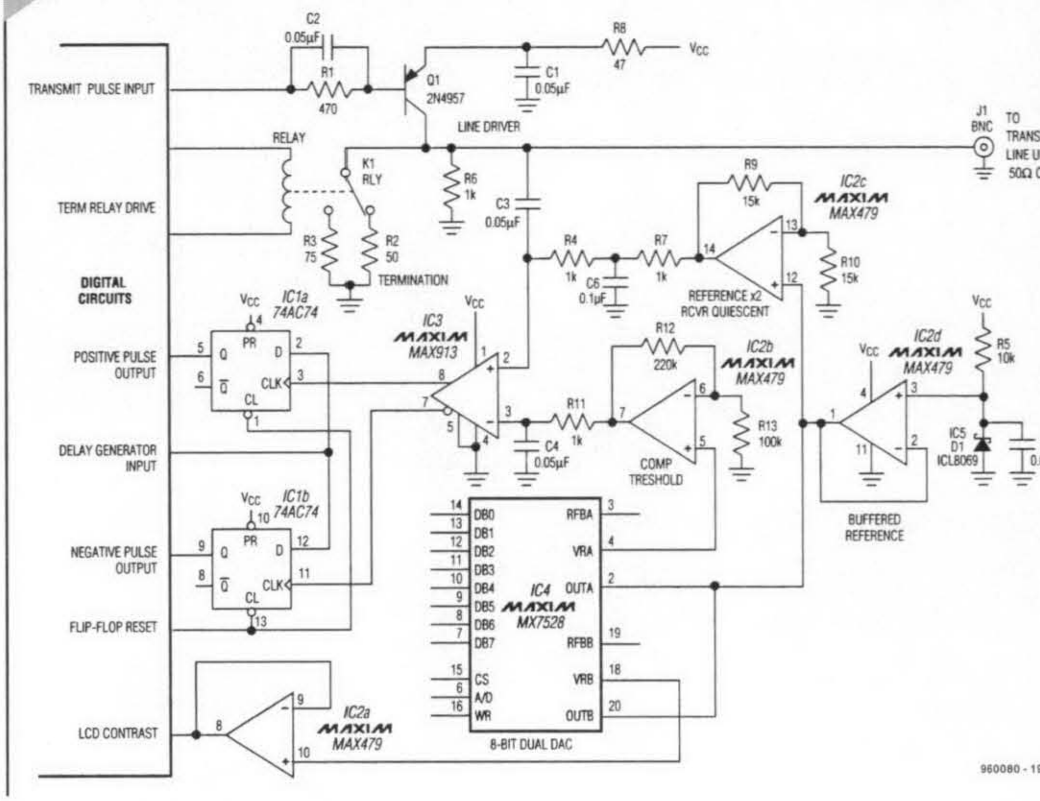
comparator not only saves cost and offers a quicker response then does an ADC: it also reduces the processor overhead.

TIME-DOMAIN REFLECTOMETRY

Finally, the low cost and low power dissipation of DAC/comparator combinations (vs ADCs) have made practical the portable time-domain reflectometer (TDR)—an instrument that detects cable discontinuities and measures the intervening transmission length. Portable, inexpensive TDRs have become popular with the proliferation of network cabling.

A TDR operates like radar: it sends a brief pulse along the line and detects any echo returned by an open, short, or other abrupt discontinuity in the line impedance. The time interval for propagation of the outward-bound pulse and its returning reflection is about 3.3 ns per foot (10.8 ns m^{-1}), assuming a line propagation of 0.6*c*, where *c* is the speed of light.

6



The ratio of received-pulse amplitude to transmitted-pulse amplitude is used to compute the reflection coefficient. Knowing the reflection coefficient and cable impedance, you can compute the impedance of the discontinuity, and from that information deduce the nature of the discontinuity. Coaxial cables introduce a complication by attenuating the pulse on its return trip, so the software must compensate for this effect by applying an amplitude correction based on the distance measurement.

An ADC in this application would have to convert every 5 ns (200 Msps). Though available, such ADCs are expensive, power hungry, and generally unsuitable for portable applications.

The analogue front end of an actual hand-held TDR (**Figure 6**) serves to illustrate the ideas described above. Digital circuitry is excluded for clarity. Though simple and without exotic components, this circuit has impressive performance. It measures termination impedance reliably and with 5% accuracy for cable lengths to 500 ft (165 m). For open or shorted terminations, it measures distances to 2000 ft (660 m). And, best of all, the system (including display and digital circuitry) can operate for 20 hours on a 9 V alkaline battery.

The comparator in Figure 6 (IC_3) provides single-supply operation with ground sensing and a propagation delay of just 10 ns. The DAC (IC_4) is a dual device in which one side helps with the pulse-height measurement and the other drives the LCD contrast control (as in Figure 3). Note that the DACs are driven backwards; the (normal) current outputs are driven together by a buffered reference, and the (normal) reference inputs serve as voltage outputs (each buffered by an external op amp).

A simple glitch-monostable circuit (not shown) drives the base of Q_1, which in turn drives the cable with positive 10 ns-duration pulses. Any reflections from the line are coupled to the comparator via C_3.

IC_5 is a bandgap reference whose 1.2 V output is buffered by op amp IC_{2d} to provide a reference voltage for the dual DACs in IC_4. This reference voltage is also doubled by gain-of-2 amplifier IC_{2c} to provide a 2.5 V d.c. level at the comparator's non-inverting input. DAC *A* applies 0–3.8 V at the comparator's inverting input. Levels above 2.5 V enable the determination of positive-going pulse heights, and levels below 2.5 V determine the amplitude of negative-going pulses.

Each pulse entering the transmission line also enters a variable delay line in the digital circuitry, which consists of a string of 20 ns delay elements controlled by a counter. This delayed pulse from the digital section jointly drives the D inputs of bistables IC_{1a} and IC_{1b}, which in turn are clocked by complementary TTL outputs from the comparator. Thus, time measurements amount to a race between the return pulse and pulse going through the delay line; if the D input arrives before a clock transition, the bistable output is high; otherwise, it is zero.

To measure, set the DAC output to a low absolute level and iteratively adjust the delay until the bistable output remains at zero, then read the counter. Similarly, to measure the height of return pulses, iteratively adjust the DAC output until the bistable output remains at zero, then read the DAC. Note that two bistables are required to capture the comparator's leading edge for both positive and negative pulses. This leading edge rises for positive pulses and falls for negative pulses; if both were applied to a single bistable, the pulse width would become an unwanted part of the delay.

[960080]

References

1. Edward Jordan, *Reference Data for Engineers*, 7th Edition, (Howard Sams, 1989).
2. Brian Kenner and John Wettroth, *The Design of a Time-Domain Reflectometer*, (*Computer Applications Journal* #29, October/November 1992).
3. Paul Horowitz and Winfield Hill, *The Art of Electronics*, 2nd Edition, (Cambridge University Press, 1989).

Applied Electronic Engineering with Mathematica®

By Alfred Riddle and Samuel Dick
ISBN 0 201 53477 0
Price £ 31·99 (375 pp - hardback)
Addison-Wesley Publishing Company Inc

Mathematica, described by its publishers (Wolfram Research Inc.) as 'A system for Doing Mathematics by Computer', is a general mathematical software system with applications in many field. It is not just a calculating program, for it is able to operate symbolically as well, which is one of its greatest strengths. It has facilities for displaying its results as formulae, text and tables, by graphics (including 3-D and animated figures in full colour) and as sound files, which can be played on computers with a sound card.

Numerous extensions of the *Mathematica* system have been written for specialist applications, including Wolfram's own *Electrical Engineering Pack*. A system of special interest to *Elektor Electronics* readers and with wide scope is *Nodal*, written by Alfred Riddle. He has now been joined by Alfred Dick to produce a book which explains how to use *Mathematics* and *Nodal* for the analysis and design of electronic circuits. The book is supplied with a disk carrying a demonstration version of *Nodal* and text files of all the examples from the book. Although the authors believe that *Mathematica* and *Nodal* are the best two pieces of software for electronic engineering, they explain the algorithms in sufficient detail to enable them to be applied to virtually any computer language. Thus, the book can be studied in its own right as a comprehensive and up-to-date guide to circuit analysis and design. Having said this, there is no doubt in my mind that the best approach is to purchase *Mathematica* and the book with disk and get down to learning the syntax. In this respect, the book has a dual function, for it provides an ideal way to learning, not only the many aspects of electronics computing, but also how to use *Mathematica* itself. *Mathematica* has hundreds of commands, many of which an electronics engineer would never use. The subset of commands applicable to electronics is much less daunting. Better still, Riddle and Dick provide a Toolbox note every time a new command is used, complete with a definition, explanation, and full syntax. This is a most useful and helpful feature of the book, and one soon feels at home in the *Nodal* environment.

Primarily, the book is a guide to using *Nodal*, which has a rich collection of electronics functions. These include a full range of components with definable characteristics, from **Capacitor** to **MESFET**, functions such as **NodalNetwork** (to define an electronic network) and **NodalAnalyse** (to analyse network and calculate specified parameters, either numerically or in symbolic form), and utilities for minor calculations, such as **ComplexToPolar**, **FourierEE**, and **Interdigital** (to specify a microwave capacitor formed by interdigitating copper strips on a dielectric substrate). It also has routines for using a Smith Chart displayed on the computer screen.

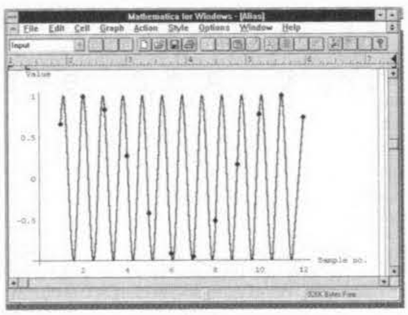


Figure 1.

```
net = NodalNetwork (VoltageSource [{1, 0}, vIn],
                    Resistor [{1, 2}, r1],
                    Capacitor [{2, 0}, c1]);
Simplify (NodalAnalyze[net, Result -> V2/V1,
                    Frequency -> Laplace])

    1
---------
1+c1 r1 s
% //. {r1 c1 -> 1/w0}
    1
---------
     s
1 + --
    w0
tf = Normal [%][[1, 2]];
Solve (Denominator [tf] == 0, s)
{{s -> -w0}}
```

Figure 2.

```
Plot3D(Abs[tf/.{s -> sigma + omega I, w0 -> 10}],
    {sigma, -5, 0}, {omega, 0, 20}
    AxesLabel -> {"s", "w", "tf"}, PlotPoints -> 29,
    PlotRange -> ({-5, 0}, {0, 20}, {0, 2})
    Shading -> False, BoxRatios -> {0.38, 1, 1},
    ViewPoint -> {3, -2, 1})
```

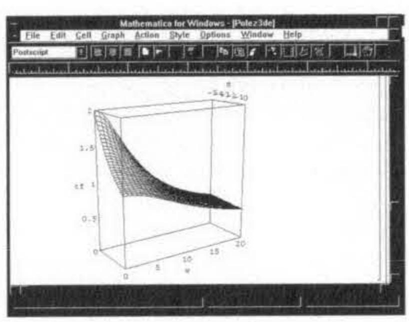


Figure 3.

As an example of the routines described in the book, **Figure 1** is an investigation of aliasing. The plot shows a high-frequency sinusoidal signal sampled at one-seventh of its frequency. The samples are shown as large dots and it can be seen that they produce a sinusoidal alias signal of much lower frequency than the true frequency. **Figure 2** shows how a network is defined and analysed. For simplicity, we have set up the simplest possible *RC* network with sinusoidal voltage source, but *Nodal* can deal with networks of much greater complexity than this. The netlist specifies component types, their node connections and their symbolic names. Then it is analysed to find an expression for the transfer function in terms of component values, r_1 and c_1. Next, we substitute $1/\omega_0$ for r_1c_1, where ω_0 is the resonant frequency. Finally (**Figure 3**), we evaluate the function numerically to produce a 3-D plot of $tf(v_2/v_1)$ against ω and σ, the imaginary and real parts of the complex frequency variable, s. The edge at the front surface demonstrates the low-pass frequency response of the filter when $\sigma = 0$ (that is, for a fixed amplitude input).

Although *Nodal* has no limitations on the number of netlist nodes or the number of graph points that may be plotted, the demo disk supplied with the book limits these numbers to 4 and 10 respectively. A simple common-emitter amplifier needs 5 or 6 nodes, so limiting nodes to 4 is too tight a restriction, frustrating students who may not be able to afford the full version of *Nodal*.

The full list of topics covered by the book includes: DC circuits, small-signal circuits, multiport analysis, component design, sensitivity analysis, times series, spectral analysis, *s*-domain analysis, filter design (which includes FIR digital filters), high-frequency circuits, and noise analysis, all copiously illustrated by worked examples. All the algorithms and routines are fully explained with great clarity, yet with an economy of style, in a way suited to the busy engineer who wishes to get on with the job. Each chapter ends with a summary of topics covered and a set of exercises to test understanding and to demonstrate further applications of the routines. There is also a comprehensive selection of references for each chapter.

The authors have aimed the book at undergraduate and graduate students, instructors, developers, and professional engineers. It fulfils its purpose admirably and I strongly recommend it not only to persons in those categories, but also to the dedicated amateur who is fascinated by the mathematical aspects of electronics.

Suppliers of *Nodal*:
Goth, Goth and Chandleri Ltd, The Old Sweet Factory, Gardner Street, Herstmonceux, East Sussex , England BN27 4LB (+44 1323 832 683).

Macallan Consulting, 1583 Pinewood Way, Milpitas, California 95035, USA (+1 408 262 3575).

Review by Owen Bishop

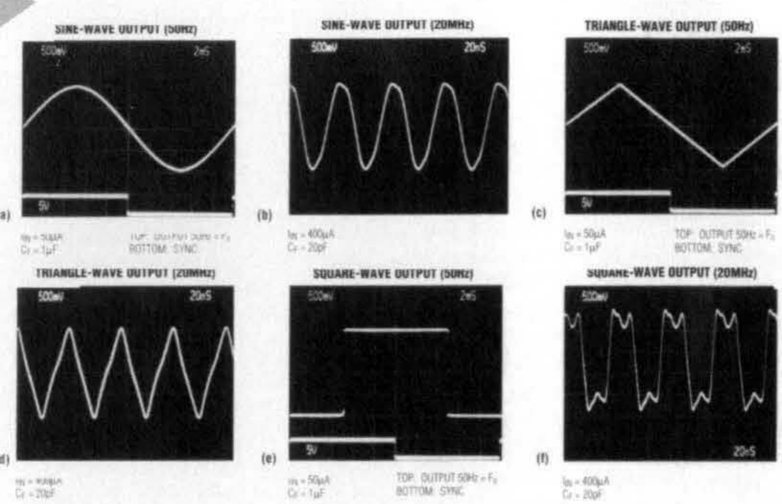
APPLICATION NOTE

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by *Elektor Electronics* or its consultants.

Waveform generator operates from 0.1 Hz to 20 MHz

The MAX038 is a precision, high-frequency function generator that produces accurate sine, square, triangle, sawtooth, and pulse waveforms, with a minimum of external component.

1



The internal 2.5 V reference (plus an external capacitor and potentiometer) lets you vary the signal frequency from 0.1 Hz to 20 MHz. An applied ±2.3 V control signal varies the duty factor between 10% and 90%, enabling the generation of sawtooth waveforms and pulse-width modulation.

A second frequency-control input—used primarily as a VCO input in phase-locked-loop applications—provides ±70% of fine control. This capability also enables the generation of frequency sweeps and frequency modulation. The frequency and duty-factor controls have minimal interaction with each other.

All output amplitudes are 2 V_{p-p} symmetrical about ground. The low-impedance output terminal delivers as much as ±20 mA, and a two-bit code applied to the TTL-compatible A_0 and A_1 inputs selects the sine, square, or triangle output waveform:

A_0	A_1	*Waveform*
x	1	sine
0	0	square
1	0	triangle

x = don't care

To synchronize MAX038 operation with other devices in the system, the internal oscillator produces a TTL-compatible SYNC output, whose duty factor remains constant at 50% regardless of the duty factor set for the output waveform. The MAX038's internal phase detector enables such synchronization as well. It also enables the demodulation of frequency-modulated signals.

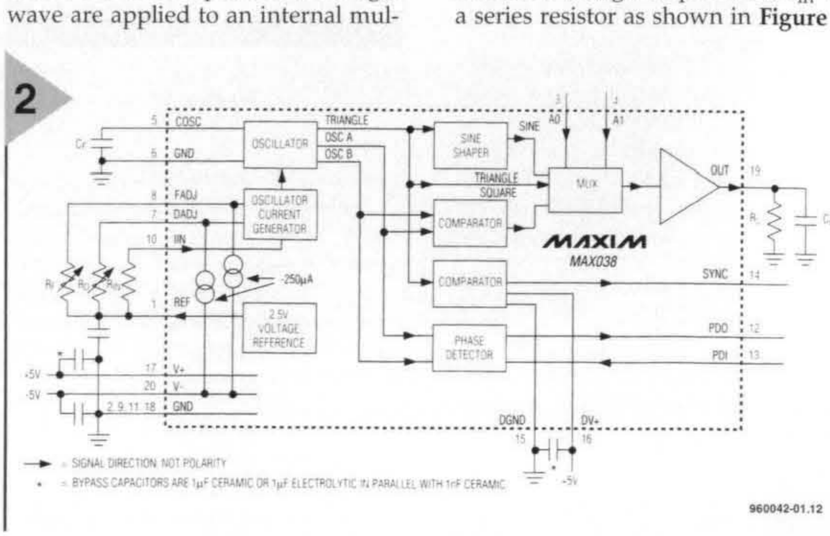
Details of operation

By alternately charging and discharging an external capacitor, the MAX038'S relaxation oscillator produces simultaneous square and triangle waves. An internal sine-shaping circuit converts the triangle to a low-distortion, constant-amplitude sine wave. The sine, square and triangle wave are applied to an internal multiplexer that lets you select the output waveform according to the state of address lines A_0 and A_1. The output amplitude remains constant at ±1 V regardless of wave shape or frequency (**Figure 1**).

See **Figure 2** for the MAX038's block diagram and operating circuit. Powered from ±5 V, the device consumes 400 mW and has a nominal output frequency set by the oscillator capacitor C_f. Coarse deviations from that frequency are made by varying the I_{in} current from 2 μA to 750 μA, a range of 375:1. The I_{in}-current can be derived from the on-board 2.5 V reference and an external fixed or variable resistor.

To adjust the frequency digitally, connect a voltage-output DAC to I_{in} via a series resistor as shown in **Figure 3**.

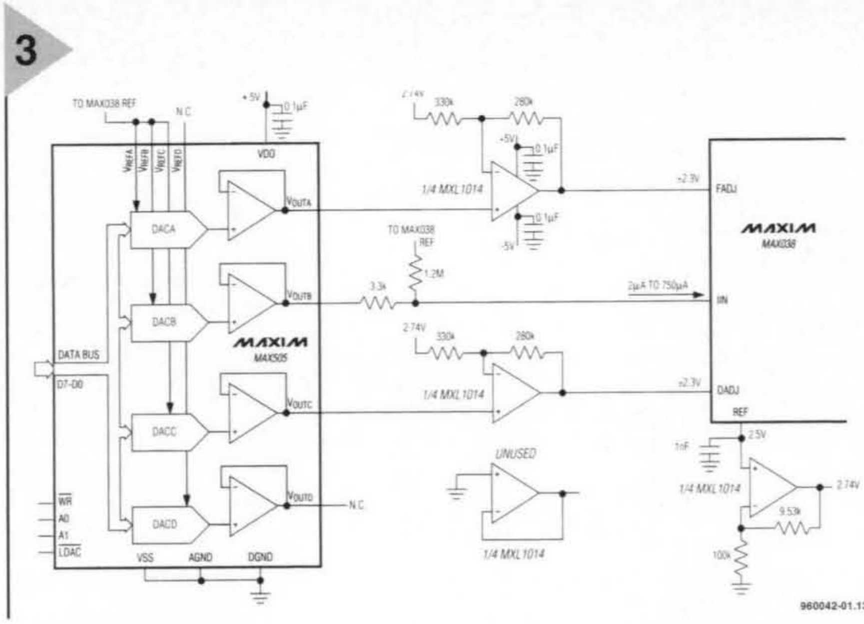
2



A Maxim Application

The converter output ranges from 0 V at zero to 2.5 V at full scale. Current injected by the converter into I_{in}, therefore, ranges from 0 μA to 748 μA. The 2.5 V reference and 1.2 MΩ resistor inject a constant 2 μA, so (by superposition) the net current into I_{in} ranges from 2 μA (at a code of 0000 0000) to 750 μA (at 1111 1111). The quad-DAC IC operates from 5 V or ±5 V. As described later, it can also provide digital control of f_{adj} and D_{adj}.

For fine adjustments (±70%), apply a control voltage in the range ±2.3 V to the frequency adjust (f_{adj}) terminal. Both f_{adj} and I_{in} have wide bandwidths that allow the output frequency to be modulated at a maximum rate of about 2 MHz. As the more linear input, I_{in} is preferred for open-loop frequency control; input voltage, f_{adj} is better suited for use in a phase-locked loop. For digital control of f_{adj}, configure a DAC and external op amp (as in Figure 3) to produce an output ranging from –2.3 V (0000 0000) to 2.3 V (1111 1111).



The duty factor (the percentage of time that the output is positive) can be adjusted in the range 10–90% by applying a ±2.3 V control signal to the duty-factor-adjust terminal D_{adj}. This signal changes the ratio of charging current to discharge current for capacitor C_f while maintaining a nearly-constant output frequency.

The D_{adj} input also lets you minimize distortion in the output sine wave. Minimum distortion occurs at a duty factor of exactly 50%, but the typical duty factor (with V_{Dadj} = 0 V) is 50% ±2%. By applying a small control voltage (typically lower than ±100 mV) to D_{adj}, therefore, you can set the exact 50% symmetry that minimizes the distortion.

The source driving D_{adj} must supply a constant 250 μA (see Fig. 2). The temperature coefficient of this internal current sink is unimportant for op amps and other low-impedance sources, but is significant when a variable resistor is used as shown. Thus, variable resistors suit manual operation only, in which the operator can correct errors through readjustment. Like f_{adj}, D_{adj} has a 2 MHz bandwidth and a ±2.3 V range. It can be digitally controlled with an identical circuit (Fig. 3).

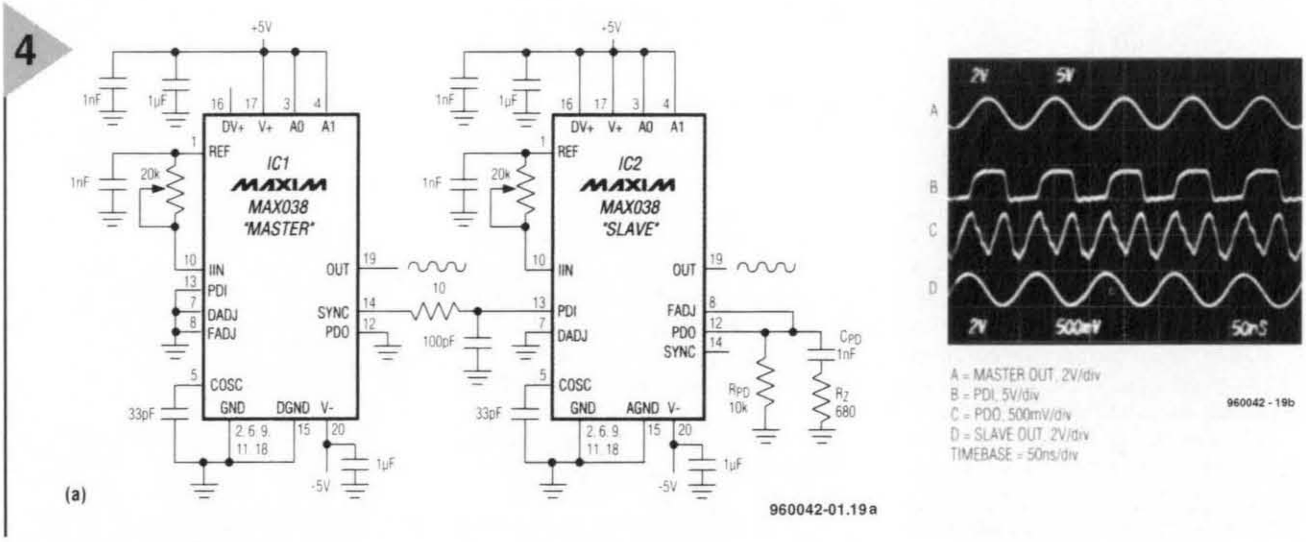
Phase-locked operation

The MAX038's internal phase detector is intended primarily for use in phase-locked-loop (PLL) configurations. In **Figure 4**, for instance, the phase detector in IC_2 enables that device to synchronize its operation with that of IC_1. You connect the applied reference signal to IC_2's TTL/CMOS-compatible phase-detector input (PDI) and connect the phase-detector output (PDO) to the input (f_{adj}) of the internal voltage-controlled oscillator. PDO is the output of an XOR gate—a mixer—which produces rectangular current waveforms at frequencies equal to the sum and difference of the PDI frequency and the MAX038 output frequency. These waveforms are integrated by C_{pd} to form a triangle-wave voltage output at PDO. The 10 Ω/ 100 pF pair at PDI limits that pin's rate of rise to 10 ns.

The PDO current-pulse levels are 0 μA and 500 μA, with a duty factor that approaches 50% when PDI and the output are in phase quadrature. Otherwise the duty factor approaches 100% when the phase difference approaches 180°, and 0% when the phase difference approaches 0°. T_{pd}, C_{pd}, and R_z form a filter that determines the PLL frequency response.

At the sync output is a square wave whose rising edge coincides with the rising edge of an output sine or triangle wave as it passes through zero volts. If the output is a square wave, SYNC's rising edge occurs at the midpoint of the positive portion, causing SYNC to lead the output by 90° (phase quadrature).

SYNC lets you slave one MAX038 to another by providing a TTL-compatible square wave at the phase-detector



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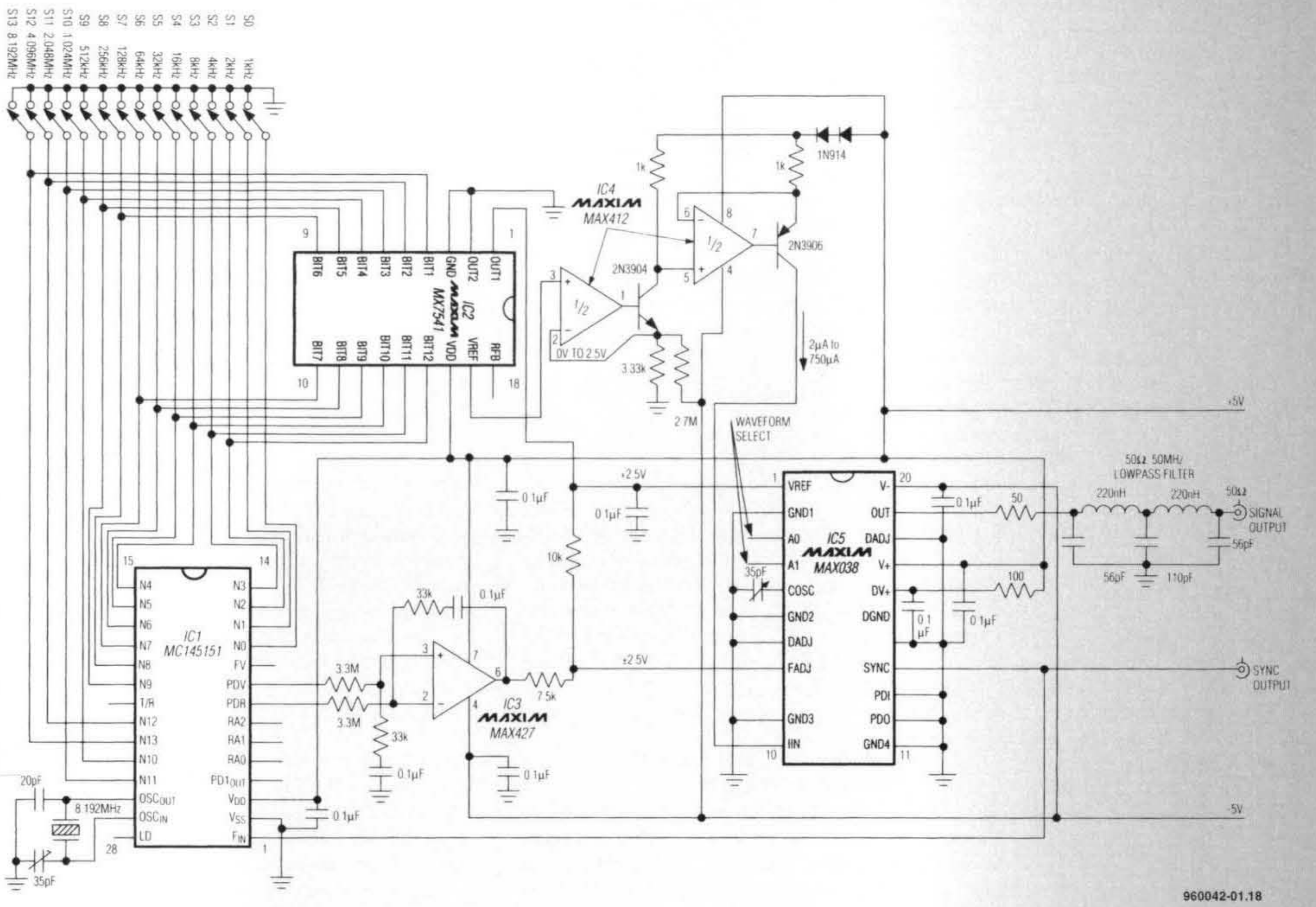


960042-01.18

input (PDI), as required by the slaved device (IC_2). On the other hand, SYNC is not available when a MAX038 is synchronized with sine or triangle waves from other sources. For those cases, the PDI input must be driven by a comparator to square up the signal and provide the appropriate level shifting.

The internal phase detector can also demodulate frequency-modulated signals.

Frequency synthesizer

The MAX038 and four other ICs can form a crystal-controlled, digitally programmed frequency synthesizer that produces accurate sine, square or triangle waves in 1 kHz increments over the range 8 kHz to 16.383 MHz (**Figure 5**). Each of the 14 manual switches (when open) makes the listed contribution to the output frequency: opening only S_0, S_1 and S_8, for instance, produces an output of 259 kHz.

The switches generate a 14-bit digital word that is applied in parallel to the DAC (IC_2) and a $\times n$ circuit in IC_1. This device also includes a crystal-controlled oscillator and a high-speed phase detector, which form a phase-locked loop with the voltage-controlled oscillator in IC_5.

The DAC and dual op amp (IC_4) produce a 2–750 μA current that forces a coarse setting of the IC_5 output frequency—sufficient to bring it within capture range of the PLL. This loop, in which the phase detector in IC_1 compares IC_5's sync output with the crystal-oscillator frequency divided by n produces differential-phase information at PDV and PDR. IC_3 then filters and converts this information to a ± 2.5 V single-ended signal, which, when summed with an offset and applied to f_{adj}, forces the signal output frequency to the exact value set by the switches.

Applying coarse frequency control with the DAC and the I_{in} terminal of IC_5 (pin 10) gives the fine-control input (f_{adj}) a reasonably fast response to switch changes. The 50 MHz, 50 Ω low-pass output filter passes 16 MHz sine, square, and triangle, waves with reasonable fidelity, while blocking high-frequency noise generated by the $\times n$ circuit.

[960042]

More information on the MAX038 and its applications is available from
Maxim Integrated Products (UK) Ltd
Unit 3, Theale Technology Centre,
Station Road, Theale, Berkshire,
United Kingdom RG7 4XX
Telephone 01734 303 388
Fax 01734 305 577

single-chip AF power amplifier

A Burr-Brown Application

If you're looking for an audio amplifier that produces a lot of power using an absolute minimum number of components, this one is for you.

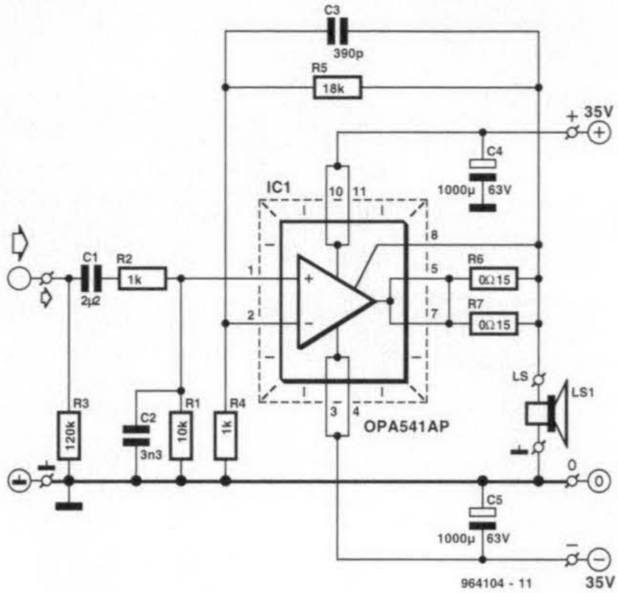
Burr-Brown's OPA541 is a power opamp capable of operation from power supplies up to ±40 V and delivering continuous output currents of up to 5 A. Internal current limit circuitry can be user-programmed with a single external resistor, protecting the amplifier and the load from fault conditions. The OPA541 is available in an 11-pin power plastic package and an industry-standard TO-3 hermetic package. The former is used here.

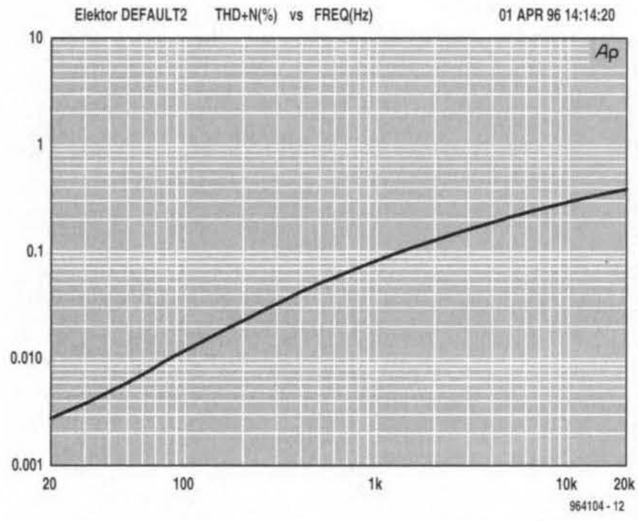
Although the OPA541 is primarily intended for applications like motor drivers, servo amplifiers and programable power supplies (says B-B), it is also fine for a medium-power AF amplifier with reasonable specifications. The design shown here is capable of supplying about 60 watts into an 8-Ω load. This is achieved with an audio drive level of $1.3V_{rms}$ and a symmetrical supply voltage of ±35 V. The on-chip current limiter is set to an actuation level of about 8.5 A by parallel-connected resistors R6/R7. This level ensures that the maximum drive margin can also be achieved with a load of 4 Ω. Note, however, that R6 and R7 do not make the amplifier short-circuit proof, because that would require a current limiter threshold of 1.8 A, assuming that the IC is operated within its SOA (safe operating area, for details consult the B-B datasheets). The value of the resistor, R_{cl}, that determines the current limiter actuation level is calculated from

$$R_{cl} = (0.813/I_{abs}) - 0.02\ [\Omega]$$

In practice, the positive half-cycle of the output current will be limited somewhat earlier, at about 10% below the calculated level. The opposite is true for the negative current, which will be about 10% higher than the calculated level.

The amplifier is not a bad performer as regards distortion. The graph shows that the THD level remains well below 0.5% over the full audio spectrum, assuming that a gain of ×6 is programmed (R5 approx. 5 kΩ) and a supply voltage of ±35 V. The curve applies to an output power of 50 watts into 8 Ω.





Because the IC operates at a quiescent current of only 20 mA, cross-over distortion occurs readily. The theoretical bandwidth is, therefore, limited to about 22 kHz by capacitor C3. Input filter R2-C2 serves to reduce IMD (intermodulation distortion), and reduces the actual bandwidth to about 16.6 kHz. The low-frequency roll-off is set to 6.6 Hz by R1-C1.

The IC must be fitted on to a fairly large heatsink with a thermal resistance of 1.2 K/W or better. A suggested type is Fischer's SK85SA/75mm, which will be just about sufficient for music into a 4-Ω load.

(964104)

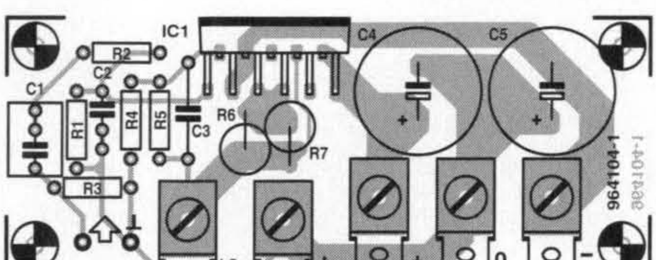
COMPONENTS LIST

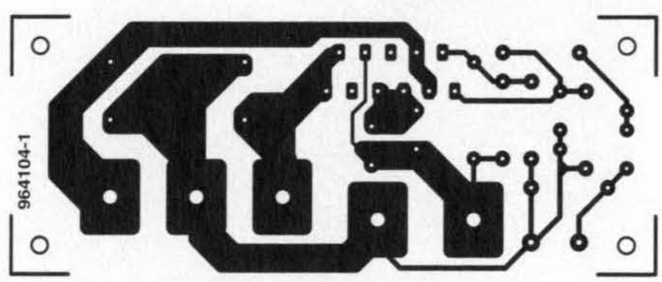
Resistors:
R1 = 10kΩ
R2,R4 = 1kΩ
R3 = 120kΩ
R5 = 18kΩ
R6,R7 = 0Ω15 5W

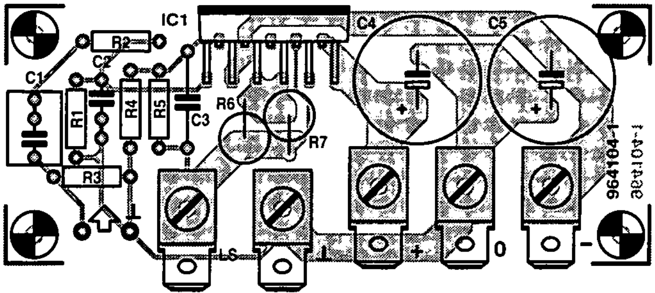
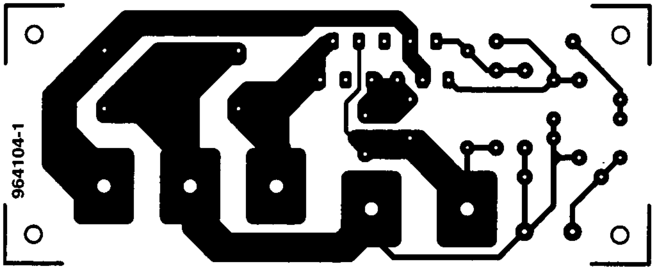
Capacitors:
C1 = 2µF2, MKT, 5mm
C2 = 3nF3
C3 = 390pF, 160V, polystyrene
C4,C5 = 1000µF 63V radial

Semiconductors:
IC1 = OPA541AP (Burr-Brown)

Miscellaneous:
5 spade terminals, screw mount
Heatsink, approx. 1°K/W
Printed circuit board, order code 964104-1 (see Readers Services page)






IC1
C4
C5
R2
C2
C1
R1
R4
R5
C3
R6
R7
964104-1
LS
+
0
-

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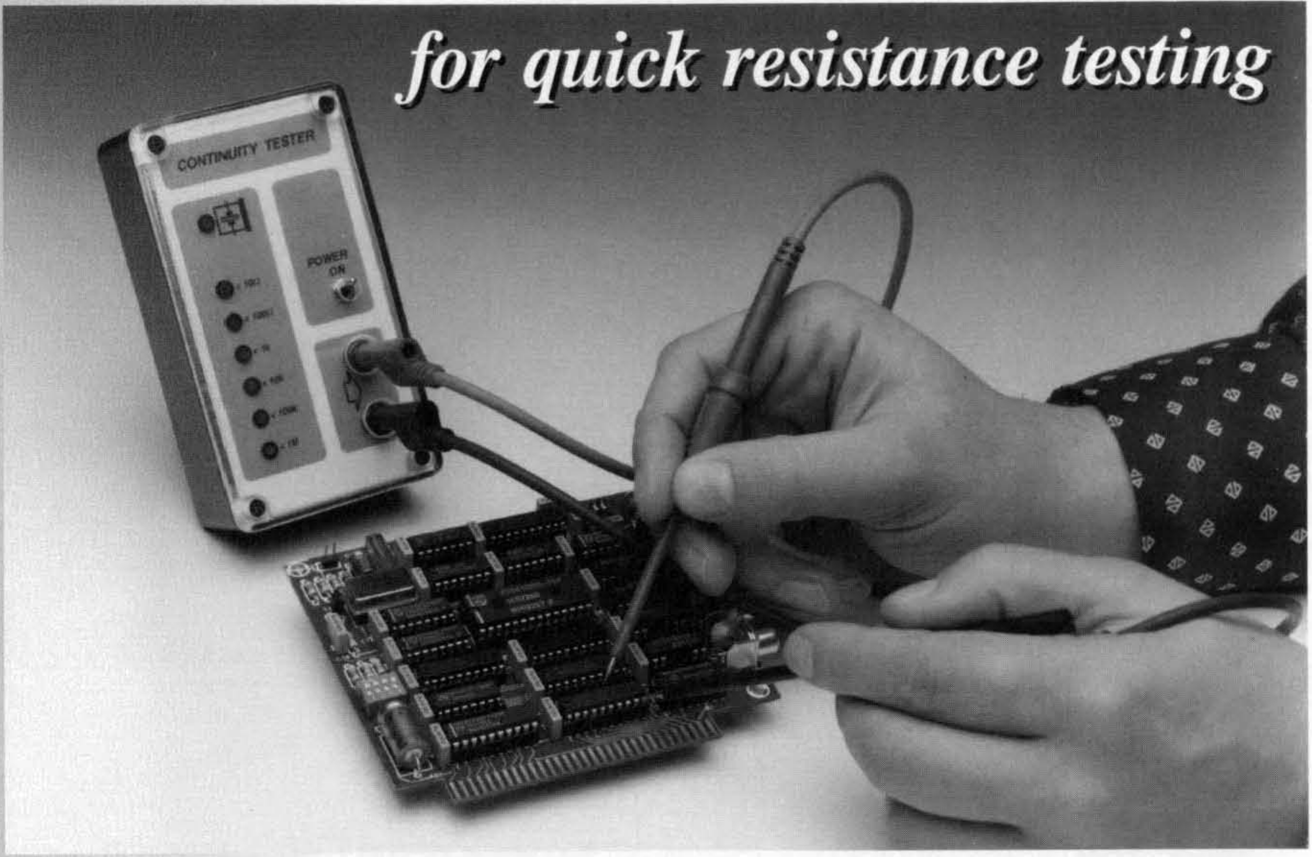
continuity tester

for quick resistance testing



Most ohmmeters and cable testers have either a moving-coil meter or a liquid crystal display (LCD). The circuit described here presents a viable alternative to these traditional indicators. A row of six LEDs is used to indicate resistance values between 10 ohm and about 1 mega-ohm, while a buzzer and another LED are activated when a resistance value between nought and 2 ohm is measured.

Design by L. J. Koch

While working on simple electrical and electronic equipment, it is often far more important to know whether a connection is intact or not, than to know the exact resistance. While testing a cable, for example, all you want to be sure of (in most cases) is that the individual wires are intact, and that there are no short-circuits between them. Arguably, a meter used for this purpose only has to be able to detect the difference between a very low resistance and a very high resistance.

The same applies when capacitors have to undergo a check for internal short-circuits. This test really allows only two states: short-circuited (very low resistance) or okay (high resistance).

With measurements on resistors, too, it is usually sufficient to check that the actual value tallies roughly with the colour code printed on the component. Here, too, high accuracy is not required.

The circuit described here is useful for all of the above mentioned applications. An LED is turned on, and a buzzer sounds, when a resistance smaller than about 2 Ω is measured. Higher values are indicated by six LEDs, each of which represents one decade (a range factor of ten). The LED row thus indicates a logarithmic resistance scale which is divided into the following ranges:

- smaller than 10 Ω
- 10 Ω to 100 Ω
- 100 Ω to 1 kΩ
- 1 kΩ to 10 kΩ
- 10 kΩ to 100 kΩ
- 100 kΩ to 1 MΩ

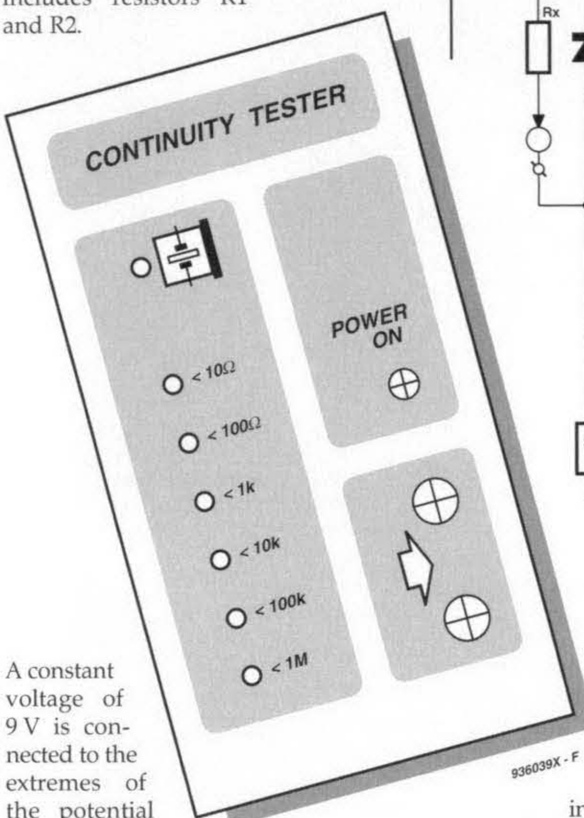
The seventh LED and the buzzer are intended for the (adjustable) range from 0 Ω to about 2 Ω.

The nice thing about this circuit is not just its original set of range indicators, but also the fact that the user is free to determine the practical layout of the circuit as regards resistance values and ranges. So, the circuit is easily adapted to meet your individual requirements, while it is also possible to increase the accuracy.

Comparators

In electronics, measuring resistance values is usually based on an indirect method. From Ohm's law (U=IR), it follows that there are a number of options: for example, send a known current through the resistor under test, and then measure the voltage it drops. The measured voltage is a direct measure for the resistance. Alternatively, a known voltage may be applied across the resistor, whereupon the current is measured. Again using Ohm's law, this current is inversely proportional to the value of the resistor under test. Whatever type of measurement is used, the resistance is not measured directly but using a voltage or current measurement. That also applies to the circuit shown in **Figure 1**.

The unknown resistance, R_X, is inserted in a potential divider which includes resistors R1 and R2.



A constant voltage of 9 V is connected to the extremes of the potential divider. Consequently, the voltage generated across the unknown resistor is a direct measure for the resistor value.

The voltage measurement is not performed with the aid of a moving-coil meter, but using a series of comparators contained in IC1 and IC2. These are biased such that each comparator output toggles at its very own input voltage.

To provide an indication of the toggling, each comparator output has its own LED. LEDs D1 through D7 light as soon as the output of the relevant comparator drops low.

Apart from an LED, the output of IC1d also controls a 'beep' generator consisting of opamp IC1d and a.c. buzzer Bz1. The buzzer produces a loud beep when the measured resistance is very low, for instance, smaller than 2 Ω (adjustable with preset P1). LED D1 then also lights.

The individual voltage levels at which the comparators toggle are created with the aid of a voltage divider which consist of resistors R12 through R18. Because the inverting input of each comparator is connected to a different tap on the resistor ladder, each input is biased at a different voltage. All other comparator inputs (that is, the non-inverting ones) are interconnected, and then taken to the unknown resistor, R_X.

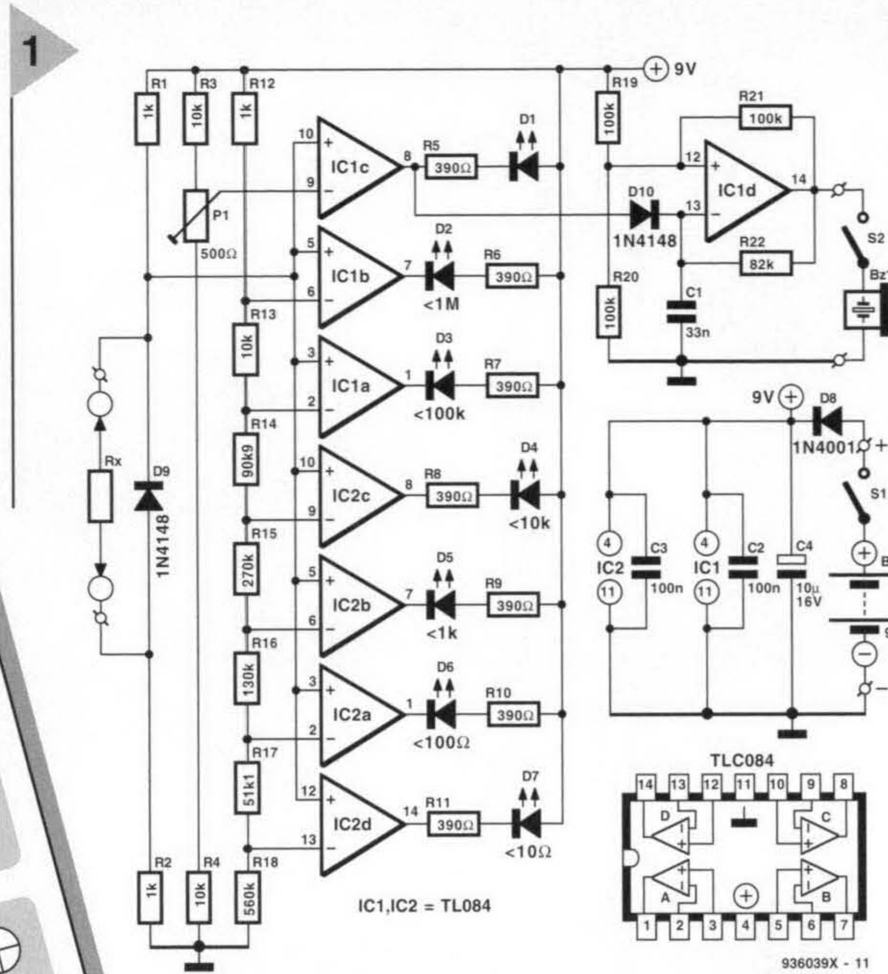


Figure 1. Circuit diagram of the continuity tester.

THE RESISTANCE SCALE

Assuming that the unknown resistor is temporarily replaced by a potentiometer of 1 MΩ which is slowly adjusted frm 0-Ω to 1 MΩ, then the voltage at junction R1/R_X will slowly increase from 4.5 V to 9 V. When the pot is set to a low value, R_X may be considered as a short-circuit, and the lower side of R1 is effectively connected to the top side of R2. Junction R1/R2 created in this way then consists of two equal resistors. It drops exactly half the voltage which exists across the entire voltage divider.

At a very high value of R_X (say, 'infinite') the lower side of R1 simply has the full supply voltage on it, or 9 V. With values of Rx which are comprised between nought and infinite, the voltage at junction R1/R_X will be somewhere between 4.5 V and 9 V, and proportional with the value of R_X. The voltage obtained in this way is measured and indicated with the aid of the comparator and the associated LEDs.

When the previously mentioned 1-MΩ potentiometer is slowly turned from 0 Ω to its maximum value, the direct voltage at the non-inverting inputs of all comparators will increase from 4.5 V to 9 V, causing the comparators to toggle one after another. The toggling takes place the instant the voltage at the non-inverting input of a comparator exceeds the voltage at the inverting input. This happens first with IC2d, whose inverting input, pin 13, is connected to the lowest tap on potential divider R12-R18 (corresponding to a low voltage at junction R1/R_X). The last comparator to toggle in the series is IC1b because its inverting input (pin 6) is held at the highest bias level.

When a low voltage exists at junction R1/R_X (brought about by a low value of R_X), all LEDs will light. When a high value of R_X is measured, none will light, or just D1.

THE LOW-R INDICATOR

The indicator for low values, IC1d/Bz1, has an adjustable input potential di-

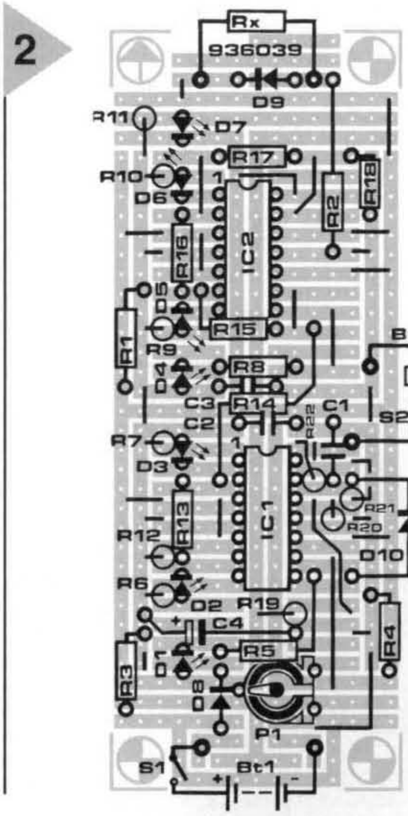


Figure 2. Component mounting plan for the UPBS-1 board.

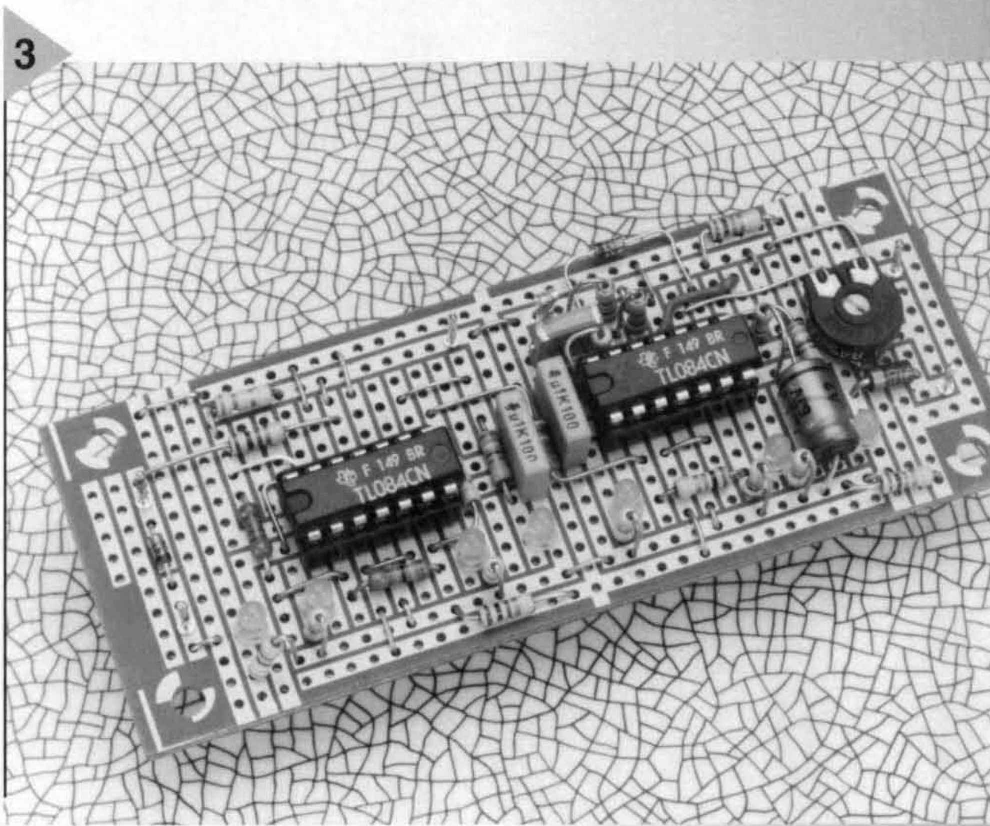


Figure 3. UPBS-1 board with all components on it.

COMPONENTS LIST

Resistors:
R1,R2,R12 = 1kΩ
R3,R4,R13 = 10kΩ
R5-R11 = 390Ω
R14 = 90kΩ9 1%
R15 = 270kΩ
R16 = 130kΩ 1%
R17 = 51kΩ1 1%
R18 = 560kΩ
R19,R20,R21 = 100kΩ
R22 = 82kΩ
P1 = 500Ω preset

Capacitors:
C1 = 33nF
C2,C3 = 100nF
C4 = 10µF 16V

Semiconductors:
D1 = LED, red, 3mm
D2,D3,D4 = LED, yellow, 3mm
D5,D6,D7 = LED, green, 3mm
D8 = 1N4001
D9,D10 = 1N4148
IC1,IC2 = TL084

Miscellaneous:
Bz1 = a.c. buzzer
S1,S2 = switch, single pole on/off
Bt1 = 9V battery with clip
Printed circuit board type UPBS-1 (see Readers Services page)
Case: Teko Coffer TP/2, 125x70x39mm

vider, P1, rather than a fixed one like R12-R18. The preset is adjusted such that LED D1 just lights, and the buzzer just starts to sound, when a resistance smaller than 2 Ω is connected to the input probes.

The oscillator is enabled when the high voltage disappears which normally arrives at pin 13 of IC1d. This happens when a low resistance R_x is measured. The cyclic charging and discharging of capacitor C1 by the output of IC1d (pin 14) provides a rectangular waveform with a frequency of a few kilohertz. This rectangular voltage causes the a.c. buzzer, Bz1, to start beeping. Note that Bz1 is a so-called passive piezo-ceramic buzzer.

If you wish, you can silence the buzzer with switch S2. That leaves you with LED D1 as an indicator for very low resistance.

CONSTRUCTION

The circuit is best built on universal prototyping board size one, which is available as order code UPBS-1 through our Readers Services. The component mounting plan is shown in **Figure 2**. The photograph in **Figure 3** shows our completed prototype of the continuity tester.

Check the completed board for incorrectly fitted parts and short-circuits, in particular, between the IC pins. If everything is in order, you may connect the 9-V battery to the board to see if the circuit works.

Close switch S1. LEDs D2 through D7 should light if you short-circuit the R_x input probes. LED D1, too, will light at a certain setting of P1, while the buzzer will produce an audible beep (provided S2 is closed). The preset should be adjusted such that the buzzer just starts to sound when a resistor smaller than 2 Ω is connected.

The fully functional circuit may then be mounted in a suitable box, which may be given a neat appearance with the aid of the front panel design shown in **Figure 1**. This may be copied or re-drawn and then stuck on the cover of the case using transparent self-adhesive foil.

(936039X)

Recognizing the number

The identification of a vehicle through its unique registration code as displayed on the front and rear number plates has a wide range of applications anywhere in the world. It is taken for granted when buying or selling a car; when driving into a reserved car parking space; when there has been a road accident and for many other purposes.

However, in the majority of situations where it is necessary to capture the vehicle number, it has to be done manually. While this is satisfactory on a one-off basis, as it is both costly and time-consuming, it cannot be done in real time without restricting traffic flow. Hence, traffic monitoring is frequently not carried out even where the results could be usefully applied.

Now, a system has been developed to extract and read road vehicle licence plates and aircraft tailcodes from video camera imagery which, by using readily available computers and video camera equipment, can automate the process.

Processing speed is such that most vehicles can be analysed in a single lane of traffic for typical flows and speeds on main roads without the need for specialized and, therefore, expensive hardware.

The recognition software is coded in the *C* language and has been implemented on Sun Sparc stations and on PCs. The images are captured with simple electronic fast-shutter cameras which are connected to the computer via a cable and controller.

There are many situations where real-time capture is required. For example, in the area of law enforcement, automatic identification would allow the systematic checking of large numbers of registration plates against computer records of stolen vehicles, where manual computer entry by police officers would require excessive efford of a tedious nature. Furthermore, an automated system could provide the police with answers sufficiently rapidly for them to take immediate action.

Intelligent barrier control

Commercial applications can include intelligent barrier control, or monitoring of areas with complex movement patterns, for example, as part of ground movement control in airports, where both road vehicle registration and aircraft tailcodes would be useful.

Road transport authorities are frequently concerned with monitoring traffic patterns (for traffic modelling, for instance), for which an identification capability is a useful analytical tool.

So buses that regularly travel along particular roads could be identified automatically and then their presence taken into account. Furthermore, buses could pass unhindered through an automated toll collection point.

Similarly, this technology could enable a vehicle arriving on site to be automatically identified. Then, traffic signals could route the vehicle without delay to the appropriate loading bay. This speedy routeing is becoming increasingly significant in manufacturing and distribution where 'just in time' is of vital importance.

For road vehicle identification, the camera is set up alongside the path of oncoming traffic so that its field of view will encompass the front elevation of oncoming vehicles. The aproach of a vehicle is detected by there being significant changes in the image received by the camera – when there is no traffic flow, there will be just a static roadway image. This change in view triggers an image field retention.

Retained image

Then, within the retained image a search is made for an area having the distributed grey-level pattern which is characteristic of a number plate. An image window is placed around the most likely area. This region is then further processed to identify the actual form and then to recognize the characters of the number plate.

Numbers must stand out from their backgrounds by being dark characters or vice versa. While the former is normal for road vehicles which have to comply with national regulations, aircraft can be dependent on the airline's particular colour scheme.

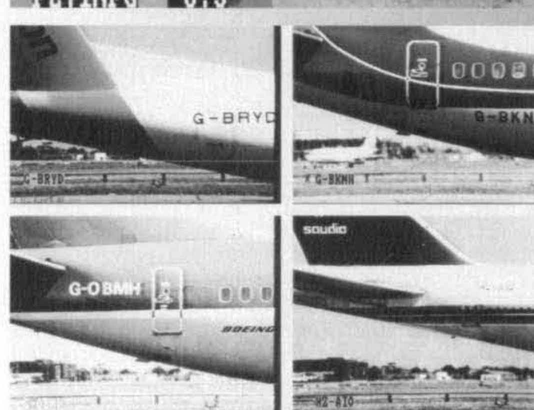
Sensitivity thresholds are set to cater for these situations and resolve the image scan into a binary form. That is, based on the threshold set, every part of the selected area must be treated as either black or white – one or zero.

A connected component finder segments the whole of the binary image into a group of objects which are of an appropriate size to be considered as characters, and groupings of characters. They are then examined for layout patterns which are consistent with those of number plates or tailcodes. However, extra care must be taken where, for example, there are number plate fixing bolts which can mask the clarity of the detected characters and thus need further analysis.

Certain characteristics

There are several styles of road vehicle number plates with the most common one consisting of a single row of characters which will have certain characteristics dependent on the country of registration.

For example, the vast majority of number plates in the UK consist of one letter followed by three digits and, finally, three letters. Thus, the software initially checks to see whether it is of that form or, if not, which of the other standard forms it is. Then, having



selected an overall 'number plate', it divides it up into the areas which relate to each discrete character for identification purposes.

It is constructive to compare the task of automatic plate recognition with optical character recognition (OCR), which is increasingly being used for document image processing. Whereas document OCR starts with good geometrical registration and has the luxury of controlled illumination, licence plate reading must cope with dirty or incomplete characters and even the presence of plate fixing studs which could give rise to errors.

In a similar manner, for tailcode location, once the presence of an aircraft is detected, a sequence of images is captured until the system recognizes that the aircraft has passed. This is detected when the background reverts to what it was previously. Complete images from the latter part of this sequence are again sent for further processing.

The selected region (or whole image in the case of aircraft) is processed for local background removal so that the position of the identification number can be located. For example, large areas that just consist of background colour can be ignored.

In addition to the extracted numbers, the video image can be stored as video on tape together with time and date information and the recognized identification number. This can provide a useful historic log for security purposes as it will show additional information such as the type of vehicle, its colour and any identifying features. [965034]

Low-cost alternative to quartz crystals

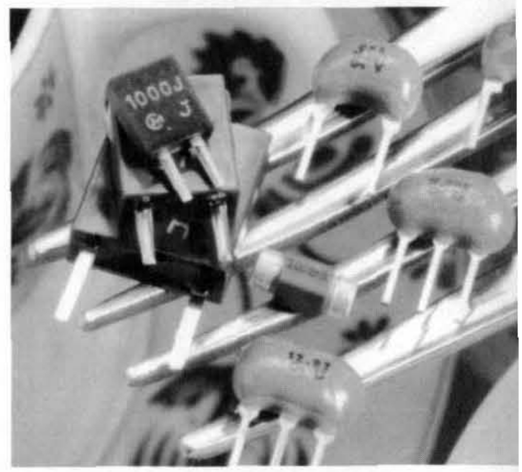
New from C&CD, the capacitor specialist, comes the range of Murata ceramic resonators. As effective as quartz crystals, yet up to 50% cheaper, these devices are currently the norm for frequency control applications in Japan.

A range of frequencies from 190 kHz to 50 MHz makes these resonators suitable for a number of applications. For automotive uses, including airbag, ABS and motor management, special versions are available. Having been subjected to a heat debugging test, these devices can operate in the −40 to +125°C temperature range. In addition, Murata ceramic resonators are ideal in communication and EDP applications. The former include wired, cordless and mobile phones, the latter comprises printer and keyboard/mouse controller uses, among others.

Available taped or bulk-packed, these devices are stable to ±0.3% of the frequency across the −20 to +80°C temperature range.

C&CD will have a complete listing of all the correct resonators to go with microprocessors from the major manufacturers.

C&CD Ltd., Lane End Industrial Park, Lane End, High Wycombe HP14 3JG. Tel. (01494) 882848, fax (01494) 882792.



Full-range C/R meter from Wavetek

The new CR50 capacitance/resistance meter from Wavetek features a CAP Zero Adjust button to compensate for test lead capacitance. The instrument measures capacitance in nine ranges from 200 pF to 20 mF with 0.1 pF resolution, and resistance in seven ranges from 20 Ω to 20 MΩ with 0.01 Ω resolution in the 20 Ω range. The low 20 Ω range, unusual in most DMMs, also features a Zero Adjust button. Accuracy is 0.5%.

The CR50 incorporates a beeper for fast and convenient continuity measurement, and a diode test. The price, complete with operator's manual, test leads and battery, is £65.00. Accessories include a protective holster and a vinyl carrying case. The meter comes with a one-year warranty. The CR50 is designed to IEC 1010-1 and UL3111 standards.

Wavetek Ltd., Hurricane Way, Norwich, Norfolk NR6 6JB. Tel. (01603) 404824, fax (01603) 483670.

Filtered Inlets Combat EMC problems

As the transitional period for compliance with the European EMC directives ends, manufacturers may be rushing to ensure that their products comply. The problem of susceptibility to mains-borne interference can be solved simply and cost-effectively with IEC inlet filters from Rendar.

Belling Lee SF series EMI/RFI mains filters come in a variety of general- and special-purpose styles with a range of output connection options to suit any application. Input connections are all IEC 320, and current ratings up to 16 amps are available.

Inlets for special purposes include low-leakage versions for medical applications, IEC 950 versions, inlets incorporating surge protection and/or an earth line choke, and versions with an integral single or twin fuse holder. Compact versions with approximately the same dimensions as non-filtered inlets can be used in space critical applications, and can be retro-fitted to existing designs.

Rendar Limited, Durban Road, South Bersted, Bognor Regis, West Sussex PO22 9RL.

Surround speakers

Visaton minis for surround sound

To convert a standard stereo installation into a surround sound setup, at least three additional speakers are needed, of which the centre one must be magnetically shielded. The miniature speakers described in this article have been designed solely for this purpose by the German loudspeaker specialist Visaton.

The surround-sound decoder published last year proved very popular with readers from all over the world. Many of them wrote, however, to ask about suitable loudspeakers.

Since many of these readers expressed a wish to build the boxes themselves, it was a godsend when the German firm of Visaton offered a set of miniature loudspeakers for review. These speakers have been designed especially for surround-sound applications and are available as kits at very reasonable prices.

The centre loudspeaker, which should be placed immediately underneath the television set, uses magnetically shielded drive units. This is a must, otherwise the TV sound and vision will be adversely affected (and how!). Shielded drive units for home construction are still few and far between.

The back speakers have a novel facility. From their own tests, Visaton knew that the directional sensitivity of these speakers had an important effect on the optimum location of the listener. The pair discussed in this article beam upwards, which gives them a more diffuse character, and this in turn enlarges the listening area of optimum surround effect. A simple, but effective solution.

Cinema-like sound with limited bandwidth

A complete surround-sound installation consists of the power amplifier(s), surround-sound decoder, the standard loudspeakers for the left-hand and right-hand channels, a centre speaker that is placed between these two, and two back speakers that provide the spatial information. The standard speakers must be of hi-fi quality, since they largely determine the overall sound quality; they are normally driven by the extant a.f. amplifier.

The centre channel is used primarily for speech and its information consists mainly of the sum of the left-hand and right-hand signals from which the low frequencies have been filtered. This is why the frequency range of this speaker need not extend into the very low frequencies. In other words, neither the box nor the drive units need to be large.

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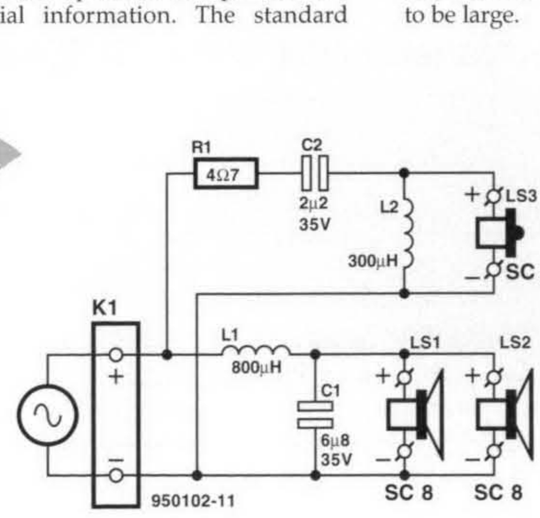

Figure 1. Circuit diagram of the cross-over filter for the Center 80. The filter has a cross-over frequency of about 5 kHz.

The frequency range of the back speakers needs to be only about 100 Hz to 7 kHz, since this is the range of decoder output. Also, the sound level from these speakers is relatively low compared with that from the other three. This means that the drive units for these speakers can be small, good-quality wide-band types.

The power rating of the back speakers need not be high either, primarily because they are not required to reproduce low frequency signals. A rating of 20 W is sufficient in almost all cases.

CENTER 80

The central speaker uses two 80 mm wideband drive units Type SC8 and a 10 mm tweeter Type SC5. These units are, as stated earlier, magnetically shielded. The associated filter, whose circuit diagram is shown in **Figure 1**, has a cross-over frequency of 5 kHz and roll-offs of 12 dB per octave.

Because of the shielding, the speaker

may be placed in close proximity to a television receiver or computer monitor.

The two 80 mm drive units are located in the bottom half of the enclosure with the tweeter above them. In many other speakers, the tweeter is placed between the two wideband units (the so-called d'Appolito configuration), but this has the drawback that the radiation pattern of frequencies around the cross-over frequency varies appreciably in the vertical direction (assuming that the speaker is upright). Normally, this does not matter much, but since the speaker in surround-sound applications is frequently used lying down, it would mean that sound reproduction varies when the listener moves his/her head slightly to the right or left and this is, of course, not the idea. With the present configuration this effect is virtually non-existent, so that the sound remains homogeneous outside the listening axis. The performance of the Center 80 can be assessed from the frequency characteristic in **Figure 2**. Note that the slight hump at 150 Hz ensures that the speaker, in spite of its modest dimensions, produces a voluminous sound.

EFFEKT 80

The effect described in the previous paragraph fortunately does not occur in the back speakers, since these use only a single 80 mm drive unit Type FRS8. In spite of their compactness, the speakers produce a an excellent spatial sound effect. As mentioned earlier, they radiate the sound upwards. This produces good scattering of the sound, and obviates the hot spot so often encountered with other surround-sound systems. (A hot spot is a single location in a room where the sound appears concentrated, although it should, of course, be evenly distributed).

The performance of the speakers was measured in a practical setup: the frequency response at a distance of 1 m from each of them, suspended from a wall at ear-height, is shown in **Figure 3**. The roll-off at higher frequencies is caused by the fact that only reflections are measured there. The 'normal' frequency curve, measured with the speaker lying down and radiating into the direction of the test microphone, is shown in **Figure 4**.

ENCLOSURES

The enclosures of all three speakers are very easily constructed. Each consists of six rectangular pieces of medium density chipboard, which many DIY retailers will saw to size for you. The boards are glued together with the aid of suitable clamps. The construction diagrams are given in **Figure 5**. The drive units may be protected by grilles or covers.

Apart from those of the apertures for the drive units, taking into account the grilles or covers, the dimensions of the enclosures are not sacrosanct.

The rear of each enclosure should have holes for the ter-

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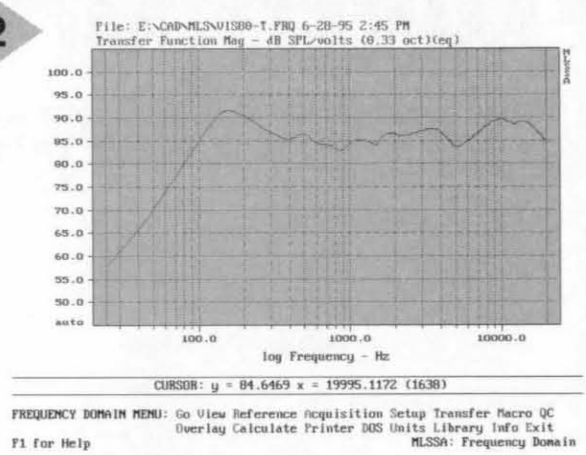

Figure 2. Frequency response of the Center 80. The slight hump at about 150 Hz ensures a voluminous sound reproduction.

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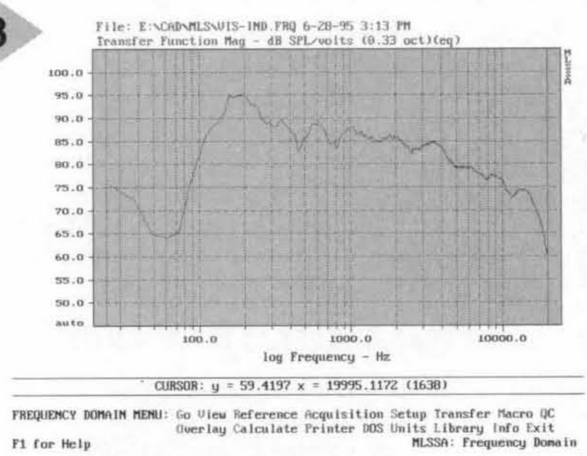

Figure 3. Frequency characteristic of the Effekt 80 when it is hanging from a wall at ear-height with the drive unit pointing upward.

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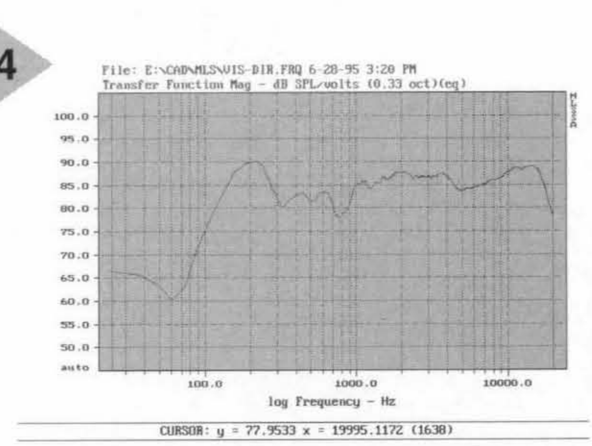


Figure 4. Frequency characteristic of the Effekt 80 with the drive unit radiating in the direction of the test microphone.

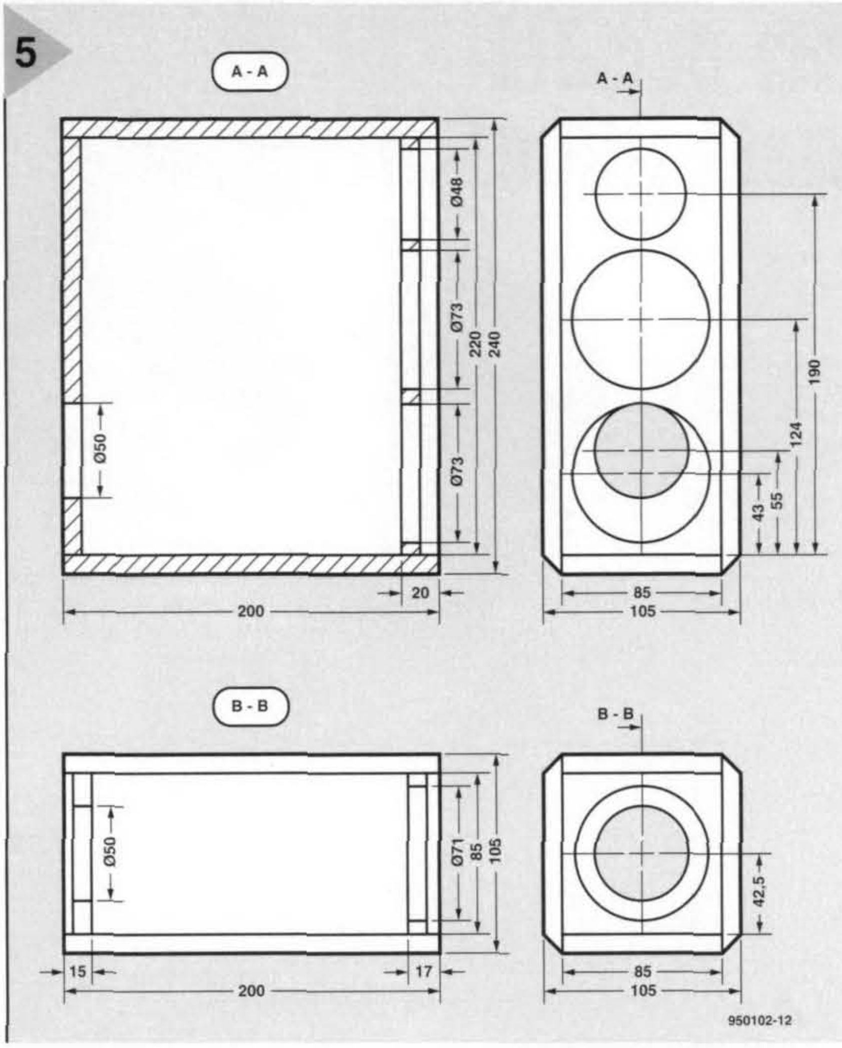


Figure 5. Construction diagram of the enclosures for the Center 80 and the Effekt

minals. Some constructors may find it more convenient to cut these holes before the enclosure is glued together.

Make sure to keep the cross-over filter as compact as possible, because there is not much room in the central speaker box.

A 15 mm hole may be cut in one of the sides of the back speakers. This hole is covered at the inside of the enclosure by a small piece of chipboard glued in place. This provides a convenient way of hanging the speakers from a wall (with the drive unit pointing to the ceiling).

The enclosures may be finished to individual taste.

When all that is done, the boxes can be wired up and the terminals and drive units screwed into place. Each enclosure should then be filled with a suitable damping material, such as polyester wool. [950102]

VISATON

Although Visaton is located in Germany, the firm is an associate member of the American Audio Engineering Society (AES).

The company has recently published a new colour catalogue, which is brimful of drive units and all sorts of accessory. All parts for the speakers described in this article are available from them: drive units, all components for the cross-over filter (or fully constructed filter board), grilles and covers. Complete construction kits are also available, as are fully constructed speakers in beautifully finished enclosures.
The address is
VISATON
Peter Schukat
Postfach 1652
D-42760 Haan
Germany
Telephone 0049 2129 552-0
Fax 0049 2129 55210

PARTS LIST

CENTER **80**
Cross-over filter:
R_1 = 4.7 Ω, 5 W
C_1 = 6.8 μF, 35 V, bipolar or polystyrene
C_2 = 2.2 μF, 35 V, bipolar or polystyrene
L_1 = 0.3 mH air-cored inductor wound from 0.6 mm dia. enamelled copper wire
L_2 = 0.8 mH air-cored inductor, wound from 1 mm dia. enamelled copper wire.

Drive units:
Ls_1, Ls_2 = 8 Ω magnetically shielded wideband unit Type SC8 (Visaton)
Ls_3 = 8 Ω magnetically shielded polycarbonate dome tweeter Type SC5 (Visaton)

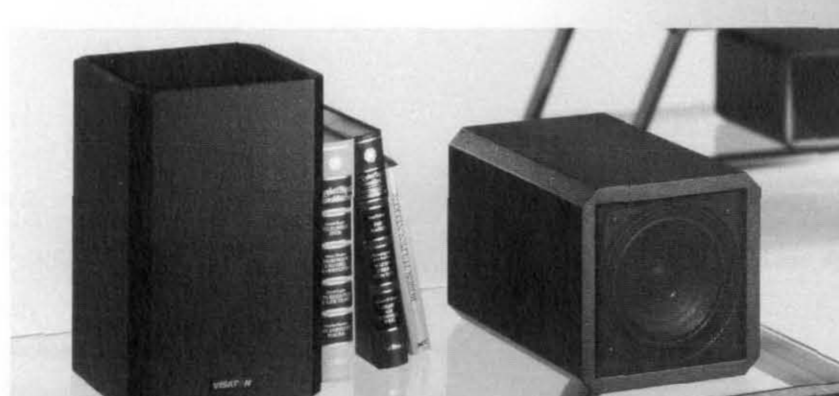
Chipboard
(10 mm thick medium density)

2 sheets 85×220 mm (fore and aft)
2 sheets 200×240 mm (sides)
2 sheets 85×200 mm (top and bottom)
Damping material
Front grille for Center 80 (Visaton)
Loudspeaker terminal

EFFECT 80 (two required)
Drive unit
Ls_1 = 8 Ω full-range driver Type FRS8 (Visaton)

Chipboard
(100 mm thick medium density)

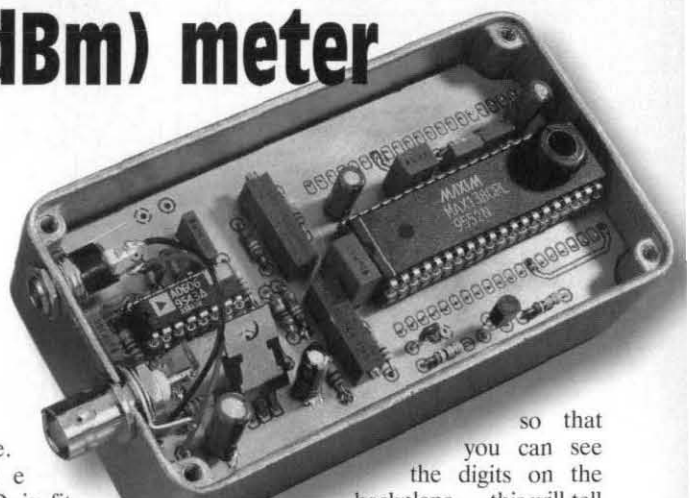
2 sheets 105×200 mm (sides)
2 sheets 85×200 mm (sides)
2 sheets 85×85 mm (top and bottom)
Damping material
Front grille for Effect 80 (Visaton)
Loudspeaker terminal



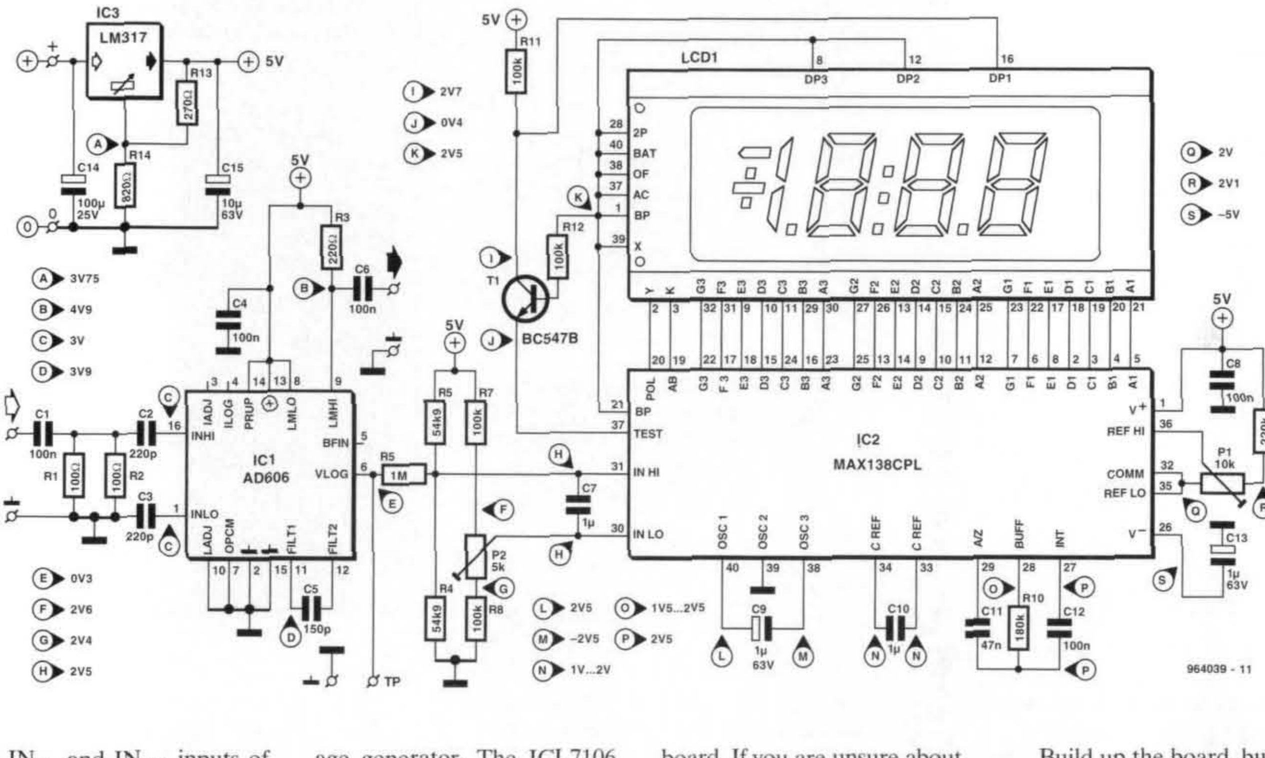
50-MHz decibel-milliwatt (dBm) meter

Two high-level integration circuits, the AD606 from Analog Devices and the MAX138CPL from Maxim, enable an accurate, wideband voltage and power meter to be built using a minimum of components. The instrument described here offers a 3.5-digit LCD readout and a bandwidth of 50 MHz. The input level range is quite large at − 80 to + 10 dBm at a resolution of 0.1 dB. The input impedance is 50 Ω.

The input signal is d.c. decoupled by C1 before it arrives on a 50-Ω termination, R1-R2. Next, the signal appears across the IN_{HI} and IN_{LO} inputs of the AD606, a *50-MHz 80-dB Demodulating Logarithmic Amplifier with Limiter Output* (says Analog Devices). This chip uses a 9-stage successive detection technique, and provides both logarithmic and linear outputs. Because we are after a decibel scale, only the VLOG output is used in this application. The log output is from an on-chip three-pole post-demodulation low-pass filter, and provides a loadable output voltage of +0.1 V to +4 V. The logarithmic scaling is such that the output is at +0.5 V for a sinusoidal input of − 75 dBm, and at +3.5-V at an input of +5 dBm (note: 0 dBm equals 1 mW into 50 Ω). Over this range, the logarithmic linearity is typically within ±5 dB. All scaling parameters are proportional to the supply voltage.

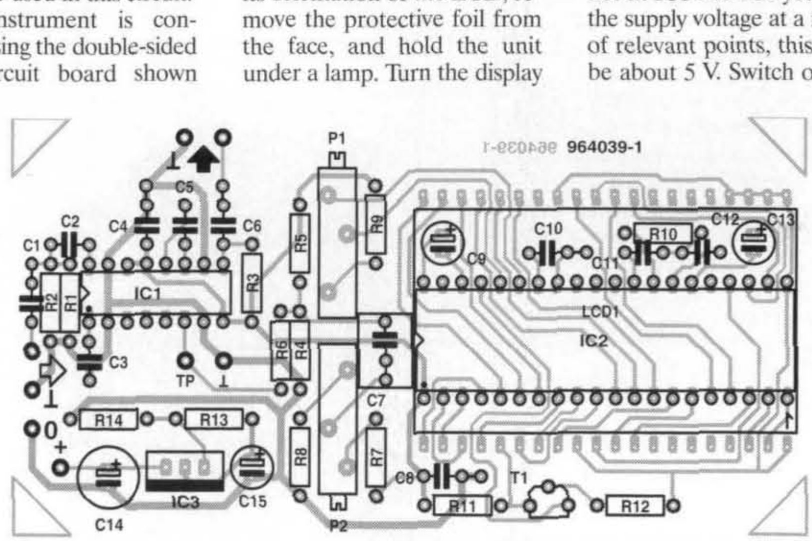


The VLOG signal of the AD606 is fed through a level converter, R4-R5-R6 before it is applied to the input of the A-to-D converter contained in the MAX138CPL. The MAX138CPL is used in its standard application circuit as a 3.5-digit voltmeter/LCD driver. The chip is largely the same as the ubiquitous ICL7106, but sports an internal negative voltage generator. The ICL7106 may not be used in this circuit.



The instrument is constructed using the double-sided printed-circuit board shown here. The LCD is fitted at the track side of the board. If you are unsure about its orientation of the LCD, remove the protective foil from the face, and hold the unit under a lamp. Turn the display so that you can see the digits on the backplane — this will tell you how to mount the component on the board.

Build up the board, but do not fit IC1 and IC2 yet. Check the supply voltage at a number of relevant points, this should be about 5 V. Switch off, then



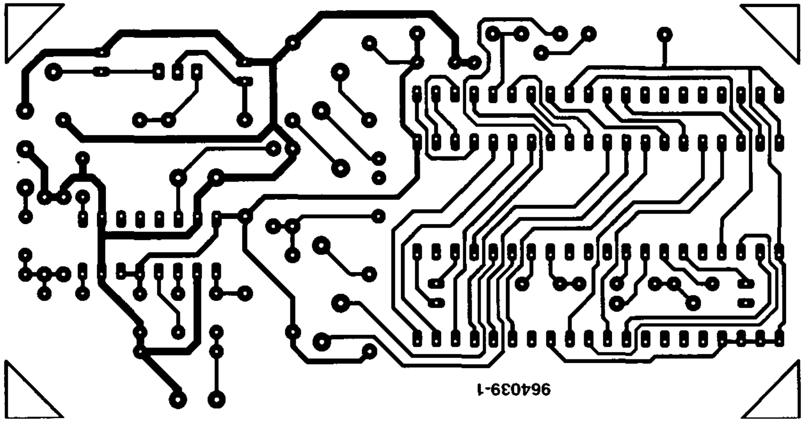
COMPONENTS LIST

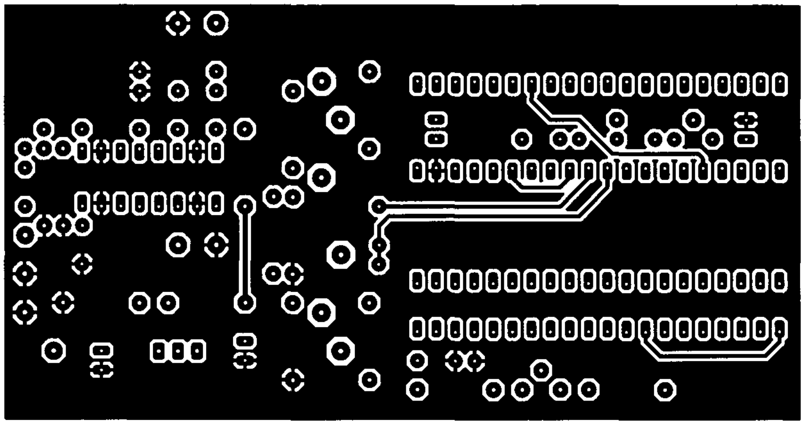
Resistors:
R1,R2 = 100Ω
R3 = 220Ω
R4,R5 = 54kΩ9 1%
R6 = 1MΩ 1%
R7,R8,R11,R12 = 100kΩ
R9 = 220kΩ
R10 = 180kΩ
R13 = 270Ω
R14 = 820Ω
P1 = 10kΩ preset 10-turn
P2 = 5kΩ preset 10-turn

Capacitors:
C1,C4,C6,C8 = 100nF
C2,C3 = 220pF
C5 = 150pF
C7,C10 = 1µF
C9,C13 = 1µF 63V radial
C11 = 47nF 5mm
C12 = 100nF 5mm
C15 = 10µF 63V radial
C14 = 100µF 25V radial

Semiconductors:
T1 = BC547B
IC2 = MAX138CPL (Maxim, KONING EN HARTMAN)
IC3 = LM317T
IC1 = AD606 (Analog Devices, TEXIM)

Miscellaneous:
LCD1 = 3.5-digit LCD, LCD3,5 (TEXIM)
8 solder pins
Case, 112x62x30mm e.g., Hammond 1590B
Printed circuit board, order code 964039-1





mount the MAX138. The current consumption should rise to about 6 mA, and the LCD should light up. Adjust multiturn preset P1 for a voltage of 100 mV between pins 35 and 36 of the MAX138. Next, adjust P2 until the voltage difference between the inputs (pins 30 and 31 is 80 mV. The display should then indicate a negative value.

Switch off, then mount the AD606. The current consumption should rise to about 20 mA. Apply an unmodulated signal with a frequency between 20 and 30 MHz, and a level of about – 35 dBm. Carefully adjust P2 until the correct level is displayed on the LCD. Check the indicated value at other dBm levels. If necessary, make small corrections to the sensitivity by tweaking P1. It may also be necessary to repeat the entire adjustment procedure for P2 and P1 a number of times.

Because of it high sensitivity and bandwidth, the entire circuit should be mounted into a metal case. As regards the power supply, go for a battery as that will ensure the highest immunity against noise. The input socket should be a BNC type (flange or single-hole mounting) which is connected to the input pins on the board using the shortest possible wires, or a length of thin coax cable (e.g., RG174/U).

The (optional) limiter output may be used to drive a frequency meter. Be sure to keep this instrument as far away as possible from the dBm meter, however, to reduce any likelihood of digital interference. A test pin is available on the board to measure the VLOG output signal of the AD606. This may be necessary for calibration or adjustment purposes.

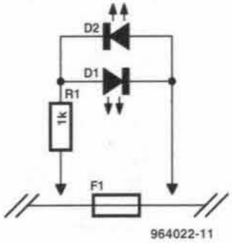
The results of measurements performed across the available frequency range are shown in the frequency response graph. The vertical scale shows the dBm level indicated by the instrument.

The indicated test voltages are applicable with no input signal applied to the circuit.

[H. C. Weddig - 964039]

car fuse tester

This miniature circuit consists of only three components and is very useful to rapidly test a car fuse without having to remove this from its holder. It concerns two anti-parallel connected LEDs with a common 1 kΩ series resistor. The circuit which the fuse protects must have its supply (12 V) on. When the tester is connected in parallel with the fuse, one of the LEDs will light if the fuse is defect. When both LEDs remain out with the supply voltage on, the fuse is all right.



Because of the anti-parallel connection of D_1 and D_2, the tester is not polarized, so that it does not matter in which way it shunts the fuse.

[A. Rietjens - 964022]

frequency meter

This article shows that not all frequency meters need to be complex and expensive. With the aid of some standard logic it is possible to determine the frequency of digital signals. The counter makes use of two 3-digit BCD counters that have a multiplexed output with buffer memory and a reset input. The multiplexed output signal is converted by an integrated BCD-to-7-segment-converter and then applied to an LED display.

The necessary clock signal is generated by a crystal of 4.194304 MHz and a counter that divides the signal by 2^{23}. The result is a stable digital signal with a frequency of 0.5 Hz. The time during which the clock signal is high, and measurements can take place, is exactly 1 s. Owing to this arrangement, a new measuring value is displayed every 2 s.

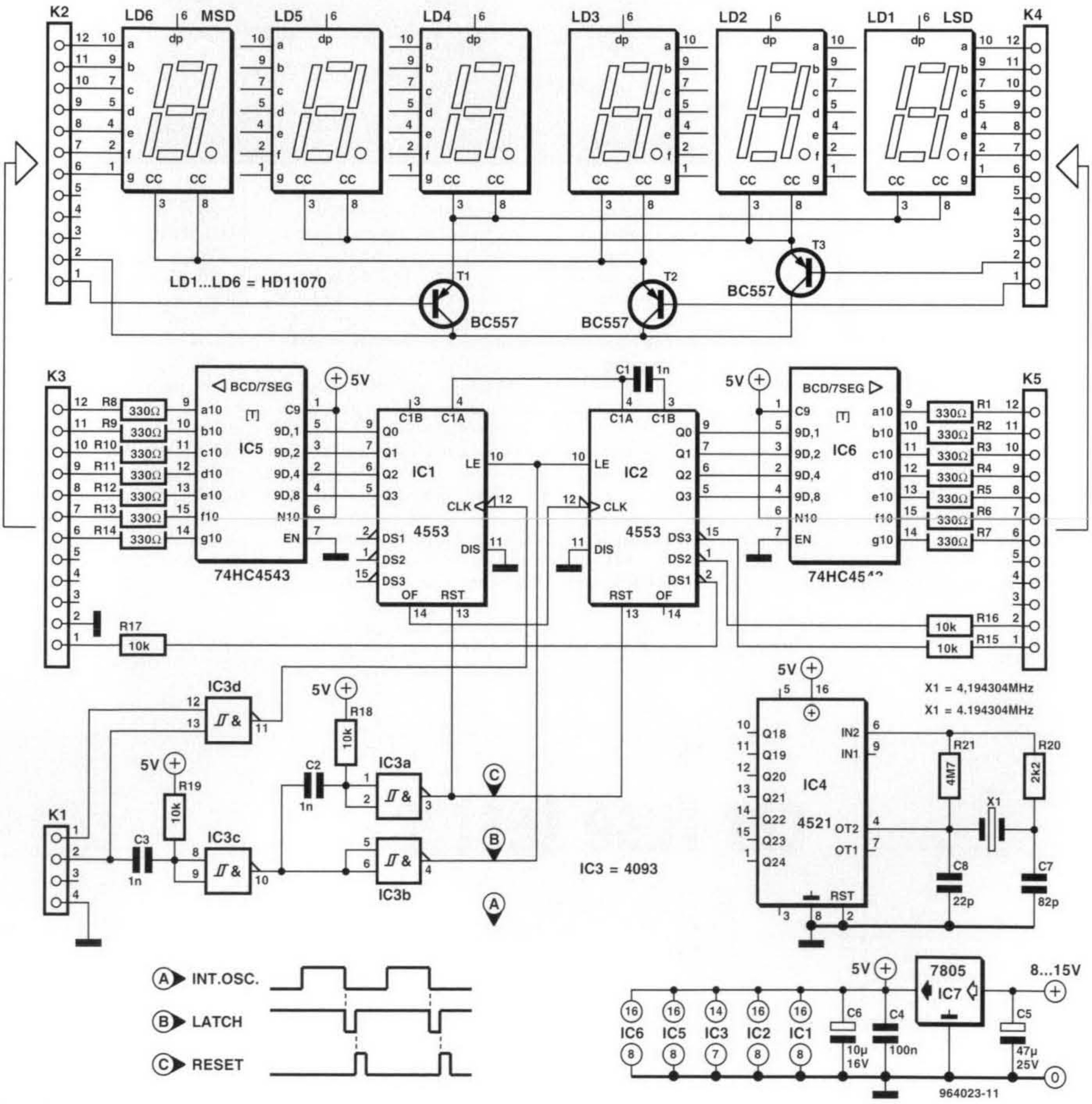
If the meter is used to measure frequency, the internal clock signal at pin 3 of K_1 must be linked to pin 2 of K_1. Gate IC_{3d} then operates as a lock: every time the clock is high the measurand at pin 1 of K_1 is applied to the clock input of IC_1. This circuit is connected in series with IC_2 to form a 6-digit counter.

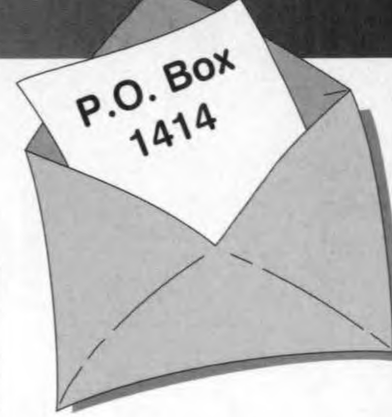
At the end of the measurement, a latch pulse is generated at the output of IC_{3c} with the aid of R_{10} and C_3. After this signal has been inverted in IC_{3b}, it is applied to the latch input of IC_1 and IC_2. At he command of this signal, the current counter state is stored in the buffer memory. At the end of the latch pulse, network R_{18}-C_2-IC_{3a} generates a reset pulse with which the counter is reset.

In the circuit as shown, the counter may be used for signals with frequencies from 1 Hz to 1 MHz. If higher frequencies are envisaged, the measurement time must be adapted accordingly. There are limits to this, though: with a supply voltage of 5 V, the 4553 may be used for frequencies up to 1.5 MHz; with 7 V, up to 5 MHz; and with 15 V up to 7 MHz. Still higher frequencies require the use of a prescaler.

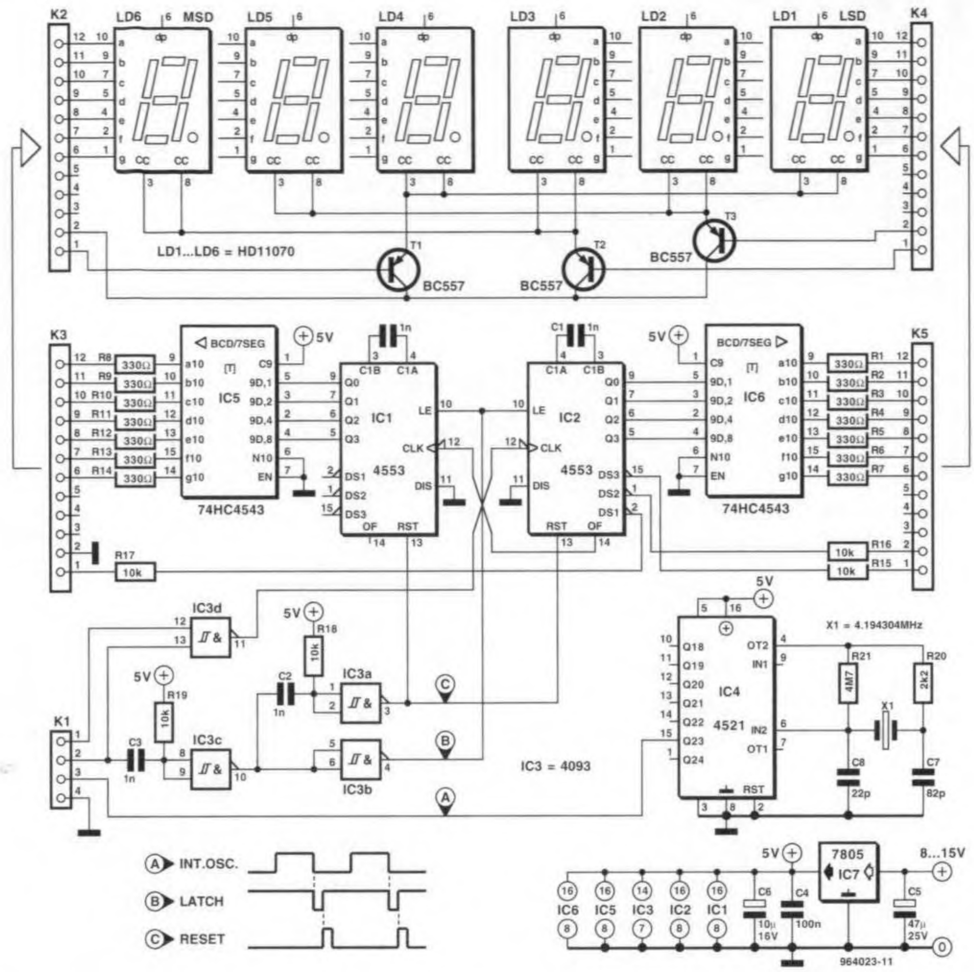
The current drawn by the circuit as shown does not exceed 50 mA, which makes a battery supply feasible.

[A. Kuyper - 964023]





Simple Frequency Meter
(July/August 1996)
964023



We extend our gratitude to Mr. Capel of Goes, the Netherlands, for pointing out a number of errors and omissions in the circuit diagram of the frequency meter described on page 68 of the July/August 1996 issue of Elektor Electronics.

*The main error is the missing link between pin 15 of **IC4** and pin 3 of connector K1. Also, pin 5 of IC4 has to be tied to the +5 V rail, while pin 3 should be connected to ground. Furthermore, pins 6 and 4 of IC4 have to be swapped.*

*Next, we have to look at **IC1** and **IC2**. On these two ICs, the clock and overflow lines have been exchanged. This problem is simple to solve by connecting pin 11 of IC3d to pin 12 of IC2, instead of pin 12 of IC1. Next, you connect pin 14 of IC2 to pin 12 of IC1. Pin 14 of IC1 is then left open. We also recommend adding an extra 1 nF capacitor between pins 3 and 4 of IC1, and breaking the connection between pin 4 of IC1 and pin 4 of IC2. Finally, if you use common-cathode displays, connect pins 6 of **IC5** and **IC6** to ground instead of to +5 V. Else, the numbers will appear inverted on the readout.*

Realising the relative complexity of all these modifications we thought it best to reprint the complete circuit diagram of the frequency meter, hopefully without mistakes this time! Having made the modifications, Mr. Capel informs us, his circuit worked flawlessly.

Magnetic-Field Meter
960100

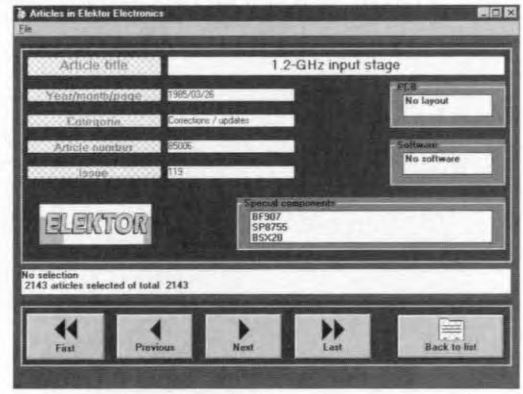
The effective length of the solder pins used to make the coil former is 7.5 mm. The nearest SWG equivalent for 0.2 mm diameter enamelled copper wire is no. 36.

New Item Tracer

Every day, a fair number of readers contact us asking when a particular article was published. "Did you ever do a bat detector?" "Where was that article on the U24-something again?" "I want to obtain all articles covering the Centronics port, can you give me an overview?"

*You can easily answer these questions yourself if you use the latest version of our **Item Tracer**, which is now available through our Readers Services. The Item Tracer is a Windows program containing an electronic contents overview of all our articles published between 1985 and 1996. You can use search keys like (part of) title, category, PCB number, article number, software number, etc. The Item Tracer also provides useful references to all published corrections and updates.*

The normal price of the Item Tracer 1985-1996 is £11.75 (US$19), but subscribers pay only £10 (US$16). The order code is 966006-1.



joystick change-over

Many people have a computer just to play games on—and why not? The PC is eminently suitable for this type of recreation.

Playing games becomes really interesting only when a joystick is used. Many I/O cards and sound cards have a standard provision of a 15-way connection for two joysticks.

Unfortunately, many programs use the connections for only one joystick. Since often several kinds of joystick are used (especially modern flight simulators have provision for very advanced, specialized joysticks), it is frequently necessary to change over connectors. As the joystick connectors are invariably found at the back of the computer, this can be a tedious operation. Moreover, in the long term, it does not do the connectors any good.

The present circuit replaces this changing over of connectors by a simple push on a button. In this way, two joysticks may be connected to the computer in a simple and user-friendly way.

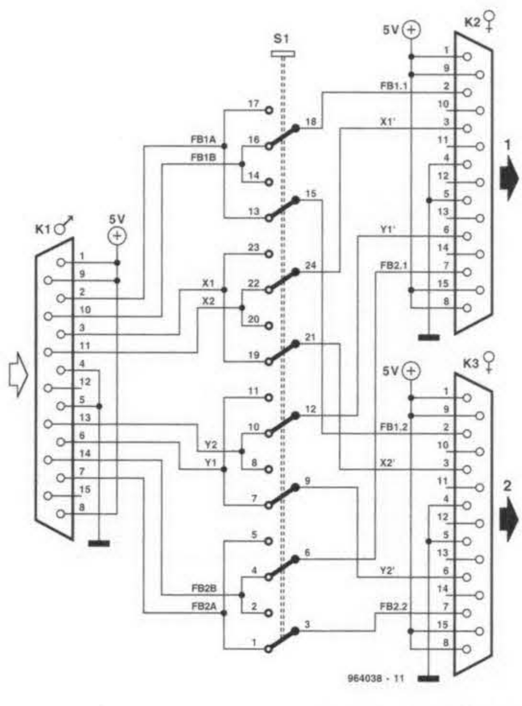
The circuit is so simple that a description of it is almost superfluous. An 8-pole switch arranges the interconnection of control signals X and Y, and fire button 1 and fire button 2.

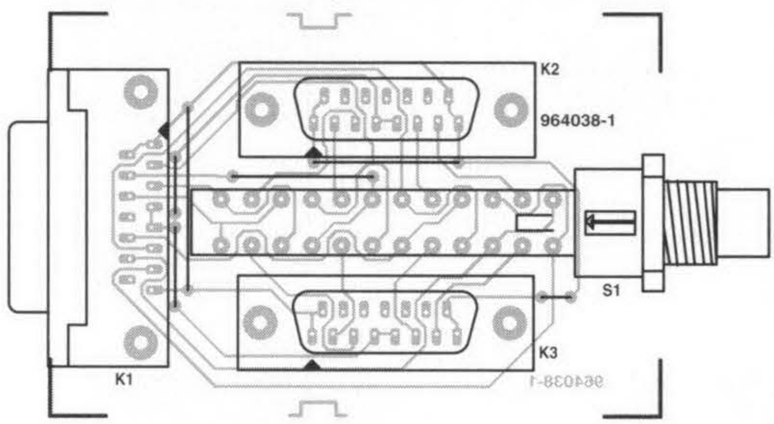
Construction of the circuit is made even simpler if it is done on the PCB shown (unfortunately not available ready made).

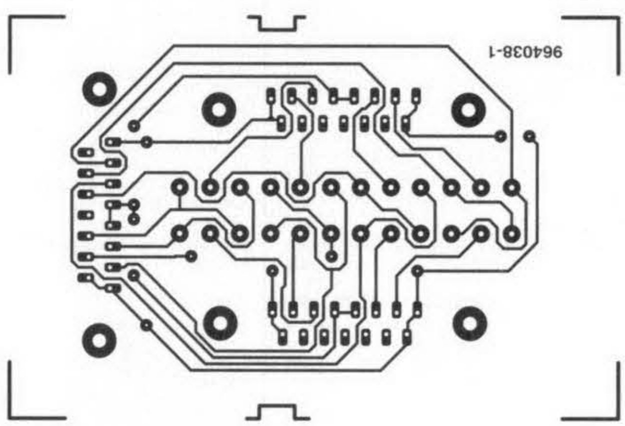
[L. Lemmens - 964038]

COMPONENTS LIST

K_1 = 15-way, right-angled sub-D connector, male, for board mounting
K_2, K_3 = 15-way sub-D connector, female, for board mounting
S_1 = 8-pole change-over switch with lock, pitch 4/6 mm (ITT Schadow Type B08-ANAP
Enclosure 141×57×24 mm (59/16×21/4×15/16 in) (e.g. Heddic Type 222B)



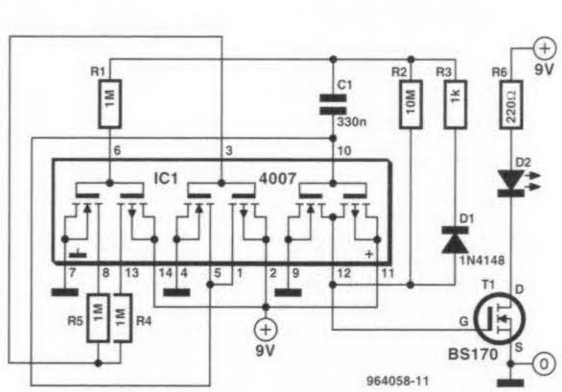




thrifty LED flasher

The dual complementary pair of switching FETs and inverter contained in a Type CD4007 CMOS IC enable an LED flasher to be made that uses very little energy.

The IC is arranged as a three-inverter-oscillator. Resistors R_4 and R_5 in series with the drains of one pair of FETs ensure that the drive current for the following pair of FETs is tiny. The high-time of the oscillator is determined by network R_3-C_1, and its low-time by R_2-C_1 (D_1 is then cut off so that R_3 is inactive).

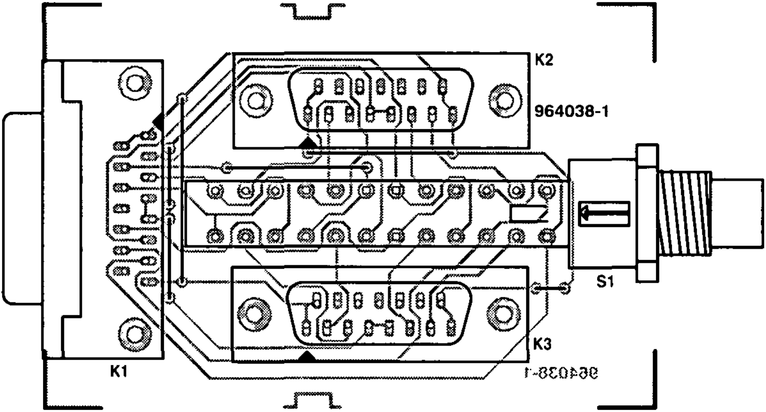


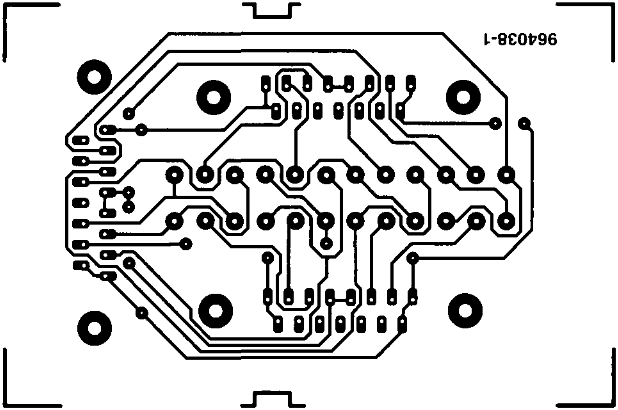
The LED is provided with current during the high-time of the oscillator by T_1. The level of this current is determined by R_6.

The values of R_2, R_3, and C_1 effect an LED off-time of 1 s and an on-time of 1 ms. Since the high-efficiency diode draws a current of 30 mA, its lighting will be clearly visible.

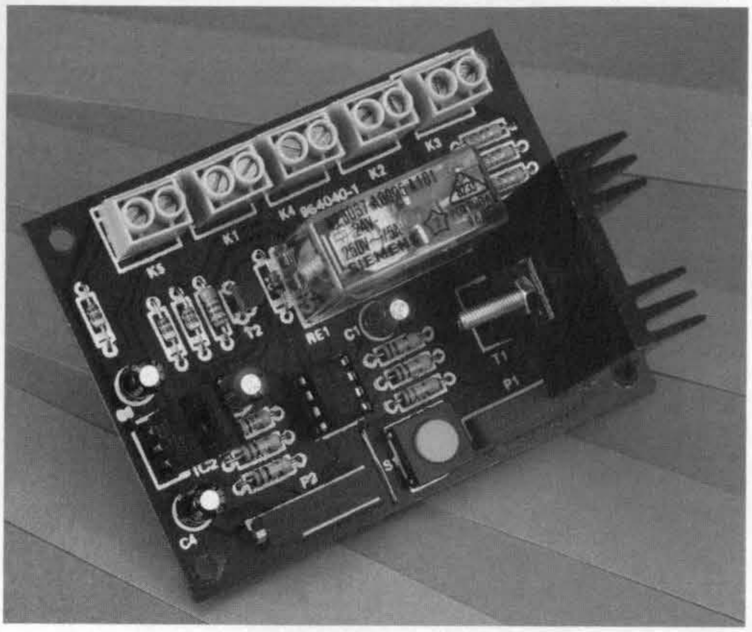
A standard 9 V battery will give continuous operation for about three years. This life span can be prolonged by increasing the value of R_6 (up to 1 kΩ). The diode does not light so brightly then, however.

[A. Rietjens - 964058]


K2
964038-1
S1
K3
K1



precision battery capacity tester

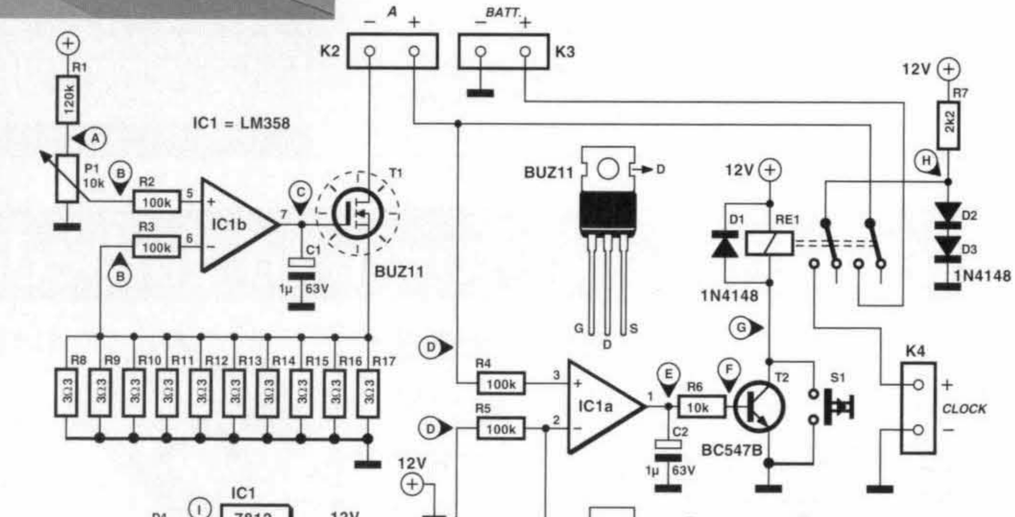


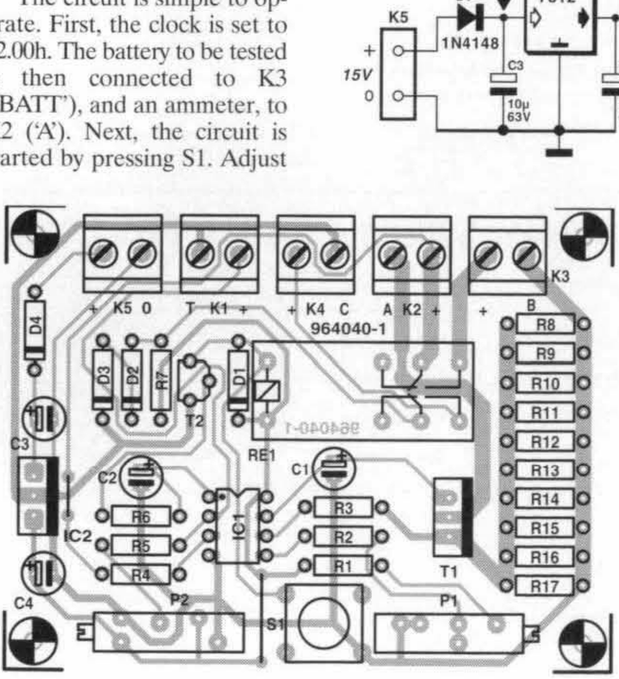
This circuit allows you to accurately measure the capacity of a rechargeable battery by discharging it at a constant current until the deep discharging voltage is reached. The time that has elapsed since starting the discharging operation then indicates the capacity of the battery under test. The capacity 'read-out' is an inexpensive 1.5-V quartz clock connected to K4. The circuit is powered by a 12-V supply which should be stable because it acts as a reference for the current sink and the battery switch-off control.

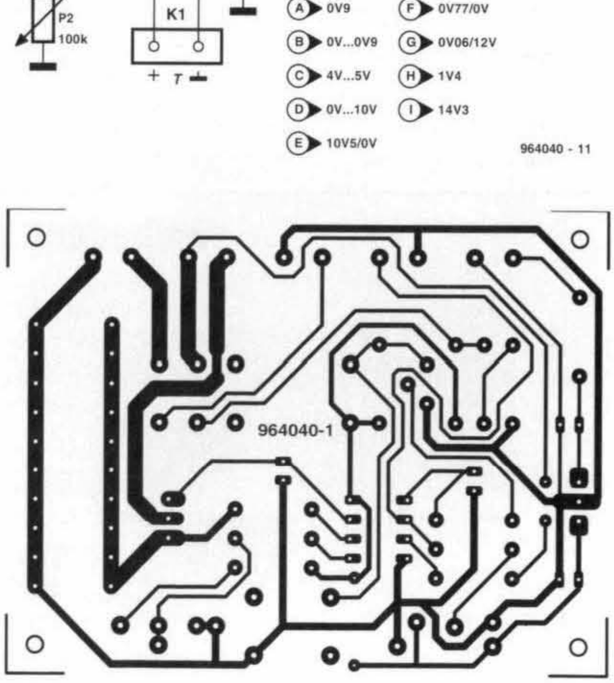
The circuit is simple to operate. First, the clock is set to 12.00h. The battery to be tested is then connected to K3 ('BATT'), and an ammeter, to K2 ('A'). Next, the circuit is started by pressing S1. Adjust P1 for the desired discharging current, for example, 1 A. Don't forget to link the terminals of K2 if you do not use an ammeter. The deep discharging voltage (at which the discharging process should stop) may be measured at K1 ('T'), and adjusted with P2. The range of this voltage is 0 V to about 12 V, allowing '9V' PP3 style NiCd batteries to be tested also (actually, these are 8.4-V types).

The discharging current has a range from a few milliamps to about 1.5 A. At the end of the discharging process, when the deep discharging voltage is reached, the battery and the clock are disconnected from the respective load/supply by the contacts of Re1. The battery capacity is computed by multiplying the time that has elapsed since starting the circuit by the discharging current.

The current source built around opamp IC1b and power MOSFET T1 adjusts itself for a voltage drop across the source resistance (R8-R17) which is equal to the voltage at the non-inverting input. The value of the current sink resistors may have to be changed to your personal requirements. Assuming that P1 supplies about 0.45 V when set to mid-travel, these resistors also drop 0.45 V. If you require a discharging current of 1 A at this setting of the pot, the equivalent value should be







COMPONENTS LIST

Resistors:
R1 = 120kΩ
R2-R5 = 100kΩ
R6 = 10kΩ
R7 = 2kΩ2
R8-R17 = 3.3Ω (see text)
P1 = 10kΩ 10-turn cermet or single-turn potentiometer
P2 = *100kΩ 10-turn cermet* or single-turn potentiometer

Semiconductors:
D1-D4 = 1N4148
T1 = BUZ11
T2 = BC547B
IC1 = LM358
IC2 = 7812

Capacitors:
C1,C2 = 1µF 63V radial
C3,C4 = 10µF 63V radial

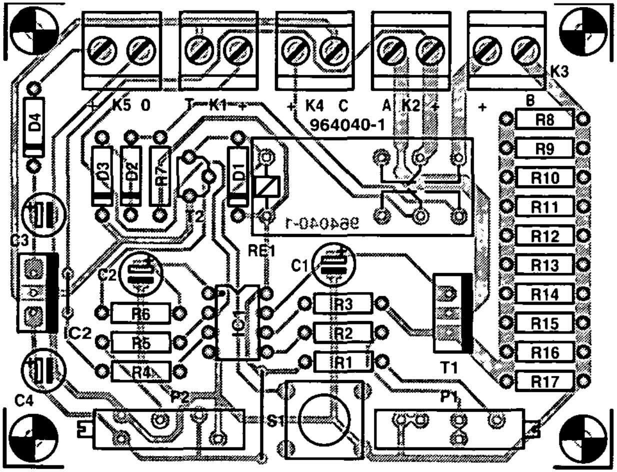
Miscellaneous:
K1-K5 = 2-pin PCB terminal block, pitch 5mm
S1 = press-key, make contact, *type CTL3*
Re1 = relay, 12V, 2x c/o, Siemens V23037-A0002-A101
Heatsink (see text)
Printed circuit board, order code 964040-1 (see Readers Services page)

0.45 Ω (0.45V/1A). In practice, you then use ten 4.7-Ω resistors in positions R8-R17. Depending on battery voltage and the discharging current you have in mind, T1 may dissipate a considerable amount of heat. The transistor may have to be fitted off the board, on a properly dimensioned heatsink, and connected with short wires. A dissipation of up to 5 watts requires a heatsink with a thermal resistance spec of 10K/W, while a 2.5K/W type is needed if the dissipation can be expected to rise to about 20 watts. Above that value, use the largest heatsink you can get and keep your fingers crossed or, in any case, away from the heatsink.

The voltage monitor is also built around an opamp, ICa. When the measured battery voltage drops below the threshold set with P2, transistor T2 is switched off, and the relay is de-energized. The non-inverting input of IC1 is then held low via the ammeter, T1 and R8-R17. Because T1 then conducts hard, the opamp will not be able to switch on the relay when the battery voltage rises above the threshold again. The 1.4-V supply voltage for the clock is derived from two series-connected silicon diodes, D2 and D3.

It is normal for the relay to come on when only the power supply is connected. The circuit should function as described once a battery is connected to K3.

The current drain from the 12-V supply amounts to about 11 mA plus about 25 mA for the relay. The 10-turn presets may be replaced by ordinary potentiometers connected to the relevant PCB points with short wires. [D. Gronholz - 964040] ✓


+ K5 0
T K1 +
+ K4 C
A K2 +
+
K3
B
964040-1
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
D4
D3
D2
R7
D1
T2
C3
C2
RE1
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IC1
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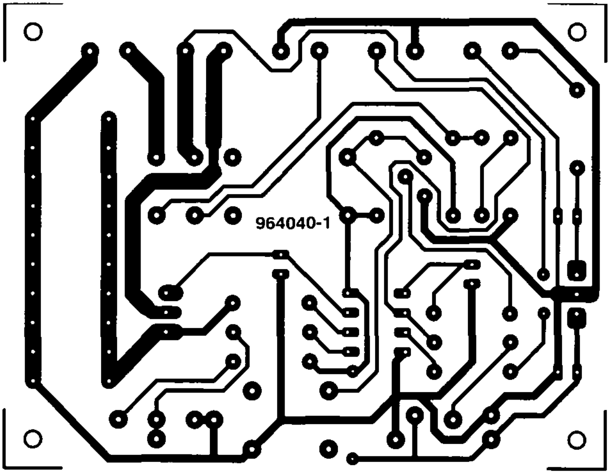
C4
P2
S1
P1


964040-1

shuttle track

This circuit enables a model train to shuttle continuously between two tracks. When the train travels from left to right across the track in the lower part of the diagram, the lower rail D is connected to the positive supply line. After it has passed diode D_B, the train will stop. Since the locomotive short-circuits the diode when it passes the break in the rail, a short positive pulse is generated on rail section B.

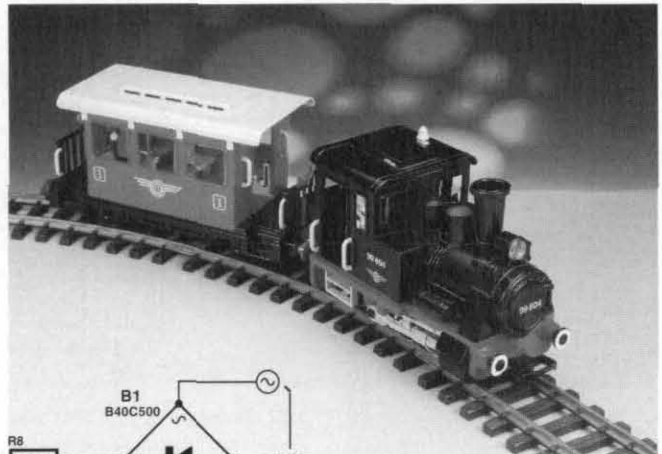
The pulse is used to set bistable IC_1, whereupon D_3 goes out and capacitor C_3 is being charged. When the potential across the capacitor rises to a sufficiently high level, transistor T_1 switches on, whereupon the relay is energized. This causes the polarity of rails C and D to be reversed. Diode D_B is then on, so that the train departs in the direction of A.

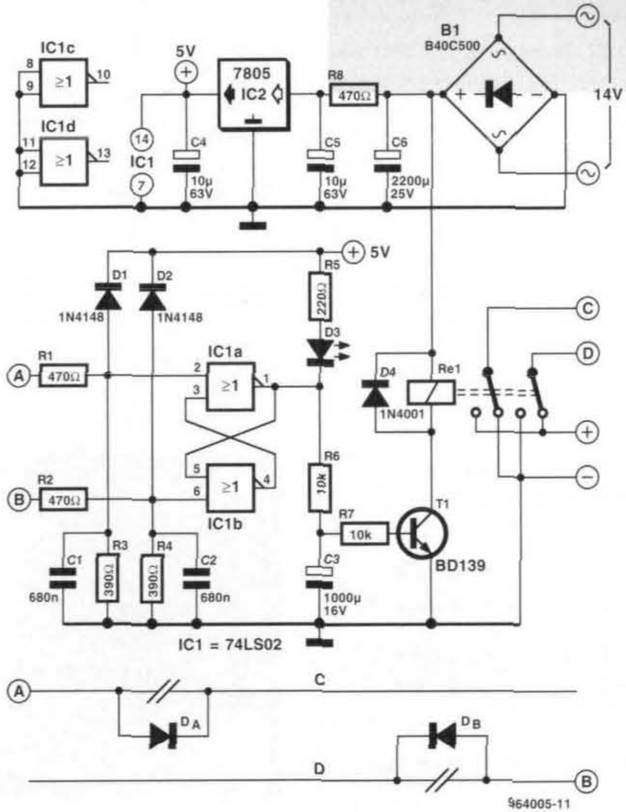
Rail C is then connected to the positive supply rail, so that when the train passes diode D_A, a positive pulse is generated on rail section A. This pulse is used to reset the bistable, whereupon the LED lights and the relay is deenergized.

After the relay contacts have reversed the polarity of C and D again, diode D_A comes on and the train departs again in the direction of B.

Circuit IC_1 may be a CMOS type from the 4000 series such as the 4001. Advantages of the 4001 compared with a TTL type are that sensitivity to interference is smaller and the current drain is lower. The disadvantage is, however, that the output current is much smaller. A 4001 can provide at most a few mA, which means that the LED must be a high-efficiency type and the value of R_5 must be increased to 2.7 kΩ.

The relay may be any type with a coil rating of 12–18 V. If the relay does not pull well, measure the voltage at the collector-emitter junction of T_1. If this is higher than 1 V, it is advisable to use a darlington transistor, such as the BC517.





The inputs are fairly low impedance. If IC_1 is an HC or LS version, the values of R_1-R_2 and R_3 may be increased to 1.2 kΩ and 1 kΩ respectively. If a CMOS-IC is used, those values may be increased even further. This reduces the sensitivity to interference and allows the values of C_1 and C_2 to be reduced accordingly (which makes the capacitors less expensive).

The current drain of the circuit is determined primarily by the relay and will be about 50 mA.

[H. Steevels - 964005]

video fader

Based on a Linear Technology application

If you try to attenuate a video signal, there is a point at which the picture becomes unstable rather than weaker. This happens because the sync pulse are attenuated also, and the monitor's internal picture timing circuits go into free-running mode, being unable to detect a valid input signal. This problem may be solved by applying a separate sync signal and attenuating the video component only. However, separate sync is a feature found on professional video mixing desks only. Here's a low-cost alternative. The circuit shown here does an adequate job at a modest investment, allowing you to fade a video signal virtually down to the black level without losing sync on the monitor.

The sync pulses are extracted from the composite video (CVBS) signal) by opamp IC2 and its surrounding components. Components C2, R11 and D2 form a video clamping circuit. Diode D3 provides a bias at the +input of IC2. Be-

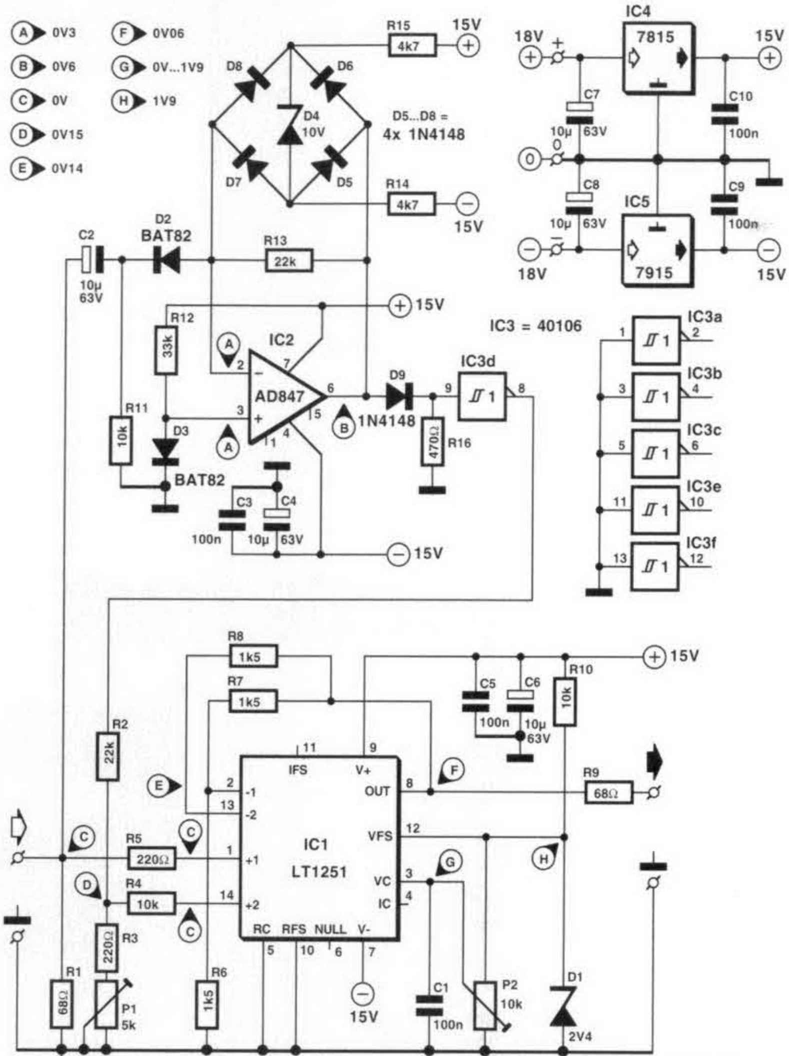
COMPONENTS LIST

Resistors:
R1,R9 = 68Ω
R2,R13 = 22kΩ
R3,R5 = 220Ω
R4,R10,R11 = 10kΩ
R6,R7,R8 = 1kΩ5
R12 = 33kΩ
R14,R15 = 4kΩ7
R16 = 470Ω
P1 = 5kΩ preset H
P2 = 10kΩ preset H or potentiometer

Capacitors:
C1,C3,C5,C9,C10 = 100nF
C2,C4,C6,C7,C8 = 10µF 63V radial

Semiconductors:
D1 = zener diode 2V4 400mW
D2,D3 = BAT82
D4 = zener diode 10V 400mW
D5-D9 = 1N4148
IC1 = LT1251CN (Linear Technology)
IC2 = LT1360 or AD847JN
IC3 = 40106
IC4 = 7815
IC5 = 7915

Miscellaneous:
Printed circuit board, order code 964076-1 (see Readers Services page)



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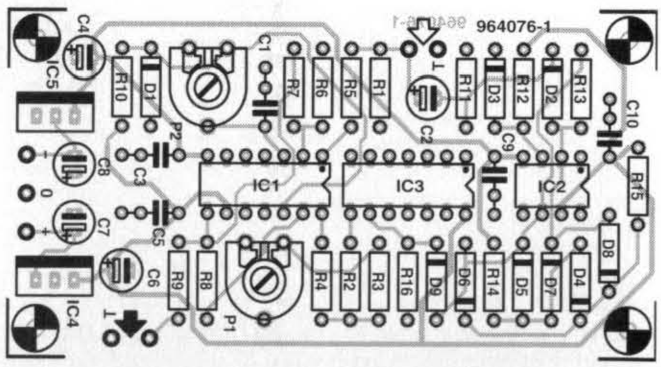
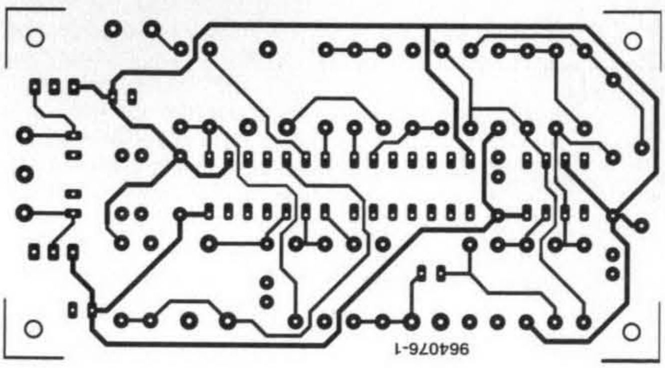
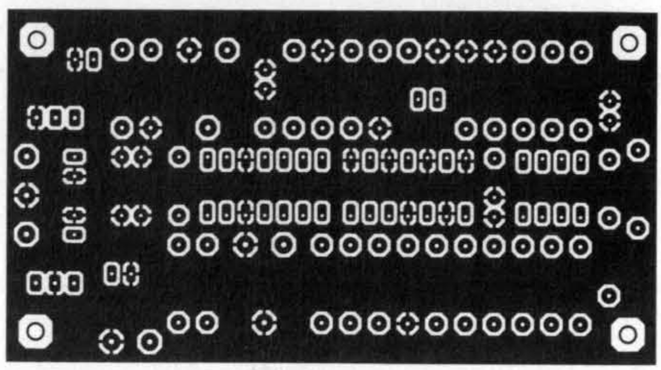






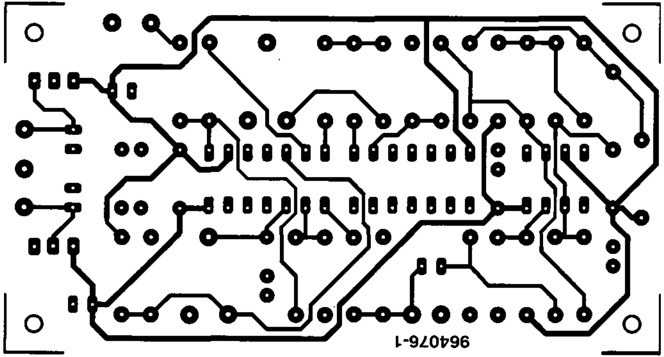
cause of the rectifying action of D2, the opamp only amplifies the negative part of the CVBS signal. The clamping circuit in the feedback path of the AD847 (D4-D8) prevents the opamp from going into saturation. The amplified sync signal is digitized by a diode, D9, and a Schmitt-trigger gate, IC3d, before it is applied to the +input of one of the two fast opamps contained in the video fader IC, an LT1251. The sync level is set to the optimum level with the aid of preset P1.

The LT1251 uses a preset (or an external potentiometer), P2, to determine the level ratio between the sync channel and the video channel. The control voltage for the fader is derived from a reference voltage created by zener diode D1. Capacitor C1 suppresses noise which may be picked up by wires if an external fade control (slide potentiometer) is used. The mixed output signal is available at pin 8 (d.c. coupled), at an impedance of about 75 Ω. Current consumption of the circuit is less than 30 mA. The indicated test voltages are applicable with no input signal applied to the circuit.

One disadvantage of the circuit should not be left unmentioned. The fader also reduces the level of the colour burst. Consequently, the picture may go black and white just before the black level is reached. Fortunately, that will be a minor drawback for most hobby applications.

[964076]

Source: Linear Technology Chronicle, April 1995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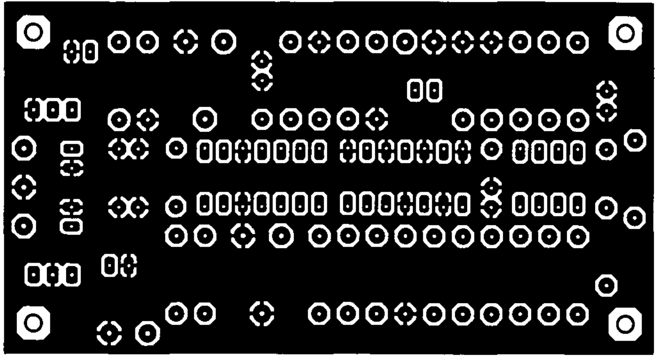
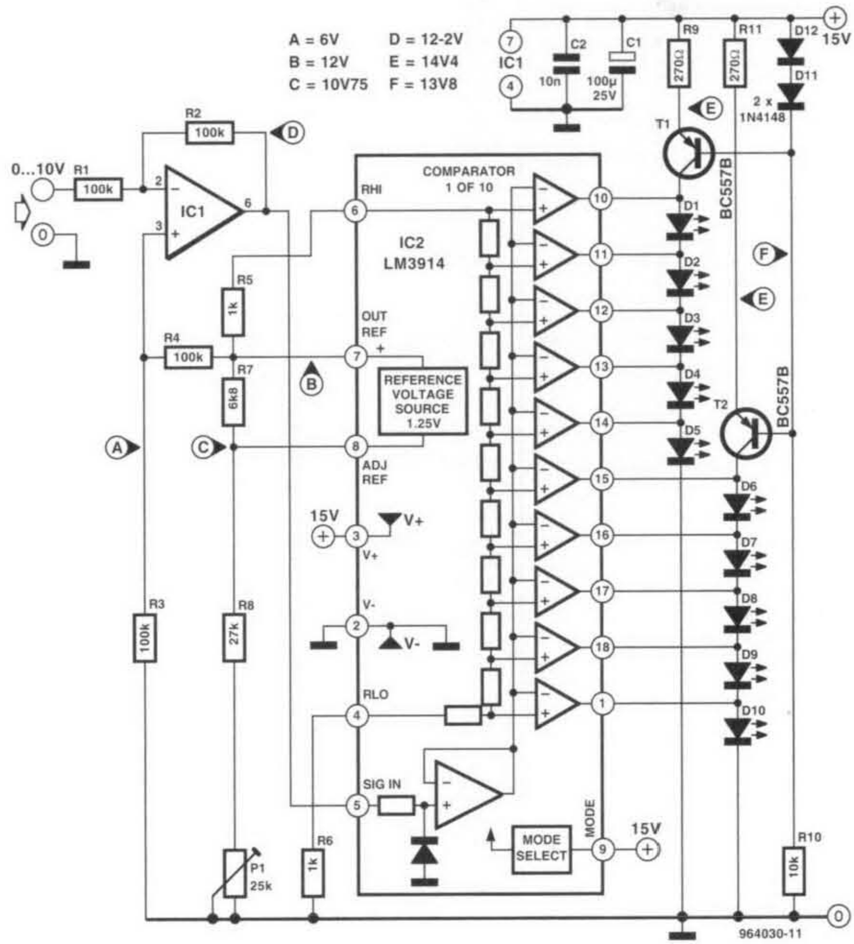


economical LED bar display

A particular difficulty with LED bar displays is the high current drain. In the diagram, LED driver LM3914 controls a chain of LEDs instead of as usual a number of parallel-connected LEDs. This means that in principle only a single diode current is needed to make several LEDs light. The cost of this is, of course, a higher supply voltage, since account must be taken of a number of diode forward voltages. The economizing effect is strengthened if high-efficiency LEDs are used. In the diagram, the current drain of about 15 mA is less than half that of the standard application (32 mA). Instead of the specified LM3914, the Type UAA180 may also be used.



The LM3914 is programmed for a reference voltage of 12 V at REFOUT, pin 7. This reference voltage is reduced by differential amplifier IC_1 by the input potential of 0–10 V. This means that the input to IC_2 is an inverted signal of 2–12 V.

The reason for an inverted signal is that the comparator chain is active low, that is, an output becomes high when the input voltage at pin 5 is lower than the reference potential. When that happens, the LED goes out, since the anodes of all LEDs in the original application are connected to the +ve supply line.

In the present circuit, however, the LEDs are in series. The current (at a level of about 2 mA) is provided by a constant-current source. This current flows through the entire chain of LEDs, except those whose anode is linked to an active low output. There, the current flows into the IC. Thus, some LEDS light, others do not. This is, however, only possible when the input signal is previously inverted. At the lowest input level (0 V), the signal input of the IC is at 12 V. The reference voltage of even the most significant comparator is then exceeded. Its output (pin 10) is then low, so that no LED lights. At the other extreme, that is, input voltage of 12 V, the SIGIN potential is 2 V, so that even the least significant comparator does not change state (go low).

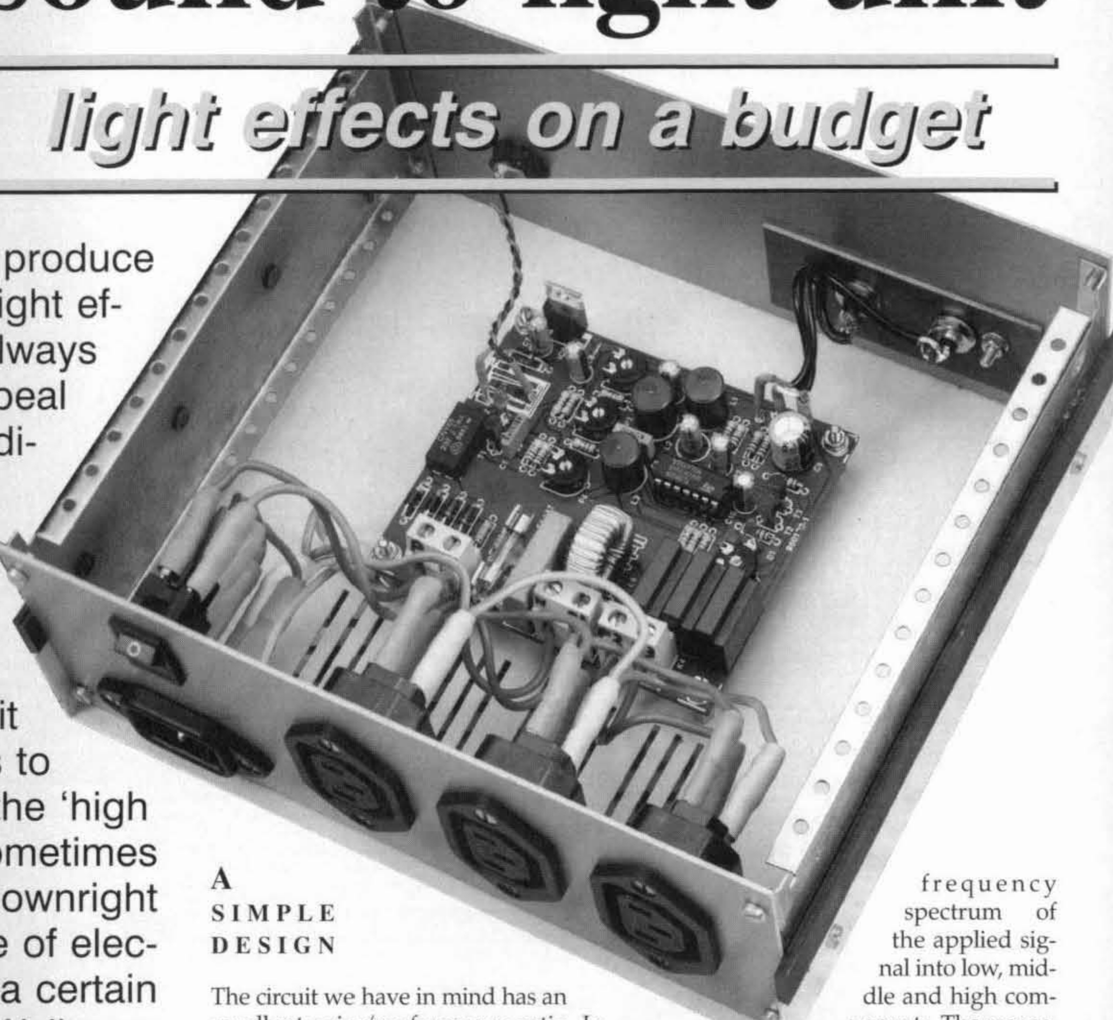
The current from the current source flows through the LEDs to earth. Note, however, that the LED chain has been split into two current paths, so that the overall current drain is about 2 mA higher. The necessary supply voltage is, however, limited: depending on their colour and type, ten LEDs (for mobile applications) drop an impractical 25 V

Resistors R_5 and R_6 are extensions of the on-chip voltage divider and both drop exactly 1 V. Consequently, the threshold of the first comparator is 2 V and that of the last, 11 V. The reference voltage must be a little higher than the maximum input voltage. In the present circuit, 15 V has been found satisfactory. To calibrate, adjust P_1 so that the potential at pin 7 of IC_2 is exactly 12 V.

[V. Bäurer - 964030]

sound-to-light unit

light effects on a budget



Designs that produce sound or light effects are always sure to appeal to a large audience. That is not surprising in itself, because that type of circuit seems to negate the 'high brow' and sometimes even downright boring image of electronics to a certain extent. Well, you won't be bored with this circuit, because it shows a quite playful side of the hobby.

The purpose of a sound-to-light unit is to support music in discos and the like with light effects. This is achieved with lamps, spotlights and sometimes even floodlights having different colours. Both the relative frequency and the volume of the components that make up the music signal are parameters which are used to control the colour and the intensity of the lighting. If a sound-to-light unit works properly, the effect is a harmonious coupling of sound and light.

Design by K. Walraven

A SIMPLE DESIGN

The circuit we have in mind has an excellent price/performance ratio. In other words, although based on a relatively simple design, the sound-to-light unit produces wonderful effects at a modest investment.

The block diagram is shown in **Figure 1**. The unit has three channels. The frequency spectrum of the music signal is, therefore, split into three ranges, each of which is responsible for the control of one lamp, or one group of lamps. In practice, it is sufficient to have three channels. We know, five or six channels may be even more fun, but the extra effects you get are only obtained at an investment which is out of proportion because of the parts that go into additional filters.

The block diagram shows that the input signal first arrives at an adjustable input amplifier. This serves to 'crank up' the signal to a higher level, so that it can be used by the rest of the circuit, and also to prevent overloading the input. Overloading presents a risk because it generates harmonics which could upset the operation of the circuit.

The amplified signal is applied to three filters: a low-pass, a band-pass and a high-pass type. These divide the frequency spectrum of the applied signal into low, middle and high components. The respective filter roll-off frequencies are 250 Hz, 700 Hz and 4,500 Hz. The three channels are processed separately to produce control signals for a lamp, or a lamp group. The switching of the lamps is done with the aid of three triacs.The filtered signals, low, middle and high, are applied to the – inputs of three comparators.

In order to make the lamp channels sensitive to volume variations, the circuit is extended with the upper two blocks in the diagram. The mains voltage is first rectified to give a pulsating 100-Hz signal, which is subsequently converted into a mains-synchronous sawtooth. The sawtooth voltage peaks occur just after the zero-crossing of the mains voltage. As shown by the block diagram, the sawtooth is applied to all three positive comparator inputs.

A triac is an electronic switch which starts to conduct when a firing pulse is applied to the gate. It switches off again when the voltage to be switched is nought, in other words, on every zero-crossing of the alternating voltage. Consequently, to keep conducting, a triac requires new gate pulses all the time. If you want such an electronic switch to be closed for the largest possible part of the each half cycle of the alternating voltage, then the gate pulses should be applied as quickly as possible after the zero-crossing. When the gate pulse occurs some time after the zero-crossing (in other words, close to the next zero-crossing), the triac will only conduct during a small part of each period, causing the lamp it controls to light only dimly.

This effect is exploited in combination with the sawtooth reference. When the music signal contains loud bass components, for example, the 'low' filter supplies a relatively high output level. Consequently, the voltage at the inverting input of the relevant comparator will exceed the level of the sawtooth fairly quickly after the zero-crossing. The triac is then switched on early, and the associated lamp lights at full intensity.

By contrast, when the music signal is relatively small, the instantaneous level of the sawtooth has to drop considerably before the comparator is enabled. The triac is then triggered much later, and the relevant lamp lights dimly.

The advantage of the switching principle applied here is that a practical circuit is within easy reach. Nearly every other properly working system requires far more parts when it comes to translating design ideas into a practical circuit. The disadvantages should also be mentioned, however: for one thing, the circuit responds exclusively to the positive half-cycles of the music signal. This disadvantage is, however, shared with

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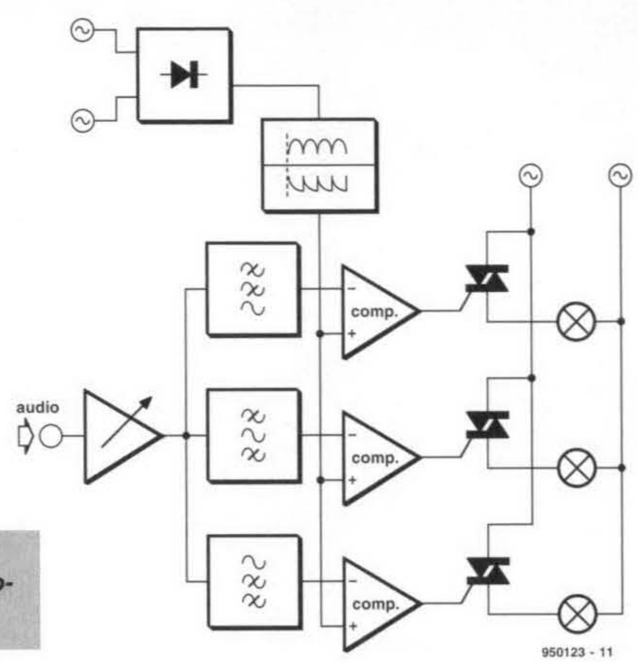


Figure 1. Block diagram of the sound-to-light unit.

2

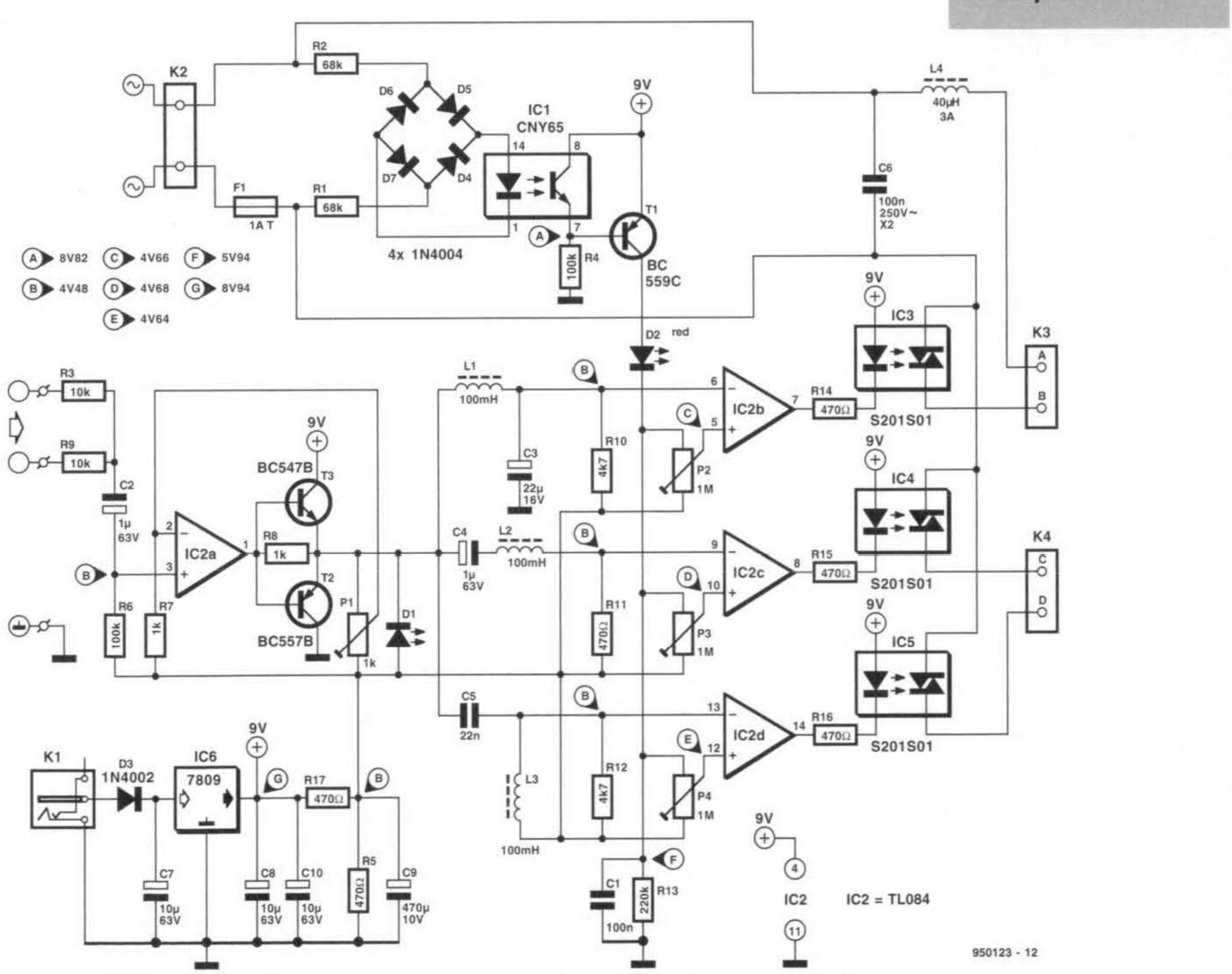


Figure 2. Circuit diagram of the unit. Note the use of opto-triacs as lamp drivers.

3

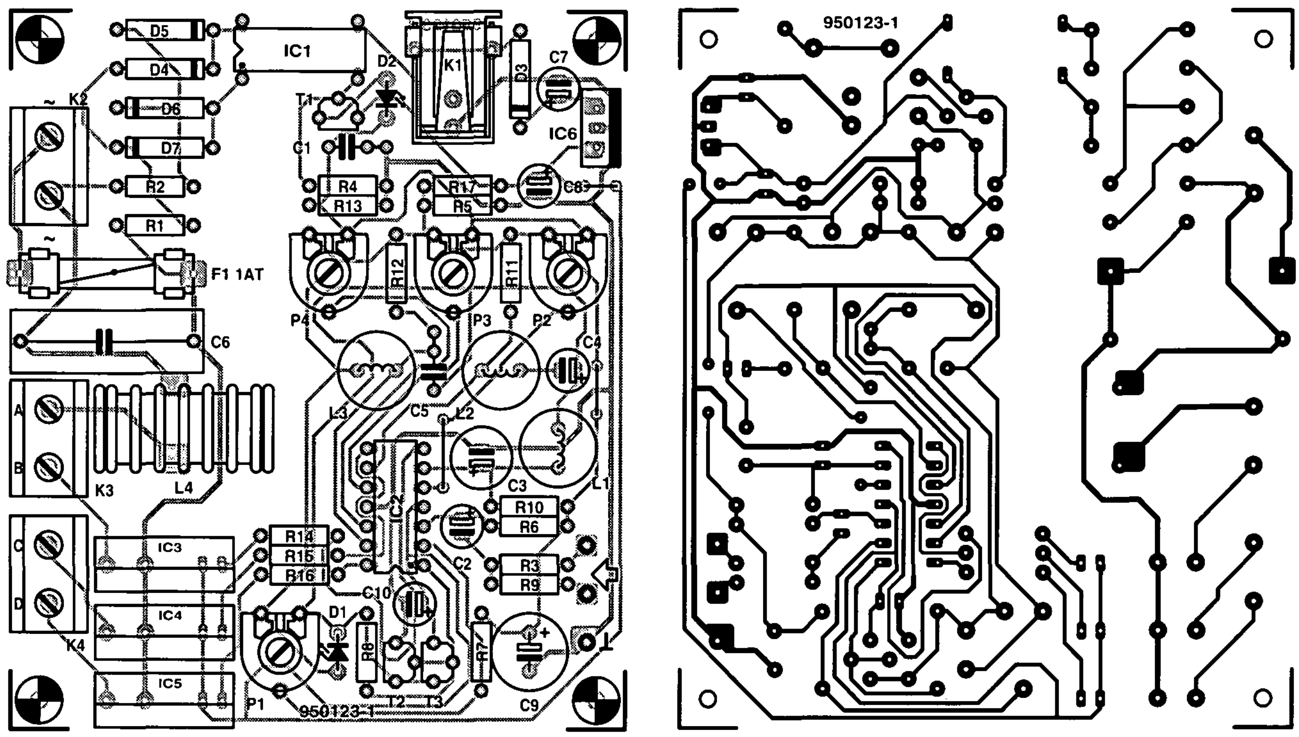


Figure 3. PCB artwork. Note the clear division on the board between the low-voltage section and the section in which the mains voltage may be present. This board is available ready-made through our Readers Services.

many other sound-to-light units, of which very few have double-phase rectifiers. Also, the system has its limitations with low frequencies. When very low bass frequencies occur, say, at 50 or 60 Hz, an unfavourable timing relation may exist between these signals and the sawtooth voltage, causing small variations in the triac conduction instant. However, as long as the music signal has sufficient volume, these limitations are hardly noticed, and the sound-to-light unit works very well.

Circuit description

The full circuit diagram of the sound-to-light unit appears in **Figure 2**. Even a cursory look at the schematic reveals the likeness to the block diagram. The various blocks are easily identified. One of the most essential differences between the two diagrams, however, is brought about by electrical safety requirements. We're talking about the opto-isolators in the circuit, IC1, IC3, IC4 and IC5, which serve to keep the dangerous mains voltage away from the rest of the circuit.

At the input of the circuit, the left and right signals are summed by R3 and R9. The resulting signal is fed to the input amplifier via coupling capacitor C2. The amplifier consists of opamp IC2a and power stage T2/T3. The two transistors boost the output current supplied by the opamp. The extra current is welcome because the filters represent a load with a relatively low impedance. The gain of the input amplifier may be adjusted with the aid of preset P1, whose practical merit was already mentioned. LED D1 is useful as an adjustment aid because it lights when a good drive signal is available for the rest of the circuit.

The input amplifier is followed by the filters. All three of these contain an L/C combination. L1/C3 is the low-pass filter, C4/L2 the band-pass filter, and C5/L3 the high-pass filter. Resistors R10, R11 and R12 ensure that the filters are properly terminated.

Because of their rather simple design, the filters are not very 'steep'. However, the roll-off frequencies are sufficiently wide apart to ensure an acceptable separation between the three channels.

The filtered signals are fed directly to the three comparators, IC2b, IC2c and IC2d. The sawtooth voltage is applied to the other (non-inverting) inputs of the comparators, via presets P2, P3 and P4.

The sawtooth is generated by the sub-circuit shown at the top of the circuit diagram. It works as follows. The mains voltage arriving via connector K2 is rectified by D4 through D7 to give a pulsating 100-Hz voltage which is used to drive opto-isolator IC1. Resistors R1 and R2 limit the current through the LED in the opto-isolator. The pulsating direct voltage which flows through the LED causes the associated phototransistor in IC1 to conduct nearly all the time. In fact, the transistor is off very briefly during the zero-crossing only. The reverse then applies to transistor T1. Because the base-emitter junction of this device is effectively short-circuited when the opto-isolator conducts, T1 will conduct briefly on each zero-crossing, charging C1 rapidly to the supply voltage (minus some 1.6 V which drops across LED D2). As soon as T1 is switched off again, C1 is discharged relatively slowly via R13 and the three presets, P2, P3 and P4. The rapid charging and slow discharging cycles create the sawtooth we mentioned earlier. The various component values in this sub-circuit have been selected such that the sawtooth drops to about half the supply voltage in the available time. The three presets, P2, P3 and P4, allow the level of the sawtooth to be adjusted individually for each channel. This creates a kind of sensitivity control.

That nearly completes our description of the circuit. The electronic switches that control the lamps are driven directly from the comparator outputs. As already mentioned, the switching is not done with ordinary triacs, but with opto-triacs (IC3, IC4 and IC5), which guarantee a perfect isolation between the dangerous lamp voltage and the comparator outputs. Here, type S201S01 modules from Sharp are used. Be sure to purchase the right type, by the way, because there are also versions which switch on the zero-crossing only (-S02 and -S04). These are not suitable for the present circuit!

The usual noise suppressor is formed by inductor L4 and capacitor C6. The latter must be a type with an a.c. specification of 250 V (400 or 600 VDC). If you can find one, an X2-class capacitor is preferred in this position. X2-class capacitors are especially suited to mains applications thanks to

COMPONENTS LIST

Resistors:
R1,R2 = 68kΩ
R3,R9 = 10kΩ
R4,R6 = 100kΩ
R5,R11,R14-R17 = 470Ω
R7,R8 = 1kΩ
R10,R12 = 4kΩ7
R13 = 220kΩ
P1 = 1kΩ preset H
P2,P3,P4 = 1MΩ preset H

Capacitors:
C1 = 100nF
C2,C4 = 1µF 63V radial
C3 = 22µF 16V radial
C5 = 22nF
C6 = 100nF 250VAC, class X2
C7,C8,C10 = 10µF 63V radial
C9 = 470µF 10V radial

Inductors:
L1,L2,L3 = 100mH (Toko)
L4 = 40µH 3A triac suppressor coil

Miscellaneous:
D1 = LED, red, low current
D2 = LED, red
D3 = 1N4002
D4-D7 = 1N4004
T1 = BC559C or BC560C
T2 = BC557B
T3 = BC547B
IC1 = CNY65
IC2 = TL084
IC3,IC4,IC5 = S201S01 (Sharp)
IC6 = 7809

Miscellaneous:
K1 = mains adaptor socket
K2,K3,K4 = 2-pin PCB terminal block
F1 = fuse 1A (T) with PCB mount holder
Case: Telet LC850 (200x180x80mm)
Double-pole mains switch with on/off indication, e.g. Russenberger R1920
Mains appliance socket, or mains cord with strain relief
Three Euro style mains-out sockets, or 3 mains cords with strain relief

Printed circuit board, order code 950123-1 (see Readers Services page)

their flame-retarding properties which, among others, cause the capacitor to behave like an open circuit rather than a short-circuit in the event of internal arc-over or electrical breakdown.

The circuit operates from a regulated 9-V supply voltage supplied by an ordinary three-pin voltage regulator, IC6. The half supply voltage level needed by the sawtooth generator is simply created by a potential divider, R17/R5. The current consumption of the electronics is very modest indeed, allowing any mains adaptor with a current capacity of about 100 mA at 12 V or so to be used. The adaptor is connected to K1 (mind the polarity).

4

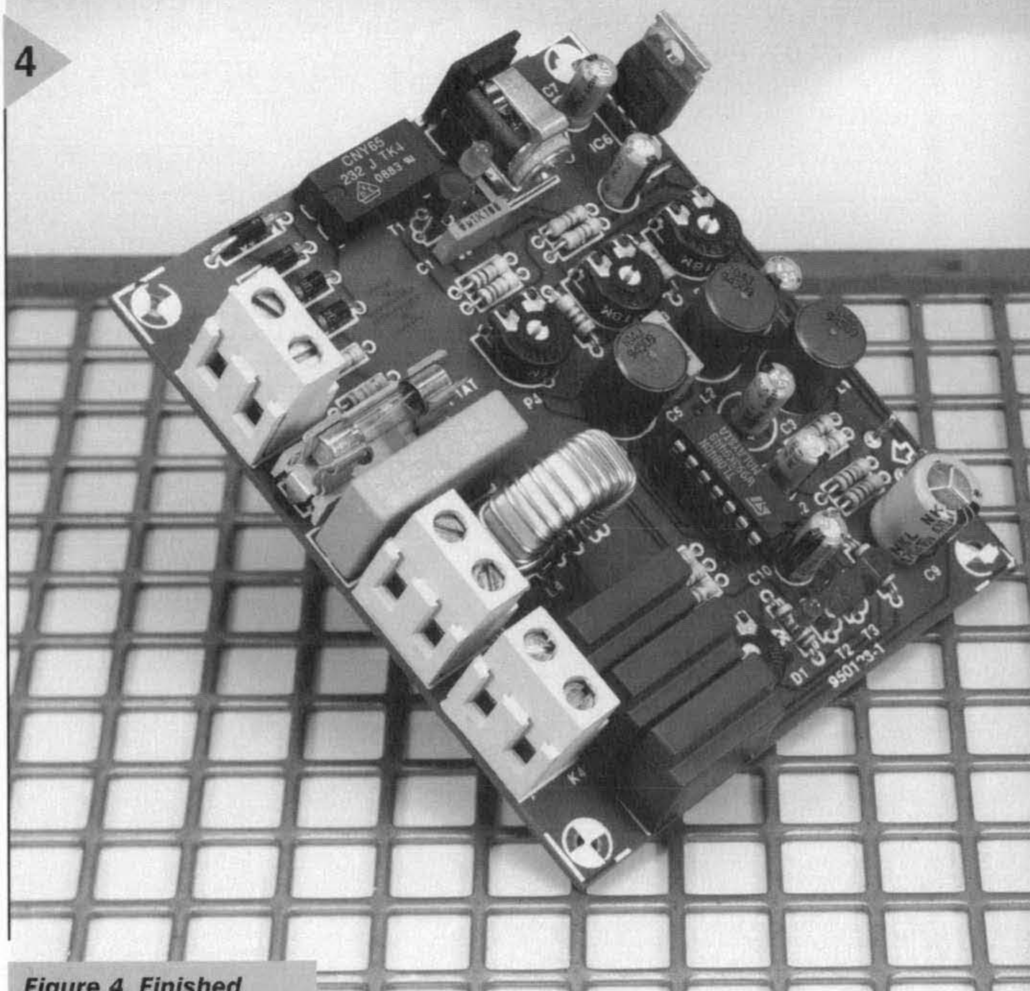


Figure 4. Finished printed circuit board with all parts fitted.

PRINTED CIRCUIT BOARD

The artwork designed for the printed circuit board is shown in **Figure 3**. The board holds the entire circuit shown in Figure 2, that is, including the triac modules, the noise suppressor and the connectors. The PCB is available ready-made through our Readers Services.

Building up the board should not present undue difficulties if you follow the component mounting plan and the parts list. It is recommended to build the circuit in steps, as detailed below.

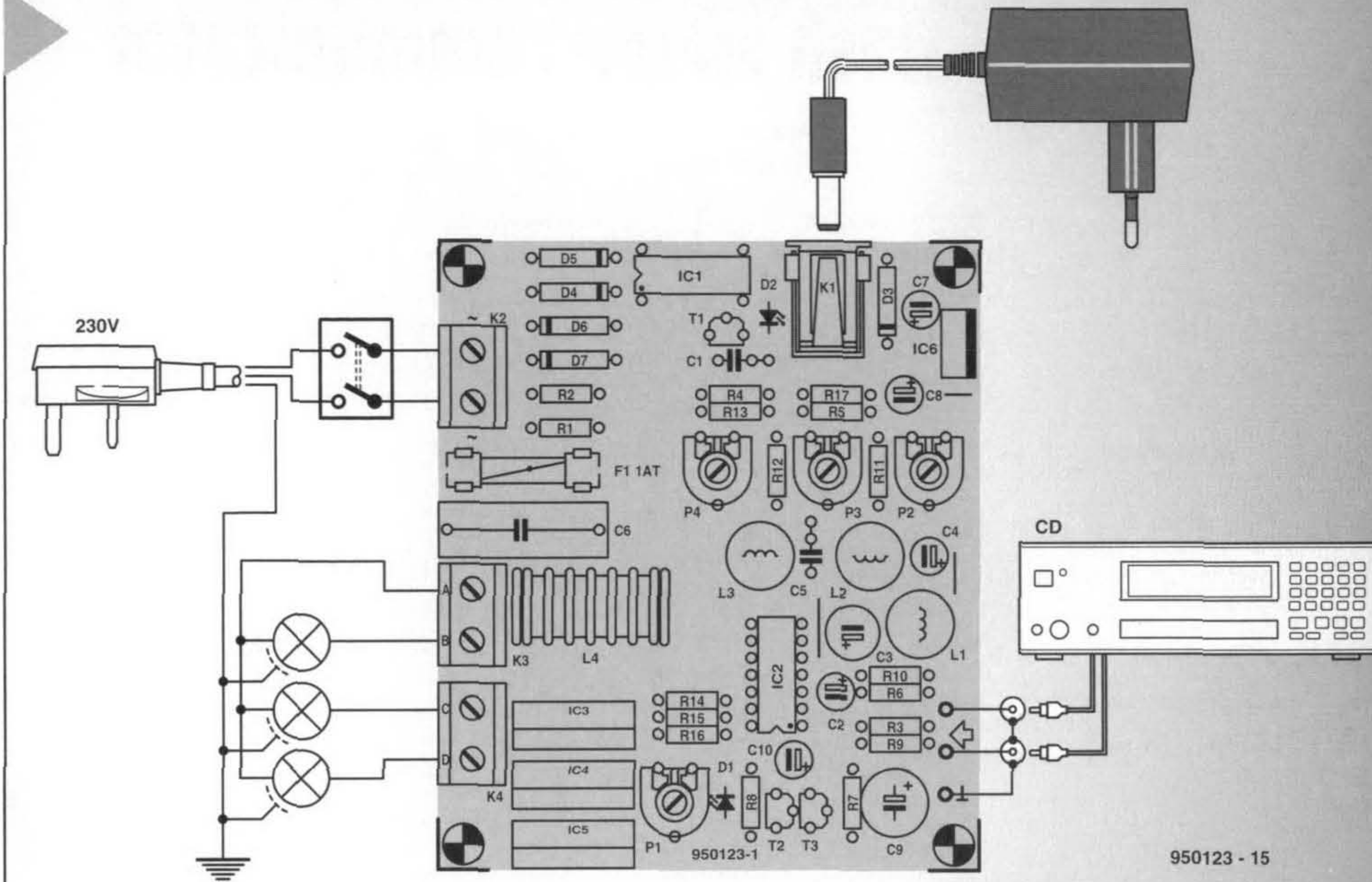
Start with the power supply around IC6. Connect the mains adaptor to K1, and check that C8 has about 9 V on it, and C9, 4.5 V. If that is all right, proceed with the input stage. Having finished that section, connect the adaptor again, and apply a music signal to the input. If everything works all right so far, it should be possible to make LED D1 light by adjusting preset P1. Also check the current consumption at this stage. You should measure about 20 mA.

Continue with the rest of the circuit. Take great care to fit any component with the utmost care and precision, as from now on you are building the section of the circuit that operates at dangerous voltages. This section is, roughly speaking, the entire left-hand area on the circuit board.

Having finished the solder work, your board should look like our prototype shown in **Figure 4**. Okay so far? Then connect the mains adaptor to K1 again, as well as the mains voltage to K2, via a properly isolated mains cord. *From here on, proceed with the utmost care.* Use a multimeter to check the voltage across C1. As indicated by Figure 2, this should be approximately 5.94 V. Those of you who have access to an oscilloscope should be able to measure a sawtooth at this point whose highest level is about 7.5 V, while the lowest level is about 4.5 V. Next, the rest of the test points indicated in the circuit diagram may be checked. The indicated voltage levels have been recorded with a high-impedance digital multimeter set to the d.c. range. Your multimeter, too, will ensure that any alternating voltage which may be superimposed on the direct voltage, is levelled out.

THE ENCLOSURE

Having verified that the circuit works properly, you are ready to fit it in a suitable enclosure. Finding one should not be too difficult thanks to the modest size of the printed circuit board. In view of electrical safety, however, it is essential to use an all-metal case which enables the four mains sockets on the



rear panel to be fitted in a reliable and safe manner (see photograph). The prototype was fitted in a metal case type LC850 from Telet (size approx. 200×180×80 mm), which offers plenty of space inside.

The various connections to the board are illustrated in **Figure 5**. A couple of remarks about the connections. The stereo audio signals are applied via a pair of cinch sockets (also known as 'line' or 'RCA style'), which must be isolated with respect to the metal case, and connected to the board via screened cables.

PCB mount terminal block K2 is connected to a double-pole mains switch with an internal on/off indicator (neon lamp). The mains switch is then connected to the mains socket on the rear panel using mains rated cable and isolation materials.

Figure 5 also shows the connection of the lamps (or lamp groups) to K3 and K4. It is recommended to mount three mains 'out' sockets on the rear panel for the lamp cables. These sockets are the same as those used on PCs for connecting the monitor. Don't forget to link all earth terminals on the sockets (including the mains-in socket), and run the earth wire to a tag on the metal case.

Finally, the introductory photograph shows the built-up prototype of the sound-to-light unit.

Adjustment and use

Adjusting the circuit is a piece of cake. The sound-to-light unit is switched on, the lamps are connected, and a music signal is applied to the audio inputs. If you haven't done so already, adjust preset P1 until LED D1 just lights. Next, adjust the filter presets, P2, P3 and P4, until the lamps respond to the music as you want them to. That's all.

Some of you may wonder why P1 through P4 are presets rather than potentiometers. The reason for this choice is that modern signal sources like CD players and DAT recorders supply signal levels which are far more constant than, for example, an old-fashioned record player. Thanks to the constant signal level, a continuously variable adjustment is not necessary.

To close off the story, a remark about the maximum power of the lamps connected to the circuit. To remain on the safe side, we recommend a fuse with a rating of 1 A. That allows one 75-watt lamp to be connected to each channel. The PCB and the opto-triac are, however, capable of handling more power. The maximum allowable fuse rating is 2 A, allowing lamps with a total power of (about) 150 W to be switched by each channel.

(950123)

Figure 5. Illustrating the connection of the external elements to the printed circuit board.

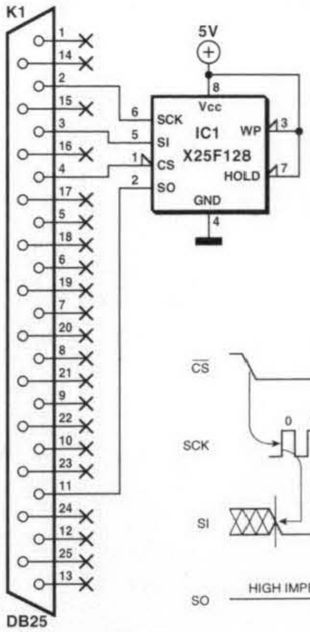
flash EEPROM communicator

Modern equipment frequently uses serial EEPROMS to store data that must not be lost in case of a supply failure. Examples are calibration settings and programming data in TV channels in television receivers and recorders.

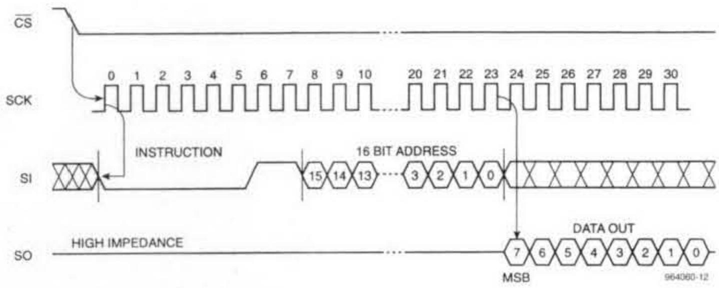
Xicor produces flash EPROMS which are inexpensive, require little energy, and are easier to program than serial EEPROMS. Models vary from a 1K×8 bit (X25F008) to a 16K×8 bit (X25F128).

With the circuit shown, it is possible to program or read such an IC via the Centronics port of a computer. Since the serial interface of a flash EPROM is identical to that of an EEPROM, the two devices can communicate with one another. This means that the present circuit can be used for either device.

There are two differing serial protocols: there are types with an I²C bus (the 24 series), and there are types with a 2-wire bus that consist of a clock, an input line and an output line for the data. Together with an earth return line, the latter type thus requires four lines. The present circuit is intended for this type only. A suitable circuit for an I²C bus can be found in *305 Circuits* ('I²C parallel printer port adaptor' – circuit 057, p. 85). Also, there is an 'I²C interface for Centronics port' on p. 10 of our February 1996 issue.



The circuit needs little comment. The IC is enabled via CS (Chip Select). The command 'read' followed by the address that needs to be read is set on to the SI input. For each data bit a leading clock edge needs to be generated, whereupon the data appear at the SO output.



The interface will work correctly at most Centronics ports. If during use the logic high level is a little low, some 4.7 kΩ pull-up resistors may be added between the Centronics outputs and the positive supply line (not SO line).

The manner in which a computer can control the Centronics port was described in 'Cenrtonics interface' in our April 1996 issue.

Full information on these ICs is available from Xicor in the USA: telephone 001 408 943 0655; fax 001 408 954 1627 or via the Internet: http://www.xicor.com.

[Xicor Appl. - 964060]

temperature monitor

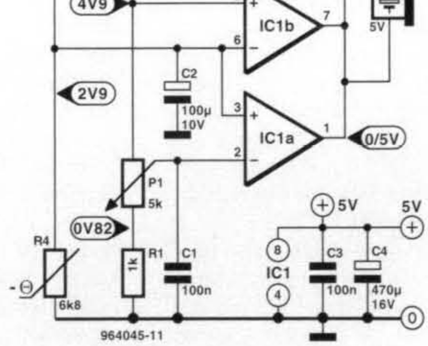
This monitor is used by the author to guard the microprocessor in his PC. The temperature sensor is a resistor, R_4, with negative temperature coefficient—NTC. As is known, the resistance of such a resistor drops when its temperature rises.

Resistors R_4 and R_3 are part of a resistance bridge whose variable branch consists of R_1, R_2 and P_1. The metering diagonal is connected to the inputs of comparator IC_{3a}.

The voltage at the inverting input of IC_{3a} is set with P_1 to a level that with normal temperatures is a little lower than that at the non-inverting input. When the temperature rises, the resistance of R_4 falls, and this causes the potential at the non-inverting input to drop below that at the inverting input. This results in the comparator changing state (to low), which causes the piezo buzzer to sound.

Strictly speaking, IC_{1b} is superfluous, but, after all, the LM393 is a dual op amp. Its output is permanently high, which, owing to the absence of a pull-up resistor (the KM393 has open-collector outputs), has no effect and cannot cause conflicts with IC_{1a}.

Care should be taken to ensure that the voltage across the metering diagonal does not drop below 3.5 V to prevent the common-mode dynamic range of the LM393 being exceeded.



The NTC may be a 5 kΩ or a 10 kΩ type, since the operating range of P_1 is sufficiently large. However, it must be in good thermal contact with the heat source. Preset P_1 must be set to a position where, after the part or device being monitored has attained normal operating temperature, the buzzer just does not sound.

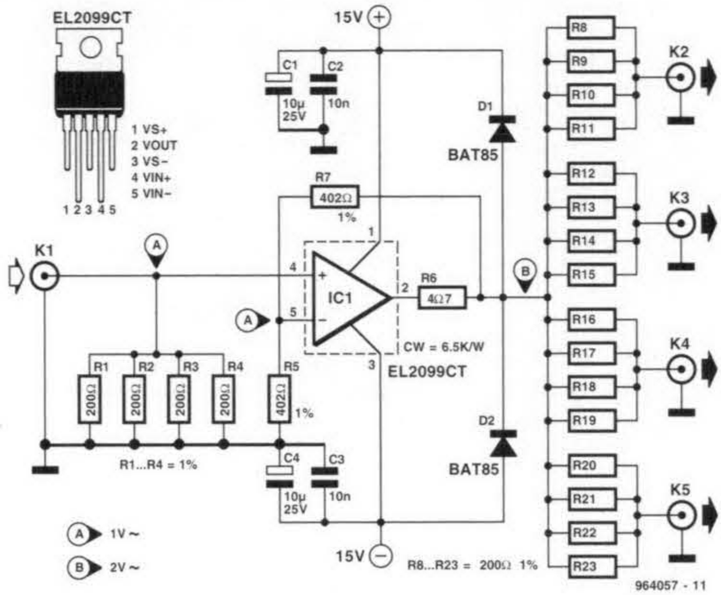
The buzzer must be a 5 V type: a 12 V type will not do. The circuit in the quiescent state draws a current of only 2 mA but, when the buzzer operates, this rises to about 20 mA.

[K. Viernickel - 964045]

power buffer for function generator

Although designed as a robust, wideband output driver for the MAX038-based Function Generator described in the June 1995 issue of *Elektor Electronics*, this buffer circuit may be used as an output booster for any other function generator which has to be extended in order to drive several loads.

The heart of the circuit is a video distribution amplifier IC from Elantec, the EL2099CT (listed by RS Components). This interesting device has a 3-dB power bandwidth of no less than 65 MHz at a gain of ×2. Here, it is used to drive up to four 50-Ω loads at a maximum signal level in excess of 10 V_{peak}. When used for video applications, the EL2099T may drive up to six 75-Ω loads.



The gain of the amplifier is 2 times, unity gain is not possible because of instability problems. The bandwidth of the circuit shown here is >10 MHz, while the output achieves a drive margin of >10V_{peak}. Curremnt consumption will be of the order of 200 mA.

To allow for the dissipation, the 50-Ω matching resistance on each output is formed by four parallel connected 200-Ω resistors. The 1% MRS25-series resistors used here have a maximum dissipation of 0.6 watt each. These resistors are supplied by Philips Components.

The input impedance is matched to 50 Ω is a similar way by four parallel resistors. These may be omitted, however, if the cable between the source and the buffer is relatively short.

Resistor R6 and diodes D1 and D2 form a protection circuit. Depending on the anticipated degree of overloading, the diodes may be replaced by higher power types.

[H. Bonekamp - 964057]

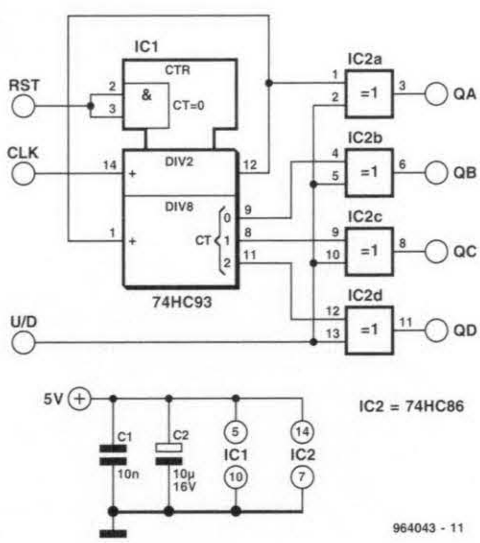
up/down counter with XOR gates

This circuit shows how a regular 4-bit binary counter may be extended with an up/down function just by adding four XOR (exclusive-OR) gates.

The principle is simple: the level at the commoned inputs of the XOR gates determines whether the gates invert the counter's Q_A-Q_D output levels or not. In this way, the outputs of the XOR gates can be made to cycle from 1111 down to 0000 instead of 0000 to 1111.

The disadvantage of this *ersatz* circuit over a real up/down counter is the jump which occurs when the level on the U/D control input is changed. The sum of the 'old' state and the 'new' state is always 15. For example, if the counter is at state '3' in count-up mode, the state becomes '12' when the U/D line is made logic high to initiate down counting.

[H. Bonekamp - 964043]



phase correction for low-pass filter

In some applications it may be desired, or even essential, that the bandwidth of the audio signal is limited, but that the phase relationship with the original signal is retained. A surround-sound encoder is a good example of this.

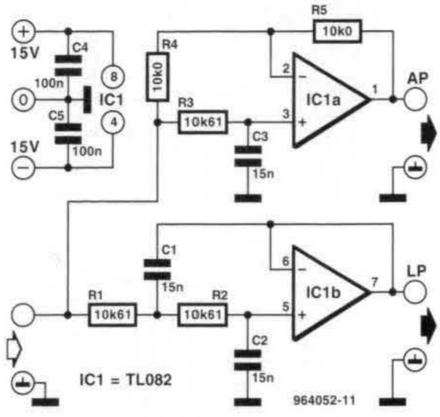
The requirement can be met by combining the low-pass filter with an all-pass section and having the filtered signal compared with the signal corrected by the all-pass network.

As it happens, the phase transfer of a 1st order all-pass filter is exactly the same as that of a 2nd order critically damped network.

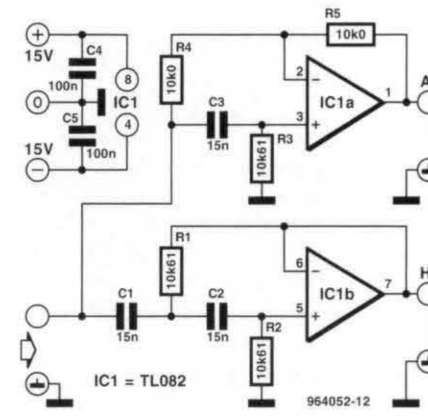
The design of such a combination is shown in **Figure 1**. In this, the all-pass network is based on IC_{1a} and the low-pass section on IC_{1b}. The –6 dB cut-off point is at exactly 1 kHz, and the –3 dB roll-off is at 642 Hz.

The critically damped filter may, if desired, be replaced by a Butterworth type. The value of R_1 and R_2 is then 11.25 Ω that of C_1 becomes 20 nF, and that of C_2, 10 nF. The Butterworth filter is compensated at exactly the –3 dB point by the all-pass filter. A factor 2 or 3 above and below the –3 dB point, the phase shift is not more than ±10°.

1



2



With a Bessel filter, the shift is not more than ±5°. The cut-off point of the filter with respect to that of the all-pass network must be lowered to 786 Hz. This requires component values as follows: R_1 = R_2 = 12.74 kΩ; C_1 = 14.43 nF; C_2 = 10.82 nF.

Figure 2 shows that a 2nd order high-pass section can be corrected in the same way. The only difference is that R_3 and C_3 have changed places. The high-pass filter may also be either a Butterworth or a Bessel type.

Any good op amp may be used. The specified TL082 is only an example. The current drawn by this type is about 4 mA.

In the practical setup take care to ensure that the source at the input is d.c. coupled, otherwise the bias settings of IC_{1a} and IC_{1b} are wrong.

[T. Giesberts - 964052]

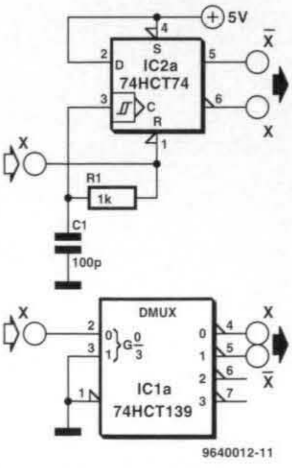
D-bistable as inverter

The interesting point of this circuit is that a D-type bistable is used as an inverter. When the level at the input changes from high to low, the bistable is reset and its Q-output goes high. When the input becomes low, the reset is removed and the Q-output goes low.

The delay introduced by network R_1-C_1 between the reset input and the clock input makes it possible to trigger the bistable at the leading edge of the input signal. As an example, in the case of a dual D-bistable Type 74HCT74, the time needed for a clock pulse to be accepted after the reset has been removed is 5 ns. Therefore, an *RC* network introducing a delay of 7.5 ns, gives a reasonable safety margin.

The reduced edge gradient of the clock pulse does not create any problems since the maximum allowed rise time of the clock input is 500 ns.

To obviate asymmetrical output signals, it is advisable to limit the input frequency to about 1 MHz with component values as specified.

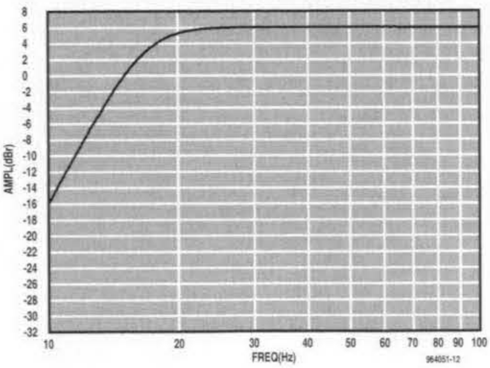


An alternative way of building an inverter is the use of a Type 74[HC(T)]139 line decoder, which does not require any external components. The input signal is applied to the A-input, whereupon the inverted and non-inverted signals may be taken from the $\overline{X}$ and X outputs respectively.

[A. Rietjens - 964012]

subsonic filter

1



The strong point of the recently published 'surround-sound subwoofer' is that its frequency response is straight down to 20 Hz. Such excellence has another side as well, however. In the article mentioned, it was achieved by additional amplification of the low tones, rising to as much as 10 dB at 20 Hz. This means that there is still appreciable amplification below 20 Hz; it is only below 10 Hz that attenuation begins to occur.

This may result in the loudspeaker being overloaded at high input signals. This is not very likely with standard recorded music, where frequencies below 30 Hz are rare. However, with surround-sound recordings, frequencies down to 5 Hz (!) are no exception. If the subwoofer is to handle surround sound, it is, therefore, no luxury to add a filter that gives additional attenuation below 20 Hz.

The present filter does just that. It is a 5th order high-pass section that provides 1 dB attenuation at 20 Hz, but below that the response drops off very steeply. The –3 dB point is at 17.3 Hz, and 13.6 Hz, the attenuation is 10 dB. The response curve is shown in **Figure 1**.

The circuit of the filter is given in **Figure 2**. Note that it is important that C_1–C_5 are within 1 per cent of one another. Their individual tolerance is not so important, since that merely affects the cut-off point. However, mutual deviations adversely affect the shape of the response, which should be a Butterworth characteristic as specified.

All resistors are 1 per cent types. Optimum correction is obtained if R_{31} in the subwoofer filter is replaced by a wire bridge.

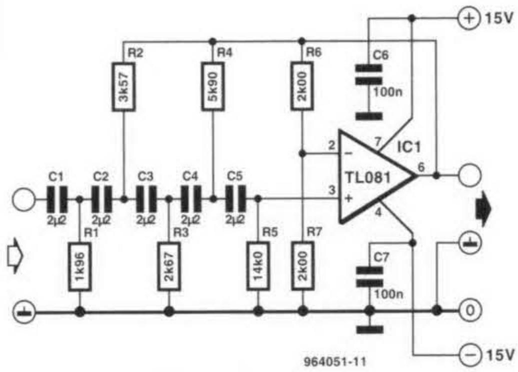
The present filter draws a current of about 2 mA.

The circuit may be improved by the use of (expensive) polypropylene capacitors for C_1–C_5.

In principle, the filter may be used for other purposes as well. As a stereo construction, it may, for instance, be interjected between a preamplifier and power amplifier to safeguard standard loudspeakers against subsonic signals.

[T. Giesberts - 964051]

2

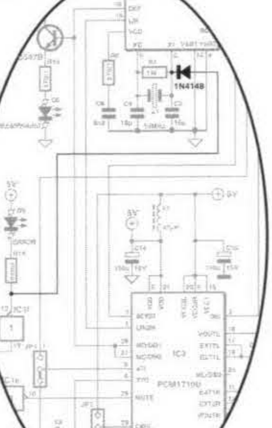


mini audio DAC upgrade

The upgrade consists of just a diode, but, if the internal system clock is used, it gives an improvement of some 6 dB in the THD+N measured over a bandwidth of 30 kHz.

The problem that is remedied with the upgrade was already known at the time the mini audio DAC was published. It appeared then that the crystal oscillator interferes with the system clock generated by an internal *RC* oscillator. Therefore, an oscillator frequency of 16 MHz was chosen since this has no connection with the sampling frequencies. In practice, however, it proved not sufficient.

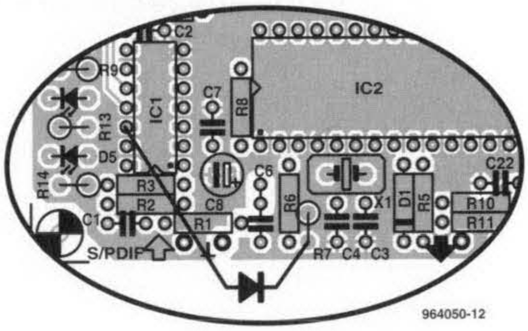
1



It has been found that there is only one way of preventing this interference and that is by disabling the crystal oscillator at the moment no error occurs and the signals are processed normally. However, during start-up or interrupting the input signal, this clock remains needed.

The solution lies in switching the oscillator on and off with the aid of a diode via the buffer for the error LED as shown in **Figure 1**.

2



When the error output of the YM3623B is high, the diode is reverse-biased and the oscillator functions normally. When the error output goes low, however, input XI of the oscillator (pin 6) is connected to a constantly high level via the diode, whereupon the oscillator stops.

The upgrade is simple and may be carried out at the component side of the board. The diode is soldered between pin 12 of IC_1 and R_7 as shown in **Figure 2**. It is advisable to fit the diode as close to R_7 as possible, so that there is no long 'antenna wire' added to IC_2. It is, however, much neater to carry out the modification at the track side of the board. Then, the cathode of of the diode can be soldered directly to pin 6 of IC_2. The anode terminal must be insulated before it is soldered into place.

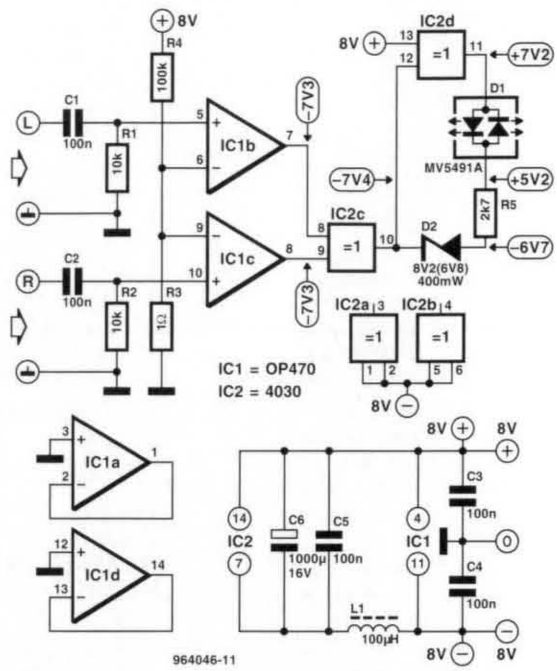
[T. Giesberts - 964050]

surround sound indicator

The proposed circuit indicates with the aid of two LEDs whether or not the input signal contains surround data. The criterion for this is the phase difference between the two channels: if this is zero, there is no surround data.

In the circuit diagram, if there is a phase difference between the two channels, the output levels of comparators IC_{1b} and IC_{1c} will differ. These outputs are constantly compared by XOR gate IC_{2c}, and, in case of a difference, the output of the gate will go high. Depending on the output state, the red or green half of D_1 will be actuated via gate IC_{2d}, which is here connected as an inverter. In case of a pure surround signal, the red half will light brightly; in case of a mono signal, the green half will. If the input is a standard stereo signal, the rapid changes in the output of IC_{2c} will cause the diode to appear yellow-orange.

The circuit is an improved version of the design published in our January 1995 issue. There are two worthwhile improvements. The first is that the comparators are now Type OP470. To make sure that the comparators react satisfactorily with small input signals, the offset in the older version had to be greater than 15 mV. With the OP470, an offset of a few mV is sufficient, so that R_3 is now only 1 Ω. The value of this resistor is determined by the requirement that the outputs of the comparators must be low (≈ –7.3 V) in the absence of a signal. If this does not happen with 1 Ω, the value of R_3 may be increased by a couple of E12 values.



The second improvement is the addition of D_2. This is because brightness of the red and green halves of the LED used here differ from one another when the currents through them are equal. This results in the stereo indication being far too red. The additional diode acts as a zener for the red half and as a normal diode for the green half. The best rating for it appears to be 6.8 V or 8.2 V.

The circuit draws a current of about 15 mA.

Inductor L_1 and capacitors C_5 and C_6 have been added to prevent IC_2 affecting the operation of the comparators via the supply lines.

A final note. Internally, there is a diode limiter between the inputs of the comparators which clips input signals above about 1 V. If, therefore, input signals higher than, say, 700 mV are expected, it is advisable to connect a resistor of a few kilo-ohms in series with C_1 and C_2.

[T. Giesberts - 964046]

camcorder battery protection

Many camcorder enthusiasts use their spare battery for powering video lights. Many such lights give no indication when the battery has gone flat, so that there is a risk of one or more of the battery cells reversing polarity. When that happens, the battery is a total write-off.

This unhappy circumstance can be avoided by the use of the proposed protection circuit. When this gets switched on, the potential across C_1 is zero, so that T_2 is cut off, the relay is inactive, and the indicator lamp lights. As long as the battery voltage remains above a certain level, T_1 is on and holds the base of T_2 at earth potential. In this state, only a small current is drawn.

When the battery voltage is no longer higher than the sum of the zener voltage, the potential set by divider R_2-P_1, and the drop across the base-emitter junction of T_1, this transistor is cut off, whereupon C_1 is charged via R_2.

When the potential across C_1 has risen to a value high enough for T_2 to be switched on, the relay is energized, and its contact disconnects the lamp from the battery. Since the current drain (≤ 70 mA) is then determined almost entirely by the relay, it is essential to remove, or disconnect, the battery from the light unit.

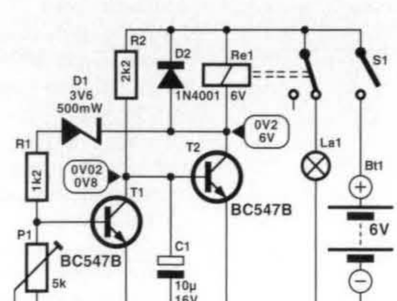
Capacitor C_1 has a further important function: at the moment of switch-on, it holds T_2 cut off and short-circuits the brief voltage dip caused by the starting current peak through the halogen lamp. This allows T_1 to begin to conduct gradually.

The switch-off voltage level, set with P_1, should be about 1 V per battery cell.

Suitable adaptation of D_1, R_1, and Re_1 allows the circuit to be used with batteries with different e.m.f., such as those used in portable tools.

The rating of D_1 should be about 70% of the switch-off potential. At the switch-off voltage, the current through R_1 should be about 1 mA, and in that condition, the relay must be energized.

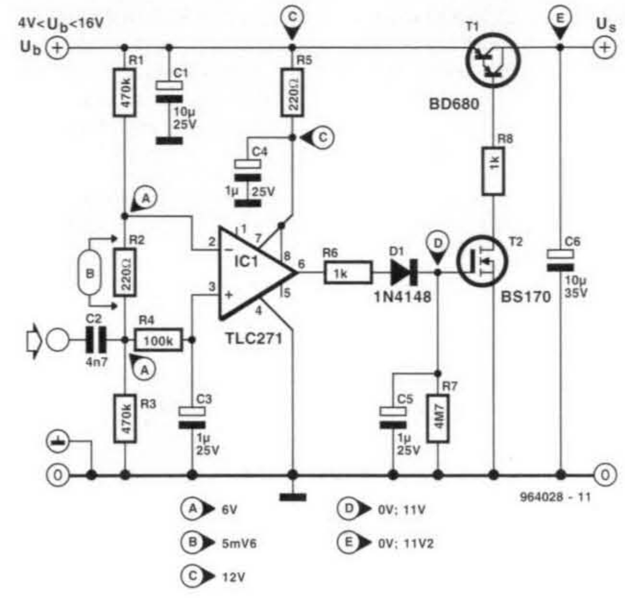
[H-R. Tuch - 964056]



signal-controlled switch I

The signal-controlled switch actuates or deactuates a.f. equipment, including preamplifiers, power amplifiers, and filters. It is particularly useful for battery-operated equipment since, owing to the low current drain of 12–14 μA, there is no need to switch the a.f. equipment off. When the switch has not detected any a.f. signal for ten seconds, it switches off the supply to the equipment.

The circuit is based on a Type TLC271 op amp from Texas Instruments. This device has a BIAS SELECT connection (pin 8) at which the current drain and the transfer ratio can be set. The IC draws least current (about 10 μA) when it is used as a comparator (pin 8 at the +ve supply line).



In the quiescent state, both inputs are held at about half the supply voltage by potential divider R_1–R_3. However, owing to R_2 that at the inverting input is very slightly higher than that at the other input. This ensures that the output of the comparator is held low. If there is no voltage at its gate, T_2 remains off, so that T_1 is also off. The divider and C_2 form a high-pass filter that prevents the circuit being actuated by low-frequency interference, such as mains hum.

When a low-frequency signal at not too high a level is applied to the inverting input, it will also reach the non-inverting input, but via high-pass section R_4-C_3. Since this *RC* network averages the signal, an additional voltage results between the two inputs. When the level of this signal exceeds about 65 mV, the potential at the non-inverting input is lower than that at the inverting input during negative half cycles, which results in the comparator changing state (output becomes high). Capacitor C_5 is then charged via R_6, whereupon T_2 is switched on, so that a sufficiently high I_{BE} flows into T_1, which is then also switched on. When the collector current of T_1 reaches a value of 1 A, the U_{CE} is some 0.8 V.

In the absence of an input signal, the output of the comparator goes low again, whereupon C_5 is discharged via R_7 until its potential drops below U_{GS}, whereupon T_2 is cut off.

The prototype took 10 s to switch off the controlled equipment, but this time span can vary widely owing to the high tolerances between individual FETs.

If the load currents are regularly larger than 1 A, it is advisable to use a higher-rating darling transistor so as to keep the dissipation low.

[C. Auerswald - 964028]

sample & hold for U2402B

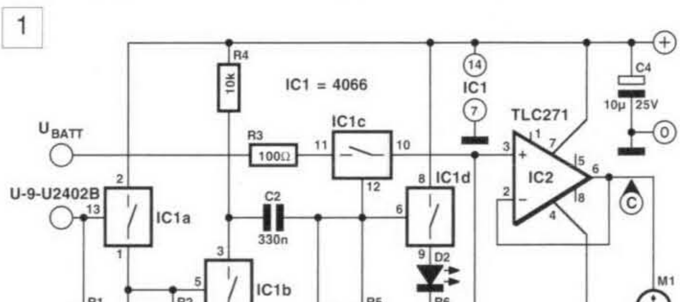
The rapid charger published earlier this year was based on the ubiquitous Type U2402B IC. The charger was able to fully charge four AA batteries in an hour and at the same time to observe caution as regards the useful life of the batteries.

The only thing that the charger really could do with is a display of the way the charging process is going on. The present article puts this right with a sample & hold (S&H)circuit and a moving coil meter or a DVM module.

The U2402B charges the batteries with 20 s current long pulses, alternating with 2.56 s intervals. An instant after the interval has begun, a 10-ms pulse appears at pin 9, which may be used for test purposes. In the present circuit, this pulse is used as a switching signal. After about one second, this signal arranges for the instantaneous battery voltage, U_b, to be applied to the meter via S&H circuit IC_{1c}-C_3 and buffer IC_2. That is, the voltage is displayed during the intervals between two charging pulses.

The delay time and the sample time are arranged by two CMOS switches, IC_{1a} and IC_{1b}. The fourth part of the device, IC_{1d}, arranges an LED to light during the measurement period.

1

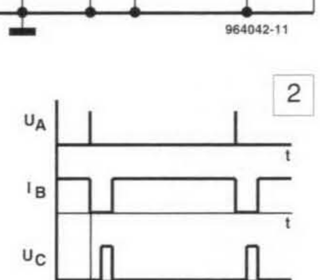


The more important signals are shown in the timing diagram in Figure 2. In this, U_A is the pulse present at pin 9 of the U2402B at the onset of the interval; I_B portrays the interruptions in the charging current pulses; and U_C is the signal applied to buffer IC_{2b} by the S&H.

The time interval between the appearing of the pulse at pin 9 and the actuating of the S&H switch is determined by the time constant R_2-C_1. The measurement period is determined by time constant R_5-C_2.

[H. Bonekamp - 964042]

2

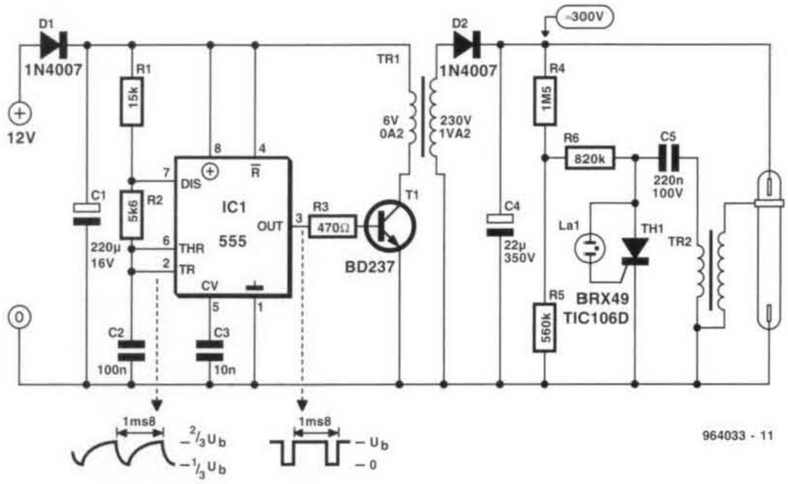


12 V stroboscope

There are inexpensive stroboscopes on the market that can be screwed directly into an E27 socket. Such devices already have the circuit to the right of mains transformer Tr_1 in the diagram. To enable the stroboscope to be operated from 12 V, a 12-240 V converter needs to be fitted inside the housing.

The circuit of the converter is simplicity itself. Diode D_1 is a polarity protection device that may be omitted. A 555 is used as an astable with a frequency of about 0.7 Hz. When T_1 is on, a current flows through the 6 V winding of Tr_1. The voltage across the 240 V winding must be such that D_2 does not conduct. This may be ensured with the aid of an oscilloscope. When the collector voltage of T_1 is nearly 0, the potential at the anode of D_2 must be negative. When T_1 becomes reverse-biased, its collector voltage rises to about 12 V and the potential at the anode of D_2 must then be positive, so that C_4 can be charged. Check these voltages, but carefully—they may be lethal!

about 300 V. This causes a potential at junction R_6-C_5 of about 100 V. The neon lamp then comes on, so that a gate current flows into the thyristor. This comes on and clears the way for C_5 to discharge through Tr_2. This starting transformer produces a secondary voltage of a few thousand volts. This is sufficient for the xenon tube to strike and at the same time discharge C_4. From then, the operation can start again.



Never operate the convertor without a load. It is, perhaps, advisable to shunt C_4 with a 100 kΩ, 1 W, resistor. The convertor charges C4 to

The circuit draws a current of about 250 mA, but this depends on the flashing rate and the type of xenon tube.

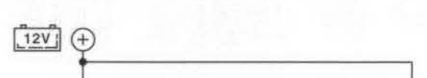
[I. & W. Wassermann-Ruch - 964033]

day running lights

In many countries, there is a legal requirement for cars and motorcycles to have lights on whenever the vehicle is moving. In even more countries, this has become a (very sensible) custom, which may well become a legal requirement in the near future. For these reasons, many vehicles have provision for (automatic) day running lights, while in others, there is a third position on the lights switch for switching on these lights. Day running lights are neither side lights nor dipped headlights; rather, they use the headlights at reduced power (normally 75%).

Motorcycles and cars not equipped with (automatic) day running lights can be so equipped with the present circuit.

The circuit is connected to the oil pressure indicating light. When the engine is not running, the contacts of the oil pressure sensor in the engine block are closed. When the ignition is then switched on, the oil pressure light comes on. The potential at *A* is then low and nothing happens.



When the engine is running, oil pressure builds up, whereupon the contacts open and the indicator light goes out. The potential at *A* is then high, so that T_1 comes on and the relay becomes energized. The relay contact in series with the headlights closes, so that the headlight is switched on. When the engine is switched off, the relay is deenergized and the headlights go out.

Although some dexterity is needed, the circuit can be built in fairly easily. It is powered from the terminals of the oil pressure indicator light. The contact of relay Re_1 is best connected in parallel with the lights switch.

[J. Bosman - 964019]

power supply for handheld rigs

This circuit is based on the well-known LM350T voltage regulator from National Semiconductor, and largely follows the standard application circuit. This power supply is useful for 'base' use of all sorts of hand-held transceivers like CB walkie-talkies, 2-m VHF 'ham' rigs, etc.

The supply has a current capacity of about 3 A, and supplies either 8.6 V or 13.6 V. The output voltage is selected with a double-pole changeover switch, S1a-b. The available voltages are standard for a lot of portable communication equipment around these days.

The rectifier diodes, D1 and D2, have anti-rattle bypass capacitors, C4-C5, which serve to suppress noise. For extra hum suppression a choke is inserted in the input voltage rail to the regulator. This inductor consists of 12 turns of 20SWG enamelled copper wire of a type 12A ferrite ring core. This choke should have a current rating of at least 4 A. Diode D3 discharges the energy stored in the choke the moment the rectifier stops conducting, by providing an alternative path for the current flowing in the choke.

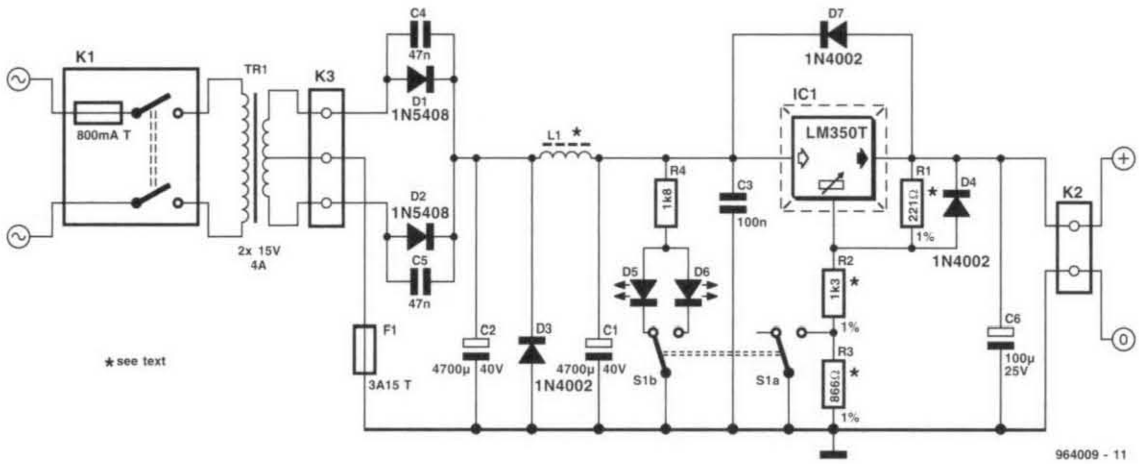
The output voltage, U_{out}, of the circuit is calculated from

$$U_{out} \approx 1.25\left(1+\frac{R_2+R_3}{R_1}\right).$$

Because the reference voltage of the LM350T is subject to a fairly large tolerance (1.2 V to 1.3 V), the actual output may differ a little from the calculated voltage.

To enable the supply to be kept as compact as possible, it is best to use a toroid mains transformer. Also, for optimum suppression of mains noise, it is recommended to use a mains filter.

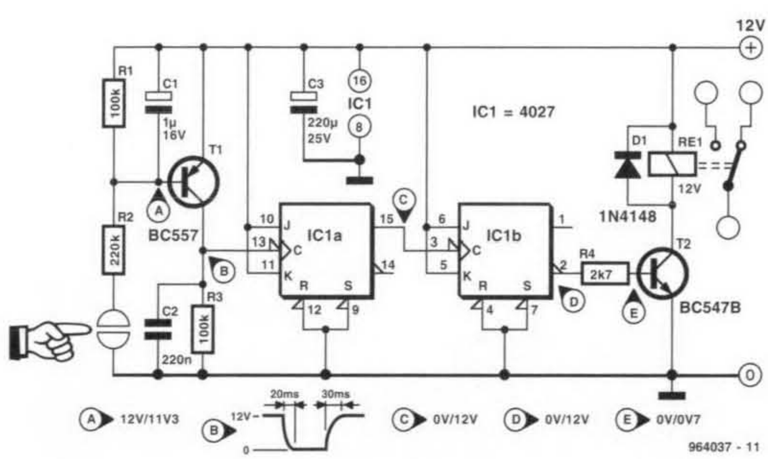
[N.S. Harisankar - 964009]



touch switch with toggle

The advantage of a touch switch over a traditional, mechanical, switch is that its operation is not degraded by wear and tear.

Upon touching the touch-plates with your finger, transistor T1 (a pnp type) starts to conduct. The resulting pulse at the clock input of the 4027 has very slow edges (because of C1 and C2). Consequently (and unusually), the first J-K flipflop in the 4027 then acts as a Schmitt trigger gate which converts the rather slow pulse at its input (pin 13) into a clean digital signal which may be applied to the clock input (pin 3) of the second flipflop. The second flipflop then works according to the textbook, supplying a real toggle signal that may be used to switch a relay on and off via a driver transistor, T2. The relay toggles any time you put your finger on the touch-plate.



Current consumption of the circuit is less than 1 mA with the relay off, and up to 50 mA with the relay on. Any relay which is more economical may be used, a long as its coil voltage rating is 12 V. When switching a mains apparatus, however, use a relay with properly rated contacts.

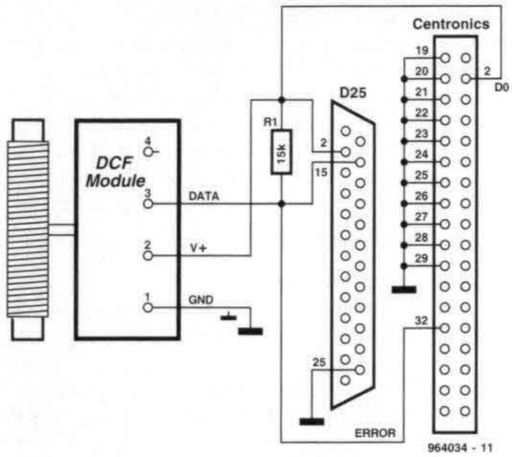
[Pradeep G. - 964037]

DCF77 time decoding software

This program is the result of some research into decoding the time signals transmitted by DCF77 (in Germany) with the aid of a personal computer. The DCF77 time signal transmitter is located near Frankfurt, and has a range of about 1,500 km.

Before the software can produce meaningful output, the hardware has to be set up. Here, an inexpensive DCF77 receiver module type BN641138 from Conrad Electronic is used. The module, which comprises an antenna and a complete receiver/demodulator, is connected directly to the PC's Centronics port via three wires. The Conrad module draws so little current that it can be powered from a Centronics data line (here, D0) which is made logic high permanently. The output of the module is an open-collector stage, hence the use of a pull-up resistor, R1. The demodulated time information is read by the PC as 0's and 1's via the Error input line on the Centronics port.

The software is spartan, and written in QBASIC. No attempt has been made to refine it with menus, bells, whistles




```
REM Dipl. Phys. Bernd Oehlerking, Haasemannstr. 4, D-30449 Hannover

DIM t%(65)
COMMON SHARED t%(), s%, k%, switch%, LPT
DECLARE SUB decode ()
DECLARE SUB measurelow ()
DECLARE SUB measurepulse ()
DECLARE SUB findstart ()

k% = 1
sp% = 1
zz% = 4
LPT = &Hxxx

CLS
LOCATE 1, 10: PRINT ">> DCF77 <<  Waiting for sync. (max. 1 min)."

OUT LPT, 1: REM POWER UP
REM goto labl
lab:
  findstart

labl:
  a = TIMER
  measurepulse
  b = TIMER
 REM  LOCATE 10, 10: PRINT (d - c) * 10

  IF (d - c) * 10 > 15 THEN
  i% = 0: k% = 1: switch% = 1
  LOCATE 1, 1: PRINT SPACE$(70)
  LOCATE 3, 1: PRINT SPACE$(65)
  LOCATE 2, 21: PRINT " DCF77 DEMO BY BERND OEHLERKING "
  LOCATE 4, 17: PRINT "e..Unit    m..Minute     h..Hour   BCD -
CODE!!"
  END IF

  IF (b - a) * 10 < 1.5 THEN
  LOCATE zz% + 2, i% + sp%: PRINT CHR$(220)
  LOCATE zz% + 3, i% + sp%: PRINT "0": Bit% = 0
  LOCATE zz% + 4, i% + sp%: PRINT STR$(i%)
  i% = i% + 1
  END IF

  IF (b - a) * 10 >= 1.5 THEN
  LOCATE zz% + 2, i% + sp%: PRINT CHR$(219)
  LOCATE zz% + 3, i% + sp%: PRINT "1": Bit% = 1
  LOCATE zz% + 4, i% + sp%: PRINT i%

  i% = i% + 1
  END IF
  t%(k%) = Bit%: k% = k% + 1: LOCATE 10, 45: PRINT " : "; i% - 1
  LOCATE 23, 50: PRINT "PC internal TIME --> "; TIME$
  IF k% = 60 THEN decode
  IF i% > 21 THEN IF i% < 26 THEN LOCATE zz% + 2, i%: PRINT "e"
  IF i% > 25 THEN IF i% < 29 THEN LOCATE zz% + 2, i%: PRINT "m"
  IF i% > 29 THEN IF i% < 34 THEN LOCATE zz% + 2, i%: PRINT "e"
  IF i% > 33 THEN IF i% < 36 THEN LOCATE zz% + 2, i%: PRINT "h"
REM IF i% > 22 THEN IF i% < 27 THEN LOCATE zz% + 2, i%: PRINT "e"

  c = TIMER
  measurelow
  d = TIMER
  GOTO labl

SUB decode

FOR i% = 0 TO 3
mine% = mine% + t%(22 + i%) * 2 ^ i%
NEXT i%
REM LOCATE 20, 20: PRINT k%, t%(22); " "; t%(23); " "; t%(24); " ";
t%(25), mine%

FOR i% = 0 TO 2
minz% = minz% + t%(26 + i%) * 2 ^ i%
NEXT i%
REM LOCATE 21, 20: PRINT k%, t%(26); " "; t%(27); " "; t%(28); " ";
t%(29), minz%

FOR i% = 0 TO 3
stde% = stde% + t%(30 + i%) * 2 ^ i%
NEXT i%
REM LOCATE 22, 20: PRINT k%, t%(22); " "; t%(23); " "; t%(24); " ";
t%(25), mine%

FOR i% = 0 TO 1
stdz% = stdz% + t%(34 + i%) * 2 ^ i%
NEXT i%
REM LOCATE 20, 20: PRINT k%, t%(22); " "; t%(23); " "; t%(24); " ";
t%(25), mine%

LOCATE 10, 30: PRINT stdz%; stde%; " : "; minz%; mine%;
mine% = 0: minz% = 0: stde% = 0: stdz% = 0

END SUB

SUB findstart

beg:
f = TIMER
WHILE ((INP(LPT + 1) AND 8))
G = TIMER: IF G - f > 5 THEN GOTO oeps
WEND

b = TIMER
WHILE ((INP(LPT + 1) AND 8) = 0)
WEND
a = TIMER
IF ((a - b) * 10) > 13 THEN GOTO ende

LOCATE 3, i% + 1
PRINT "X"
i% = i% + 1

GOTO beg
oeps: LOCATE 3, 20: BEEP: PRINT "ERROR!! No signal from DCF!"
      LOCATE 5, 20: PRINT "Please check connections and signal!"
ende:

END SUB

SUB measurelow
WHILE ((INP(LPT + 1) AND 8)) = 0

WEND

END SUB

SUB measurepulse
WHILE ((INP(LPT + 1) AND 8))
WEND

END SUB
```

etc. Once started, the program waits for the start bit transmitted by DCF77. This bit is transmitted with the '58' and '60' seconds markers every minute ('59' is omitted).

The program builds the hr:min:sec information in BASIC and puts this information on the screen, along with the time information supplied by the PC's real time clock (*Now's* a good time to adjust it…).

In QBASIC (which should be supplied with any recent DOS package) you press the F2 key to enter and exit subroutines that you think require editing. The tenth line of the program defines the printer port address. Substitute the printer port address in hex for the xxx's. If you don't know the address, have the computer tell it to you — simply run Microsoft Diagnostics (MSD) from the DOS prompt, and make a note of the printer port address. The address is displayed by the DCF77 program if you press 'L' after starting it. Press Control-Break to stop the QBASIC program.

DCF77 transmits CET. To make the program indicate GMT (CET−1) as used in the UK, decrease the variable Stdz% by one just before it is PRINTed. If Stdz% equals −1, then make it '23'.

The author encourages all readers of *Elektor Electronics* who live within the range covered by DCF77 to copy and use the program, provided his name is left in the listing. The author can be contacted at Haasemannstrasse 4, D-30449 Hannover, Germany. Tel. (+49) 511 457123.

[B. Öhlerking - 964034]

chronometer/counter

The chronometer has four 7-segment displays which can show a time lapse of 000.0 s to 999.9 s with a resolution of 0.1 s or a count from 0000 up to 9999.

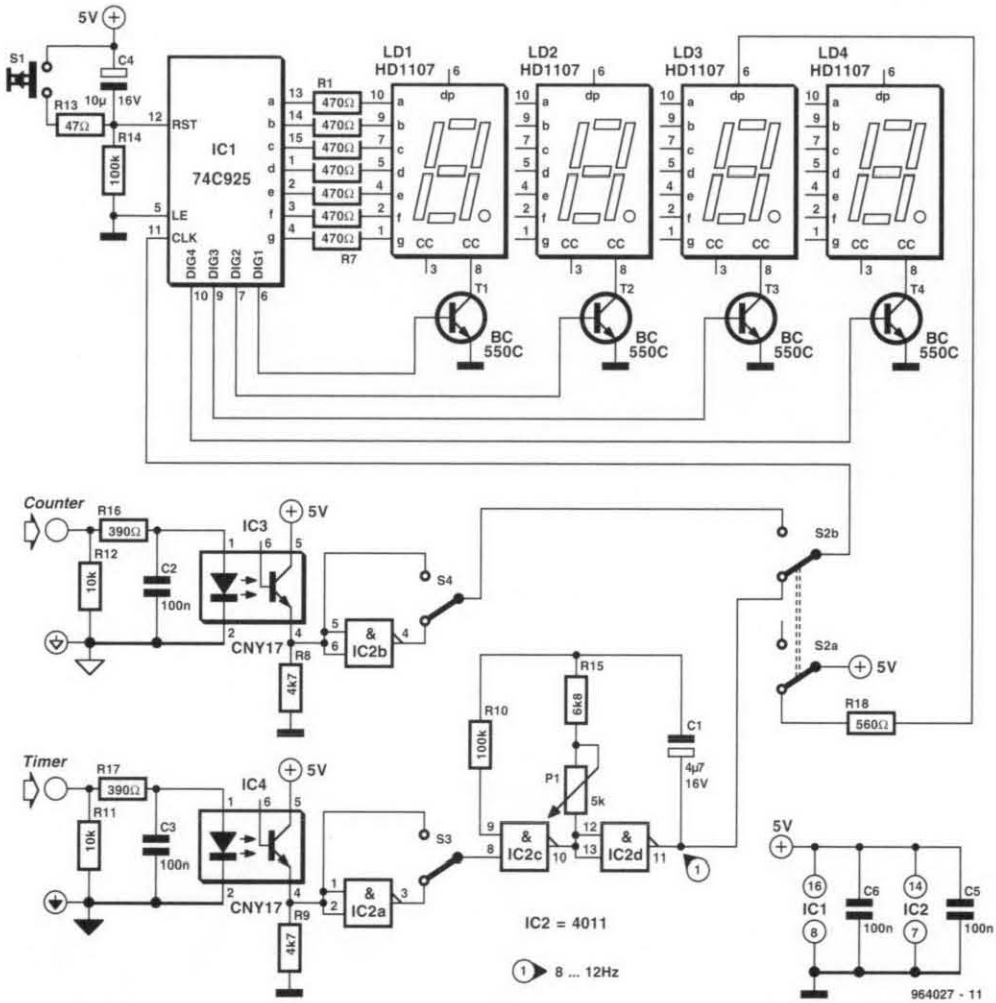
The chronometer is based on the Type 74C925 counter IC with integrated display driver from National Semiconductor. The device draws a current of about 40 mA from a +5 V supply.

On power-up, the counter is set to 0000 by network R_{14}-C_4 or by S_1. The IC can derive a clock from two different sources: the internal oscillator or an external one via the count input.

The oscillator is formed by IC_{2c}, IC_{2d} and is enabled via the CHRON input. The enabling is effected manually by S_3 or by inputting a given level, high or low, depending on the position of S_3, into CHRON. Only when pin 8 is high is it possible to measure an 8–12 Hz signal at the output of the oscillator. This frequency can be set to exactly 10 Hz with the aid of a frequency counter, but, if this is not to hand, also with the aid of a good watch.

Inputs CHRON and COUNT are identical but are separated electrically from one another and from the signal source by optoisolators. This allows input potentials of up to 25 V_{pp} to be applied to either of them.

As with the CHRON input, the level at the COUNT input may be either high or low and is selected by S_4.



The position of S_{2b} determines whether the time or count function is active. Switch section S_{2a} inserts the decimal point between the third and fourth display digit when CHRON is selected.

Whereas a simple level is needed to start the oscillator, the signal at the COUNT input needs more if the module is to work error-free. The signal must have steep edges; it must be free of interference; at low level, it must be well below 1 V; and at high level, it must well above 2 V. Moreover, if a switch is used at the COUNT input, this must be debounced adequately.

[M. Bulet - 964027]

lambda probe monitor

The lambda probe is part of the exhaust system fitted on cars with a catalyser. It is fitted at a location between the exhaust manifold and the catalyser, where it measures the oxygen level in the exhaust gases. Its output signal is used by the injection control to determine the fuel/air mixture at which the catalyser can develop its highest filtering effect.

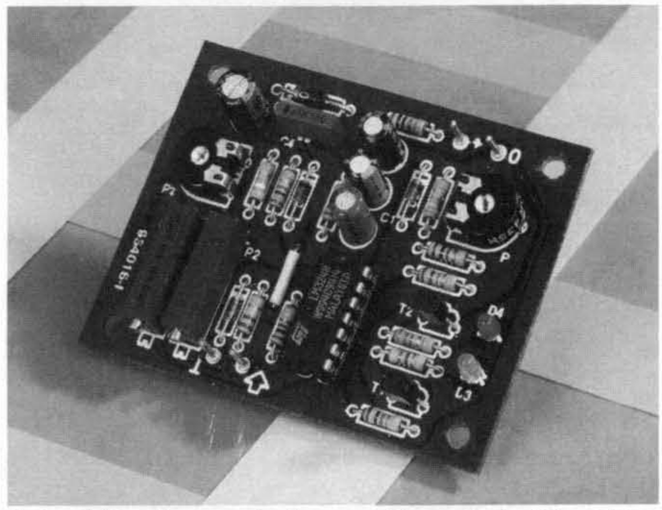
This circuit allows experienced car electric technicians to check the operation of the lambda probe as an essential component in the control loop formed by the injection system.

Depending on the oxygen concentration in the exhaust gases, the so-called lambda voltage has a range of 0 to 0.9 V, with the optimum concentration occurring roughly at the centre of the range. A high lambda voltage indicates an oxygen deficit ('rich' mixture, too much fuel), while a low voltage indicates a oxygen surplus ('poor' mixture, too much air). It should be noted that a lambda probe only responds to changes in the exhaust gas composition at its nominal operating temperature of about 600 °C. The measured lambda voltage indicates one of four conditions:

1. Normal operation. Depending on the response time of the control loop, the lambda voltage shows a certain variation around 0.5 V. Its frequency of between 1 Hz and 5 Hz indicates that the probe is working properly.

2. Probe inactive. A steady voltage of about 0.5 V indicates a fault in the probe or the control loop. It may also indicate that the probe has not yet reached its operating temperature, for example, when the engine is cold, or when you drive downhill for a long time with the throttle closed.

3. Lambda voltage constantly above 0.5 V. The carburettor mixture is too rich. Either the engine is still cold, or the throttle valve is fully opened, and extra fuel is injected at full engine loading. This voltage may also indicate a fault in the injection system, for example, an engine which, although hot in reality, is deemed 'cold' by the electronics because of a faulty temperature sensor.



4. Lambda voltage constantly below 0.5 V. The carburettor mixture has a fuel deficiency (rpm >1500, accelerator not pressed), or the engine has a fault (e.g., insufficient fuel pressure).

The circuit indicates these four conditions by means of a red and a green LED:

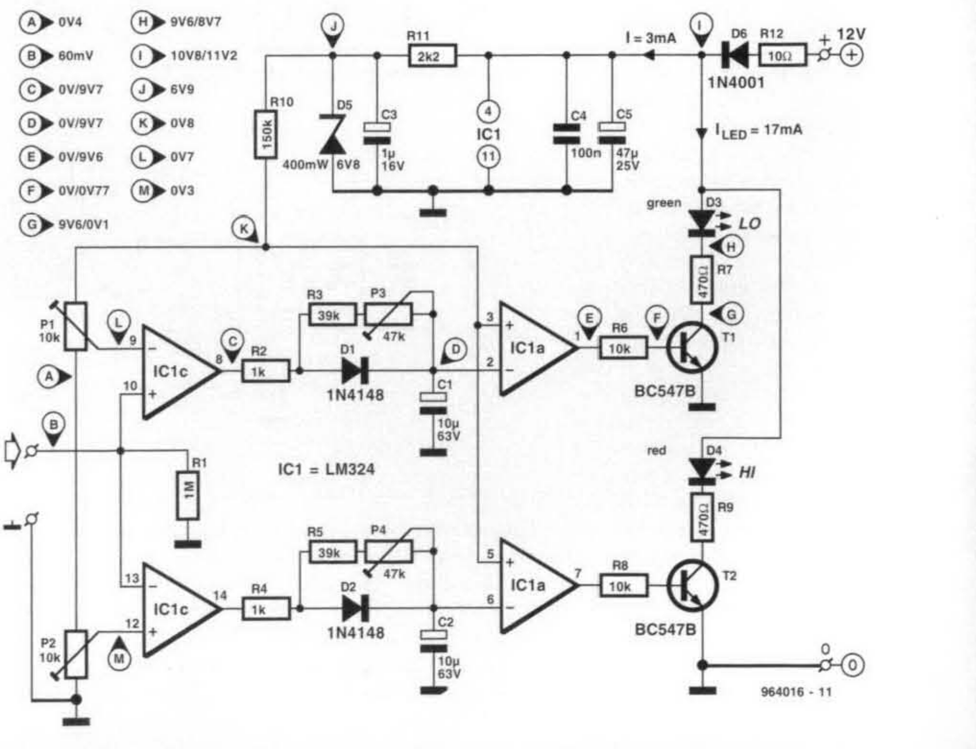
1. Normal operation: no indication, both LEDs off.
2. Probe inactive (cold start): both LEDs light.
3. Rich mixture (extra fuel at full load): red LED lights
4. Poor mixture (throttle valve closed): green LED lights

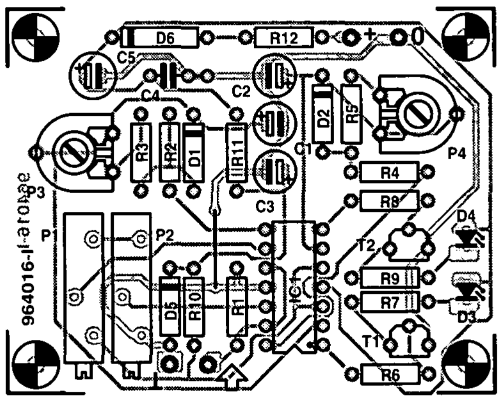
The operation of the circuit is relatively simple. Only commonly available parts are used.

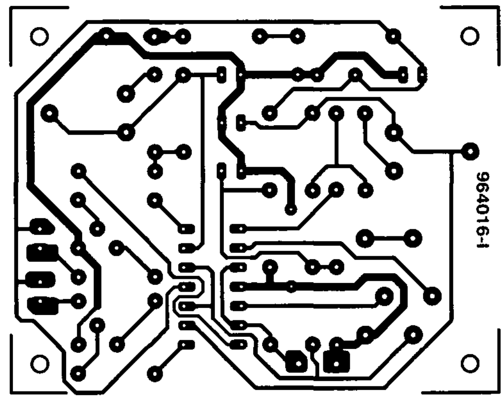
Zener diode D5, resistor R11 and capacitor C3 provide a stabilized voltage of about 6.8 V. The potential dividers formed by presets P1 and P2 step this voltage down to an adjustable level of about 0.7 V and 0.3 V at the − and + inputs of opamps IC1c and IC1d respectively. Both opamp outputs drive a delay network. Each of these is designed such that capacitors C1 and C2 are rapidly charged via relatively small resistors, R2 and R4, and their associated diodes, D1 and D2. The same capacitors are however, slowly discharged via much higher resistances (R3-P3 and R5-P4) because of the blocking action of the diodes. The delay so obtained is adjustable between 1 and 2 seconds. The capacitor voltages are compared against a 0.8-V reference by two further opamps in the LM324. If they drop below this threshold, the relevant LED (D3, D4) lights.

Normally, the lambda voltage swings around 0.5 V, just tripping the upper and lower threshold set with P1 and P2. Opamps Ic1c and Ic1d therefore supply a constant train of pulses which keep C1 and C2 charged to a level above the 0.8-V threshold. The result is that both LEDs remain off. However, when the lambda voltage does not reach the upper or lower threshold, the relevant capacitor is discharged, and the relevant LED lights. In this way, the two LEDs may indicate all four engine conditions mentioned above. If the lambda probe is not connected, resistor R1 keeps the inputs of IC1c and IC1d at ground level. The indicated test voltage of 60 mV is caused by the bias current of the two opamps, and applies with no lambda probe connected.

The delay times set with P3 and P4 should be sufficiently long to prevent the indicators flickering as a result of brief level changes of the lambda voltage. Both the delay and the low/high threshold settings will







COMPONENTS LIST

Resistors:
R1 = 1MΩ
R2,R4 = 1kΩ
R3,R5 = 39kΩ
R6,R8 = 10kΩ
R7 = 470Ω
R9 = 560Ω
R10 = 150kΩ
R11 = 2kΩ2
R12 = 10Ω
P1,P2 = 10kΩ 10-turn cermet
P3,P4 = 47kΩ preset H

Capacitors:
C1,C2 = 10μF 63V radial
C3 = 1μF 16V radial
C4 = 100nF
C5 = 47μF 25V radial

Semiconductors:
D1,D2 = 1N4148
D3 = LED, green
D4 = LED, red
D5 = zener 6V8 400mW
D6 = 1N4001
T1,T2 = BC547B
IC1 = LM324

Miscellaneous:
Printed circuit board (not available ready-made through our Readers Services).

depend on the vehicle and fuel injection type, and may have to be tweaked in practice for the best operation. In practice, the delay presets may be set to the centre of their travel, and have to be re-adjusted only if there is noticeable flickering of the LEDs while driving.

The output voltage of the lambda probe is tapped and connected to the circuit via a short length of screened cable. The circuit itself may be fitted at a suitable position in or behind the dashboard. Care should be taken to ensure the lowest possible ground resistance. The ground connection is preferably made directly on the engine, or on the negative terminal of the car battery. If you use the ground connection of another load, the range of the lambda voltage may be shifted several hundred millivolts, requiring quite different input threshold settings than those mentioned above. The positive supply is taken from a point behind the ignition switch, for example, at the switch for the rear window defroster.

The author has successfully used this circuit in a Fiat Uno 75i.e. with a Bosch Jetronic injection system, achieving a mileage of 125,000.

(W. Schmidt 964016)

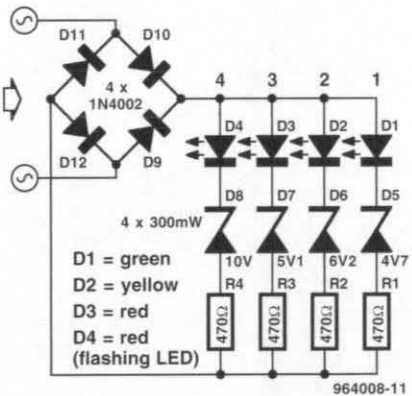
Warning. Working on a hot and/or running car engine is dangerous if you do not take proper precautions.
Warning. Do not adjust the circuit while driving.
Warning. Car exhaust fumes are highly toxic. Do not leave the engine running in a closed room. Be sure to use an approved exhaust extension hose and fume extractor system.
Warning. Installing this circuit may void the warranty on the car. Improper connection may cause damage to the engine, the fuel injection system and/or the catalyser. For installation and adjustment, seek the assistance of a qualified car mechanic.

battery monitor

The monitor is a handy aid in cars and is particularly suitable for radio amateurs who power their equipment from a car battery.

Although straightforward, the monitor is a very practical means of controlling the battery voltage. All that is needed are four FET current sources, four zener diodes and four LEDs. Bridge rectifier D_9–D_{12} ensures that the battery cannot be connected with incorrect polarity.

The zener voltage of diodes D_5–D_8 increases in standard steps, so that the battery voltage needs to be higher to cause successive LEDs to light. In other words, the higher the battery voltage, the more LEDs will light. The component values



are chosen so that at a battery voltage of 9 V—battery poor—only D_1 lights; when it is about 11 V—battery doubtful—D_1 and D_2 light; when it is 13 V—battery fine—D_1, D_2 and D_3 light.

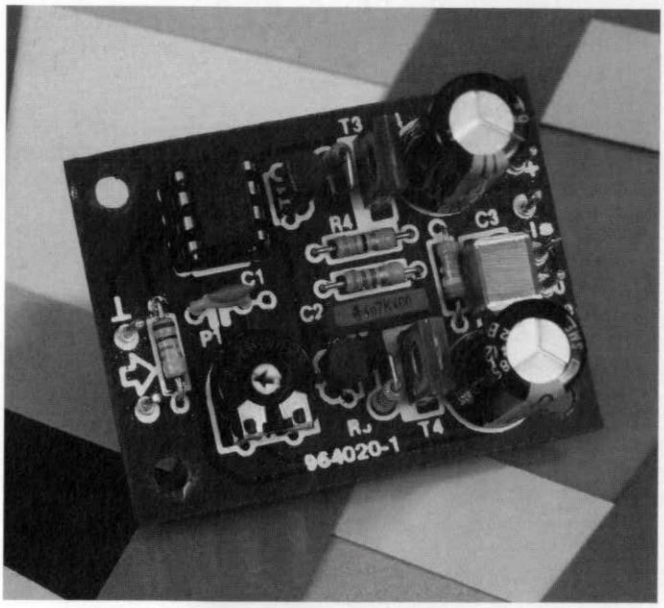
Diode D_4 is a flashing LED. The value of zener diode D_8 is such that the LED begins to flash when the battery voltage approaches 15 C, that is, an overvoltage situation. It may indicate a fault in the alternator, the associated rectifier diodes or the voltage regulator.

Since the drop across an LED is dependent not only on its colour, but also on its type, it may prove useful to experiment with the ratings of the zener diodes (with the aid of a variable power supply). It is always possible that the practical rating is slightly different from that specified.

The circuit draws a current of not more than 40 mA when D_1–D_3 light.

[N. Harisankar - 964008]

miniature power amplifier



There are quite a few applications of an audio power amplifier in which power and hi-fi characteristics are of secondary importance. If, for instance, an active loudspeaker for a portable radio receiver is needed, compact dimensions and low current drain are far more important considerations.

These properties are the prime design basis for the present mini amplifier. It continues working satisfactorily with a battery voltage down to 1.5 V. Its quiescent current drain is about 1 mA, and its efficiency is a worthwhile 70 per cent. It provides an output power of 500 mW into 8 Ω (or 800 mW into 4 Ω), has a sensitivity of 400 mV, and its distortion is never higher than 1.2 per cent.

The low current drain is obtained through a combination of a low-power op amp followed by a discrete Class-B stage. The op amp is a Type TLC271 operating in its high-current mode (pin 8 to ground). Any complications arising from the common-mode range are prevented by using the amplifier as an inverting type. The voltage amplification is set with feedback resistance P_1.

The discrete power stage consists of two complementary darlingtons, each composed of a BC and a BD transistor. Resistors R_2–R_5 limit the internal amplification. Capacitors C_1, C_2, and C_6, are compensation devices.

Boucherot network R_6-C_3 ensures amplifier stability when the load is very low or very high.

Since the output transistors have no emitter resistor, the voltage is determined solely by the knee voltage of T_3 and T_4. With a load of 4–8 Ω, these voltages are limited to 0.2–0.3 V, so that the transistors can be driven virtually up to the supply voltage. This is the reason for the atypical high efficiency of the amplifier.

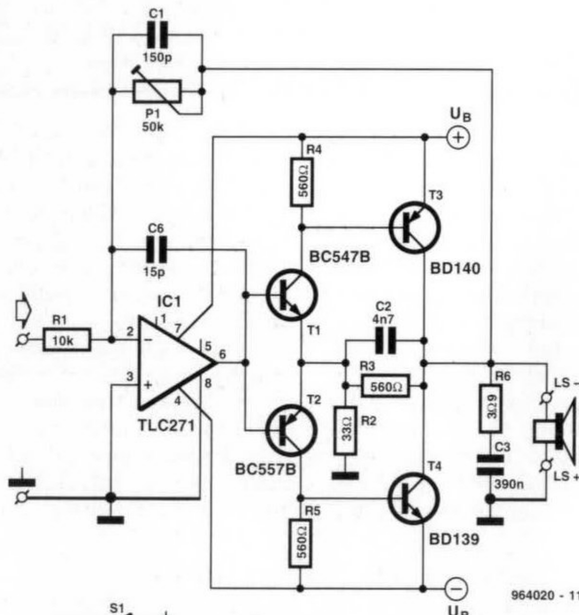
The overall bandwidth of the amplifier is limited to not less than 21 kHz at the maximum amplification of ×5.

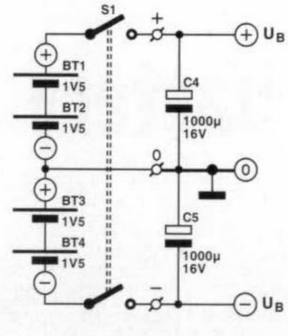
With a 4 Ω load, the peak output current is 700 mA. A 315 mA fuse in series with the output is, therefore, a simple, but effective short-circuit protection. At maximum drive with a music signal, the average current is only 50 mA. In practice the drive will never be continuously maximum, so that the actual current drain will be much lower. A set of four penlight batteries should last about 200 hours.

The amplifier is best built on the printed-circuit shown, which, unfortunately, is not available ready made.

On a final note: since the four batteries form a symmetrical supply, on-off switch S_1 needs to be a double-pole type.

[T. Giesberts - 964020]





PARTS LIST

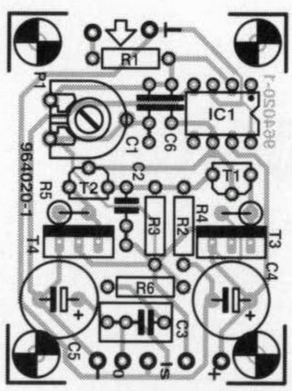
Resistors:
R_1 = 10 kΩ
R_2 = 33 Ω
R_3–R_5 = 560 Ω
R_6 = 3.9 Ω
P_1 = 47 kΩ preset

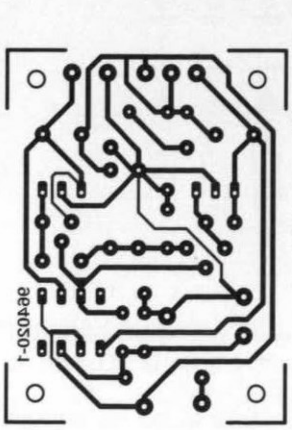
Capacitors:
C_1 = 150 pF
C_2 = 4.7 nF
C_3 = 390 nF
C_4, C_5 = 1000 µF, 16 V, radial
C_6 = 15 pF

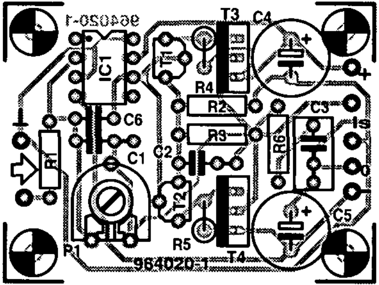
Semiconductors:
T_1 = BC547B
T_2 = BC557B
T_3 = BD140
T_4 = BD139

Integrated circuit:
IC_1 = TLC271CP

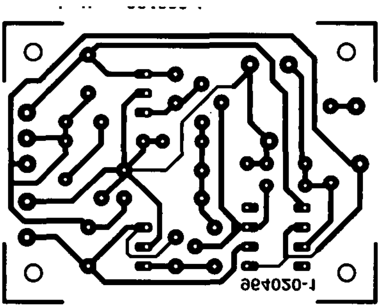
Miscellaneous:
S_1 = double-pole on/off switch
Bt_1–Bt_4 = battery, 1.5 V







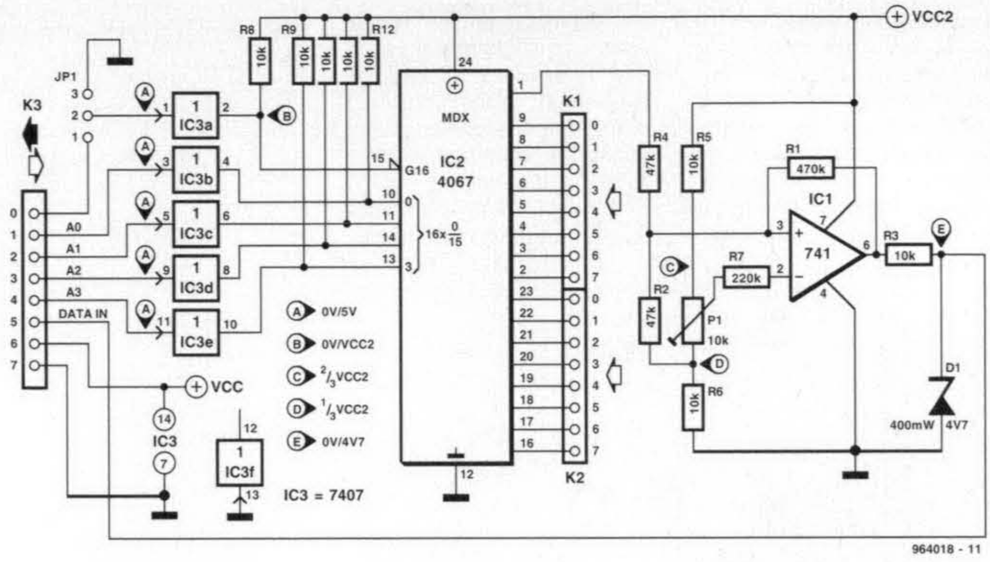
964020-1
IC1
T1
T3
C4
R4
R2
R3
R6
C3
C6
C1
C2
R1
T2
P1
R5
T4
C5
0
+



display-to-μP interface

Many measuring instruments are provided with a 7-segment display, LED bar or discrete LEDs, which are controlled directly by an analogue-to-digital converter (ADC), such as the ICL7107, or an LED chain driver, such as the LM3914.

To build in such an instrument an interface for a microprocessor system is not so simple, since the data are normally not available in binary form. However, the present circuit offers a solution to this difficulty.



The 16 inputs at K_1 and K_2 are linked to the LEDs or segments (with common anode)to be read. The microprocessor system controls the four switching inputs, A–D (pins 10–14) of the 16-to-1 demultiplexer, IC_2, via K_3 and IC_{3b}–IC_{3e} and selects one of the 16 inputs, which is then linked to the X-output.

The potential at the X-output is compared with a reference voltage, which is preset with P_1. The output of comparator IC_1 is high or low, depending on whether the segment or LED is actuated or not not respectively.

The output level of IC_1 is read by the microprocessor system and reconverted into a number, after all relevant inputs of K_1 and K_2 have been scanned. The relevant software must be adapted to the relevant types of controller and display.

Since usually several supply voltages are used in display circuits—7-segment displays often need more than +5 V— conversion of the +5 V supply (from the microprocessor) to the level required by the display is needed. This is provided by the open-collector outputs and pull-up resistors of buffers IC_{3a}–IC_{3e} The supply for IC_2 may be 3–18 V. At the output of the microprocessor, the level ensured by D_1 is lowered again to 5 V.

Jumper JP_1 determines whether the 4067 is always switched on or only when a signal at interface line 0 is enabled. This is particularly useful when several circuits are to be driven in parallel.

In case of multiplexed displays, the software becomes a little more complicated since ever more measurements must be taken to ensure that the display lights or not.

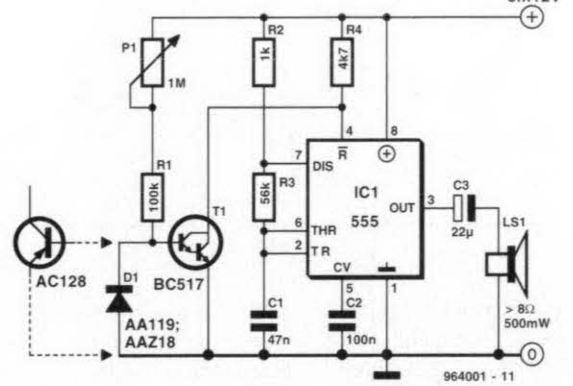
The circuit as shown draws a current of 10–20 mA from the +5 V line and not more than 5 mA from the V_{CC2} line.

[D. Dittmann - 964018]

overheating alarm

This little circuit may help to prevent costly disasters caused by overheating of semiconductors fitted on heatsinks, to mention but one application. It is built from low-cost and generally available components only.

A reverse-biased germanium diode, or the base-emitter junction of a germanium transistor, acts as a temperature sensor. At room temperature (approx. 25 °C), the resistance of this sensor is relatively high, so that transistor T1 conducts and holds the reset pin (terminal 4) of the 555 timer IC at a low level. Consequently, the free-running oscillator built around the 555 is disabled.

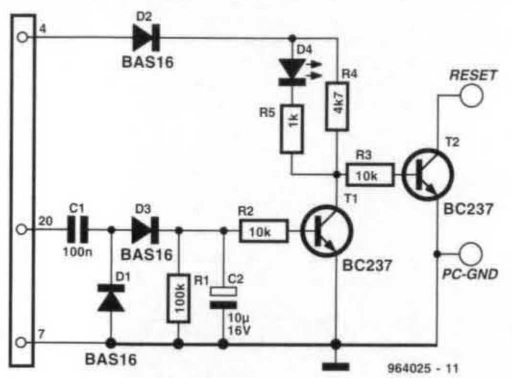


When the temperature measured by the sensor exceeds about 80 °C, the resistance of the germanium semiconductor junction becomes low enough for T1 to stop conducting because of the low bias voltage at its base terminal. Next, the oscillator is enabled via pin 4 of the 555, and the loudspeaker sounds.

The temperature at which the alarm is activated may be adjusted with preset P1. The circuit can work from any supply voltage between 6 and 12 V d.c. Its current consumption in the non-activated state is between 1 and 2 mA, which is probably a little too high for the unit to be permanently powered from a small 6 V or 9 V battery. (Pradeep G. 964001)

watchdog for PCs

The watchdog is intended to monitor a microprocessor and determine whether this functions correctly or not. It and its software are suitable for use in the background with any PC that runs under DOS or Windows. The hardware is linked to the serial interface, which is then controlled by the software




```
Watchdog-Test
#include
#include
#include

#define com2 0x02f8    COM2

void main(void)
{
int i;

  {
   while(1)
   {
    outp((com2+4),3);  PIN 4 and PIN 20 high
    delay(2);
    if(bioskey(1))     RESET test at switch push
      return 0;
    outp((com2+4),2);  PIN 4 high, PIN 20 low
    delay(2);
    if(bioskey(1))     RESET test at switch push
return 1;
}
```

After the computer has been switched on, the data connections at the serial interface are low. The watchdog software is started at the same time as the selected application program. It provides a permanent rectangular signal at pin 20, which results in C_2 being charged and T_2 conducting. Pin 4 is made high, so that the computer cannot receive a reset signal. This condition is stable as long as the program runs.

If the computer fails (crashes), the rectangular signal falls out and C_2 is discharged via R_1. This causes T_1 to be switched off, whereupon the base of T_2 goes high. This transistor is then on and pulls the reset line of the computer to ground. The computer then restarts.

Note that the circuit works only if a computer reset also causes the serial interface to be reset, since that is essential for the high level at pin 4 to be removed. It is only when this pin is at ground level that the reset pulse is terminated and the computer can reboot.

The C++ program is a test for the hardware; the real program is easily adapted for the particular use.

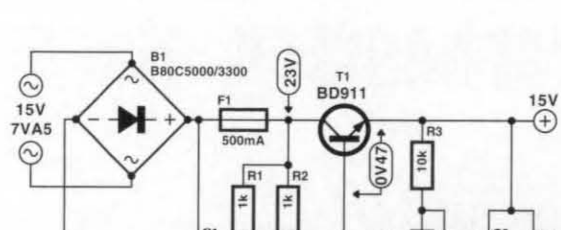
The reset connection of the processor is normally not difficult to find: follow the cable from the reset switch.

The watchdog draws a current of about 5 mA from the computer.

[J. Ochs - 964025]

15 V power supply

Many designers nowadays almost automatically include one of the popular 3-pin voltage regulators in power supply designs. It is almost as if they have forgotten that there are other ways of regulating as well. The present circuit, for instance, shows a simple regulator which is useful if the requirements on the power supply are not too stringent. The circuit is very simple and inexpensive to build. Moreover, it has the advantage that the output voltage can be easily adapted to requirements.



The circuit is based on integrated shunt regulator IC_1, used here as variable zener diode. In conjunction with T_1, the IC forms a simple voltage regulator. Since, unlike a zener diode, the device has three terminals, its output voltage can be determined within certain limits with variable potential divider R_3-P_1-R_4. Parallel-connected resistors R_1 and R_2 ensure a sufficient current through IC_1 and T_1. The cathode current of IC_1 must be at least 0.4 mA.

The maximum output current depends on the mains transformer. The current drawn by the circuit itself depends on the applied alternating voltage: in the prototype, which has a supply of 15 V, the current drain is 16.5 mA. Providing an output current of 400 mA, the prototype provided a ripple suppression factor of 25.

If the circuit is to be used as the basis for a symmetrical supply, it is best to use a mains transformer with isolated windings and build an identical circuit for the negative supply line. Connect the +15 V output of this line to the earth return of the positive supply line. This return will then serve as the return line of the entire symmetrical supply. A real negative version with a p-n-p transistor is not readily possible because the 2.5 V reference of IC_1 is with respect to the lowest potential (here, the anode).

[T. Giesberts - 964044]

signal-controlled switch II

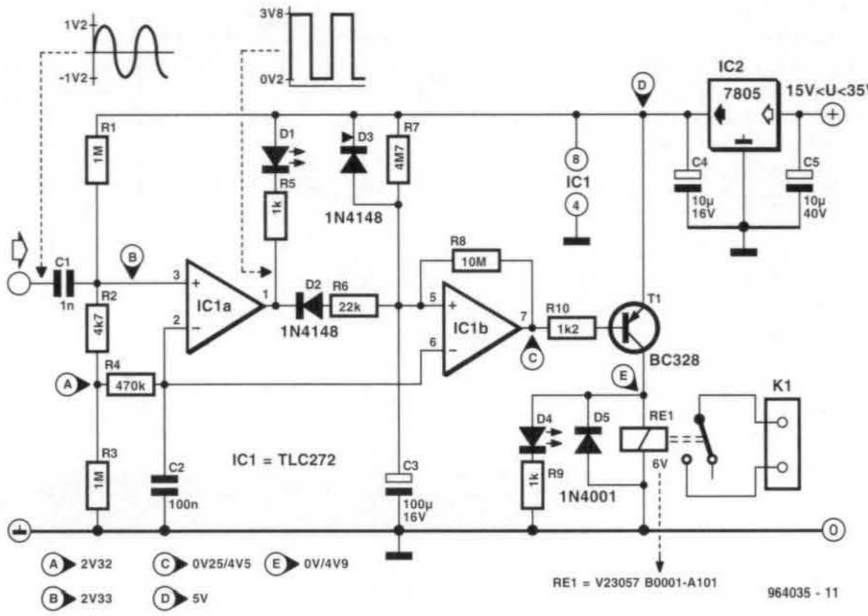
This circuit is another variant of the switch described elsewhere in this issue. Its function is to switch off an audio system if there has been no audio input for five minutes. Its signal input is simply connected to the line output of the preamplifier or ahead of the volume control in the power amplifier. Its output energizes a relay with single contact to switch off the mains to the audio system.

The circuit is fairly simple. At its input, the audio signal is likened to a small direct voltage by comparator IC_{1a}. In the quiescent state, the potential between the inputs is 12 mV. The output of the comparator is high so that time delay capacitor C_3 can be charged slowly via high-value R_7. When the potential across C_3 has reached a level of about half the supply voltage, the second comparator, IC_{1b}, changes state (goes high), which causes the relay to be deenergized.

The audio signal is applied directly to the non-inverting input, but its level at the inverting input is very low, owing to C_2 that forms a virtual short-circuit to earth. During the negative half waves of the signal and its level is sufficient (20-50 mV), the comparator output is low. This causes C_3 to be discharged fairly rapidly, so that the level at the non-inverting input of IC_{1b} cannot reach half the supply voltage. This comparator then actuates the relay, whose contact switches on the mains to the audio equipment. The switch-on period is about 1.5 s (that is, $R_6 \cdot C_3 \cdot \log_e 2$).

Diode D_4 is in tandem with the power-on indicator of the audio equipment, while D_3 indicates whether a sufficiently strong audio signal is present.

Power for the circuit is taken from the audio system: the voltage may be anywhere between 9 V and 35 V. Since the circuit draws a current of not more than 80 mA, a heat sink for IC_2 is only needed if input voltages of ≥ 30 V are regularly encountered.

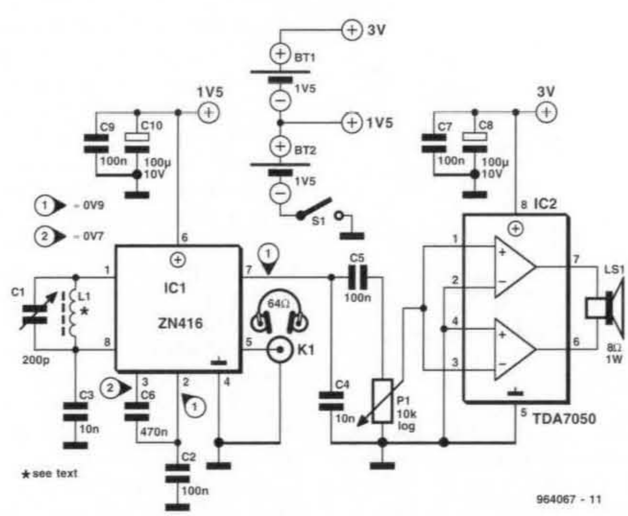


[I. Studer - 964035)

two-IC medium-wave pocket radio

Believe it or not, but it's fashionable ('cool') these days to listen to medium-wave radio stations. Ferranti's ZN416 integrated circuit contains a complete radio receiver with AM demodulator. All you need to do is strew a couple of decoupling ICs around the IC, connect an antenna to the balanced RF input (pins 1 and 8), and a pair of headphones to the AF output (pin 5).

The antenna is an inductor, L1, consisting of about 60 turn of 0.2-mm (SWG36) enamelled copper wire (e.c.w.) on a ferrite rod with a diameter of 12 mm and a length of about 12 cm.



The inductor is tuned with a 500-pF foil dielectric variable capacitor, C1 (Conrad order code 582315-88).

The audio power amplifier, a TDA7050, is only required if you want to use a small loudspeaker instead of, or in addition to, the headphones. The AF power amplifier also adds the luxury of a volume control to the receiver.

The receiver IC operates at 1.5 V only from one of two series-connected AA (penlight) batteries which supply 3 V to the TDA7050. Current consumption is of the order of 8 mA. [Pradeep G. 964067]

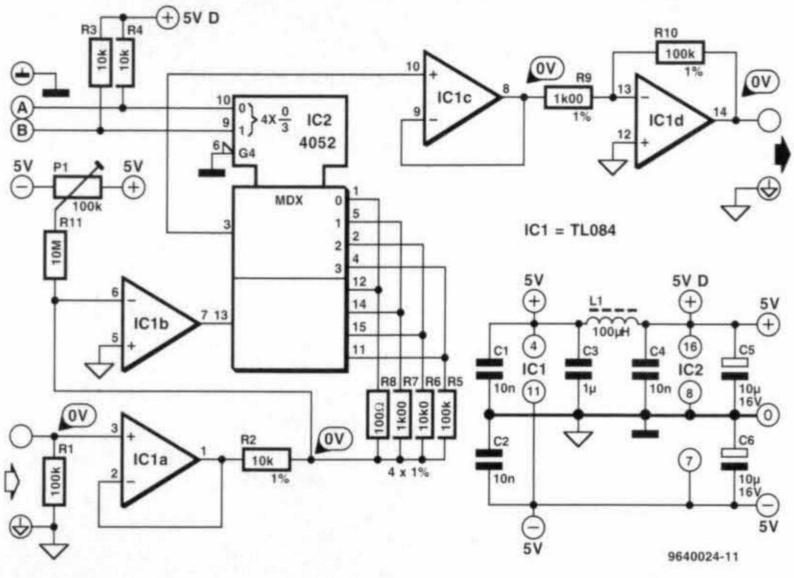
programmable amplifier

The programmable gain amplifier—PGA—is ideal for applications like data loggers and automatic measuring instruments. The amplification can be set anywhere between unity and ×1000. The bandwidth at whatever amplification is >30 kHz. The current drain does not exceed 7 mA.

The input signal is buffered by IC_{1a} and then applied to amplifier IC_{1b}. The amplification of this stage depends on how feedback resistors R_5–R_8 are switched into circuit by IC_2. How the resistors are intercoupled depends on the logic levels at inputs A and B. The inter-relation between the resistors, the total amplification and the logic levels is shown in the table.

After the output signal of IC_{1b} has passed through the multiplexer, it is applied to ×100 amplifier IC_{1d} via buffer IC_{1c}. The overall amplification is set with logic levels at inputs A and B as shown in the table.

The amplification of the first stage has been kept low purposely to ensure that the value of the feedback resistor does not have to be high, which makes the effect of the leakage current of the multiplexer negligible.



A	B	Amplification	
0	0	1	$(R_8/R_2) \cdot (R_9/R_{10})$
0	1	10	$(R_7/R_2) \cdot (R_9/R_{10})$
1	0	100	$(R_6/R_2) \cdot (R_9/R_{10})$
1	1	1000	$(R_5/R_2) \cdot (R_9/R_{10})$

The effect of R_{DSon} of the multiplexer has been eliminated by taking the input signal to IC_{1c} from the output of the first multiplexer via the second multiplexer.

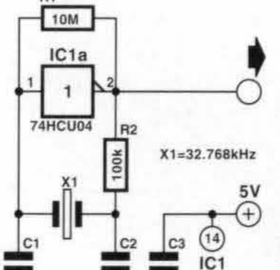
The offset of the circuit is set to zero with P_1 when the logic level at both inputs is high.

When both A and B are left open, R_3 and R_4 arrange for the circuit to be set automatically to an amplification of ×1000. [H. Bonekamp - 964024]

32 kHz oscillator

A standard CMOS oscillator IC does not work with a watch crystal (32.768 kHz). At best, it starts to oscillate when the supply voltage is switched on, but as soon as the voltage rises to its nominal value, oscillations cease. The solution is simple and consists of adding a resistor between the crystal and the IC (R_2 in the circuit diagram). Once this is done, the oscillator works fine and is not fed too much energy (which would cause it to give up the ghost within a short time). Capacitor C_2 may be a trimmer to enable the frequency to be set accurately.

The reason that R_2 enables the oscillator to work well is as follows. Capacitors C_1 and C_2 and the crystal form a π-section that causes a phase shift of 180°. Circuit IC_1 is an inverter which also causes a phase shift of 180° There is thus a total phase shift of 360°, necessary for oscillations to be sustained.



Without R_2, the crystal is driven by the inverter at low impedance, which causes so much damping that the π-section gives a phase shift well below 180°. The additional resistance reduces the damping, so that the phase shift is restored to 180°. Since the impedance of the π-section is high, R_2 does not create much attenuation, so that the overall amplification remains larger than 1: a prerequisite for oscillations.

As regards the DC setting of the IC, R_1 is necessary to set the input of the device to about half the supply voltage. To prevent damping, the value of R_1 must be at least 10 MΩ, which is a normally available value. The value used in many of such oscillators is 1 MΩ, but with this value the oscillator does not work.

The waveform at the input is sinusoidal, but that at the output is rectangular.

Note that the IC is an HCU, that is, unbuffered, type. The oscillator may work with an HC type, but that cannot be guaranteed.

The circuit draws a current of not more than 1 mA with a 5 V supply.

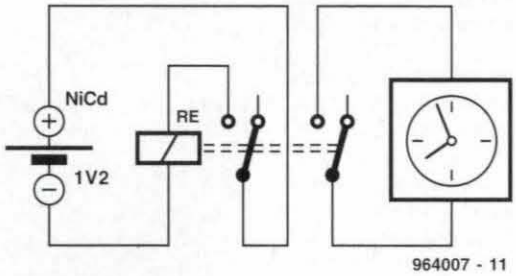
[K. Walraven - 964021]

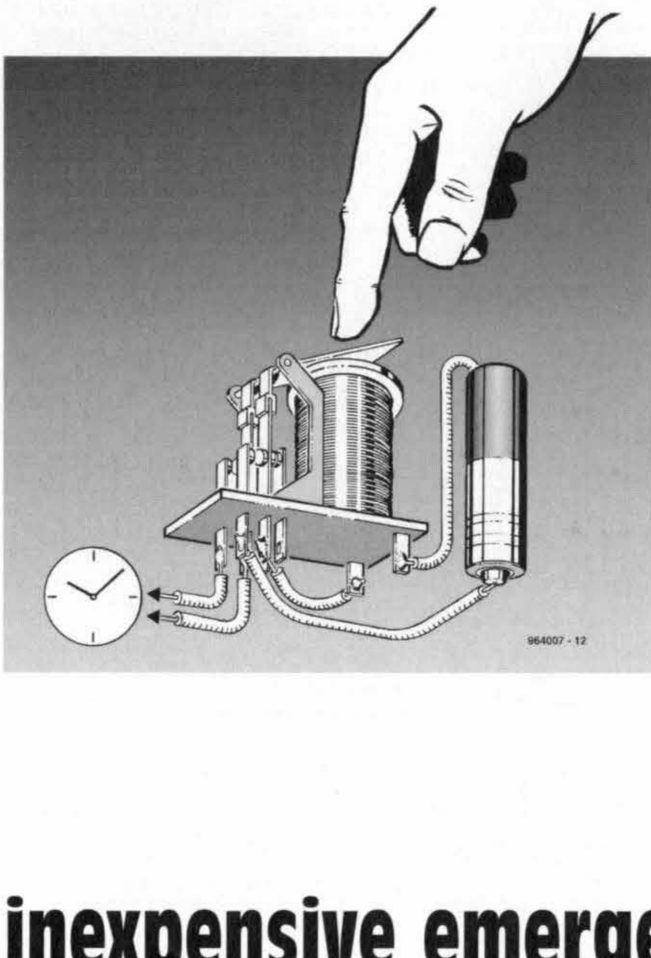
NiCd battery capacity tester

This is an enhanced version of the NiCd-battery tester published in the July/August 1995 issue of *Elektor Electronics*. In that design, the NiCd battery under test is discharged at a rate of 100 mA, while it is also used to power a small quartz clock. When the resistor has drained the battery to a voltage of 1.05 V, the clock stops, and the time that has elapsed since inserting the battery allows the capacity (in Ah) to be calculated.

The present circuit improves on the operation of this (shoestring budget) test principle by using a rewound relay to stop the discharging automatically at about 1 volt, thereby preventing deep discharging of the battery. The author has some cells which are over twenty years old, and still give good performance.

The novelty of the present version is that the battery is discharged across a relay coil rather than a resistor, while it powers the clock via the relay contacts. The timer created in this way is started by pressing the relay armature so that the contacts uphold the coil current. Provided the coil resistance is correct, the relay will be de-energized at the above mentioned minimum cell voltage. The time recorded by the clock then indicates the battery capacity just as with the earlier circuit. Assuming a coil resistance of 12 Ω, the discharging current is 100 mA. Multiply the discharging period by 0.1, and you have the measured battery capacitance. For example, if the clock stops after 8 hours, the battery capacity is 0.8 Ah.



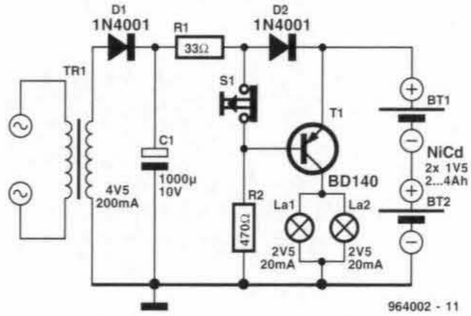


Unless you are lucky enough to find a relay with a normally open (n/o) contact, a coil resistance of exactly 12 Ω, and a de-actuation voltage of about 1 V, a new coil winding will have to be made with fewer turns, and using thicker wire. The use of a copper wire gauge table is recommended for the resistance calculation, after which a number of experiments should be carried out to make sure that the value of 12 Ω and the desired de-actuation voltage are reached. Also, the armature of the relay should be accessible to enable the contacts to be closed by manual pressure. In most cases, that means using a rather bulky relay. Fortunately, that is not a problem because the relay can be secured to a battery holder to form one assembly. Sealed relays are obviously not suitable for this application, unless you remove the enclosure. [P.J. O'Neil - 964007]

inexpensive emergency light

The low-cost circuit charges two nickel-cadmium cells from the mains to provide a stand-by power supply for a two-lamp emergency light which is automatically switched on in the event of a mains failure. The best place to mount the circuit is probably in the electricity locker in your home. That location is also convenient because the 4.5 V alternating voltage may be tapped from the doorbell transformer.

Diode D1 and smoothing capacitor C1 form a conventional single-phase rectifier circuit with an output voltage of about 6 V. This voltage is used to continuously charge two series-connected NiCd batteries with a current of 80 to 100 mA, which flows via R1 and D2. At this rate, a 2 Ah (ampere-hour) NiCd battery can be safely charged for extensive periods.



The voltage drop across D2 reverse biases the base-emitter junction of p-n-p transistor T1. Consequently, the transistor is turned off, and the lamps connected to its collector do not light.

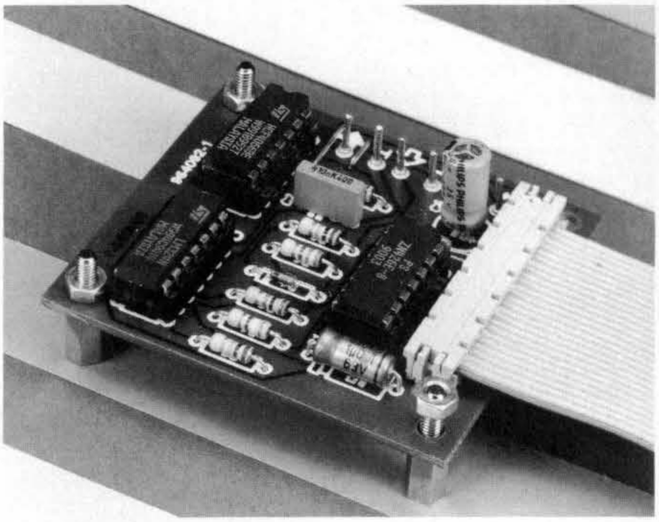
When a mains outage occurs, T1 is supplied with base current (from the batteries) via R2, whereupon the miniature lamps are turned on. As soon as the mains power is restored, T1 is switched off again, and the batteries are charged again via R1 and D2.

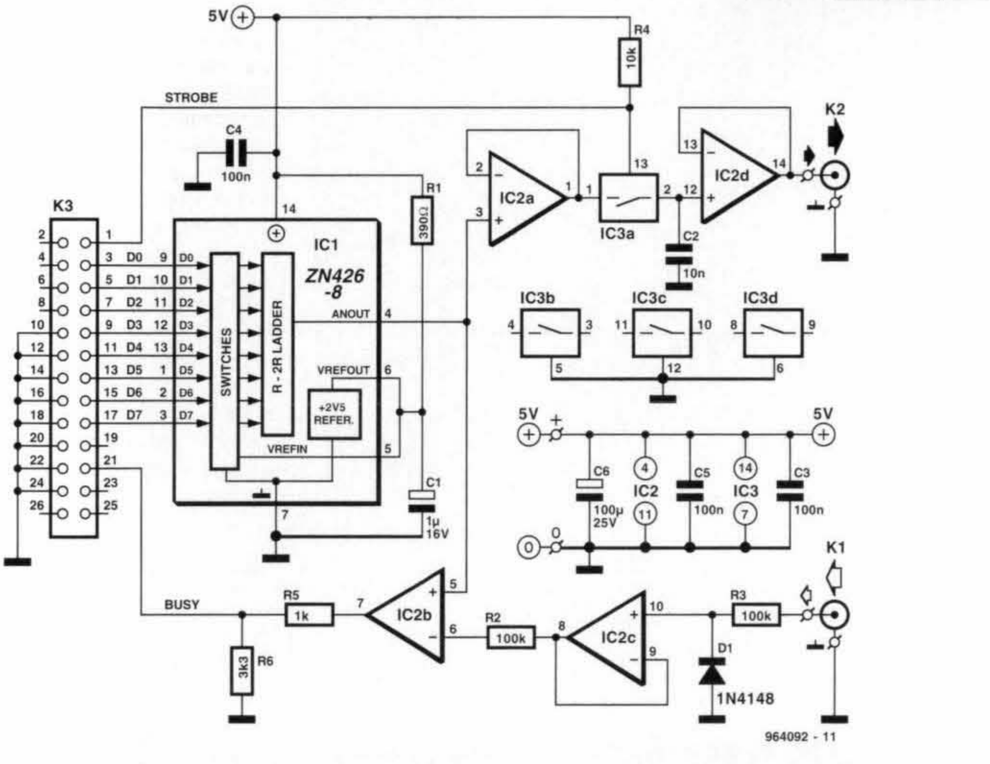
[Pradeep G. - 964002]

inexpensive AD/DA converter

Ferranti's ZN426-8 is an 8-bit monolithic digital to analogue converter containing an R/2R ladder network with precision bipolar switches and a 2.5-V precision voltage reference. The circuit shown here is connected to the PC's parallel printer port, and provides a simple means of communication with the analogue world. It is capable of generating as well as reading voltages between 0 and 2.55 V in steps of 10 mV. The ZN428 also acts as an A-D converter with the help of a comparator. The circuit is powered by an external 5-V source, and controlled by a small Pascal program.

The PC's printer data lines are connected directly to the digital inputs of the ZN428. The 8-bit value sent to the chip is translated into a corresponding analogue voltage (0 to 2.55 V), which is buffered by opamps IC2a and IC2b before it is available to the analogue output, K2. An electronic switch, IC3a, in inserted between the opamps. It is closed by the strobe signal supplied by the computer.





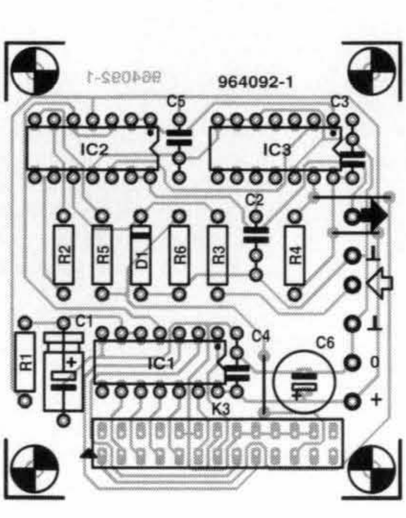
COMPONENTS LIST

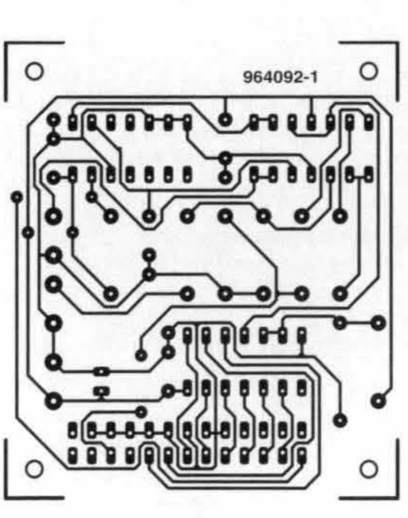
Resistors:
R1 = 390Ω
R2,R3 = 100kΩ
R4 = 10kΩ
R5 = 1kΩ
R6 = 3kΩ3

Capacitors:
C1 = 1µF 16V
C2 = 10nF
C3,C4,C5 = 100nF
C6 = 100µF 25V radial

Semiconductors:
D1 = 1N4148
IC1 = ZN426-8 (Ferranti)
IC2 = LM324
IC3 = 4066

Miscellaneous:
K3 = 26-way flatcable IDC plug.
Software on diskette, order code 966009-1.
Printed circuit board not available ready-made.



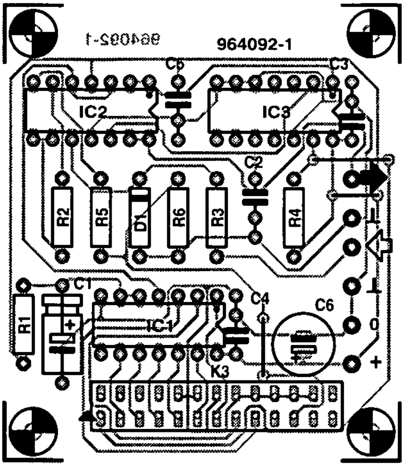


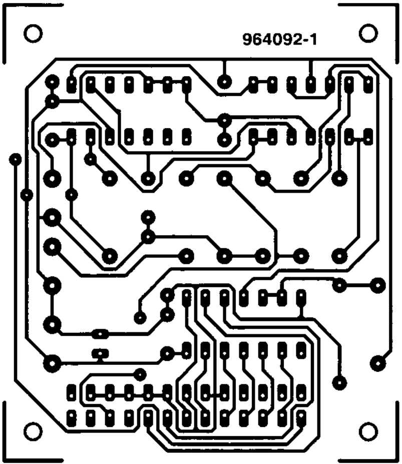
The A-to-D conversion is based on successive approximation. The analogue input voltage to be measured (range: 0 to 2.55 V) is applied to input socket K1. The printer port is programmed to supply a series of voltage levels, each of which is compared with the analogue input voltage by comparator IC2b. The output of IC2b drives the BUSY line, which is interrogated by the program to check if the DAC output voltage is higher or lower than the voltage at K1. During the A-to-D conversion, switch IC3a is opened. During that (brief) period, capacitor C2 and opamp IC2d hold the analogue voltage at K2.

The control software for the

AD/DA converter is available on diskette through our Readers Services under order code **966009-1**. This disk also contains all relevant source code files. A Pascal unit called ADDAConv provides the routines which are necessary to control the circuit. An object 'ADDAC' is initialised with the number of the parallel port to which the converter is connected (LPT1, 2, or 3). The procedures 'getVoltage' and 'setVoltage' serve to read and supply analogue voltages respectively. The program ADDATest demonstrates the application of this Pascal object.

[S. Reichelt - 964092]


964092-1
C5
C3
IC2
IC3
C2
R2
R5
D1
R6
R3
R4
C1
R1
C4
C6
IC1
K3
0
+


964092-1

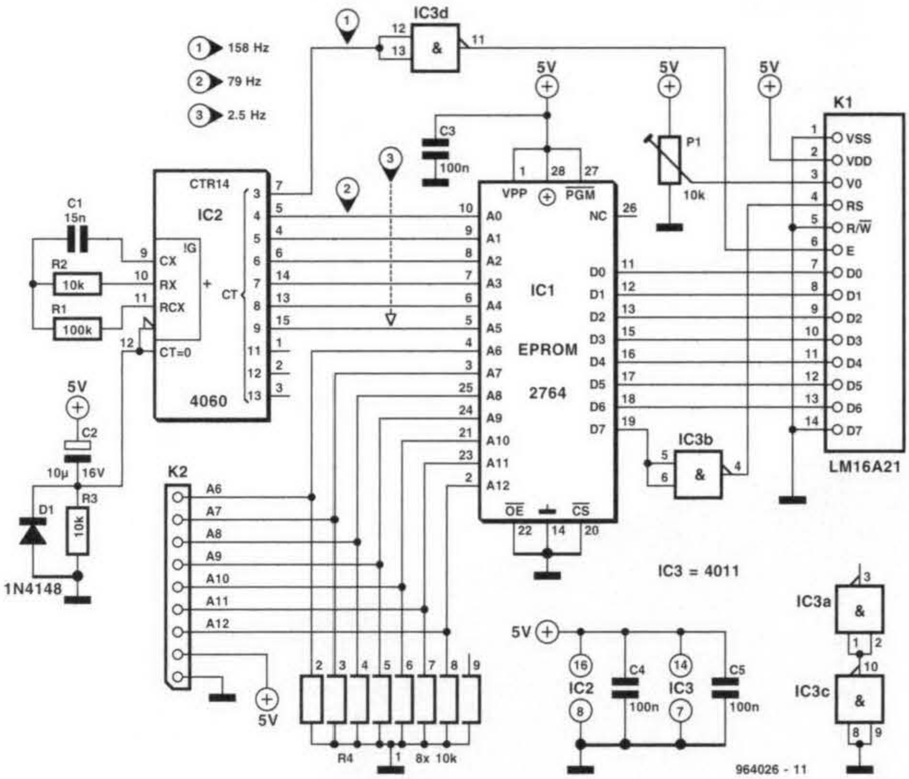
general purpose text display

The circuit can store a maximum of 128 texts each of two lines and 16 characters and present one of them on a standard display.

The texts are stored in an EPROM and may be exported upon a relevant address at the seven TTL compatible inputs of K_2.

Oscillator/counter IC_2 not only generates the enable signal for the display, but also arranges for the six lower address lines of the EEPROM to be scanned, so that the texts are sent constantly to the LCD. Thus, a new text is displayed after only a short delay when a different line at K_2 is addressed.

The display drive is not straightforward, because there is no actual initialization, so that the mode of operation depends on a power reset of the display controller, but in practice it works well.



Text programming

The programming of the EPROM will be clarified by an example. For instance, the text

regulations are
for guidance

will be output when pin 5 of K_2 is high and all other address lines are low. Pin 5 controls address bit 10, so that from address 400_H, before each text, four control bytes are programmed as follows:

$0B8_H$ – 8-bit communication, two rows;
$08C_H$ – display on, no cursor;
086_H – addressing mode;
082_H – cursor home.

Then follows the text of the first line followed by 24 blank spaces and the second line. A text entry always consists of 60 bytes.

Communication with the display is straightforward. Since the R/W line is at earth potential, it can only receive data. The busy flag is not strobed, so it cannot be ascertained whether the next byte can be sent. Fortunately, the data transfer is so slow (enable is clocked at about 160 Hz, which is equivalent to a time lapse of some 6 ms) that the LCD module has more than enough time to display the received character before the next byte arrives.

The EPROM content is composed in a simple manner by the short BASIC program TEXTDISP.BAS in the box. This is more convenient than each and every HEX editor. The program provides a file TEXTDISP.BIN, which can be called upon for programming.

[U. Hartig - 964026]

textdisp.bas

```
rem constant MaxMessage = no of display texts
const MaxMessage = 3
open "textdisp.bin" for output as #1
for Message = 1 to MaxMessage
        cls
        print#1, chr$(&hb8); chr$(&h8c);
chr$(&h86); chr$(&h82)
        print "Display text no"; Message
        print "Input line 1"
        input mess1$
        print "Input line 2"
        input mess2$
        print #1, mess1$
        for j = 1 to 40 - len(mess1$)
                print #1, " ";
        next j
        print #1, mess2$
        for j = 1 to 20 - len(mess2$)
                print #1, " ";
        next j
next Message
close #1
end
```

DVM as phase meter

The present circuit makes it possible for the phase difference between two sinusoidal voltages to be measured with an inexpensive DVM (digital voltmeter) or multimeter.

The circuit consists of four distinct parts: analogue comparator, digital comparator, low-pass filter, and power supply.

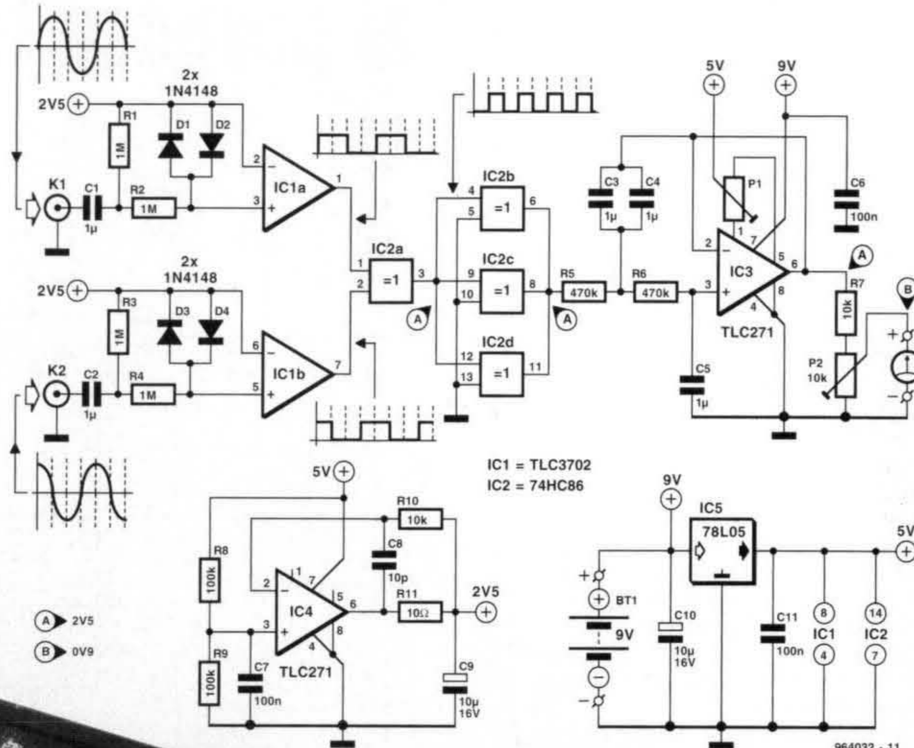
The input signals are applied to comparators IC_{1a} and IC_{1b} via K_1 and K_2. Their level is limited by anti-parallel connected diodes D_1–D_4.

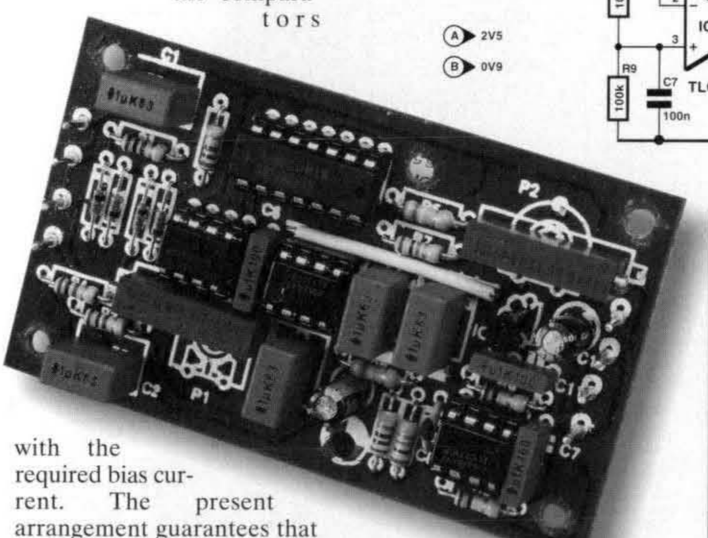
The comparators convert the sinusoidal signals into rectangular ones. Resistors R_1-R_2 and R_3-R_4 ensure that the diodes do not affect the input impedance unduly. When the diodes are off, the input impedance is 500 kΩ, when they conduct, it is 1 MΩ.

The resistors also provide the non-inverting inputs of the comparators with the required bias current. The present arrangement guarantees that the sensitivity of the comparators is maintained when the diodes are off (in many other circuits, R_1 is in parallel with D_1, so that the input voltage drops by 6 dB when the diodes are off).

Exclusive-OR stage IC_{2a} functions as digital comparator. It likens the rectangular waveform outputs of IC_{1a} and IC_{1b} and produces a logic 1 at its output when the two are not equal. Consequently, the duty factor of the output signal of IC_{2a} is directly proportional to the phase difference between the two signals.

The remaining gates of IC_2 are connected in parallel and used as buffer to make the output impedance as low





PARTS LIST

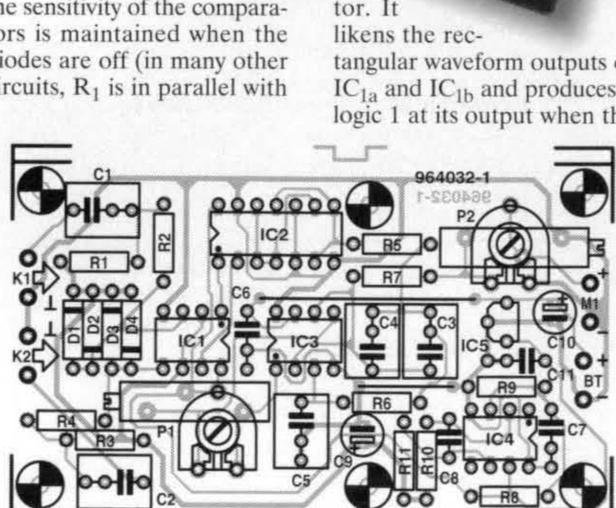
Resistors:
R_1–R_4 = 1 MΩ
R_5, R_6 = 470 kΩ
R_7, R_{10} = 10 kΩ
R_8, R_9 = 100 kΩ
R_{11} = 10 Ω
P_1 = 20 kΩ preset, see text
P_2 = 10 kΩ preset, see text

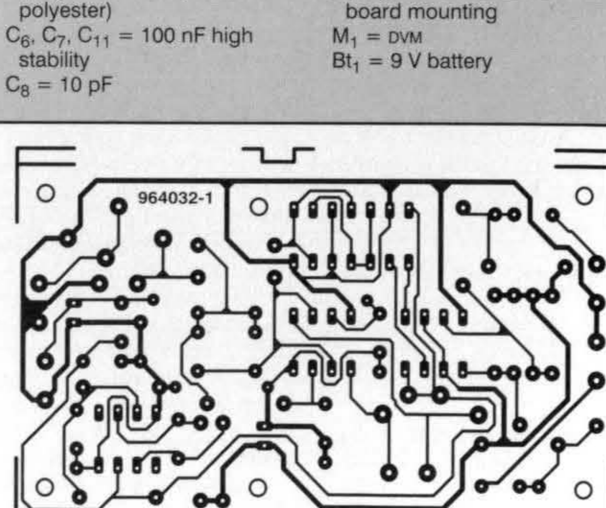
Capacitors:
C_1–C_5 = 1 µF MKT (metallized polyester)
C_6, C_7, C_{11} = 100 nF high stability
C_8 = 10 pF
C_9, C_{10} = 10 µF, 16 V, radial

Semiconductors:
D_1–D_4 = 1N4148

Integrated circuits:
IC_1 = TLC3702
IC_2 = 74HC86
IC_3, IC_4 = TLC271
IC_5 = 78L05

Miscellaneous:
K_1, K_2 = BNC socket for board mounting
M_1 = DVM
Bt_1 = 9 V battery





as possible.

The phase-dependent duty factor is converted by low-pass filter IC_3 into a direct voltage that can be read by the DVM. The active 2nd-order filter removes the a.c. component from the signal so that only the direct voltage remains. Preset P_2 is adjusted such that the DVM shows the correct phase shift.

So as not to make the circuit too complex, some facilities have purposely been omitted. For instance, in expensive phase meters the signal from the analogue input comparator is halved to enhance the symmetry, but this is not really essential. Also, in the digital section there is no detection of leading or lagging of the signal, which means that this has to be ascertained from viewing the oscilloscope.

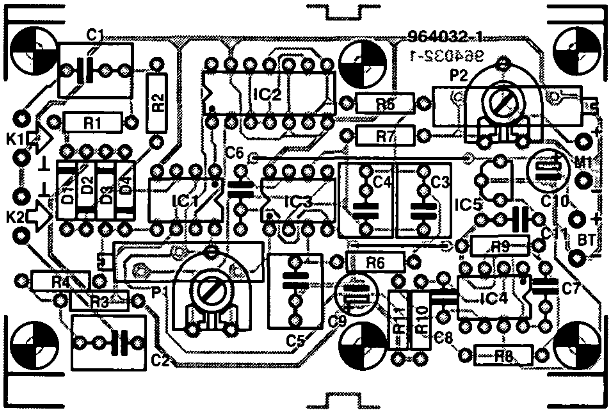
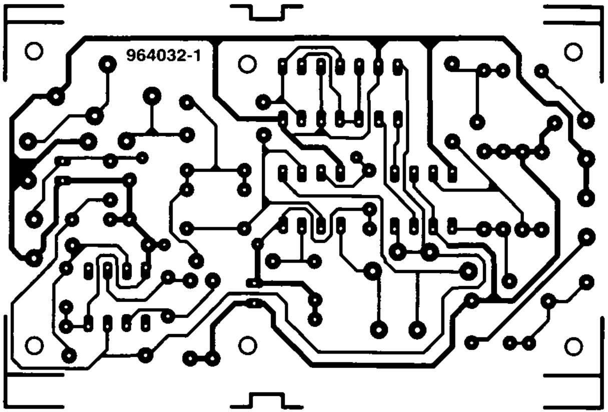
The circuit is powered by a 9 V alkaline battery, which feeds IC_3 directly. A stable 5 V supply for IC_1 and IC_2 is provided by regulator IC_5. The +5 V supply is halved by IC_4 to provide the +2.5 V supply for the input section.

The PCB has been designed to cater for standard as well as multiturn presets in the P_1 and P_2 positions. The latter types are, of course, preferred.

A known reference signal or a reliable phase meter for calibrating P_2 is indispensable.

The offset of IC_3 is compensated with P_1. Contrary to the usual way, here this needs to be done with an input signal applied (not at 0 V), because of the asymmetric supply of the op amp.

[H. Bonekamp - 964032]


964032-1
C1
R2
IC2
R5
P2
R1
K1
R7
C6
M1
D1
D2
D3
D4
IC1
IC3
C4
C3
IC5
C10
K2
C11
BT
R9
R6
R4
R3
P1
IC4
C7
C9
R11
R10
C5
C8
C2
R8

964032-1

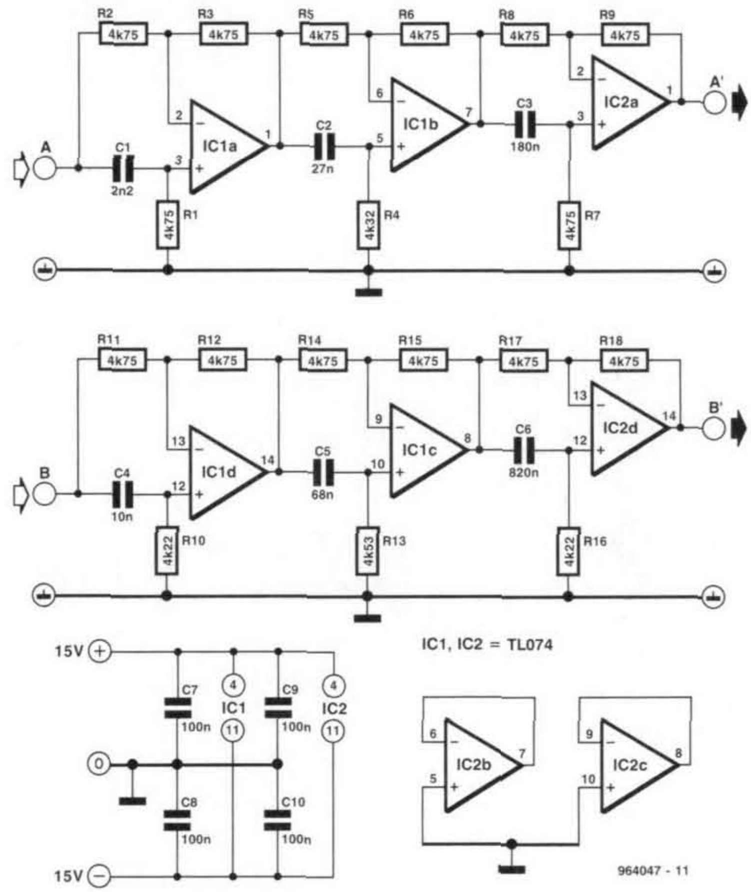
constant-phase sine/cosine filter

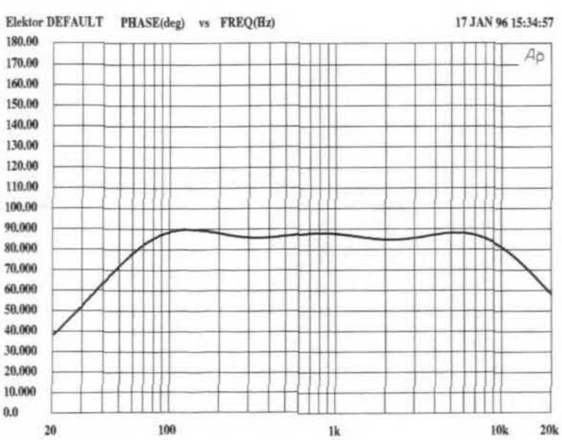
The sine/cosine filter has several applications in audio equipment thanks to its virtually constant phase shift. As an example, the design shown here is tailored for use in a surround-sound encoder, in which the surround information is shifted 90° and then added to the stereo channels. For a proper effect, the bandwidth has to be limited to 100 Hz to 7 kHz with the aid of a filter. Unfortunately, that filter causes further phase shifts. The alternative solution to this problem is phase correction for high and low-pass filters, described elsewhere in this publication.

The left (L) and right (R) channels are each sent through a filter section 'A', while the surround-sound signal is sent through the lower circuit, 'B'. The encoding operation then consists of adding B' to A'(L), and the inverted B' signal to A'(R). The centre channel may be added directly to A'(L) and B'(R).

This filter allows a simple encoder to be used. On the down side, the signals in the L and R channels are affected by propagation delays. In section 'A', the propagation delay is between 2 ms at 20 Hz, and 9 µs at 20 kHz. Similarly section 'B' introduces a delay between 6.5 ms and 3.6 µs. Section 'A' is therefore the best choice for the L and R signals because it has the smallest effect. Both channels then 'suffer' from the same delay (causing heavy distortion of square wave signals, as you can try out for yourself), but that is not a problem because the stereo effect is hardly degraded (the filter has unity gain across the range 20 Hz to 10 kHz).

Current consumption of the filter sections is about 16 mA. If you are after better quality, we recommend using dual opamps, because they often have better specifications (we're not talking of the TL072 class, though).





The measured phase response is shown by the graph. Note that the maximum phase ripple is limited to about 5° between 100 Hz and 7 kHz. In theory, that would be 1.5°. Take into account however, that (1) the accuracy of the measurement is about 1%; (2) the nearest available 'real' values are used for R1, R4, R7, R10 and R16; and (3) the capacitors used are 5% tolerance types. The absolute error of about 5° is then not a bad figure at all. Finally, to complete the story, the theoretical values of the above mentioned resistors: R1=4,795 Ω, R4=4,319 Ω, R7=4,760 Ω, R10=4,225 Ω, R13=4,564 Ω, R16=4,180 Ω.

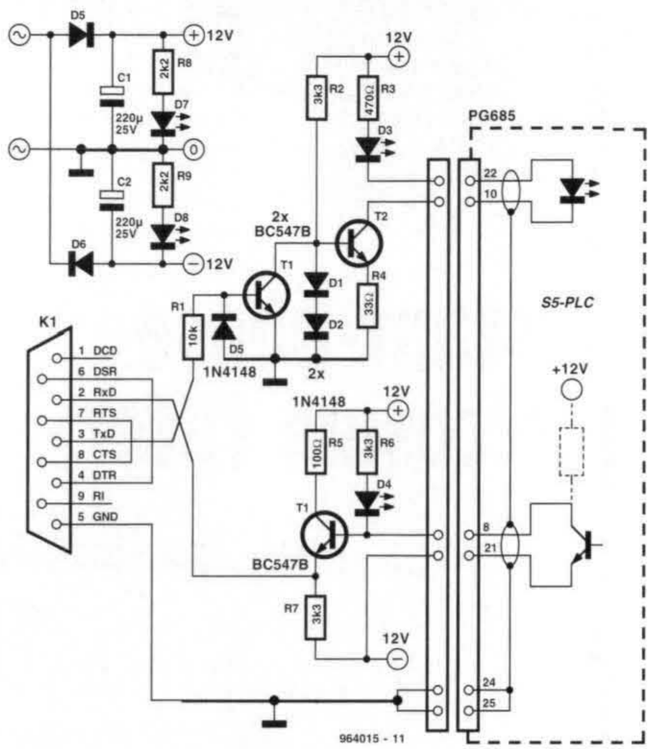
[T. Giesberts - 964047]

interface convertor

The circuit converts the voltage levels at an RS232 interface into current signals. In the quiescent state, send signal TXD, which has a level between –15 V and –5 V, is converted into a quiescent current of about 20 mA. In operation, the level becomes between +5 V and +15 V, depending on the set bit. At this level, the current loop must be interrupted. At the other end, in the quiescent state, the PLC sends a current of about 20 mA which is converted into a voltage between –15 V and –5 V.

If the PLC interrupts the current loop during the transfer of the bits, the convertor must provide a voltage between +5 V ands +15 V. To this end, signal TXD controls transistor T_1. In the quiescent state, the signal is negative and T_1 is cut off. Transistor T_2 is fully on via R_2 and causes a quiescent current of about 20 mA: diodes D_1, D_2, in conjunction with R_4, form the relevant current source.

When in operation TXD becomes positive, T_1 comes on, which removes the base current from T_2, so that this transistor is cut off. Diode D_3 lights when current flows and this indicates a correct link between computer and PLC.



The send section of the PLC switches on its transistor in the quiescent state, so that a current flows through D_4 which consequently lights. The base of T_3 is at emitter level, so that the transistor is cut off and the level of the RXD line is –12 V. In operation, the SPS switches on the transistor, which causes the level to rise to about +12 V.

The circuit uses readily available components, so that its construction should not present supply problems.

The circuit is connected to the computer by a 9-way sub-D socket (AT COM connection), which is expanded to 25-way by a conventional adaptor. At the SPS end, a suitable 25-way socket is used. The LEDs must be fitted so that they can be viewed from outside: they indicate whether the supply is on and whether the link to the PLC is all right.

The circuit may be supplied by a mains adaptor unit, which is modified by soldering two lengths of insulated circuit wire to the secondary of the transformer **before** the rectifier. These wires are then linked to D_5 and D_6 as shown in the diagram.

If the mains adaptor has no transformer, which is often the case, a symmetrical ±12 V power supply must be used.

The circuit draws a current of about 30 mA.

[W. Kasten - 964015]

polarity corrector

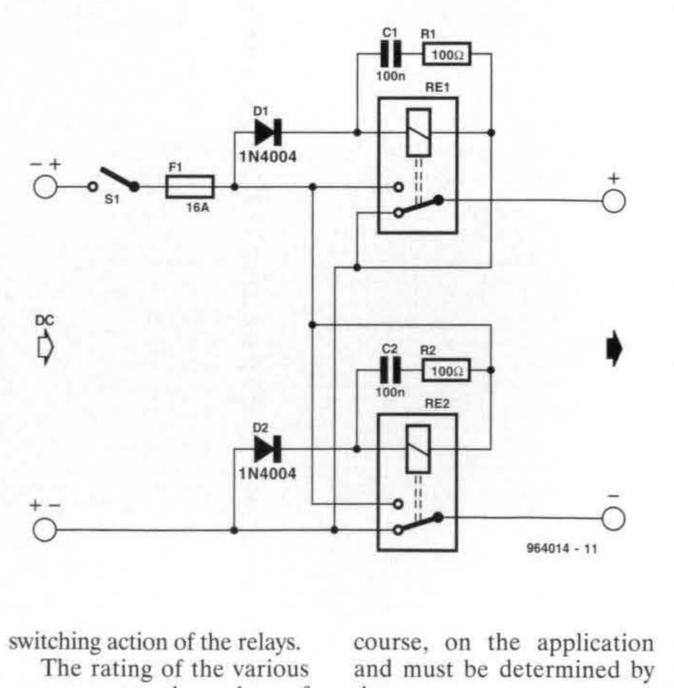
The corrector has the task to always connect a load to a direct-voltage source with correct polarity. It thus functions in the same way as a polarity protection diode, but does not lower the voltage by 0.4 V (in case of a Schottky diode) or 0.7 V (in case of a silicon diode). Its slightly higher cost is, therefore, justified in cases where millivolts count.

If the +ve pin of the voltage source is connected to the upper terminal in the circuit and S_1 is closed, D_1 conducts and a current flows through Re_1. The relay contact then connects the upper input line to the upper output line. At the same time, D_2 is cut off, so that Re_2 remains unenergized. The lower line is then connected to the –ve pin of the voltage source.

If the connections to the voltage source are reversed, Re_1 remains unenergized and its contact links the lower input line (which is then connected to the +ve pin of the voltage source) to the upper output line. At the same time, Re_2 is energized, and its contact links the upper input line to the lower output line. In this way, correct polarity of the voltage source is guaranteed at all times.

The circuit may be switched on with a switch at the input, otherwise, there is always a relay on and this uses energy. The fuse is optional.

The *RC* networks across the relay coils are essential since they smooth out any current peaks caused by the



switching action of the relays.

The rating of the various components depends, of course, on the application and must be determined by the user. [A. Rietjens - 964014]

Uwe Kardel

Dear Editor—With reference to the letter from J. v Oyen in *Elektor Electronics* May 1996: if the VCR has an AUDIO DUB facility, then this can be used to record audio signals on video tape as follows:

- record television programmes on full length of video tape;
- rewind;
- as if editing, use AUDIO DUB to overwrite with new audio signal the audio track on the video tape; AUDIO DUB leaves intact the previously recorded sync track

F. Sugden
Northwich

Thank you for this information, which we ourselves and, no doubt, many readers will find very useful. [Editor]

Dear Editor—I read with interest R. Williams' letter, which appeared in the April issue, concerning his difficulty in obtaining software for the 68HC11 processor board. Recently, I wrote a Windows-based software system, which enables a user to write, assemble and download program code to the processor's RAM or EEPROM, and also to receive dat back and store it in a file. The system also allows the user to configure the serial port for any communication protocol, and to diagnose communications problems. I would be happy to make this program available to the readers of *Elektor Electronics* free of charge, perhaps through the Readers' Services.

Patrick A. Gaydecki
University of Manchester

Mr Williams has been advised of your offer and he will, no doubt, be in touch personally. Furthermore, we thank you on behalf of other readers who may wish to take advantage of your generous offer. [Editor]

Dear Editor—I am writing to make a request that you ask of authors of constructional articles to publish the address of the supplier of components they used for their original design in their articles; particularly where they are using PCB mounted components, and they have designed a PCB layout to fit those components.

I am in the process of building a design for an electronic exposure timer that was published in your March 1991 issue. I have been unable to locate suppliers for some of the PCB mounted components that fit the author's design. It is not clear what nationality the author is, and therefore impossible to say where he would have got his components from.

In your February edition this year, you published a design for a stereo FM receiver using surface mounted components. Again, I have been unable to find a supplier of the FM ICs used in the design.

Peter Bann
Dover, Kent

As far as a large part of the world is concerned, most passive components are made by a number of manufacturers to the same specification. It is, therefore, impossible to say where such components may be obtained, except, of course, if it is a special one, such as certain sensors or thermistors.

Unfortunately, our designers are of many nationalities and often obtain components as 'samples' from manufacturers or importers, particularly in the case of ICs and semiconductors. But here again, many of these devices are made by a handful of manufacturers to near-identical specification. Most of these originate from the USA, but a fair number come from Japan, Germany or France. For instance, the TDA devices you mention are manufactured by Philips (the Netherlands), Siemens (Germany), SGS Thomson (France), Signetics (USA), and others. If you have contacted the many retailers who advertise in the UK magazines and they do not stock what you need, then there is a problem. But even then, our Dorchester office can often advise whom to contact in the EU. For instance, the TDA ICs you mention may be had readily from C-I Electronics (see page 112).

[Editor]

CONSTRUCTION GUIDELINES

Elektor Electronics (Publishing) does not provide **parts and components other than** PCBs, fornt panel foils and software on diskette or IC (not necessarily for all projects). Components are usually available form a number of retailers – see the adverts in the magazine.

Large and small values of components are indicated by means of one of the following prefixes :

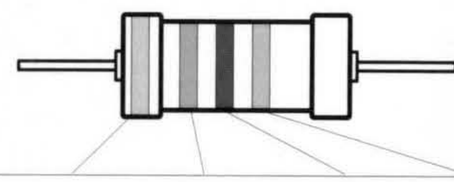
E (exa) = 10^{18}	a (atto) = 10^{-18}
P (peta) = 10^{15}	f (femto) = 10^{-15}
T (tera) = 10^{12}	p (pico) = 10^{-12}
G (giga) = 10^{9}	n (nano) = 10^{-9}
M (mega) = 10^{6}	μ (micro) = 10^{-6}
k (kilo) = 10^{3}	m (milli) = 10^{-3}
h (hecto) = 10^{2}	c (centi) = 10^{-2}
da (deca) = 10^{1}	d (deci) = 10^{-1}

In some circuit diagrams, to avoid confusion, but contrary to IEC and BS recommandations, the value of components is given by substituting the relevant prefix for the decimal point. For example,

3k9 = 3.9 kΩ   4μ7 = 4.7 μF

Unless otherwise indicated, the tolerance of resistors is ±5% and their rating is ⅓–½ watt. The working voltage of capacitors is ≥ 50 V.

The value of a resistor is indicated by a **colour code** as follows.



color	1st digit	2nd digit	mult. factor	tolerance
black	–	0	–	–
brown	1	1	$\times 10^{1}$	±1%
red	2	2	$\times 10^{2}$	±2%
orange	3	3	$\times 10^{3}$	–
yellow	4	4	$\times 10^{4}$	–
green	5	5	$\times 10^{5}$	±0,5%
blue	6	6	$\times 10^{6}$	–
violet	7	7	–	–
grey	8	8	–	–
white	9	9	–	–
gold	–	–	$\times 10^{-1}$	±5%
silver	–	–	$\times 10^{-2}$	±10%
none	–	–	–	±20%

Examples:
brown-red-brown-gold = 120 Ω, 5%
yellow-violet-orange-gold = 47 kΩ, 5%

In **populating a** PCB, always start with the smallest passive components, that is, wire bridges, resistors and small capacitors; and then IC sockets, relays, electrolytic and other large capacitors, and connectors. Vulnerable semiconductors and ICs should be done last.

Soldering. Use a 15–30 W soldering iron with a fine tip and tin with a resin core (60/40) Insert the terminals of components in the board, bend them slightly, cut them short, and solder: wait 1–2 seconds for the tin to flow smoothly and remove the iron. Do not overheat, particularly when soldering ICs and semiconductors. Unsoldering is best done with a suction iron or special unsoldering braid.

Faultfinding. If the circuit does not work, carefully compare the populated board with the published component layout and parts list. Are all the components in the correct position? Has correct polarity been observed? Have the powerlines been reversed? Are all solder joints sound? Have any wire bridges been forgotten?

If voltage levels have been given on the circuit diagram, do those measured on the board match them – note that deviations up to ±10% from the specified values are acceptable.

Possible corrections to published projects are published from time to time in this magazine. Also, the readers letters column often contains useful comments/additions to the published projects.

Safety Guidelines

Safety requirements refer mainly to the 240 V mains voltage, but also to the temperature of touchable parts and fire protection. Most problems connected with a mains power supply can be prevented by the use of approved and correctly rated mains adaptors. As regards mains-operated equipment, there are two classes of insulation: Class I: single insulation, which always requires a three-core supply cable with earth, and Class II: double insulation, which requires no earth and only a two-core supply cable. Thus, the requirement is always for double protection. With the enclosure shut, all touchable, conducting parts must be at earth potential.

Class I

Class I requires insulation between the mains voltage and each and every touchable part that withstands a flashover voltage of 2120 V. To prevent flash-over, the distance between mains voltage carrying parts and touchable parts must be ≥ 3 mm. All touchable, conducting parts must be properly earthed.

Class II

The requirements of Class II are Identical to those of Class I except that the test voltage is 4240 V and the flashover distance is ≥ 6 mm.

Practical considerations

A safe rule of thumb is to keep the distance between mains carrying parts and other parts as large as possible, but never less than required. Try to make the mains carrying part as compact as possible. Use an approved mains entry with integrated fuseholder and on/off switch. Note that the manufacturer's statement 'suitable for 250 V' does not mean that insulation of the switch is approved, merely that it does not break down at 250 V.

If you do not use an integrated entry, use a strain relief on the mains cable at point of entry.

1. A single-pole mains on/off switch is allowed on equipment that is powered by transformers with isolated primary and secondary windings.

2. An on/off switch not in the mains circuit is allowed if the transformer has isolated primary and secondary windings, and the power consumption in the 'off' position is not more than 10 W. There must be a visible indication that the equipment is plugged into the mains.

3. An on/off switch is not required if the power consumption of the equipment is ≤ 10 W or if the equipment is intended for continuous use, such as an antenna amplifier.

Equipment not meeting these three conditions must have a double-pole on/off switch.

Fuses, inductors, capacitors and resistors for interference suppression need not be switched off. It is advisable, though not mandatory, to precede the switch by a fuse.

Never solder mains carrying wires directly to a printed-circuit board: use solder tags. The use of crimp-on tags is also good practice.

The mains earth must be connected to other parts that need to be grounded by a yellow/green wire. Pay particular attention to the metal spindles of switches and potentiometers: if touchable, these need to be earthed as well.

Close to each and every fuse, even if fitted on a PCB, must be a label stating its rating and type.

One of the side panels, or the rear panel, must have a label stating the identity of the equipment, for instance, EE power supply from no. 213, the mains voltage, and mains frequency. If operation from a.c. only is possible, the label must carry the symbol ~. In case of a failure, there should not be any danger to the user.

The temperature of touchable parts must not be so high as to cause injury or create a fire risk.

All risks can be eliminated by the use of correct fuses, a sufficiently firm construction, correct choice and use of insulating materials and adequate cooling through heat sinks and by extractor fans. The rating of a slow fuse should be not greater than 1.25 times the normal operating current, whereas that of a fast fuse should be equal to the normal operating current.

Fast fuses are used, for instance, in case of several secondary windings, but if there is an electrolytic capacitor behind the secondary, a slow fuse must be used to allow for surges in the charging current.

The equipment must be sturdy: repeatedly dropping it onto a hard surface from a height of 50 mm must not cause damage. Greater impacts must not loosen the mains transformer, electrolytic capacitors and other important components.

Do not use dubious or flammable materials that may emit poisonous gases.

Shorten screws that come too close to other components.

Keep mains-carrying parts and wires well away from ventilation holes, so that an intruding screwdriver or inward falling metal object cannot touch such parts.

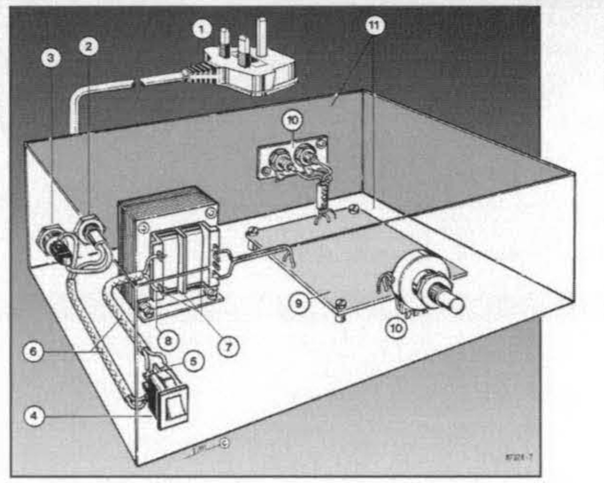


Figure 2. It is advisable, and also practical, to build equipment to Class II. Important aspects are:

1. ***Use a mains cable with moulded-on plug.***
2. ***Use a strain relief on the mains cable.***
3. ***Attach a label near the fuse holder stating the mains voltage and frequency, and the value of the fuse.***
4. ***Use an approved mains on/off switch; this should not have a metal lever since that is normally not insulated properly.***
5. ***Push wires through the eyelets and solder.***
6. ***Use insulating sleeves for extra protection.***
7. ***The distance between transformer terminals and core and other parts must be ≥ 6 mm.***
8. ***Use wire with an insulation of ≥ 4 mm and a core diameter of 0.75 mm.***
9. ***There are no special requirements for the board and circuit other than that it must be secured firmly.***
10. ***The earth of the circuit may be touched because the mains transformer is double insulated.***
11. ***Although the enclosure may be a metal one, since the transformer is double insulated, a plastic one is preferred.***

Transformers

Figure 1 shows how a transformer should be connected in line with safety requirements. Although double-pole on/off switches are shown, these may be single-pole since in both cases the transformer is a double-insulated type. It is as-sumed that the transformers are short-circuit-proof, whence the absence of primary fuses. If the assumption is not true, a primary fuse must be used. The figures ① and ② indicate, respectively, whether single or double insulation is required.

Working in safety

As soon as you open an equipment, there are many more potential dangers. Most of these can be eliminated by unplugging the equipment from the mains before the unit is opened. But, since testing requires that it is plugged in again, it is good practice (and safe) to fit an earth leakage switch rated at not more than 30 mA to the mains system (this may be fitted inside the outlet box or multiple socket). Earth leakage switches more sensitive than 30 mA need to be used only if the leakage current is expected to remain below 30 mA, which is rarely the case.

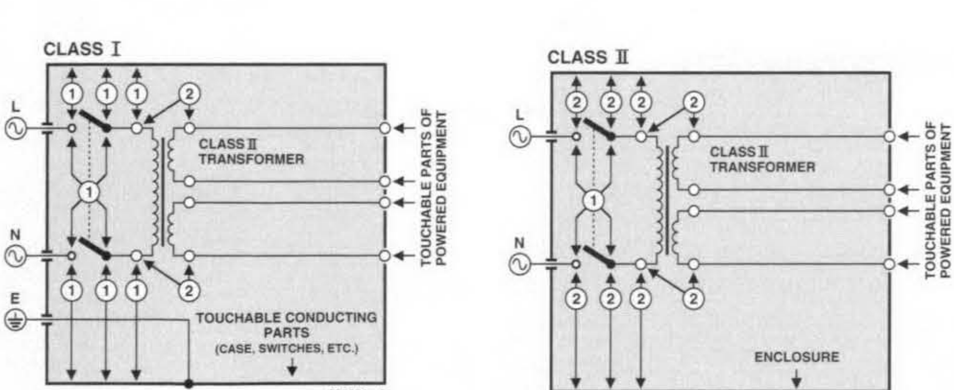


Figure 1. At the left a Class I equipment powered by a double-insulated transformer. All touchable, conducting parts must be properly earthed: outputs need not. At the right a Class II equipment also powered by a double-insulated mains transformer.