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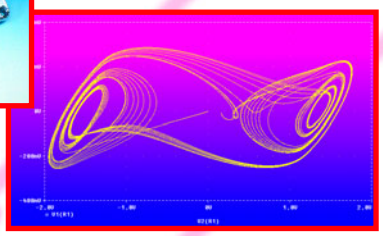

chaos in electronic circuits

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chaos in electronic circuits

seeing is believing

Today some aspect of chaos theory is often seen in science magazines and even newspapers. Does it have any relevance to radio and other electronic circuits? Yes, it does.

By Chris Meadows G4KWH

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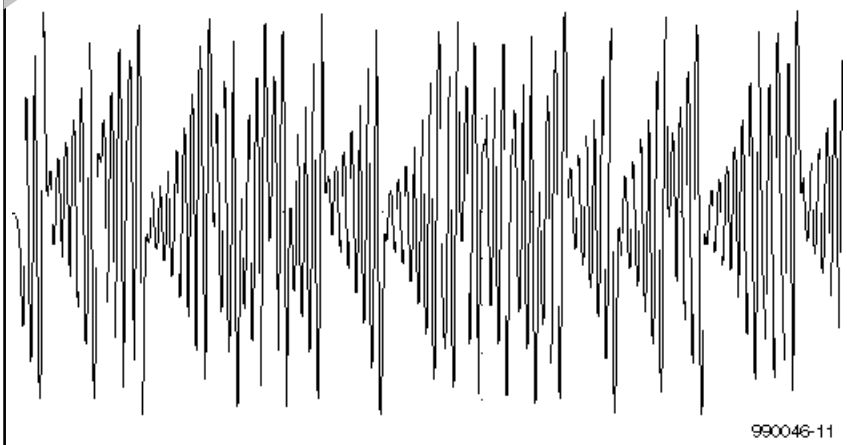

Figure 1. Trace of a chaos time diagram.

The term chaos may conjure up random uncoordinated movements of people in panic or the up and down movement of the stock market. In the scientific and engineering use of the term, chaos is not random in spite of the manner in which it shows itself. I hope you will be convinced of this by simulating or actually constructing the small chaotic electronic circuit given in this article.

What is chaos? How may it be defined? Two main tests can by applied to check for chaos. Firstly an electronic circuit may be exhibiting chaos if its output waveform shape can be significantly altered when a component value is changed by a small amount, say 1%. A typical chaotic time output waveform may be seen in **Figure 1**.

Secondly, if two different voltages (or currents) that exist in the circuit are able to produce a 'strange attractor', using the X-Y feature on an oscilloscope, then the circuit under test is behaving chaotically. This test depends on the interpretation of the image as a strange attractor. A strange attractor image is shown in **Figure 2**.

Why is the image strange? The picture we see exists in three-dimensional space. We are looking at a trace that never intersects itself; the loops (they are not circles) are infinitely deep but continually fold back, but never touch or join. For all of this we see it as a complete figure; strange indeed. Figures such as these coexist with other dynamical phenomena such as Fractals and Mandelbrot sets.

BACKGROUND

Chaos was pondered mathematically well over one hundred years ago, but it was not until computers were used to investigate the subject that the modern notion of chaos was born. All this happened in the early 1960s at Massachusetts Institute of Technology (MIT). It began when a weather man working at the institute wondered why the sea tides could be predicted exactly but not the weather. He set out to try and remedy this situation.

With access to the MIT's computers and a set of math equations, he discovered the roots of modern chaos theory. Computer analysis indicated that only a slight change in just one of the many parameters in his weather equations brought about significant changes in the outcome.

A process romantically summed up by saying that the movement of a butterfly's wing in South America can effect a weather change in Europe.

ELECTRONIC CHAOS

Can we as electronic constructors create our own electronic butterflies and strange attractors? The answer is yes and with not too much effort. There is the option of simulating a chaos circuit or actually building it.

THE SIMULATION ROUTE

If you have a copy of MicroSim's Pspice (the evaluation MSDOS version is fine) it is easily used to load in the netlist given in **Table 1**. This program will

generate time diagrams and strange attractors similar to the waveforms seen in Figures 1 and 2. Pspice software may be downloaded from the Edream BBS in the UK on telephone (01442) 256362. The book by Tuinenga listed at the end of this article is a reasonable introduction to Pspice and the netlisting of circuits.

The netlist is created from one of the first circuits used to analyse chaos. The circuit consists an inductor-capacitor (LC) arrangement that is connected to a negative resistor circuit provided by two op-amps. The full circuit is shown in **Figure 3**.

The circuit is called the Chua Diode Circuit after Professor Chua who created and analysed the arrangement in the 1980's.

Once the Pspice program is running, type in the netlist and save it. Most types of error are reported at this stage automatically. Nine times out of ten a reported problem is typographical. Then go to menu bar and select Analyse and run Pspice to simulate the circuit (the process takes about one minute on a 300-MHz machine running Windows 95 in DOS Shell mode). After the simulation is complete you are presented with a display screen. Press the enter key for Add_Trace then press key F4 and highlight V1 and Enter. A trace similar to Figure 1 is developed. To display the strange attractor, go to the X_axis, Enter, and then the X_variable and Enter. Now press F4 and select V2 and Enter. An image similar to Figure 2 is developed. Try a few of the other listed voltages or currents to develop different attractors.

The chaos test can be applied by changing the inductor value by, say, 1%, and then looking at the new time diagram: it changes shape. Change to the X-Y feature and note that the strange attractor diagram keeps its shape.

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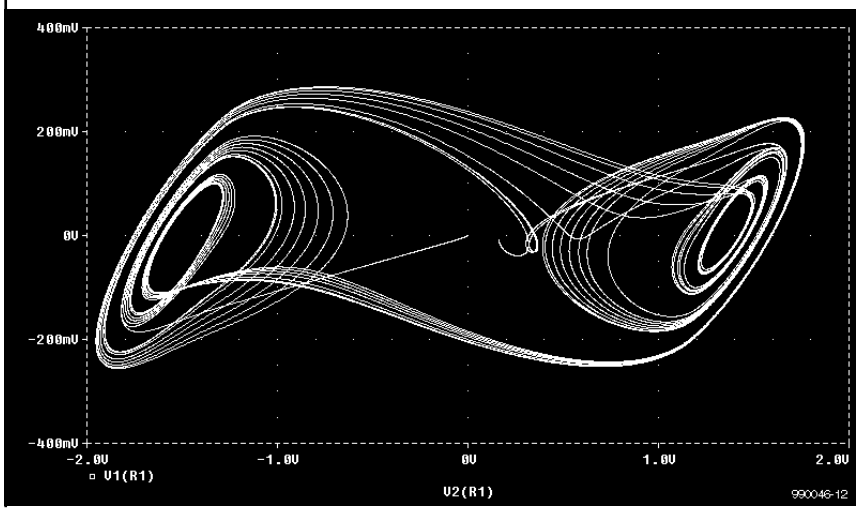
Figure 2. Strange attractor image often called the Lorenz 'butterfly'.



CHAOS UNDER WINDOWS

MicroSim do publish a Windows evaluation version of Pspice called DesignLab. It may be downloaded from their Web site at *http://www.microsim.com*.
If you choose to use this version rather than the DOS one described above, follow this procedure (Pspice v. 6.2):

Draw the circuit diagram.
Select ANALYSIS, SETUP, TRANSIENT.
Set transient to PRINT STEP= 20ns, FINAL TIME= 20ms, STEP CEILING= 500ns.
Activate SIMULATE.
Select X-axis settings in PROBE.
Select AXIS VARIABLE.
Select ALIAS NAMES.
Select V2(R1).

THE CONSTRUCTION ROUTE

If computers and simulation are not for you, then similar results may be obtained if the Chua diode circuit is actually built.

Component values and DC voltage are not critical. Instead of using two UA741 it is expedient to use a double op amp IC such as a LF412 or a TL052 or 62.

Table 1. Netlist of a circuit exhibiting chaotic behaviour (for Pspice DOS version).

Netlist some chaos

The netlist below is for the Chua diode circuit, and intended for DOS versions of Pspice.

```
Always have a netlist title on the 1st line. Comments after ";" are ignored by the program
R1 0 3 3.3k ; no value listed here is critical.
R2 3 4 22k
R3 2 4 22k
V+ 5 0 12V ; not critical say 10 to 15V
V- 0 6 12V
X1 2 3 5 6 4 UA741 ; the only op-amp available in version 5.2 but it works fine.
.LIB EVAL.LIB
R4 0 7 2.2k
R5 7 8 220
R6 2 8 220
X2 2 7 5 6 8 UA741
C1 2 0 10n ic=0V ; zero volts for initial conditions
C2 1 0 100n ic=0V
L 1 9 18m ; some interaction with this value and R1
R7 0 9 12 ; value is within the wire forming L1
R8 1 2 1.5k ;use a preset up to 2k
.tran 10u 20m 0 10u uic ; sets up the analysis times and to use initial conditions
.END ; must always end with an .end statement.
```

TESTING

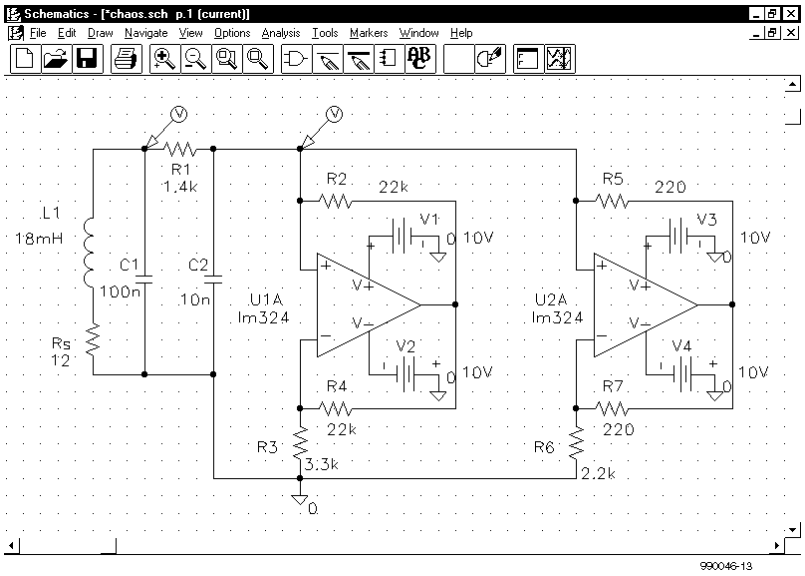
Connect an oscilloscope probe to the top end of C_1 and adjust the controls for a trace. The signal is at audio frequency. A different chaotic waveform can be seen by connecting the probe to the top of C_2. Switch the oscilloscope for X-Y mode and connect the signals from capacitors C_1 and C_2 to the X and Y inputs. Adjust the variable resistor (DOS: R8; WIN: R1) carefully to obtain the strange attractor shape seen in Figure 2.

CONCLUSION

Many people ask "What use is chaos?" A factitious answer might be "Why climb Everest?" The question is more usefully answered by the fact that chaos theory has been and is of great use in providing systems reliability. It has been a motivator to develop mathematical tools necessary to analyse and understand the problems associated with instability and oscillations in not only electronic circuits but also mechanical systems. Many complex circuits thought to be stable have been found, under certain conditions, to be unstable and exhibit chaos. Such a regime renders the system unserviceable with possible dire consequences. Another area of experimentation and research consists of using chaotic waveforms to modulate transmitted messages. Encrypting a message in this manner may yield a competitive advantage over current covert transmission techniques.

(990046-1)

Figure 3. The Chua diode circuit (drawn using Pspice Windows version).



For further reading

The following books are well worth consulting for further information on the subject of chaos.

I Stewart, *Does God Play Dice?* Penguin Books 1990.

J Gleick, *Chaos*. Cardinal 1989.

P W Tuinenga, *SPICE*, Prentice-Hall 1992.

Edited by N Hall, *New Scientist Guide to Chaos*. Penguin Books 1992.

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 ⅛–½ watt. The working voltage of capacitors is ≥ 50 V.

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.

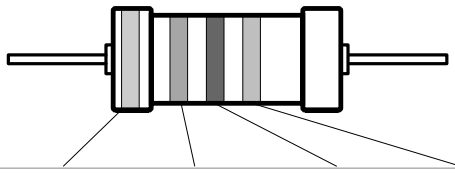
Soldering. Use a 15–30 W soldering iron with a fine tip and tin with a resin core (60/40) Insert the terminals of components in the board, bend them slightly, cut them short, and solder: wait 1–2 seconds for the tin to flow smoothly and remove the iron. Do not overheat, particularly when soldering ICS 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.

The value of a resistor is indicated by a **colour code** as follows.



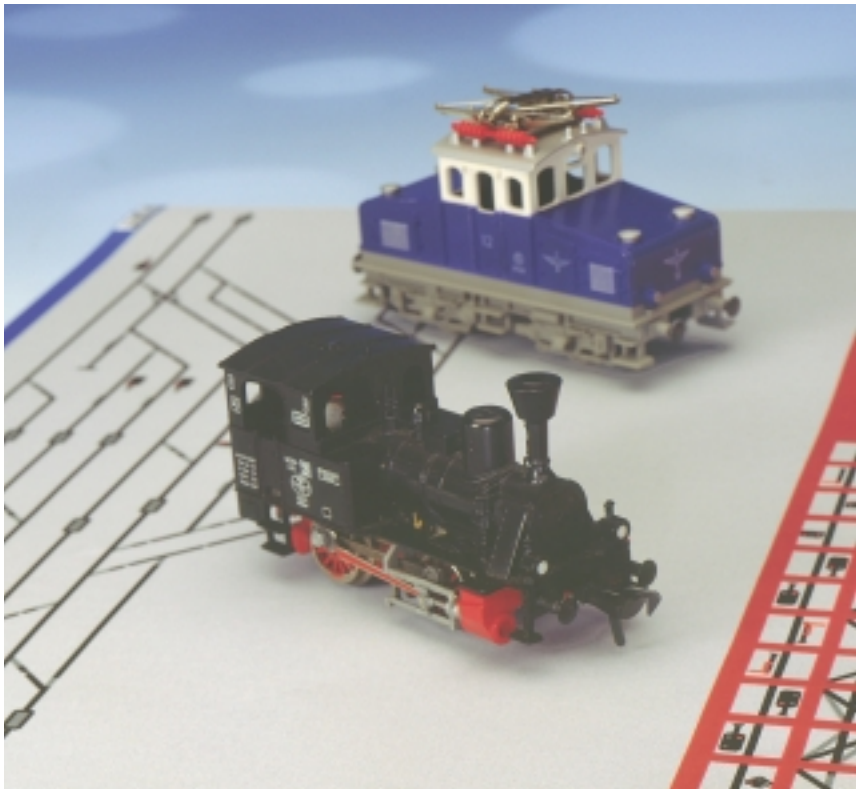
color	1st digit	2nd digit	mult. factor	tolerance
black	–	0	–	–
brown	1	1	$\times 10^{1}$	±1%
red	2	2	$\times 10^{2}$	±2%
orange	3	3	$\times 10^{3}$	–
yellow	4	4	$\times 10^{4}$	–
green	5	5	$\times 10^{5}$	±0,5%
blue	6	6	$\times 10^{6}$	–
violet	7	7	–	–
grey	8	8	–	–
white	9	9	–	–
gold	–	–	$\times 10^{-1}$	±5%
silver	–	–	$\times 10^{-2}$	±10%
none	–	–	–	±20%

Examples:
brown-red-brown-gold = 120 Ω, 5%
yellow-violet-orange-gold = 47 kΩ, 5%

digital control for model trains

design considerations

Although most hobbies could count on the interest of vast numbers of people not all that long ago, times have changed and they now attract only a handful of faithful adherents. One of the more popular hobbies was that of model trains and this retains a core of enthusiasts. One of the aspects of this hobby that has changed considerably is the amount of electronic units that is now available to the discerning few. This article discusses how digital circuits may be used to control locomotives, points, and signals.



By L. Lemmens

INTRODUCTION

A basic model train set consists of a railtrack, a locomotive (loco), perhaps a coach or two, and a variable power supply. The supply voltage may be adjusted within certain limits with a simple potentiometer to make the train go faster or slower. Such a set is available from most toyshops at relatively low cost.

Developments in digital electronic engineering and the fact that a model track is in essence a two-way bus. form the basis for a digital control system. A bus is a signal route to which several items of a system may be connected in parallel so that signals may be passed between them. A bus is commonly called a trunk in the USA and sometimes a highway in the UK.

There are two kinds of model railtrack: one in which the two rails carry different voltages, and one in which a central conductor is used. The advantage of the latter is that the polarity of the signals is independent of the direction of the train. In the two-rail system, measures must be taken to ensure that the loco receives digital signals of correct polarity. After all, changing the direction of travel necessitates reversal of the polarity of the digital signals.

Märklin, a popular manufacturer and supplier of model train sets, uses the central conductor, whereas most other makers use the two-rail system. This does not make much difference to the principles of the control units, so that this article remains general and is based on the control signals used in Märklin sets.

DIGITALLY CONTROLLED TRAIN

The basic setup of a digitally-controlled model railway is virtually the same as an analogue one—see **Fig-ure 1**. However, in a conventional analogue sys-

tem, electric motors are used that can work from a range of voltages, direct or alternating, it matters not. The higher the voltage (within limits), the faster the train travels. The voltage on the rails is generally in the range 4–16 V, but there is also a voltage of 24 V to actuate a direction switch. When this switch is operated, the train reverses its direction of travel.

In a digital setup, these elements are not easily recognized, since all control signals are digital ones generated by a computer or microprocessor. The digital controller is called the control unit.

In a digital system, the supply voltage is usually pulse-shaped whose peak value of ± 15 V is independent of the speed of the train. This means that the digital signals have a dual function: supply and control. This implies that instructions may be sent in tandem with the supply voltage from the central control unit via the track to the users (loco, points, etc.).

A simple test in which a lightbulb is connected across the track (rails O and B) makes this clear. The brightness of the bulb is independent of the speed with which a digitally-controlled train is driven along the track.

In the quiescent mode, there is a potential of –15 V on rail B, but when control pulses are transmitted, the polarity changes from –15 V to + 15 V. Resistive users, such as the bulbs in coaches, signals along the track, or the lighting of houses near the track are not affected by this reversal.

When a digital track system is used, it is advisable to use locomotives that have been designed for this, since the reaction of conventional locos used on such a track is quite unpredictable. Some do not react at all, while others travel at full speed at all times.

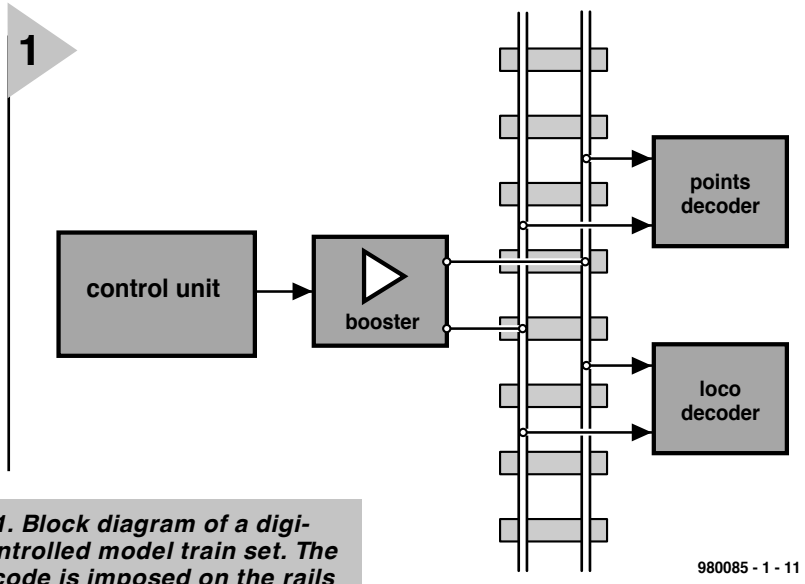


Figure 1. Block diagram of a digitally controlled model train set. The digital code is imposed on the rails by an electronic control unit. This code is detected by a decoder and translated into an action.

DATA ALONG THE TRACK

All units that are to react to digital data must contain a dedicated decoder to translate the instruction for the specific unit from the pulse signals. Address and data bits are transferred serially, that is, bit 1 is sent first and bit 9 last. The pulse train may be two-state or three-state.

Since the protocol is based largely on Motorola components (which is why the name Motorola format is often used), the term three-state* is used, which means that apart from the binary logic high (or 1) and logic low (or 0), there is a third logic level: the open input. These three states are encoded as follows:

- logic 0 – two short pulses
- logic 1 – two long pulses
- open input – a long and a short pulse.

The shape of these signals on the railtrack is shown in **Figure 2**.

In three-state logic, the smallest information unit is a *trit*. In the protocol used, four trits determine the decoder address. They provide $3^4 = 81$ different combinations. This means that, in theory at least, 81 locomotives may be used simultaneously on the track. However, address 68 is reserved for future expansion, so that only 80 loco address are available.

The four trits are followed by five data bits (32 combinations), which contain all the data for the item being controlled, such as speed of travel, direction of travel, special functions, or magnet energizing.

It is clear that the complete code of nine logic bits contains all necessary data for the control of locomotives, signals, points, and other units along the track.

The transmission of the control code requires 18 pulses (two per logic bit). **Figure 3** shows a possible composition of a complete instruction.

The reliability of the transmitted instruction is enhanced by sending the command twice in succession. If the relevant decoder reacts as if there were two different instructions, the data are ignored.

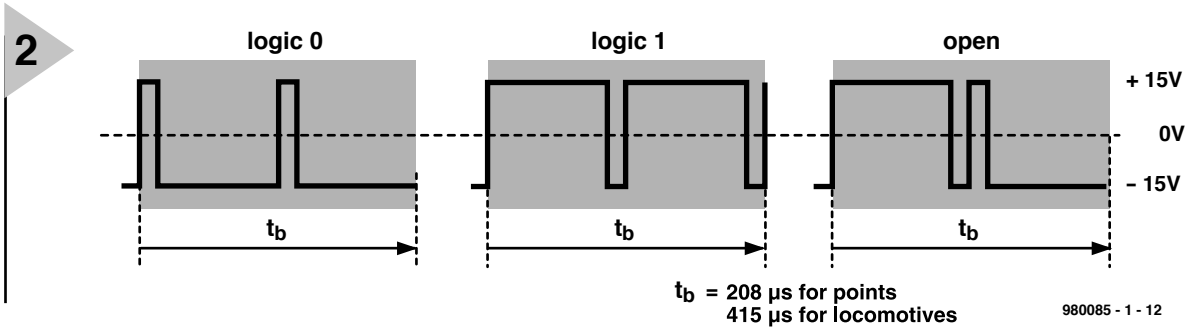
There is, of course, energy required for driving the locos, points, signals, and so on, and this is obtained by passing the pulses, which have a peak value of 15 V, through a rectifier, so that a direct voltage of 15 V ensues for energizing motors and electromagnets.

DECODERS

There are two kinds of decoder: mobile ones such as found in locomotives, and fixed ones as used in points and signal sets. These are

* *Motorola calls this 'trinary', but this is not (yet) an industry acccepted term.*

Figure 2. Three logic combinations are coded with pulse-shaped voltages.



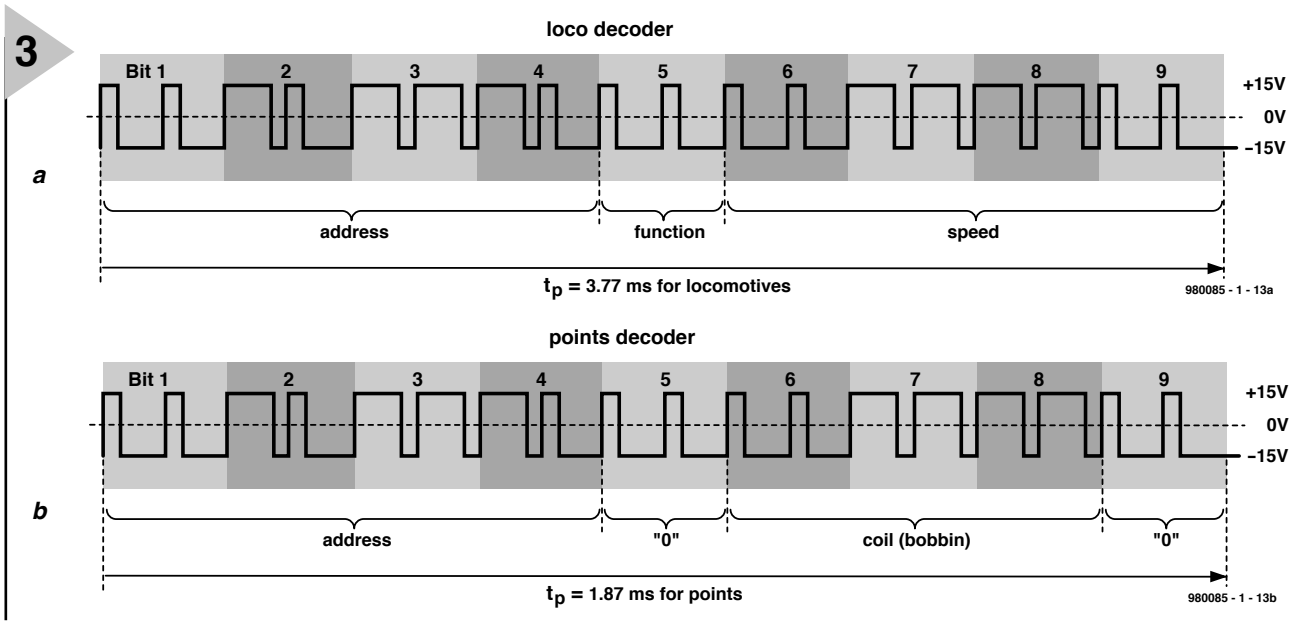


Figure 3. A complete instruction, in this case for a locomotive decoder, consists of 18 pulses.

termed locdecoders and point/signal decoders respectively.

Since, owing to the varying quality of nothe electrical connection between track and loco, locdecoders are particularly vulnerable to interference, they are provided with extra protection against such interference. Another means of reducing the sensitivity to interference is the use of a lower bit speed for locos. This has a secondary advantage in that differing baud rates enlarge the address range.

Points decoders are accessed at a baud rate of 4810 bit s^{-1}, whereas locos are controlled at a rate of 2045 bit s^{-1}. This means that the two pulses forming a bit or a trit last 4.4 ms, whereas in the case of a locdecoder the data need a time of 8.8 ms.

In this setup, decoders ignore signals with a bit rate not associated with them. That is, locdecoders do not detect the instructions to fixed decoders, and vice versa. This is of great practical benefit, since the available instructions (81 different address and 32 different blocks of data) may also be used for the locdecoders (64 addresses and 16 combinations).

execution of instructions

Every decoder contains a circuit that converts the detected digital signals into an action. To ensure that each decoder reacts in a specific way, it is provided with a compact DIP address switch. Such as switch may be replaced by an EEPROM.

loc decoder command								
Trit 1	Trit 2	Trit 3	Trit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9
trinary address				function	speed			

Figure 4. The structure of an instruction for a mobile decoder.

turnout decoder command								
Trit 1	Trit 2	Trit 3	Trit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9
trinary address				low	actuator no.			enable

Figure 5. The structure of an instruction for a fixed decoder.

special-function decoder command								
Trit 1	Trit 2	Trit 3	Trit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9
trinary address				high	functions 1 – 4			

Figure 6. The structure of an instruction for a decoder.with which special functions can be switched on or off.

In locdecoders, the transmitted data consist of three constituents:

- address (four trits long)
- function (one bit long)
- speed (four bits long)

The function of the address is clear: it selects the relevant locomotive. Function, for instance, lighting, a steam whistle or smoke from a funnel, may be switched on or off with the function bit.

Of the four bits (16 combinations) with which the speed is controlled, bit 6 is the least significant (LSB) and bit 9 the most significant (MSB). A value of 0 means stopping and standing still. A value of 1 means a change of direction, while bits 2–15 contain the actual information on speed.

This means that an instruction may look like this: loco 20, travelling at speed 4, extra function on. This is shown schematically in **Figure 4**.

Similarly, in the case of a points decoder the instruction may be: points decoder 10, points 3 energize coil.

In the case of points decoders, there are four trits for the address, then comes bit 5 which is always 0, and then bits 6–8 for the points address.

The ninth and last bit (9) determines whether the coil is to be energized. The structure of this combination is shown in **Figure 5**.

The code used with the decoder for special functions is different in that bit 5 is always 1. The remaining four bits are available for controlling the four functions. The structure of this is shown schematically in **Figure 6**.

address decoding

All decoders have an 8-way DIP switch with which the four trits long address is set. As seen in **Figure 7**, trit is defined by switches S_1 and S_2, trit 2 by switches S_3 and S_4, and so on. All switches are in either position low or high.

The switch combinations associated with the desired addresses are tabulated in **Table 1**. Bear in mind that address 68 cannot be used, since this is reserved for future functions. The same applies to address 81 (all inputs open). New control units put this address on the track as long as no other addresses are called. Note that address 80 at which the used bits are all low, should really be address 0.

There are also so-called Δ-decoders, such as the 6603, which use four switches, S_1–S_4. These are analogous to switches S_1, S_3, S_5, and S_7, of a standard locdecoder. The limitation of this arrangement is clear: only addresses in which S_2, S_4, S_6, and S_8, are not used (identified by the – in Table 1) can be set. In other words, the price for miniaturization is a limited number of available addresses.

DIP switch/trinary address allocation								
DIP-switch	S1	S2	S3	S4	S5	S6	S7	S8
address	Trit 1		Trit 2		Trit 3		Trit 4	
controls	low	high	low	high	low	high	low	high

Decoder	trinary address				corresponding switch position							
	Trit 1	*Trit 2*	*Trit 3*	*Trit 4*	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*
01	high	low	low	low	–	X	X	–	X	–	X	–
02	open	low	low	low	–	–	X	–	X	–	X	–
03	low	high	low	low	X	–	–	X	X	–	X	–
04	high	high	low	low	–	X	–	X	X	–	X	–
etc.												
53	open	open	open	high	–	–	–	–	–	–	–	X
54	low	low	low	open	X	–	X	–	X	–	–	–
55	high	low	low	open	–	X	X	–	X	–	–	–
etc.												
79	high	open	open	open	–	X	–	–	–	–	–	–
80 (0)	low	low	low	low	X	–	X	–	X	–	X	–

Figure 7. Each mobile decoder contains a DIP switch with which the three-state address can be set.

UPDATED FORMAT

A 'new Motorola format' was introduced by Märklin in 1994 and was first used in their control unit 6021.

This new format can, and does, give rise to incompatibility in certain respects with the earlier format. However, the control units may be reverted to the old standard with a DIP switch. In the new format, the standard serial speed for the locdecoders is 38 400 baud, while that for fixed decoders is 76 800 baud.

The encoding of signals has also undergone changes. The digital signals imposed on the rails are formed at low speed by 26 μs long pulses. At high bit rates, this is halved to 13 μs. Eight of these pulses form a digital block whose length is therefore 104 μs or 208 μs.

These basic blocks are used to encode the two-state 1 and 0, and the three-state 1, 0 and open—see **Figure 8**.

A packet consists of 18 two-state or nine three-state codes. Each packet is followed by a pause during which no pulses are sent. A double packet consists, as would be expected, of a sequence of two packets that are separated by an interval.

LOCO CONTROL

When a loco is controlled via the new Motorola format, the first four trits, that is, the first eight pulses being received, contain an address between 0 and 80. The fifth bit is a two-state bit, and this is followed by four trits.

The difference with the previous format is that in this four two-state bits were used, with which 16 combinations could be formed. These are used in the new format as eight independent pulses with which 2^8 (256) combinations can be set up. In other words, the number of possibilities has been increased appreciably.

In practice, the foregoing is not entirely true, since, because of compatibility requirements with the previous format, certain combinations are not allowed.

In brief, the difference between the old and new formats lies primarily in the last eight of the 18 pulses that represent an instruction.

finally

The foregoing 'theoretical' considerations form the basis for a new digital train control with a PC interface, the first of which is planned to be published in the June issue of this magazine.

[980085]

8

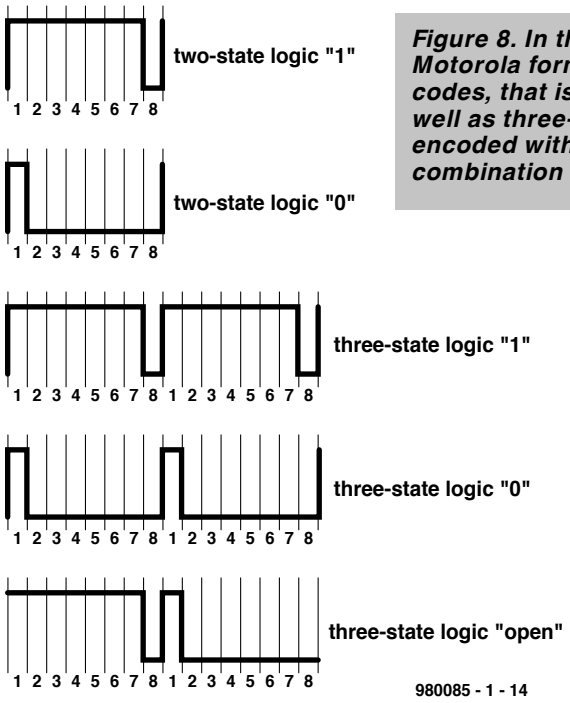
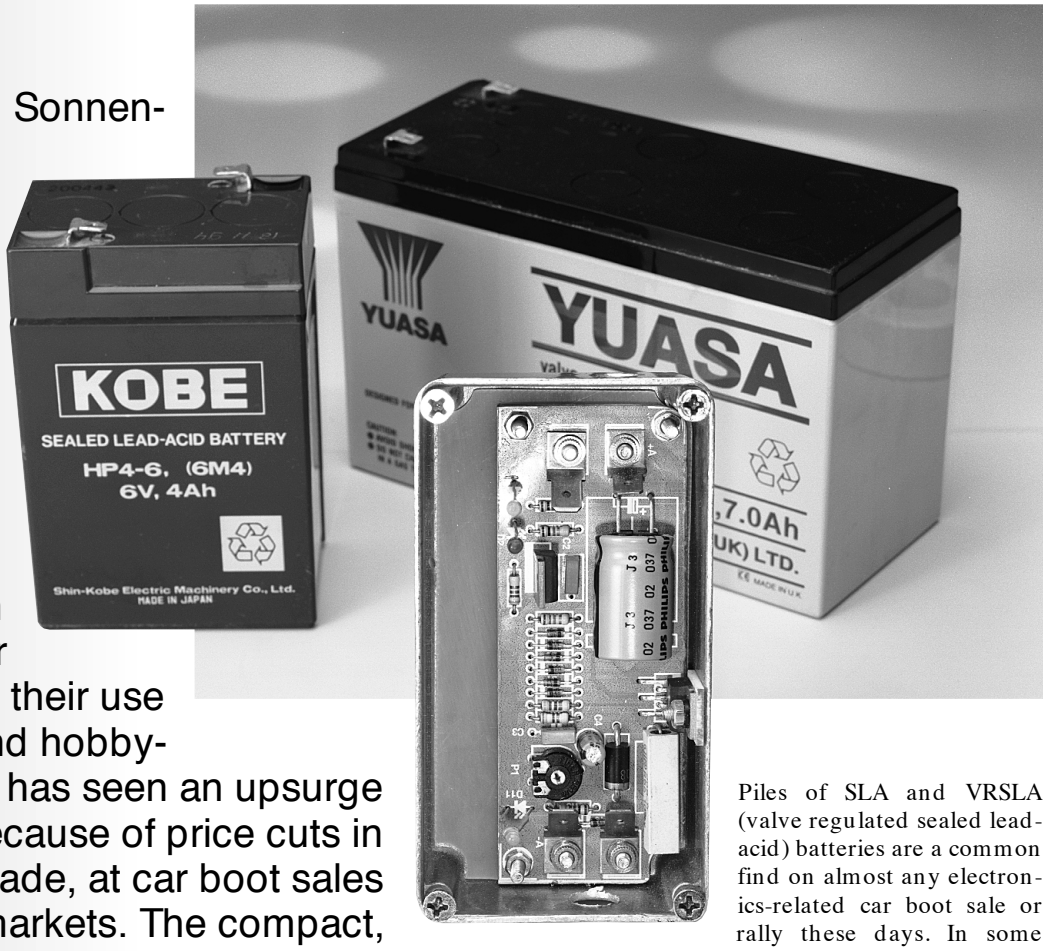


Figure 8. In the 'new' (1994!) Motorola format all used codes, that is, two-state as well as three-state, are encoded with a discrete combination of two pulses.

sealed lead-acid (SLA) battery charger

for 6 V and 12 V (VR)SLA batteries



Yuasa, Kobe, Sonnenschein and Varta are but a few of countless manufacturers of sealed lead-acid (SLA) batteries. Although these batteries have been around for many years, their use in amateur and hobbyists circles has seen an upsurge recently because of price cuts in the surplus trade, at car boot sales and flea markets. The compact, easy to handle 6-volt and 12-volt types with capacity ratings up to 30 Ah can be picked up cheaply and appear to be the most popular. SLA batteries require a simple but fairly unusual charge algorithm for which a low-cost circuit is described in this article.

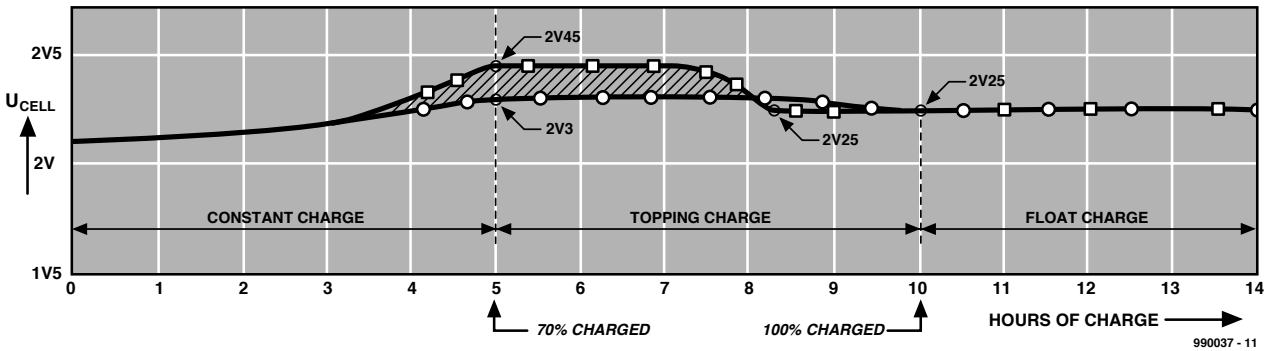
Design by K. Walraven

Piles of SLA and VRSLA (valve regulated sealed lead-acid) batteries are a common find on almost any electronics-related car boot sale or rally these days. In some cases, the batteries are claimed to be new, and indeed we have the seen the odd SLA with the manufacturer's seal still clamped on to the terminals. Most SLA batteries found in the surplus trade are, however, the result of 'contractual maintenance work' on commercial equipment, usually surveillance or computer-related.

Whatever the source of the SLA battery, whether it is 'used', 'new', 'ex-equipment' 'reconditioned' or 'fully tested & guaranteed', what you take home for a fiver or so will rarely achieve the capacity specified by the

1

Figure 1. Manufacturers of (VR)SLA batteries specify this charging algorithm. The choice between the lower and higher cell voltage (lines marked with ❍ and ❑ respectively) to begin the topping-charge phase will mostly depend on the time available for charging. Note that the duration of the topping-charge phase applies to low-level charging only (max. cell voltage 2.30 V).



manufacturer. This is because the battery will typically have been in storage for a long time with no standby charge applied.

Although buying an SLA battery on a flea market is always something of a gamble, do remember that if your bargaining was right you should not have paid more than one tenth of the original cost and the battery you are taking home may have enough capacity left for years of trouble-free use in or around the shack. If you do not like gambling and want to have the full battery capacity as printed on the device (the Ah figure), then leave flea markets for what they are and prepare for the shock you will get when enquiring about a the one-off price of a new, guaranteed SLA battery.

SLA BATTERIES — GENERAL

The plastic-contained SLA battery is actually no more than a technical refinement of the *flooded* lead-acid battery originally invented by Gaston Planté in 1859. The *sealed* or *valve-regulated sealed* version, sometimes also sold under the trademark 'Gelcell', is typically used in portable equipment. Compared with the common-or-garden flooded lead-acid battery (as used in your car, for example), the SLA is marked by a lower over-voltage potential which has to be strictly observed during charge to stay well below the gas-generating level which causes water depletion. Most SLAs will vent at about 5 psi, a condition which is to be avoided at all times because highly corrosive and flammable gases are released.

A typical capacity range for SLA batteries obtainable in the surplus trade is 4 Ah to 30 Ah and their original applications include UPS (uninterruptible power supply) systems, wheelchairs, security lighting systems, biomedical instruments and transportable radio and satellite uplinking terminals. The designer of the charger described in this article employs a 6-volt 4-Ah SLA battery to power a helmet light for his cave exploration hobby.

The advantages of SLA batteries are low self-discharge, the total absence of the dreaded 'memory effect', minimal maintenance requirements, very high charge retention and, of course, low cost. On the down side, the SLA battery is heavy and does not lend itself to very fast charging. It also has the lowest energy density of all rechargeable batteries and, importantly, it must be stored in a charged state. Failure to comply with the latter requirement may cause *sulfation*, a condition which, depending on its progress, gradually prevents the SLA from accepting charging current! Finally, because of its lead content, an SLA battery has to be disposed of according to the regulations provided for Chemical Waste Disposal by your local Council.

CHARGE ALGORITHM

The charge algorithm for SLA batteries is basically 'voltage-limit' (rather than 'current-limit' as used for NiCd and NiMH batteries). Normally, a slow 14 to 16 hours are required to fully charge an SLA battery.

The algorithm illustrated in **Figure 1** is the 'official guide' and based on the use of a so-called *multistage charger*. The algorithm comprises three phases: (1) *current charge*; (2) *topping charge* and (3) *float charge*. Note that the voltage

Sulfation
(or, storage — free of charge)

Even the shiniest SLA battery you may bring home from a car boot sale, rally etc., may fail to achieve the rated capacity (in Ah) boldly specified by the manufacturer on the plastic case. The reduced performance is caused by a metabolism inside the battery, called ***sulfation****. Sulfation occurs to a small extent in any lead-acid battery, but in the case of SLA batteries the process is helped by the long-time absence of the float-charge (or 'maintenance') voltage, or the occasional topping-charge, while the battery is in storage.*

A simple but by no means foolproof method of estimating the chances of (partial) recovery from sulfation is to measure the battery terminal voltage under light load conditions. A cell voltage equal to or greater than 2.10 V (i.e., 12.6 V or 6.3 V) indicates a good chance of regaining at least some of the lost capacity.
Suggested methods to restore the battery include applying a charge on top of a charge (observing a 24-48 hour rest period) and applying an over-charge voltage of 2.5 Volts per cell for one or two hours. The latter method requires (1) extreme caution, (2) extensive battery temperature checking and (3) equally extensive safety precautions against the risk of the cell pressure exceeding the venting level (usually at 5 psi). Don't try this at home!

2

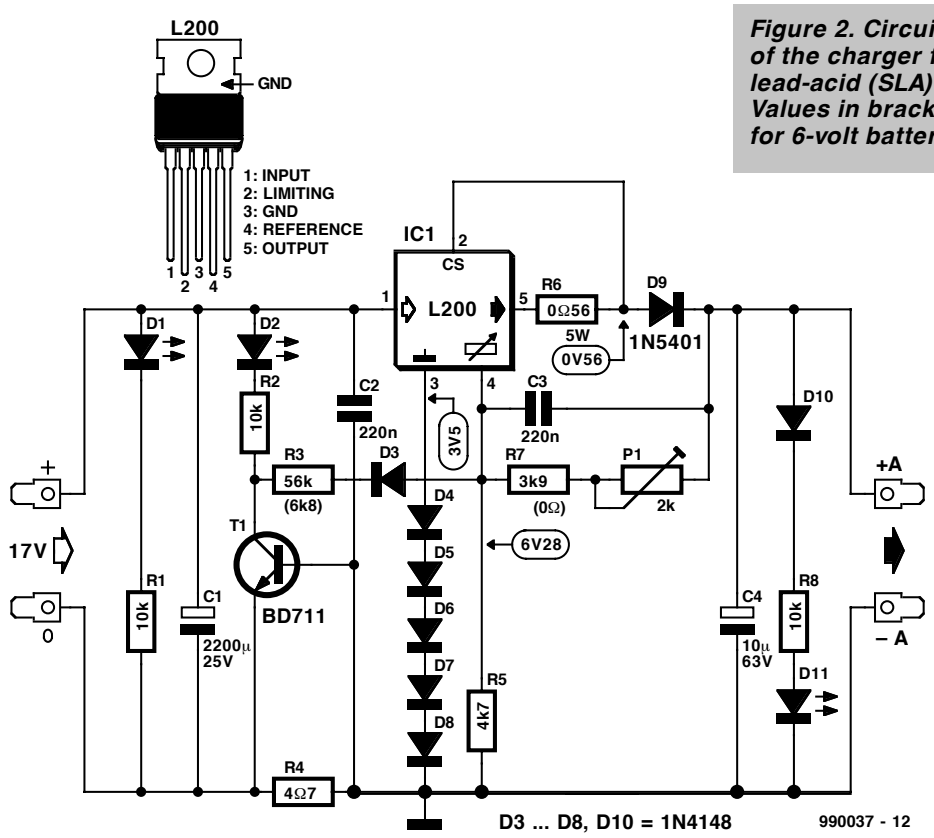


Figure 2. Circuit diagram of the charger for sealed lead-acid (SLA) batteries. Values in brackets are for 6-volt batteries.

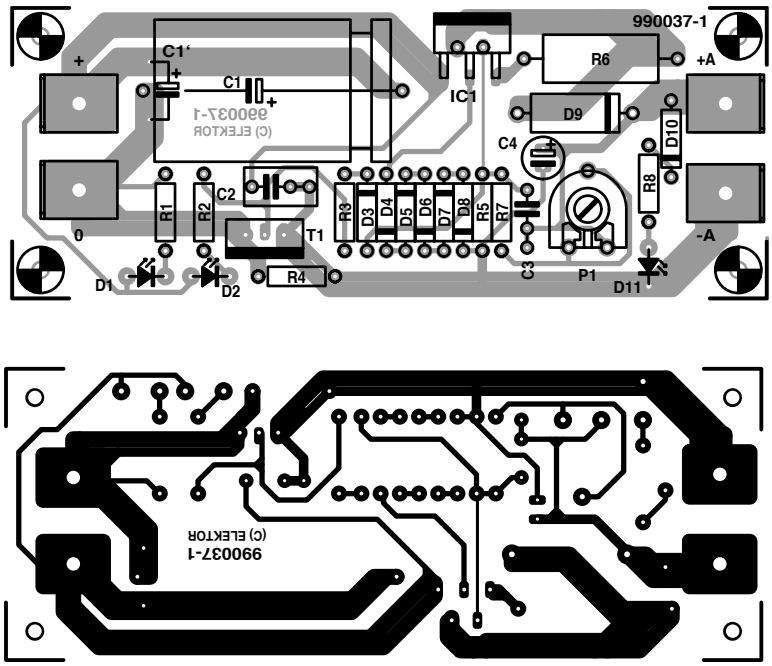
shown on the vertical axis is the cell voltage, *not* the battery voltage. A 6-volt SLA battery has three cells, a 12-V battery, six.

During the first five hours or so, the battery is charged with a current of up to 0.5 *C* ampères (typically 0.2 or 0.3 *C*) to about 70% of its nominal capacity. The remaining 30% are accumulated during the topping-charge phase, which should typically last another five hours. It commences when the cell voltage reaches a value between 2.30 V and 2.45 V. These two levels represent the lower and upper extreme respectively, and their use is governed by advantages and disadvantages as shown in **Table 1**. According to the book, the float-charge voltage should be 2.25 V. For a 12-V battery that works out at about 13.5 V.

As shown in Figure 1, the charge time may be reduced by a few hours by using the higher charging voltage of 2.45 V. The float-charge voltage (phase 3) remains the same, however, at 2.25 V (typically) and may be applied for years on end if necessary, which makes the SLA ideal for standby

Figure 3. PCB design (board available ready-made).

3



COMPONENTS LIST

Resistors:
R1,R2,R8 = 10kΩ
R3 = 56kΩ (6kΩ8 for 6V)
R4 = 4Ω7 (see text)
R5 = 4kΩ7
R6 = 0Ω56 5 watt (see text)
R7 = 3kΩ9 (for 12V) or wire link (for 6V)
P1 = 2kΩ preset H

Capacitors:
C1 = 2200µF 25V radial
C2,C3 = 220nF
C4 = 10µF 63V radial

Semiconductors:
D1,D11 = LED, green, low current
D2 = LED, red, low current
D3-D8,D10 = 1N4148
T1 = BD711
IC1 = L200C

Miscellaneous:
PCB, order code 990037-1, see Readers Services page.
Diecast case, size approx. 110 (l) x 60 (w) x 30 (h)
Insulating material for L200C
4 off car-type spade terminal
Mains adaptor socket

Table 1. Max. cell voltage selection		
	2.30-2.35V per cell	*2.40-2.45V per cell*
↑	Longest service life, SLA remains cool during charge; charging allowed at ambient temperature > 30°C.	Reduced charge time, smaller risk of damage owing to undercharge. Higher and consistent capacity readings.
↓	Long charge period. Sulfation may occur if no periodic topping charge is applied. Low, inconsistent capacity readings.	Higher battery temperature during charging may reduce battery life. Overcharging may occur owing to cell voltage limit never reached.

use!

Remember that the above is the *algorithm*, i.e., a theoretical construct suggested by the battery industry. In practice, SLA batteries are so resilient and easy-going that a multistage charger with a built-in timer is rarely used.

PRACTICAL CHARGER CIRCUIT

The circuit diagram in **Figure 2** shows an old faithful, the L200 voltage regulator. No boos and catcalls we reckon — this device was chosen because it is cheap, easy to use and widely available. Although the five diodes inserted in its ground line introduce a voltage drop of about 3.5 V, they have in principle nothing to do with the output voltage or current regulation — their purpose is to match the temperature coefficient of the charger (–3.85 mV/°C) to that of a typical SLA battery. This means that you can safely use the charger at any ambient temperature allowed for the battery (typically –20°C to + 40°C; check manufacturer's specs). There's another Easter egg: the diodes protect the L200 against reverse-polarized voltages at the output. *Still, don't try this at home.*

Initially, the battery is charged with a current of about 0.2 *C*. This current is determined by the value of R6, see **Table 2**. The resulting voltage drop on R4 is enough to fully open transistor T1. A power transistor is used here because nearly all of the charge current flows through the base-emitter junction (the BD711 is specified at max. 3 A in this respect) LED D2 lights as result of the current flow through T1. The (small) current through R3 causes the output voltage to rise by 0.6 V (12-V configuration) or 0.3 V (6-V configuration).

The actual charge process differs from the theoretical one in a number of respects. Initially, the battery is 'pumped' using a constant current of 0.2-0.5 *C* and the 'low' cell voltage of 2.30 V (i.e., a battery voltage of 13.8 V or 6.9 V). A flat battery will draw enough current (but never more than determined by R6) to make the L200 supply its 'elevated' output voltage of 2.45 V per cell. This will happen so quickly as to create the impression that the charger supplies 2.45 V/cell straight away. Normally, the charging current resulting from (1) the empty battery and (2) the elevated cell voltage will be so high as to cause the L200 to go into current-limiting (using R6) and keep functioning like that for several hours on end. As the battery gradually accepts the charging energy, its cell voltage rises to the charging level of 2.3 V/cell or 2.45 V/cell. The charging current then drops because the battery can not accept more current. However, there is sufficient current flow to keep T1 conductive (via R4) and so maintain the elevated charging voltage.

At a certain point, the charging current will have dropped to a value of about 0.02 *C*. The battery is then considered 'full'. With T1 being turned off by R4, the L200 switches to the lower cell voltage of about 2.3 V/cell which serves as the 'float charge' voltage. The present charger is 'intelligent' in as far as it does not produce the elevated charging voltage any longer than strictly necessary. Also, in standby use, the battery is automatically switched to 'rapid' charging when a large amount of current is consumed by the load.

If no voltage is applied to the charger input, a battery left connected to the output will discharge across the same output. Thanks to diode D9, the discharge current is limited to about 1 mA plus the current through low-current LED D11 (approx. 2.5 mA). No cause for alarm!

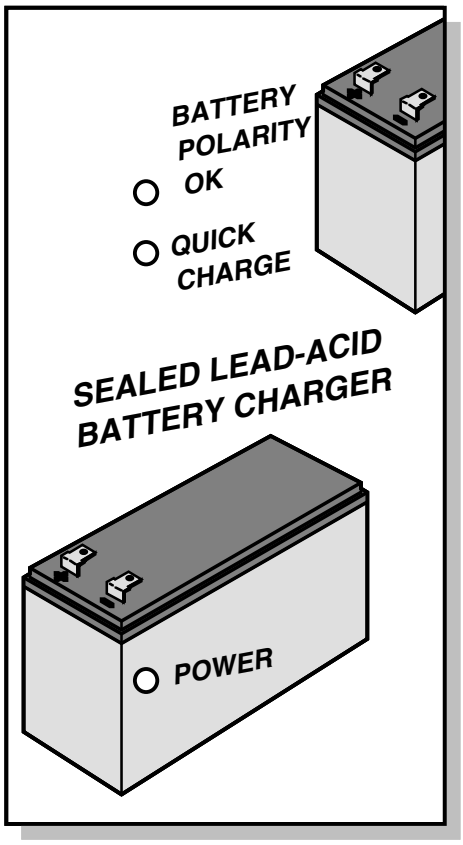
SLA batteries being allergic to large ripple voltage levels, the circuit has been extended with a large reservoir capacitor, C1. A much smaller capacitor, C3, has been added to keep the L200 unconditionally stable.

INPUT VOLTAGE TO THE CHARGER

Unless you are using high-capacity SLA batteries (*C*> 10 Ah) a mains adaptor with dc output is recommended as the input voltage source. With safety and cost in mind, this is an obvious

4

Figure 4. Suggested layout of front panel on diecast case.



990037-F

Table 2. Component values			
Component	***6-volt SLA battery***	***12-volt SLA battery***	***Notes***
R7	Wire link	3.9 kΩ	
R3	6.8 kΩ	56 kΩ	
R6	0.45 x *I* [ohms]	0.45 x *I* [ohms]	Determines maximum charging current only. *I* = 0.2 *C* to 0.5 *C*
R4	0.5/0.02 *C* [ohms]	0.5/0.02 *C* [ohms]	Determines threshold for cell voltage reduction to 2.3 V and standby charging current. Select nearest E12 value, target standby current is 0.02 *C*
C = nominal capacity of battery (Ah specification) *I* = initial charging current			

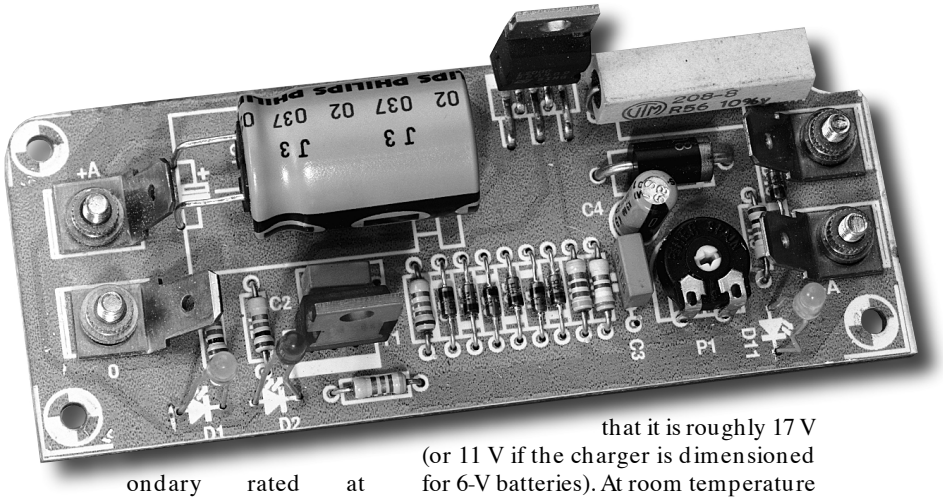


Figure 5. Prototype, ready for fitting into the diecast case. The L200 has to be secured to the inside of the case using heatsink insulating materials.

choice. The power rating of the adaptor depends on the capacity of the battery and the patience you can put up for a complete charging cycle. Typically, a mains adaptor set to '12V' will easily supply 17 V to light loads, and that is just about sufficient for the present circuit. Do check however that this voltage does not drop below 17 V when a current of 0.2 *C* is drawn. For example, if you are using a 12-V 4-Ah SLA, the initial charge current is of the order of 0.8 A, so a fairly hefty mains adaptor will be required. By the way, there is no objection against charging with a lower current. Indeed, while the charge process will simply take longer, the benefit is that you may get away with the use of a medium-power (500-mA) mains adaptor!

For all cases where a mains adaptor falls short of output voltage and current, we recommend the use of a regulated power supply set to 18 V or so. Failing this, build a dedicated PSU consisting of a mains transformer with a 15-V secondary rated at 1.4 times the maximum required current, a bridge rectifier and a smoothing capacitor with a capacitance of about 2200 μF per ampère. Observe safety regulations for all wiring and connections at mains voltage!

CONSTRUCTION

The charger is built on the compact PCB shown in **Figure 3**. This board is easily fitted in a small diecast enclosure that also acts as the heatsink for IC1. The L200 must be fitted with an insulating set (mica washer and a plastic mounting bush). A suggested front panel layout is shown in **Figure 4**.

ADJUSTMENT

Do not yet connect a battery to the output. Apply the input voltage and check that it is roughly 17 V (or 11 V if the charger is dimensioned for 6-V batteries). At room temperature (20-25°C), adjust P1 for an output voltage of 13.8 V (12-V charger) or 6.9 V (6-V charger). Use a short piece of wire to temporarily short-circuit the collector-emitter junction of T1. The output voltage should rise to 14.4 V (12-V charger) or 7.2 V (6-V charger). A tolerance of ±0.1 V is acceptable here. If the voltage is much too high, increase the value of R3. The converse applies if the voltage is much too low.

PRACTICAL USE

Make a habit of following this order:

- Observe the battery polarity
- Connect the battery to the charger
- Check that D11 lights
- Apply the input voltage to the charger

990037-1

call for papers

Technical authors and designers are now invited to contribute to the Autumn and Winter 1999 issues of *Elektor Electronics*, in which we plan to cover the following subjects:

- *Digitizing audio signals*
- *New battery and charging technologies*
- *New PC technology*
- *Digital medium and short-wave radio*
- *The 20th century in retrospect*

Advice on style, article size and technical requirements regarding text and illustrations (file formats, etc.) may be obtained from the Editor.

We also call for stories covering interesting topical subjects in the field of electronics and computers, as well as for reviews and construction projects with an extensive explanatory text. Some experience in writing is appreciated, but not essential (who knows, you could be a natural talent).
If you have recently finished an interesting construction project, write a text with it and send us the article. Preferably, the text and illustrations should be supplied on floppy disk. The same applies to reviews and topical stories.

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If you would like to offer your free-lance writing services for assigned subjects, inform us (in writing) about your specialism or favourite interest, and any proposals you may already have. Even if your specialism is not mentioned above, we would still like to hear from you in view of other subjects to be covered next year.
Every article is judged by the editorial staff on the basis of its publication value. You will receive our verdict as soon as possible. If your article is of interest, you will also receive our conditions for publication.
This call is also addressed to companies having press releases and other interesting background information available on the subjects mentioned above.

Eye pattern meter
PC Topics Supplement, March 1999, p. 13. (992002)
The moving coil meter shown in Figure 3 should have a sensitivity of 100-200 µA f.s.d.

Electronics Freeware
May 1999, PC Topics Supplement, p. 4 (990011-1)
The correct url for Digital Works is

http://www-scm.tees.ac.uk/users/d.j.barker/digital/digital.htm

Battery capacity measurement by PC
PC Topics Supplement, December 1998, p. 14-16. (982093)
With reference to the circuit diagram, a number of logic gates in IC4 have been transposed to improve the PCB layout. Functionally, this is of no consequence.
However, one track on the board is missing: that between pin 2 and pin 8 of IC1 (ADC0804). If this link is added, C1 is effectively connected and the circuit will work as described.

Sealed lead-acid battery charger
May 1999, p. 26-31. (990037-1)
In Table 2 (Component Values), the two formulas for R6 should read

0.45 / I [ohms].

D9 is missing from the parts list. As indicated in the circuit diagram, this diode is a type 1N5401. If the charger always supplies currents smaller than about 1 A, diode D9 may also be an 1N4001 or similar.

General Coverage Receiver
January & February 1999 (980084).
In the preselector section, the upper varicap diode, D14, has no dc path. A suggested method of improving the behaviour of the varicap (without modifying the PCB) is to replace capacitor C83 (220pF) with a wire link.

Flash Designs – address information
April 1999, New Products, p. 73.
In the New Products section, the address and telephone number of Flash Designs should be changed to read

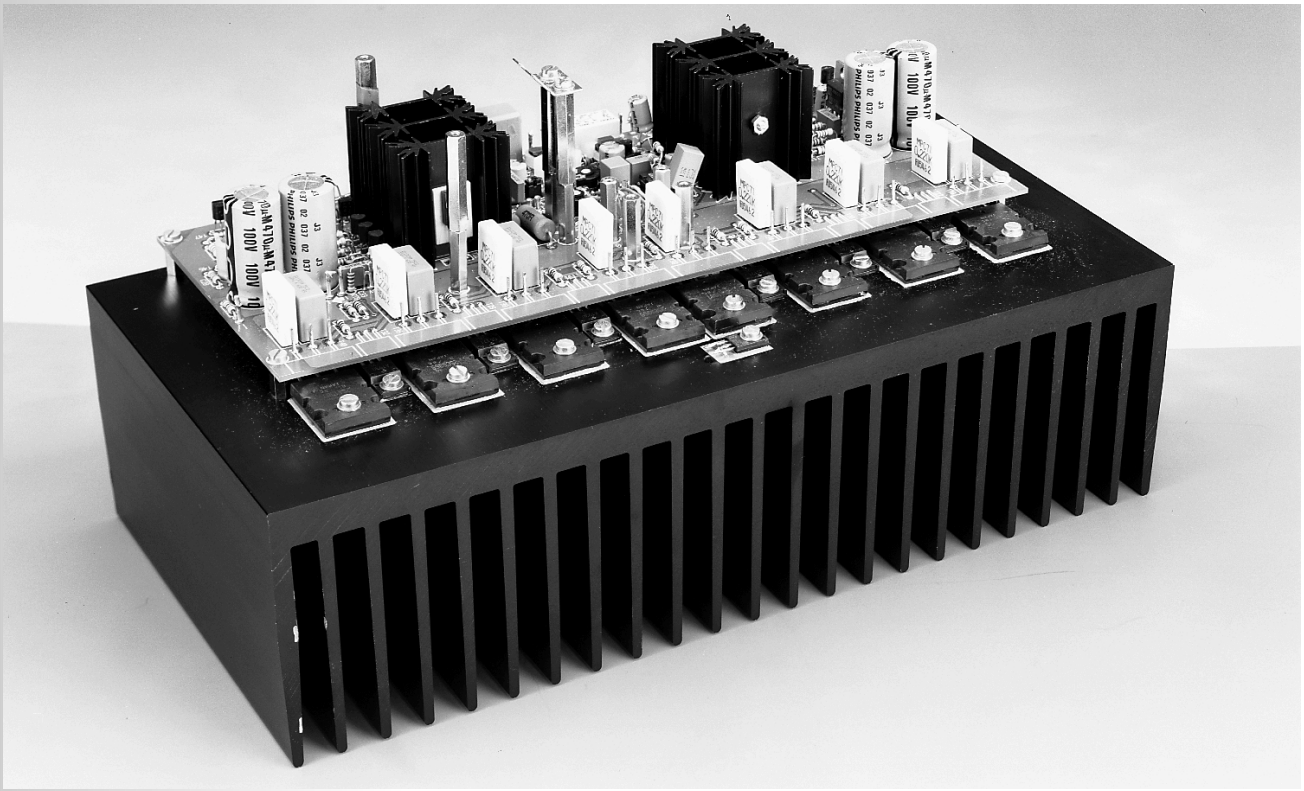
Flash Designs, Ltd.,
North Parade House,
North Parade,
Bath BA2 4AL.
Tel. (01225) 448630.

We extend our apologies to Flash Designs and our readers for any inconvenience caused by the incorrect address information.

Electronic Spirit-Level
July/August 1998, p. 36 (984038).
In the circuit diagram, all LEDs (D2 through D10) should be reversed. The PCB layout is all right.

Titan 2000

Part 4: wiring and performance



This fourth of five parts deals primarily with the wiring up of the amplifier and ends with a brief resume of its performance and specifications. The fifth and final part of the article in a forthcoming issue will deal with the temperature control, bridge configuration and some other practical hints.

Design by T. Giesberts

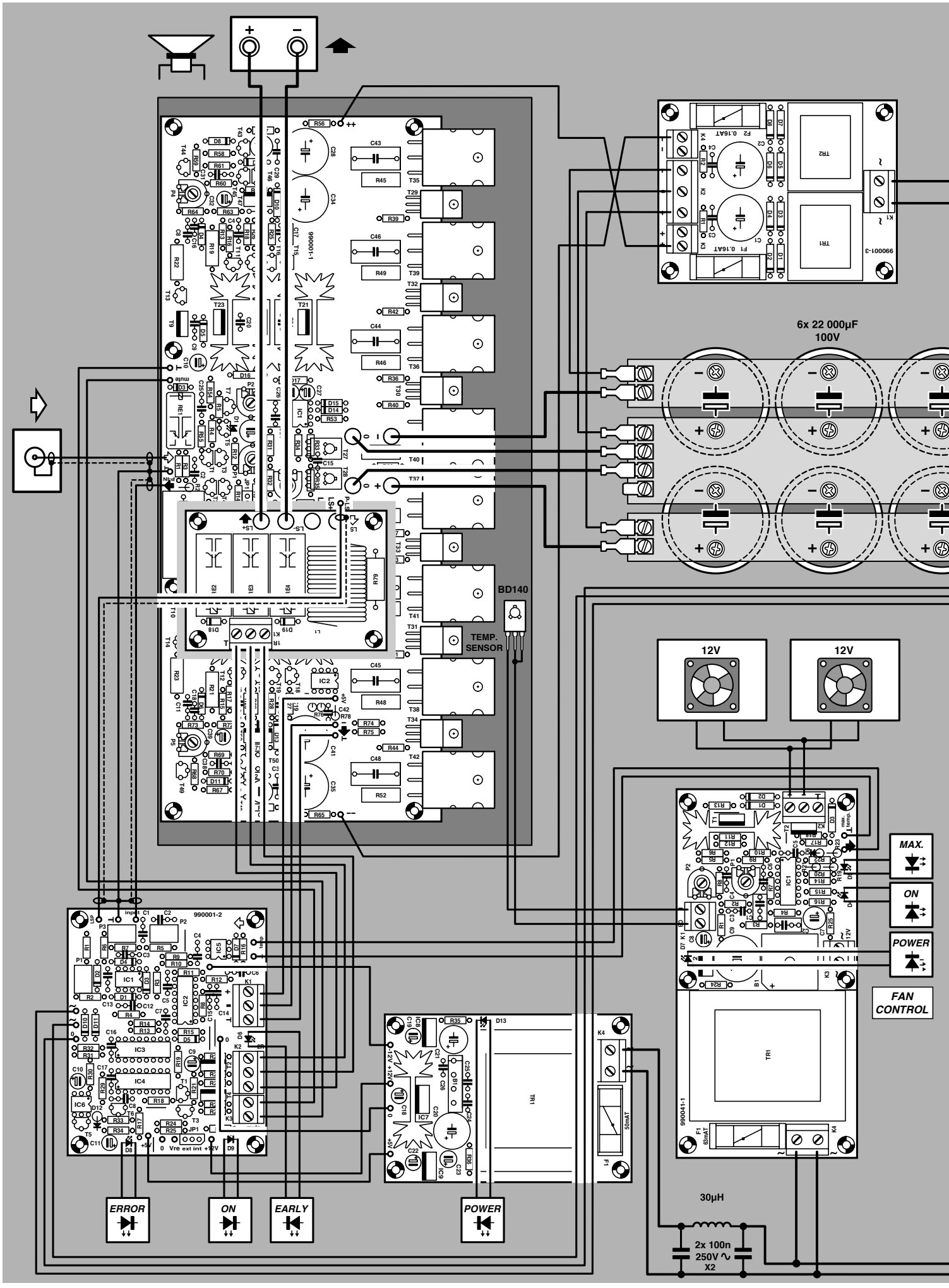
WIRING UP

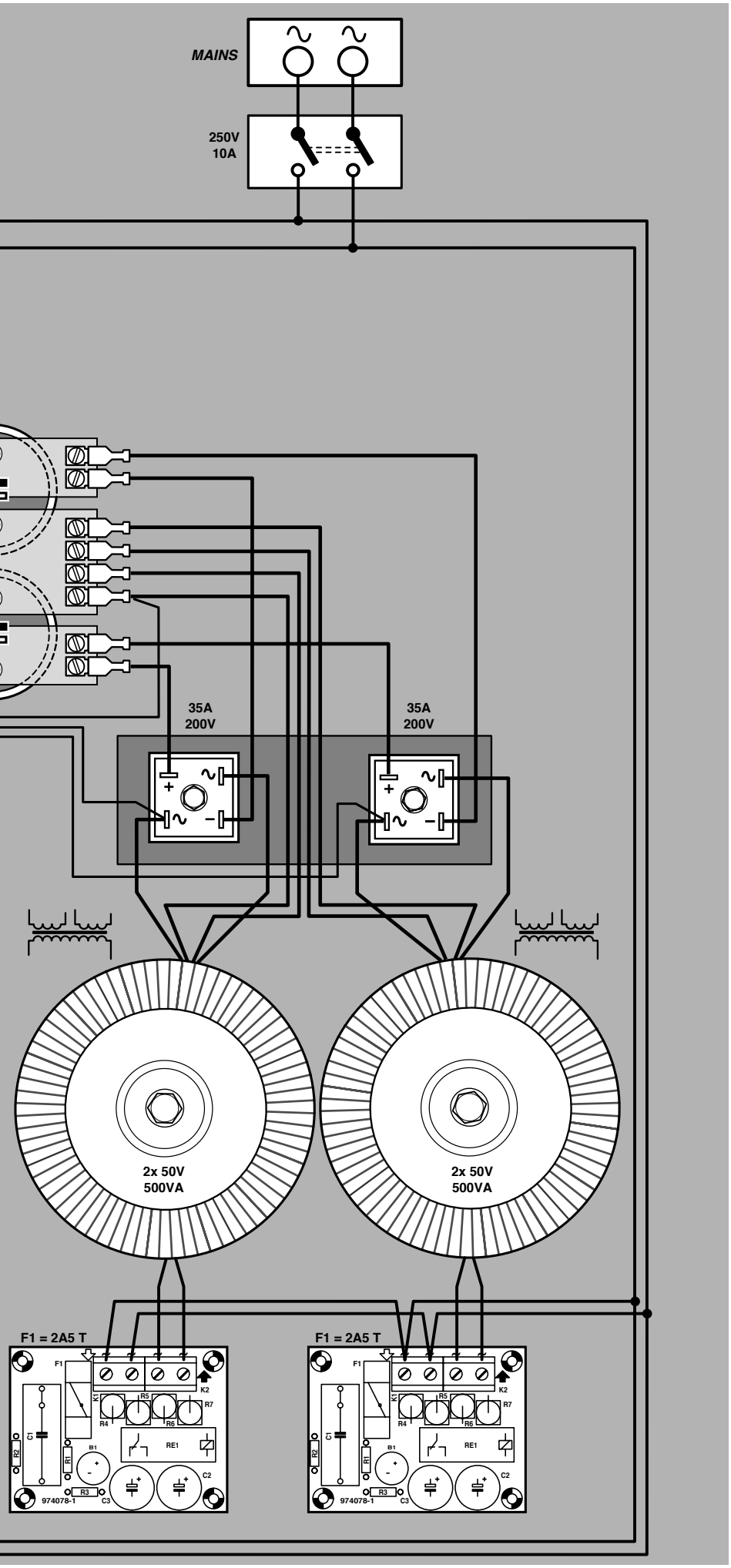
How the various board, power supplies, controls and terminals are combined into an effective and interference-free unit is shown in **Figure 16**.

As already mentioned in Part 2, all wiring carrying the main supply voltage (± 70 V) must be insulated, high-current wire to BS6321 with a conductor size of 50/0.25 (2.5 mm^2). This wire should also be used to link the output terminals of the power transistors and the loudspeaker terminals. Any wiring between smoothing capacitors and the board should not exceed 15 cm and be preferably much shorter. This kind of wire is best terminated into car-type connectors.

Other wiring may be made in light-duty, stranded, insulated hook-up wire. It is advisable (and may prove to be very helpful in case of problems) to use wire with different colour insulation for dissimilar functions.

The connections between the input socket and board must, of course, be in screened audio cable. To avoid earth loops, the socket should be isolated from a metal enclosure. Bear in mind that the supply earth and the enclosure are linked by metal spacers between the two '0' terminals and the heat sink. It is, therefore, essential that the heat sink is firmly strapped to the metal enclosure.


6x 22 000µF
100V
BD140
TEMP.
SENSOR
12V
12V
MAX.
ON
POWER
FAN
CONTROL
ERROR
ON
EARLY
POWER
30µH
2x 100n
250V ~
X2



The on/off indicator, the functional indicators, and the mains on/off switch should, of course, be fitted on the front panel of the enclosure. The mains on/off switch must be a 10 A or 15 A type.

If the output power of the amplifier is limited to no more than 500 W, in which case the enclosure does not need fan cooling, the heat sink may be mounted at the outside of the enclosure or even form the sidewall or back of a home-made enclosure.

For greater output powers, cooling fans with relevant apertures at the front and back of the enclosure are a must. The heat sink must then be located in the enclosure in such a position that it is directly between the two fans, ensuring a continuous supply of cooling air.

PERFORMANCE

The specification and associated comments in the box cannot, of course, give a full impression of the performance of the amplifier. It is a well-known fact that amplifiers with an almost identical specification, and using identical loudspeakers, can sound quite different.

Particularly at low frequencies, the amplifier maintains good control over the loudspeaker, which results in a clean fast (i.e., taut over the whole audio range) sound, totally lacking in reverberation. High and medium frequencies were also reproduced with excellent definition and without any trace of tizziness.

The overall impression is that the amplifier has plenty of reserve and is not strained in any circumstances.

In next month's final instalment, the temperature control and possible bridge configuration will be discussed.

[990001-3]

ELEKTOR	
240V~	50Hz
No. 990001	
1000 VA	F = 2 x 2,5 A T F = 63 mA T F = 50 mA T

Figure 16. The wiring diagram clearly illustrates how the various parts of the amplifier are combined into a single unit.

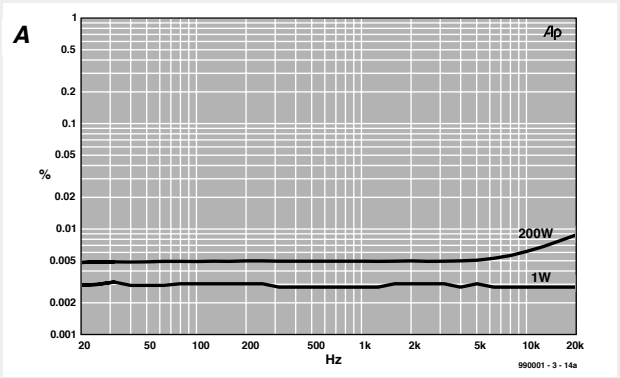
Technical specifications

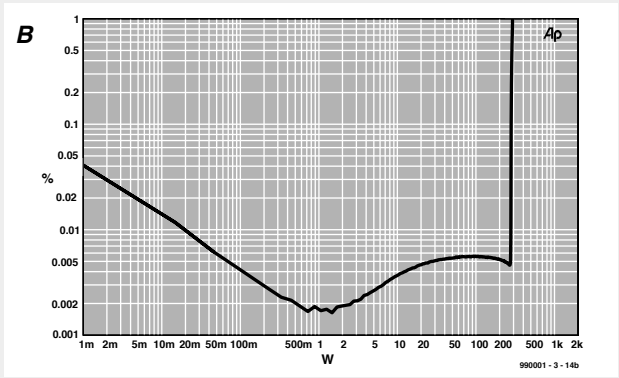
(Supply voltage = ± 70 V; quiescent current = 200–400 mA)

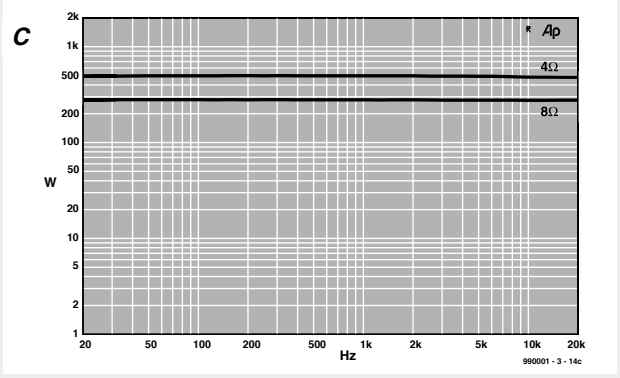
Input sensitivity			*1.1 V r.m.s.*
Input impedance			*47.5 kΩ*
Sine-wave power output (0.1% THD)			*280 W into 8 Ω; 500 W into 4 Ω; 800 W into 2 Ω*
Music power (1% THD)*			*300 W into 8 Ω; 550 W into 4 Ω; 1000 W into 2 Ω*
Slew limiting			*85 V μs^{-1}*
Open-loop bandwidth			*53 kHz*
Open-loop amplification			*×8600*
Power bandwidth			*1.5 Hz – 220 kHz*
Signal-to-noise ratio (1 W into 8 Ω)			*101 dB (A-weighted); 97 dB (B = 22 kHz)*
Damping factor (at 8 Ω)			*> 700 (1 kHz); > 300 (20 kHz)*
Output impedance			*1.6 Ω*
Harmonic distortion (THD) (B = 80 kHz)	*8 Ω*	*4 Ω*	*2 Ω*
at 1 kHz	*0.003% (1 W)*	*0.0046% (1 W)*	*0.01% (1 W)*
	0.005% (200 W)	*0.0084% (400 W)*	*0.02% (700 W)*
at 20 kHz	*0.009% (200 W)*	*0.018% (400 W)*	*0.07% (700 W)*
Intermodulation distortion (IM)			
(50 Hz:7 kHz = 4:1)	*0.004% (1 W)*	*0.01% (1 W)*	*0.034% (1 W*
	0.016% (150 W)	*0.025% (300W)*	*0.07% (500 W)*
Dynamic IM			
(square wave 3.15 kHz with sine wave 15 kHz)	*0.003% (1 W)*	*0.0036% (1W)*	*0.0055% (1 W)*
	0.003% (200 W)	*0.005% (400 W)*	*0.0085% (700 W)*

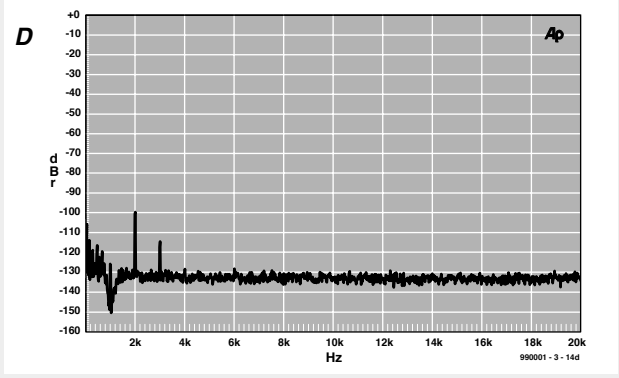
**See Part 1 about the validity of this meaningless quantity.*

The specified figures were measured after the amplifier had been switched on for two hours. The figure show that the Titan 2000 compares favourably with most amplifiers. The slew limiting is a measure of the speed of the amplifier, which is exceptionally good in the Titan 2000.
Figure A shows the total harmonic distortion plus noise (THD+ N) for an output of 1 W into 8 Ω (lower curve) and for 200 W into 8 Ω. The latter figure corresponds with 70% of the peak sine wave power and the curve shows that the distortion increases clearly only above 10 kHz.
Figure B shows the THD+ N at 1 kHz as a function of the drive with an output impedance of 8 Ω. The curve is purposely drawn for a bandwidth of 22 kHz so that the noise above 20 kHz does not degrade the performance of the amplifier. From about 2 W, the distortion increases slightly with increasing drive, which is normal in most amplifiers.
Figure C shows the peak output of the amplifier at a constant distortion of 0.1% and a load of 4 Ω (upper curve) and 8 Ω. The bandwidth was 80 kHz.
Figure D shows a Fourier analysis of a reproduced 1 kHz signal at a level of 1 W into 8 Ω. It will be seen that the 2nd harmonics are down just about 100 dB, while the 3rd harmonics are down to –114 dB. Higher harmonics lie below the noise floor of –130 dB.





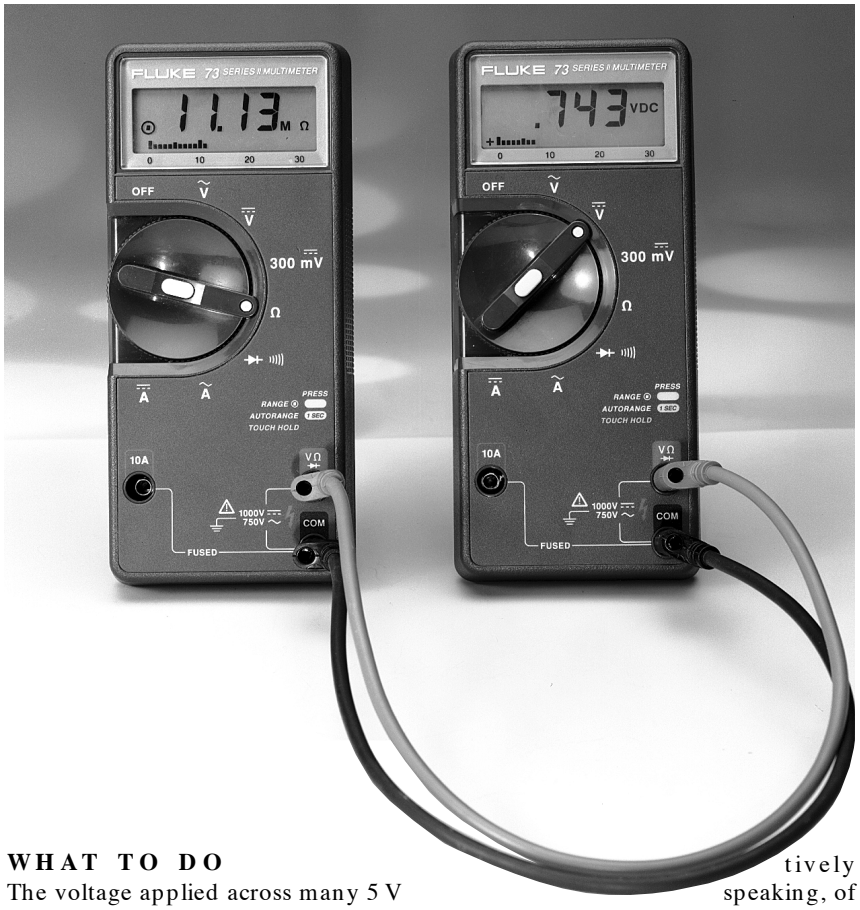




measurement oddities

faultfinding with an ohmmeter

Faultfinding with a multimeter set to measure resistance yields quite a lot of information, but is not without risks. This is because when the meter is set to this range, there is a potential across its terminals.



By K .S.M. Walraven

INTRODUCTION

When a multimeter is set to a voltage or current range, it is a passive instrument that simply measures the potential across, or the current through, a component, line or network. Clearly, it has some effect on the component (or line or network), since in the first case it is shunted by a high-value resistance, and in the second case, a small resistance is coupled in series with it. In almost all cases, this effect is negligible, however.

When the meter is used to measure resistance or circuit continuity, it behaves as an active instrument, because for those purposes it needs to apply a voltage across the component (or line or network). It is this voltage that gives rise to concern, since sensitive, expensive components may be damaged by it, sometimes irreparably so.

WHAT TO DO

The voltage applied across many 5 V integrated circuits must not exceed 6.5 V, while modern 3.3 V integrated circuits are even more sensitive. It is, therefore, necessary to know the level of voltage across the meter terminals when this is set to the resistance range.

This is easily established with the aid of a second multimeter. Link the test leads of the two instruments in parallel, set one meter to a resistance range and the other to a (low) direct voltage range. The second meter then reads the test voltage provided by the first.

It is essential to carry out this measurement on all resistance ranges. This is because many multimeters have several resistance ranges as well as a diode/continuity test range and the test voltages in these ranges can differ appreciably from each other. The test voltage is often particularly high (relatively speaking, of course) in the diode/continuity range: usually well above the diode voltage (forward bias) of 700 mV (in case of a silicon diode).

Inspection of various multimeters shows that the test voltage can vary from about 300 mV to as much as 4.5 V.

It is rather more difficult to determine the test voltage of meters with an autoranging facility. This is because when a voltmeter is connected to one of these types, it detects a high resistance and switches automatically to the MΩ range. To ascertain the test voltage in the other resistances ranges, a number of resistors, say, 100 Ω, 1 kΩ, 10 kΩ, and 100 kΩ are needed to shunt the voltmeter terminals.

MEASURING

It may be assumed that when the test

voltage is not higher than 300 mV, any component, line or circuit can be tested without any risks. If the test voltage lies between 700 mV and 2 V, the same applies, but it should then be borne in mind that diodes, transistors, and ICs in the network on test may come on and influence the measurement.

Test voltages higher than 2 V should not be used, because they affect the operation of the network on test. Some analogue meters, especially moving-coil instruments, are particularly risky to use. Tests show that these may have test voltages of up to 22.5 V. Clearly, this is a dangerous voltage to test the continuity of a network.

Reverting to the case where the test voltage lies between 700 mV and 2 V, it should be noted that, as said, diodes and transistors may come on, but in some cases that is an advantage. When, for instance, the base-emitter junction of a transistor is examined with a test voltage of 300 mV, the meter will invariably show ∞, which means very little. If the test voltage were 700 mV, the meter will show ∞ in one (reverse bias) direction, and a few hundred ohms in the other (forward bias) direction, indicating that the base-emitter junction is sound—see **Figure 1**.

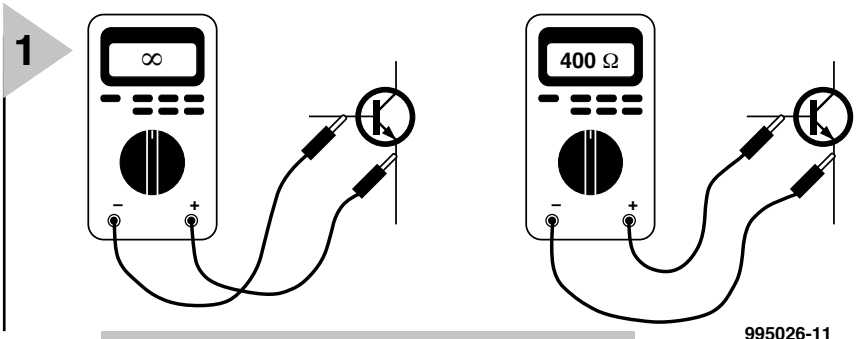


Figure 1. When the level of the test voltage is sufficiently high and the positive line is applied to the base of an n-p-n transistor, the resistance across the base-emitter junction is low. When a p-n-p transistor is checked, the polarity of the test voltage must, of course, be reversed.

Finally, note that in analogue multimeters the polarity of the test voltage is reversed with respect to the pin indication, that is, the positive test voltage is at the black (COM or earth) terminal or probe, while the negative test voltage is at the red terminal or probe. In digital multimeters, the positive test voltage is at the red terminal or probe and the negative test voltage at the black or COM terminal or probe.

[995026]

WHEN ELECTRONICS WAS YOUNG (5)

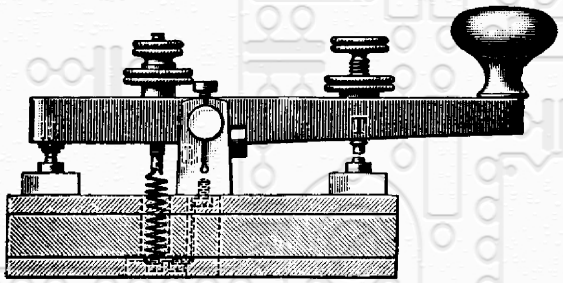
It took the genius of Gauss, probably the greatest mathematician who ever lived, to see the proper importance of the discoveries of Oersted: electric current – magnetic needle – telegraph. Gauss and his friend and colleague Professor Weber began experimenting on these lines and in 1832 the needle telegraph was completed. However, neither Gauss nor Weber had the time or inclination to concern themselves with the practical development of the electric telegraph.

Samuel Morse, born in 1891 in Charlestown, Massachucheths, after graduating from Yale, travelled through Europe in the late 1820s to study the various schools of painting in the countries of their origin. During these travels he became deeply impressed by the electro-magnetic experiments carried out in Europe, and during his return journey to the USA in 1832 he devised a new type of telegraph.

In those days, there were vast technical difficulties which cannot easily be appreciated in our time. For instance, there was no such thing as insulated copper wire. Inventive as ever, Morse used the wire (insulated) used by New York milliners to make fashionable hats for society ladies.

Morse did not use the magnetic needle; instead he employed an electro-magnet to press a pen against a paper strip which was unrolled slowly and uniformly. Short impulses on the transmitter resulted in dots on the strip and long impulses in dashes. Combinations of dots and dashes represented letters, numbers, and symbols; this was the Morse code, patented in 1840. With this apparatus Morse telegraphed, in his first tests in 1837, over a distance of ten miles. For six years he worked to improve his technique and his code, whereupon Congress in 1843 approved the installation of the world's first telegraph line between Washington and Baltimore at a cost of $30,000. The line was officially taken into use on 24 May 1844.

Werner von Siemens built the first telegraph connection in Europe (between Berlin and Frankfurt-am-Main) which was taken into use in 1849. Von Siemens still used the needle telegraph which he had improved. However, by the early 1850s the Morse telegraph system had became accepted worldwide as the (then) only reliable means of communication over long distances. When Morse died in 1872, the telegraph had already girdled the earth.



995046 - 11

At about the same time, the English physicist John Daniell developed a new primary battery, which is still in use and named after him. It is a non-polarizing cell with zinc (negative) and copper (positive) electrodes. The zinc plate is in a porous cup containing a weak zinc-sulphate solution; the cup is in a jar filled with a saturated copper sulphate solution in which the copper electrode is immersed. The e.m.f. of the cell is about 1.1 V.

Another aspect of electricity that had the attention of researchers and technologists was lighting. The world had to wait for the incandescent lamp developed by Edison later in the century, but nevertheless in the middle of the century New York, London, Paris, Berlin, and some other cities had a kind of electric lighting in some important thoroughfares provided by arc lamps.

[995046]

component ordering by Internet

towards the digital Edgware Road?

Relative newcomers to the noble art of electronics may find it hard to believe that it was once possible to obtain a wide range of electronic parts from a local shop. Alas, the inroads mail order business have made into the electronic component trade have caused the virtual disappearance of whole clusters of small but well-stocked electronics shops from the high-street. Where once there were countless electronic component suppliers along London's Edgware Road, the diversity is gone for good. Today there are only half a dozen or so 'broad-range' suppliers left, while much smaller specialist suppliers successfully serve the remaining niche markets. Recently, all and sundry in the mail order business have discovered the Internet to sell components and take orders.

In hobby as well as professional electronics, it is hard to imagine a situation without mail order companies. By contrast, local shops are having an increasingly difficult time to offer the customer an ever expanding range of components. Although many hobbyists and professionals will be familiar with the huge catalogues published by Farnell and RS Components (to mention but a few), it is increasingly noticed that the available component range, huge as it may be, does not include that one special component you may be looking for to complete your project. That is not to say that the catalogues are useless, on the contrary, as most of you will agree they often contain a staggering amount of worthwhile information. The point is that the product range is too broad to allow space for special components.

Elektor Electronics construction projects, too, often contain special components that are not easily found in mail-order catalogues. Fortunately, that specific market niche is aptly addressed by kit suppliers like Viewcom (the UK outlet of Stippler Elektronik) and C-I Electronics who advertise in this magazine are able to obtain reasonable stocks of such parts for our readers.

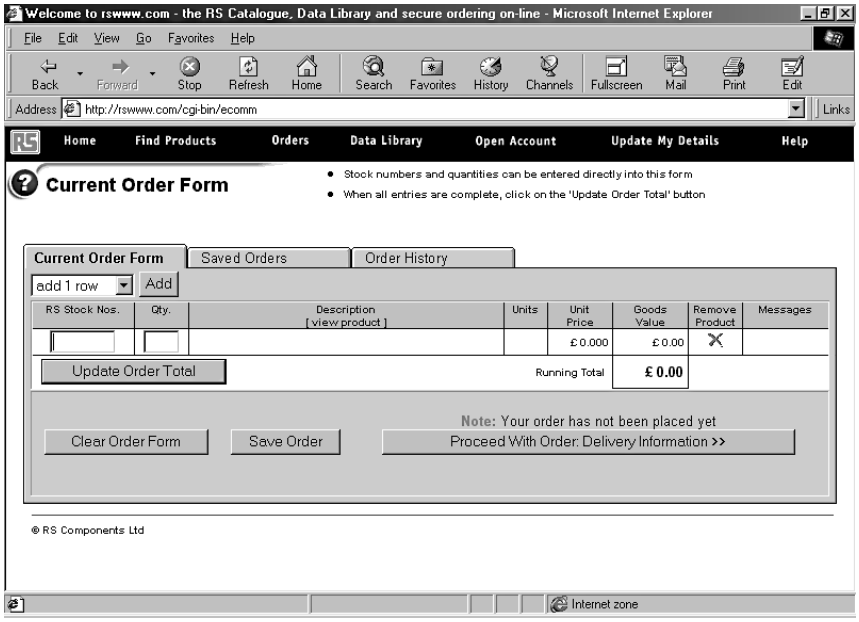
PAN-EUROPEAN ASPIRATIONS

A number of big component suppliers like Farnell, RS Components (Electromail) and, recently, Conrad Electronics, have gone *pan-European* and claim to be able to supply any item from their product range to anyone in any EEC country. Others like Maplin stick to the UK market only (although expansions have been announced). A general trend, however, is that the mail-order giants in true market-oriented fashion enable customers to place orders via email or the Internet. Although this article is by no means intended as a comprehensive market survey, we have gathered some information that may be useful to our readers when it comes to ordering parts 'digitally'. Because of space constrictions for this article the information has been kept concise, and readers are encouraged to contact the companies listed for further information. This may include enquiring about minimum order value or quantity, an overview of the product range (for example, as a downloadable file, or on a floppy disk), delivery options, the availability of a technical hotline, a printed catalogue or a CD-ROM. Because many of our readers live overseas, special attention should be given to customs procedures and postage and packing (P&P) charges.

PITFALLS

Not so long ago, the main problem encountered in obtaining parts from mail-order companies was not the actual process of placing an order, but the minimum order quantities some suppliers seemed to insist on. At some point, this made it totally impossible for hobbyists (and repair technicians!) to obtain 'one-offs' of essential parts like

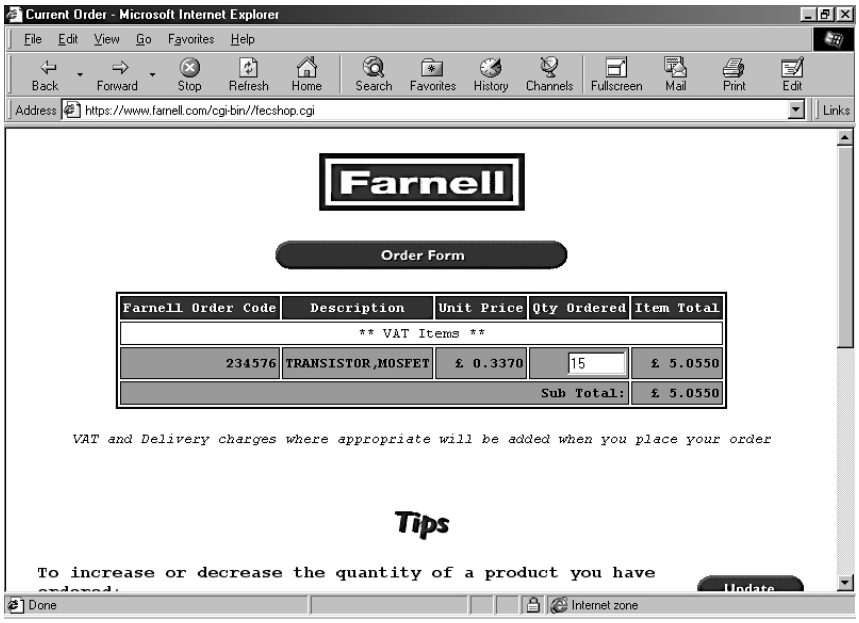
semiconductors, electromechanical parts and 'passives'. Although most suppliers have dropped this very undesirable requirement, there is still a snag: a surcharge for small quantities!



The RS Components web site and its component ordering features are pretty extensive. Our advertiser Electromail is the retail branch of RS Components — its component range is available on CD-ROM. The website shown here may be found at http://rswww.com

ENTER EMAIL AND THE INTERNET

The arrival of the Internet and in particular electronic mail (email) has given electronic product suppliers and their customers unprecedented opportunities to get in touch and do business. Today, it is possible to browse catalogues over the Net, place orders and simply wait for the postman or courier to deliver the goods. There are, of course negative sides to this development, including



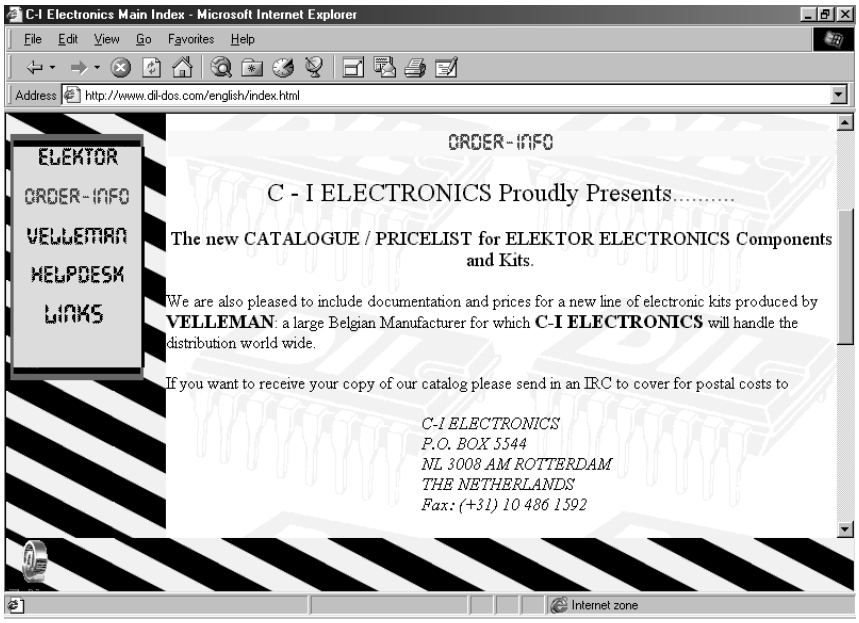
Although the appearance of the website run by Leeds-based Farnell Components is fairly Spartan, the product range is overwhelming and the ordering facilities set an example to the competition. Have a look a www.farnell.com

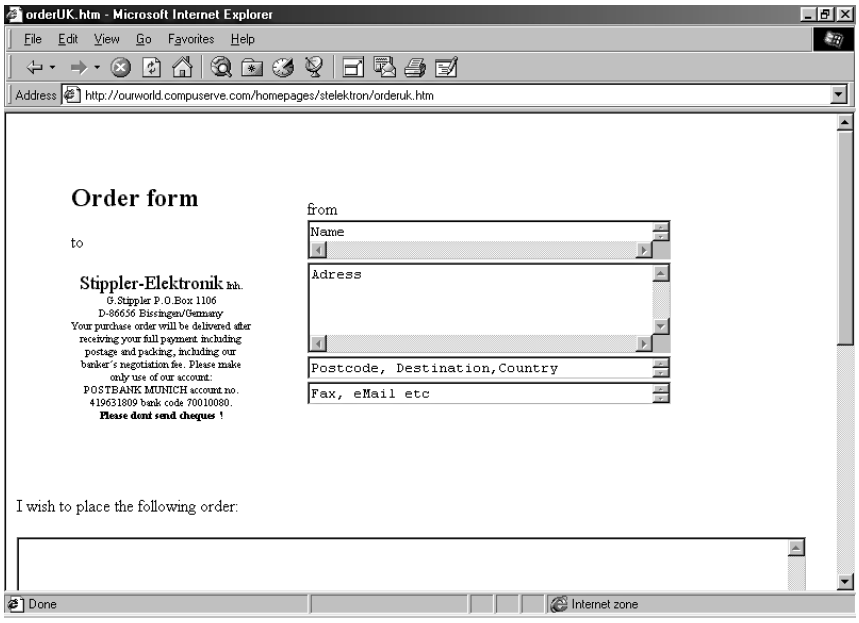
minimum order quantities or values;
- 'hidden' charges;
- anonymity (i.e., the lack of personal contact and advice);
- the inability to actually see a component before buying;
- being unable to browse around in a real shop

Although the traditional means of communicating an order to a component supplier are still very much in use (telephone, fax and letter), nearly all suppliers of components, tools, software, ready-made products and even surplus goods can now be reached by email. In some cases, wonderfully designed websites allow the customer to 'shop around', fill a virtual shopping cart with goods and 'check out' by credit card payment.

Remarkably, order turnaround

Unfortunately the web site run by Maplin at www.maplin.co.uk was being 'refurbished' at the time of writing this article. Maplin's continued support of the UK electronics hobbyist is still exemplary, witness the Maplin catalogue and the opening of retail stores throughout the country.





times have not greatly diminished since the arrival of email. UK mainland delivery within 24 or 48 hours can usually be guaranteed however, with faster options available at extra cost to the customer.

If you are looking for a kit to build an Elektor Electronics project then a visit to the C-I Electronics web site may be worth your while. This Rotterdam-based mail-order specialist also stocks a vast range of special components. Their web site is found at www.dil-dos.com

NOT FOR ONE-OFFS...

Just as we find an ever smaller number of traders taking orders from private customers, so the number of broadline suppliers to the industry has dwindled to half a dozen or so over the past 10 years. A long series of company mergers have resulted in just a few players left in this field. Although two of these, Farnell and RS Components, have already been mentioned, it should be noted that they do, in principle, supply to individual customers (Farnell, directly, while RS Components employs its 'Electromail' retail branch for this purpose).

Conrad Electronic, originally active on the Germany market only, gives evidence of their pan-European aspirations by running an English-language website with full on-line ordering facilities. The website is at www.conrad-electronic.com.

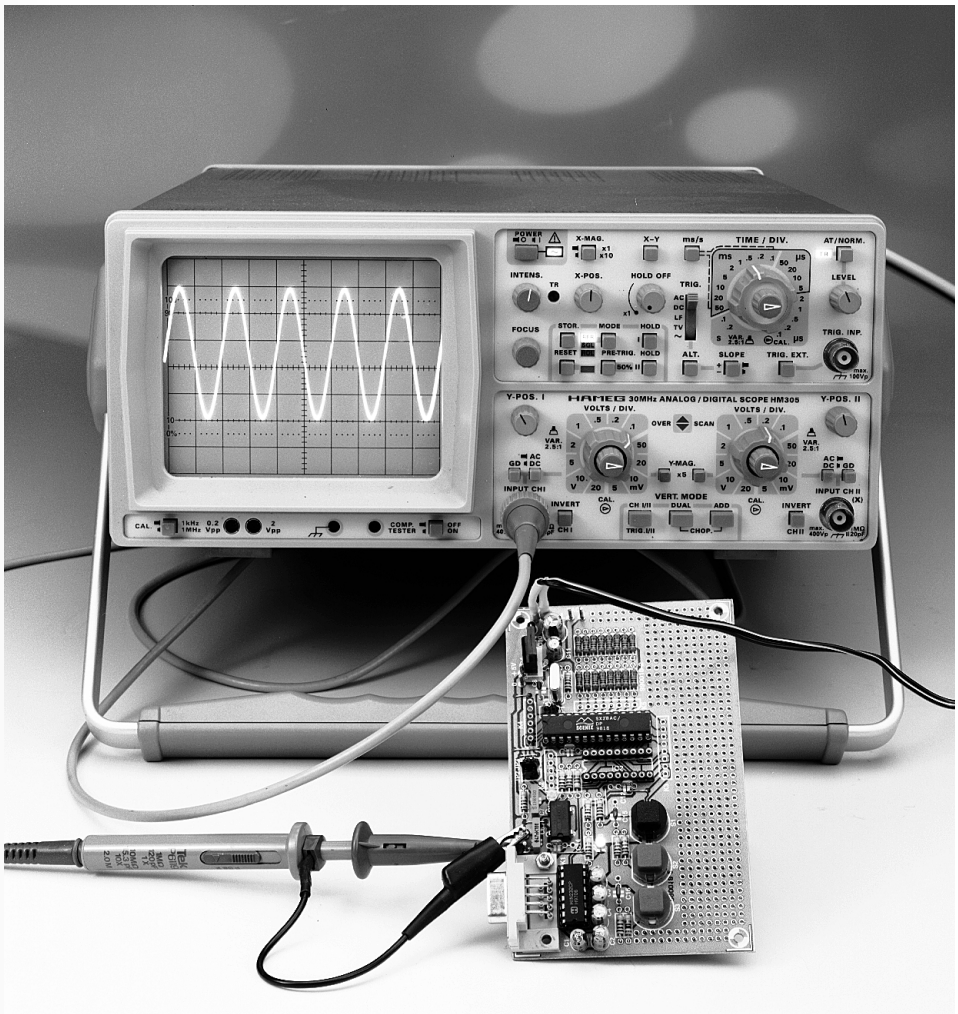
Two competitors in the pan-European field, Spoerle (*www.spoerle.com*) and Eurodis (*www.eurodis.com*), should be mentioned here. Although neither has an on-line ordering system up and running using a 'shopping basket' function or similar, you should at least know their names because they are two of the main wholesale suppliers to the retail trade when it comes to special parts used in *Elektor Electronics* projects. The UK branch of Eurodis is Bolton-based HB Electronics. So, if your local retailer can't supply it, tell him to try Spoerle of Eurodis.

(990020-1)

In the UK, the kits and special components stocked by our advertiser Stippler Elektronik are available through Viewcom Electronics.
The website to visit is http://ourworld.compuserve.com/homepages/stelektron

SX-microcontroller evaluation system (4)

part 4 (final): more programs, applications and tips



In this fourth and final instalment we propose a few more programs and applications for the SX microcontroller from Scenix. Some of the programming examples give a good impression of the SX controller's raw speed and the resulting applications. To close off some frequently made programming errors are mentioned. As with PIC programming, dealing with the SX will require discipline and some getting used to, and the closing section is particularly aimed at experienced 8051 programmers.

Design by Dr M. Ohsmann

The first loose end we have to tie up is the clock source selection, for which the SX offers a number of options. The SX prototyping board described in last month's instalment enables three different oscillator configurations to be set up by fitting jumpers. In our first example program, the oscillator circuit was set to HS (high-speed) mode. By fitting jumper JP2 it is possible to clock the SX

micro at 48 MHz. The result is that all programs are executed three times as fast as on 16 MHz. The SX chip also has an internal RC (resistor-capacitor) oscillator, which provides a clock signal of 4 Mhz. Via a prescaler, this clock signal arrives at the processor core (see datasheet), but only if the first and second program lines are modified as follows:

```
device turbo, osc1Mhz, pins28
divider equ 15
```

The modified program example is available on the project disk, its name is IRC1.SRC. The processor clock frequency is then set to 1 MHz. At the same time, because of the changed value of 'divider' the inner timing loop is executed only 15 times (instead of 200). Using this program the LED will flash at about the same rate as before, while a quartz crystal is not even required. Alternatively, you could use an external oscillator by connecting an R-C network to the OSC1 pin. On the processor board, that can be done by fitting jumper JP3 (after successful programming). The program should be modified to begin as follows:

```
device turbo, oscrc, pins28
divider equ 1
```

On the project disk, the modified program may be found as 'RC1.SRC'. Using the external components C7 = 1nF and R6 = 10kΩ we get a clock frequency of about 80 kHz. Because the timing loop is executed once only (see the value of 'divider'), the LED flashes at about the same rate as before.

Any oscillator version can be programmed by appropriate setting of bits in the FUSE word. The available device options are listed in **Table 1**. The 'device' instruction also allows all other possibilities of the SX controller to be selected. However, to make sure you get what you want, be sure to read the datasheets in great detail. Fortunately, all programs on the project disk have been tested, and they are ready for use without any editing whatsoever.

SERIAL INPUT/OUTPUT

Of course you don't need a 50-MHz RISC processor to make an LED flash at a 1-second interval. But then, when it comes to programming your own very high-speed applications, the problem of testing and debugging will crop up at some point. A successful method applied by the author is to control a program and supply it with data by first entering and outputting a couple of test values through the serial interface. The program 'SERIO1.SRC' is an example of how this may be done in practice. This program waits for two hexadecimal 16-bit values to arrive via the RS232 interface at a speed of 19,200 bits/second, and then produces the sum of the two input values. The data rate applies if you clock the SX micro at 16 MHz. By using a 48-MHz clock, the communication will run at 57,600 bits/s. If you study the program you will learn how simple I/O functions may be implemented. At the same time, this example program supplies you with ready-made subroutines for serial input and output, which may be employed in many other programs.

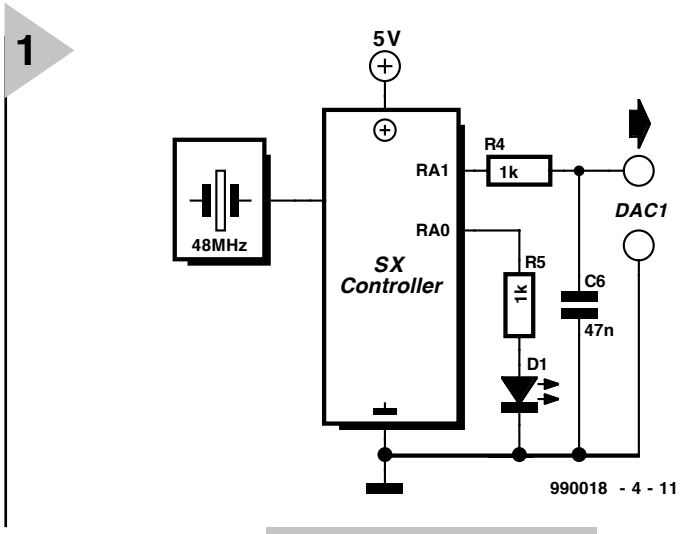


Figure 1. Basic circuit of the hardware configuration used in the example programs.

TOWARDS HIGH SPEED

After all this theory, a practical example requiring high processor speed is badly needed. The function of the program may be formulated as follows: using a kind of pulsewidth modulation, generate a software-controlled direct voltage. On port RA1, a pulse sequence is generated whose arithmetic average equals the desired direct voltage. This output voltage is then filtered out by low-pass R4-C6 on the SX prototyping board, and may subsequently be read off a digital voltmeter (DVM) (**Figure 1**) connected to output 'DAC1'. The pulse train itself is generated by the program section

```
pwmlp
```

The idea was found in a Scenix application, and is based on the fact that the continuous adding of the constant 'value' to a register, the number of CARRY pulses will equal the average value of 'value'. As you can see, this is not true pulsewidth modulation as you may know it from other applications. The algorithm is contained in the example program SERPWM1.SRC on the project disk. This program actually generates two such signals, they are available for measuring at pins RA0 and RA1. The signal at the RA0 pin is used to control the average brightness of LED D1, which is connected to RA0 via resistor R5. The two voltage levels are adjusted with the aid of a 16-bit hexadecimal numbers which arrive via the RS232 serial interface (operating at 19,2 kbit/s when using a 16-MHz clock). After a reset, the program expects a 16-bit hexadecimal number (for example, 8028) to be input. The lower-order byte determines the voltage at the DAC1 output, whereas the higher-order byte programs the aver-

age value of the voltage at the RA0 pin, and so the LED brightness.

AF SINEWAVE GENERATOR USING HIGH SPEED AND INTERRUPTS

Now's the time to rev up. In principle, we keep using the previously discussed method of generating an analogue digital. This time, however, the value to be output is a sinewave rather than a direct voltage. Because the sinewave is created inside an interrupt routine, it is possible to control the period of the sinewave (signal frequency) in the main program, using the RS232 interface. In this way, the circuit shown in Figure 1 is turned into a simple sinewave generator with a frequency range of up to a few kilohertz and a resolution of 0.1 Hz (yes !). The associated program, SINGEN1.SRC is available on the project disk, and may serve as an example of how timer-controlled interrupts are programmed. Details of the control program are not given here because of lack of space. The comment found in the program listing together with the SX datasheets and the instruction descriptions should enable you to analyse the program and learn quite a lot.

A FAST SINEWAVE GENERATOR

On the SX prototyping board, a simple D-A converter (output DAC2) is connected to port RC. By using a sinewave look-up table which is read out by a numerically controlled oscillator (NCO, see Ref. 1) it is possible to employ the SX chip to generate accurately defined sinewave voltages right into the MHz range. Not bad, we'd say, for such a relatively cheap microcontroller.

The file 'SINGEN2.SRC' on your project disk is an example of a 455-kHz signal generator derived from a 48-MHz clock. By suitable programming, this example may be extended to create a sinewave generator whose output frequency is programmable via the RS232 interface.

WAKE-UP AND INTERRUPTS

Besides the timer (or counter) driven interrupt, the SX micro also allows pulse edges on port RB to act as interrupt requests. An example to illustrate this feature and the way it has to be initialised is available as 'MIW1.SRC' on the project disk. In the main program, LED D1 is in principle controlled by means of pulsewidth modulation just as in the PWM1 example. This time, however, the brightness may be increased or decreased by pressing push-button S2 or S3 respectively. In the program, any push-button action generates an interrupt which, in turn, causes the LED brightness to be controlled. The result is a basic dimmer function.

FURTHER OUTLOOK

That concludes our discussion of the example programs supplied on disk for the SX microcontroller. The same disk, however, contains extra stuff, while the SCENIX website is also a great source of additional software examples. The examples discussed here and the ones found on the Internet are good starting points when it comes to putting your own ideas in practice. With the elementary information available, you should be ready to start making your own programs, and, of course, errors!

COMMON ERRORS

Of course, the author learned a lot of his mistakes while developing the example programs. Some pitfalls are discussed here to help you avoid them.

Special attention should be given to the CARRY flag in relation to the CARRYX bit in the FUSEX register. The behaviour of arithmetic commands (and some conditional jumps employing arithmetic commands as macro commands) is governed by the CARRYX bit. This may cause subroutines that you want to share to behave differently depending on the CARRYX bit being set or not.

When using several register stacks you should make sure that each and every subroutine complies with the conventions you have set up.

The next mantrap is the limited range of CALLs and jumps. Here, too, be careful, and closely read the datasheets. Do not start programming just like that — it equals time lost on debugging and false accusations in the direction of the manufacturer.

Subroutine nesting also requires careful programming. A stack with a depth of eight levels only becomes available when you activate the STACKX option. This depth may be reached sooner than you would expect. If you frequently exchange 18-pin and 28-pin SX micros, you should remember to use the appropriate 'pins28' and 'pins18' option in the assembly code. If you don't, the programs will not run because of an incorrectly programmed bit in the FUSEX register. Some of the quirks mentioned here are simply compromises resulting from the speed requirements on a processor core which had to remain as simple as possible.

(990018-4)

Reference:

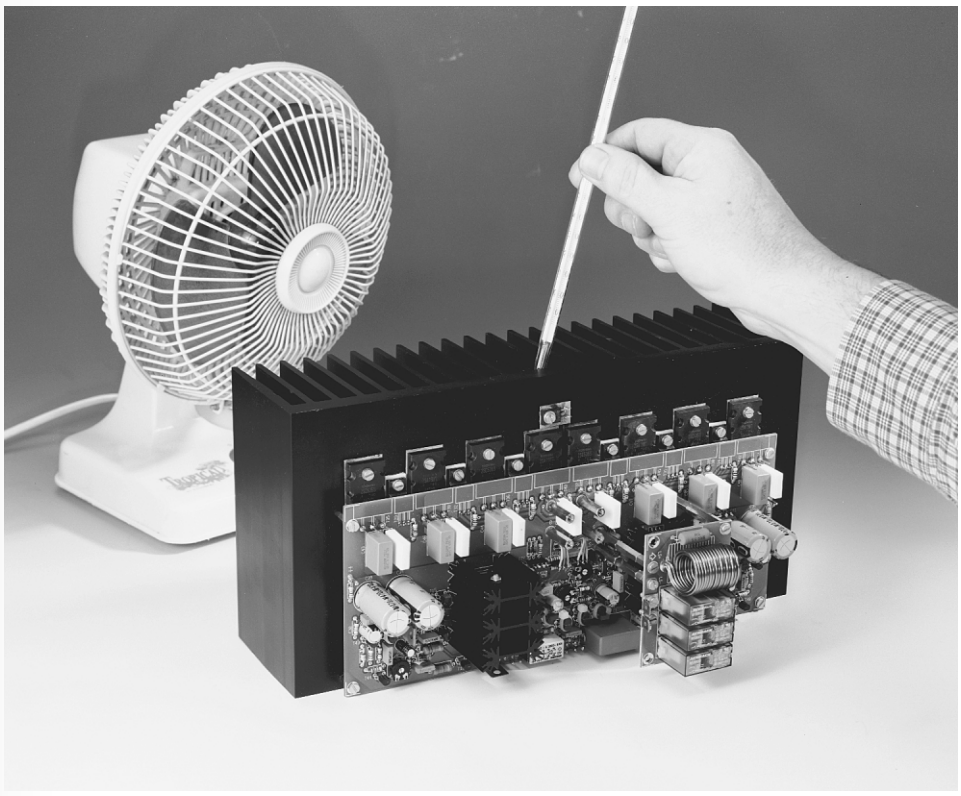
1. AVR-RISC Evaluation System, *Elektor Electronics*, Supplement October and November 1998.

Table 1. Assembler options for 'device' command

Name	Function
PINS28	specify 28-pin chip
PINS18	specify 18-pin chip
OSCHS	high-speed quarz crystal
OSCXT	regular quarz crystal
OSCLP	low power quarz crystal
OSCRC	activate RC oscillator
OSC4MHZ	internal RC oscillator, division by 1
OSC2MHZ	internal RC oscillator, division by 2
OSC1MHZ	internal RC oscillator, division by 4
OSC500KHZ	internal RC oscillator, division by 8
OSC250KHZ	internal RC oscillator, division by 16
OSC125KHZ	internal RC oscillator, division by 32
OSC62KHZ	internal RC oscillator, division by 64
OSC31KHZ	internal RC oscillator, division by 128
BROWNOUT	4.2 Volt brown-out
TURBO	activate Turbo mode
STACKX	activate 8 level stack
OPTIONX	extended option register
CARRYX	include Carry with ADD/SUB
INSYNC	synchronous input
WATCHDOG	activate Watchdog
PROTECT	activate code readout protection

fan control

for high-power output amplifiers



Most domestic amplifiers are cooled solely by convection, but it may happen that a standard heat exchanger does not provide adequate cooling for a certain output amplifier. In such a case other means must be used, normally a fan or fans. The circuit described in this article provides a temperature-dependent, proportional control for such a cooling fan. It enables the turn-on threshold and the control characteristic to be set as needed within a given range. It also provides over-temperature indication which may be used to actuate the protection circuit of the amplifier.

Design by T. Giesberts

INTRODUCTION

Although the heat sink of the Titan 2000 is of reasonable dimensions, the amplifier, like other output amplifiers, has its limits as regards dissipation. With loads down to 4 Ω the heat sink is perfectly capable of dissipating the generated heat, but with lower loads and maximum drive levels, forced cooling must be used.

The design of the present circuit ensures that when a predetermined heat sink temperature is exceeded, two small fans are switched on which rotate at a speed that is directly proportional to the heat sink temperature. When maximum fan speed is reached, the over-temperature indication is enabled and the protection circuit of the ampli-

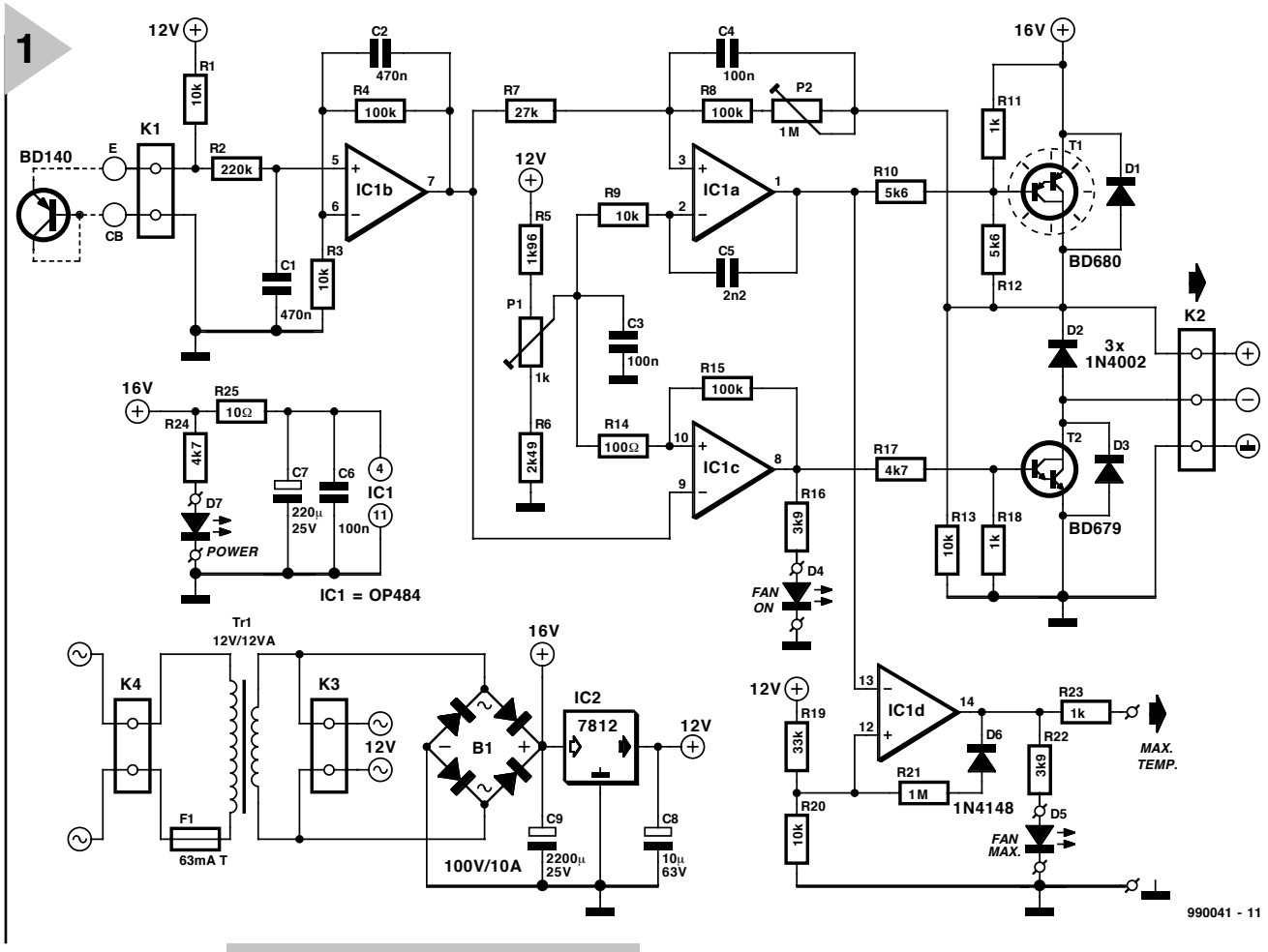


Figure 1. Two amplifiers, a pair of comparators and a couple of light-emitting diodes (LEDs) provide the desired control characteristic and indications.

fier may be actuated via a separate output.

There are two indicator LEDs: one for the turn-on threshold (when the fans are turned on), and the other for maximum temperature. The fans in the prototype are small 12 V models. The rotational speed of these can be varied readily with the supply voltage: they start reliably from voltages as low as 5 V. It is of great importance that the fans are very quiet types to avoid intrusive fan noise in the listening room during low programme levels.

The temperature sensor is a standard Type BD140 transistor mounted on the heat sink. Its forward voltage (like that of any silicon transistor or diode) decreases by exactly 2 mV °C^{-1}, which makes it eminently suitable for use as a sensor.

DESIGN

The circuit diagram of the control is shown in **Figure 1**.The over-temperature signal appears on pins 'max temp', the fans are linked to connector K_2, and the sensor is connected to K_1.

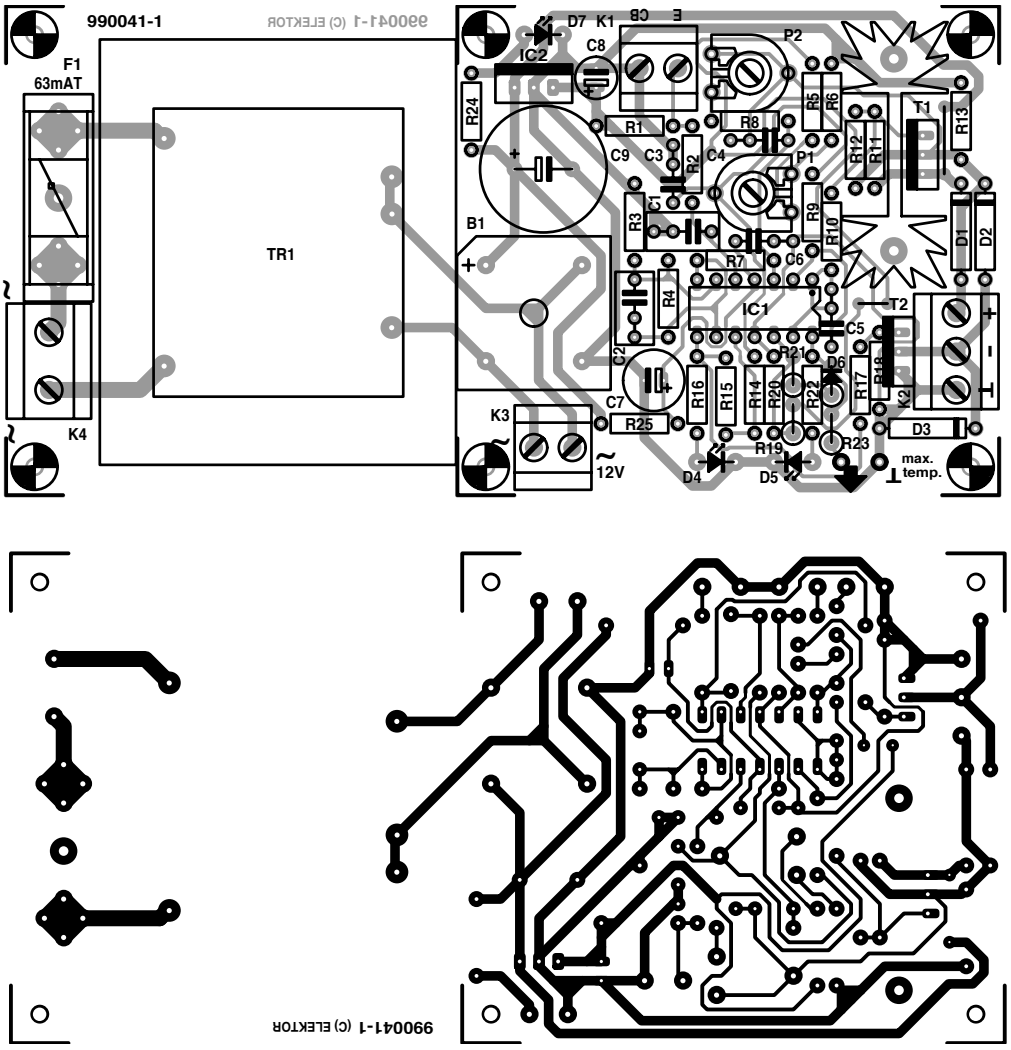
The sensor, which is arranged as a diode, is biased via resistor R_1. The temperature-dependent potential across the p-n junction is filtered by network R_2-C_1 and then amplified ×11 by operational amplifier IC_{1b}. To make sure that there is adequate control voltage for the fans, amplifier IC_{1a} provides additional gain. This op amp is arranged a an inverting amplifier to ensure that the control voltage is directly proportional to the heat sink temperature. Transistor T_1 provides the level of current needed by the fans.

Preset P_2 in the feedback loop sets the gain of IC_{1a} and thus the degree to which the control voltage follows the temperature-dependent sensor output.

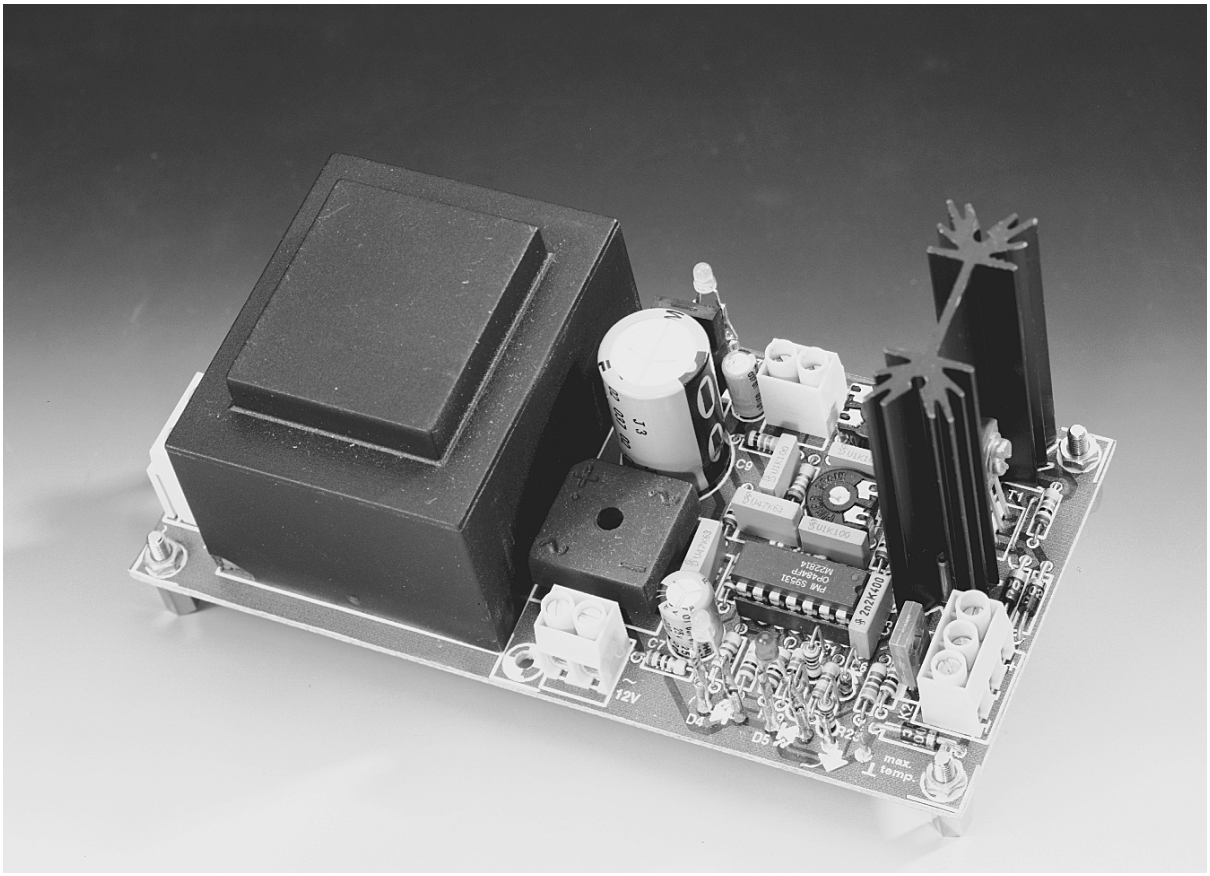
The fans are switched on via IC_{1c}, which compares the output signal of IC_{1b} with the reference potential derived from network R_5-P_1-R_6. At a given threshold, set with P_1, IC_{1c} changes state, whereupon the –ve pin of K_2 is linked to earth, resulting in the fans being switched on. Diode D_4 lights to indicate this happening. The threshold set with P_1 is also used as a reference for IC_{1a} to ensure that the initial control voltage is equal to the switching threshold.

Circuit IC_{1d} provides the over-temperature indication signal. This comparator guards the output voltage of amplifier IC_{1a} and changes state when the fans are working at full speed. Diode D_5 lights and a high level is passed to the 'max temp' output via

2


990041-1
F1
63mAT
TR1
K4
K3
12V
B1
IC2
IC1
D7
K1
C8
P2
T1
T2
D1
D2
D3
D4
D5
D6
K2
max. temp.
990041-1 (c) ELEKTOR

3



Parts list

Resistors:
R_1, R_3, R_9, R_{13}, R_{20} = 10 kΩ
R_2 = 220 kΩ
R_4, R_8, R_{15} = 100 kΩ
R_5 = 1.96 kΩ
R_6 = 2.49 kΩ
R_7 = 27 kΩ
R_{10}, R_{12} = 5.6 kΩ
R_{11}, R_{18}, R_{23} = 1 kΩ
R_{14} = 100 Ω
R_{16}, R_{22} = 3.9 kΩ
R_{17}, R_{24} = 4.7 kΩ
R_{19} = 33 kΩ
R_{21} = 1 MΩ
R_{25} = 10 Ω
P_1 = 1 kΩ preset
P_2 = 1 MΩ preset

Capacitors:
C_1, C_2 = 0.47 µF
C_3, C_4, C_6 = 0.1 µF
C_5 = 0.0022 µF
C_7 = 220 µF, 25 V, radial
C_8 = 10 ≤ F, 63 C, radial
C_9 = 2200 µF, 25 V, radial

Semiconductors:
D_1–D_3 = 1N4002
D_4, D_5, D_7 = high-efficiency LED, yellow red, green respectively
D_6 = 1N4148
T_1 = BD680
T_2 = BD679

Integrated circuits:
IC_1 = OP484FP (Analog Devices)
IC_2 = 7812

Miscellaneous:
K_1, K_3 = 2-way terminal strip for board mounting, pitch 5 mm
K_2 = 3-way terminal strip for board mounting, pitch 5 mm
K_4 = 2-way terminal strip for board mounting, pitch 7.5 mm
B_1 = rectifier, 100 V, 10 A, horizontal, 19×19 mm
Tr_1 = mains transformer, 12 V, 12 VA (see text for external transformer or mains adaptor)
F_1 = slow fuse 63 mA, complete with holder for board mounting
Heat sink (T_1), e.g., Fischer SK104/50
Two off 12 V fans (see text)
PCB Order no. 990041 (see Readers Services towards the end of this issue)

Figure 2. The design of the board allows the transformer section to be cut off.

resistor R_{23}. This high level may be communicated to the protection board in the Titan 2000 for use as a switching signal. In other amplifiers, it may be used via a buffer to, say, energize an output relay.

The supply for the circuit has been kept as simple as possible. The fans are driven by the rectified secondary voltage (16 V) of the transformer. The 16 V line is additionally decoupled by network R_{25}-C_6-C_7 for use as a supply for IC_1. The + 12 V supply needed for the various references and setup networks is obtained by applying the 16 V voltage to IC_2. Diode D_7 functions as on/off indicator.

Figure 3. Photograph of the completed prototype control.

SETTING UP

The turn-on threshold is set with P_1 and the range of rotational speed of the fans with P_2. These settings are empirical and to individual requirements, for which an accurate thermometer is required.

Two extreme settings are possible. The first is with the turn-on threshold fairly high (60–65 °C) and maximum gain. The maximum rotational speed will then occur at a temperature only 6–7 °C higher than the turn-on threshold. The second is to set the turn-on threshold fairly low, say, 50 °C and the amplification low. This provides the largest possible control range, but the fans cannot reach maximum speed.

It is clear that the most practical setting is somewhere between these extremes. It is advisable to use a maximum heat sink temperature of 70 °C, in which case D_5 should light.

CONSTRUCTION

The control is best built on the printed-circuit board shown in **Figure 2**.

Since it may happen that the specified transformer cannot be obtained, the board may also be used with an external transformer or mains adaptor. The secondary of the transformer or the output of the mains adaptor is linked to the board via a two-way terminal strip for board mounting (K_3). If required, the transformer section of the board may then be cut off.

Since the dissipation of T_1 may rise to 6 W, the component must be mounted on a heat sink. If a Fischer Type SK104 is used, the supporting pins of this may be soldered to the board. An isolating washer is not strictly needed, but, since the collector of the transistor is linked to the case, care should be taken to ensure that the heat exchanger does not touch other components.

Figure 3 shows the completed prototype.

The sensor is connected to K_1 via two twisted lengths of thin, stranded, insulated circuit wire. Also, the output "max temp' is linked to input 'temp' on the protection board via two twisted lengths of similar wire.

The light-emitting diodes (LEDs) are, of course, not placed on the board, but mounted on the front panel of the amplifier. They, too, are linked to the relevant positions on the board by twisted lengths of thin, insulated, stranded circuit wire.

The fans are connected in parallel to K_2.

When the control is used with the Titan 2000, all connections are shown on the wiring diagram of that amplifier (Part 4, Figure 16 elsewhere in this issue).

When the control is used with a public-address amplifier (PA), the fans may be connected to '+ ' and '⊥' on K_2 instead of to '+ ' and '–'. If this is done, the fans are on continuously, but still at a speed that depends on the heat sink temperature.

The peak output current of the circuit is 1 A, which is more than adequate since most fans need only 200–250 mA.

The peak voltage available at K_2 is equal to the rectified transformer voltage less the knee voltages of T_1 and T_2. In practice, this is about 13 V.

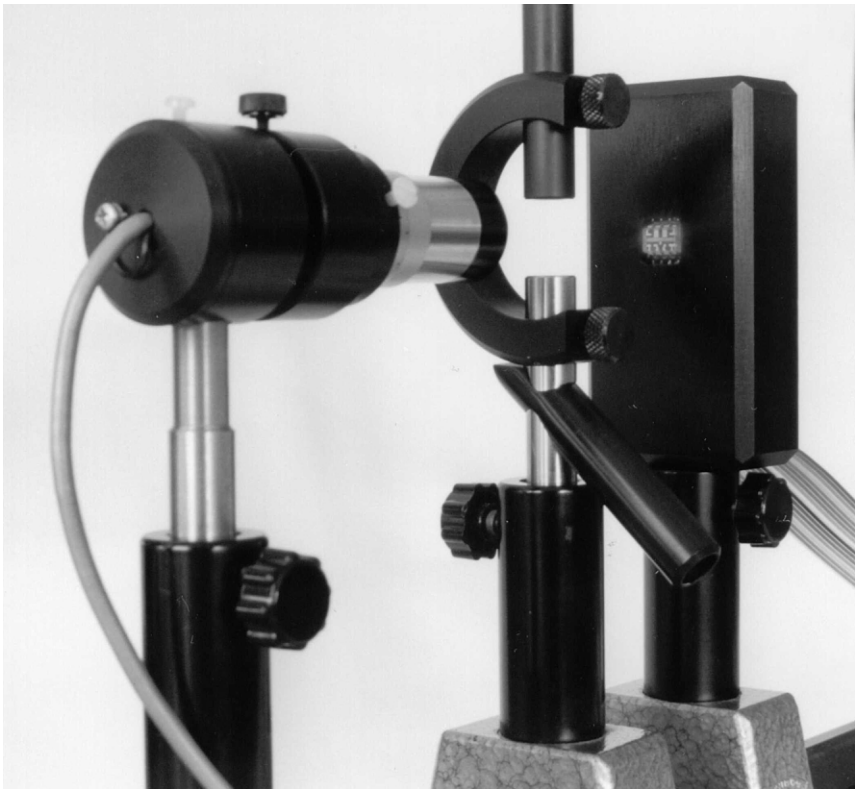
[990041]

Laser-based vernier calliper gauge

enables contact-less measurements

The calliper gauge described in this article is not an optoelectronic* device, although it is based on the marriage of a laser (optics) and electronics. It is an excellent example of the way optics and electronics can be made to work together. Like its mechanical counterpart, it is very accurate, gives fast results and need not touch the object to be measured.

By Prof. Dr A Kettler
Technical University, Aalen (Germany)



THE PRINCIPLE

Mechanical vernier calliper gauges have two parallel surfaces between which the object to be measured is placed: it does not matter how it is so placed—see **Figure 1**. In the optical equivalent the object is scanned by a parallel beam of light. Such a beam may be obtained by passing light from a point source through a collimator. An excellent point source for the present purpose is a laser diode.

A collimator is a device or system that produces a beam of (near) parallel light. For use with a laser diode, it needs a very short focal length (of the order of millimetres) to convert the strongly divergent beam from a laser diode into a parallel beam. Since with such a short focal length serious image errors may occur, the collimator is usually a combination of lenses instead of a single lens.

In the vernier calliper gauge, the eyepiece of a microscope was used, but the tube of a small pair of binoculars will also do. The reader may note that multi-lens collimators are commercially available.

The object to be measured is placed in the parallel laser beam so that it throws a shadow on to an optical sensor, a diode array or a charge-coupled device—CCD. Owing to the parallelism of the beam, the dimensions of the shadow are exactly the same size as those of the object—see Figure 1.

*Optoelectronics is the study and application of electronic devices that emit light (lasers, light-emitting diodes), amplify light (optical amplifiers), detect light (photodiodes, phototransistors), and control light (Kerr cells).

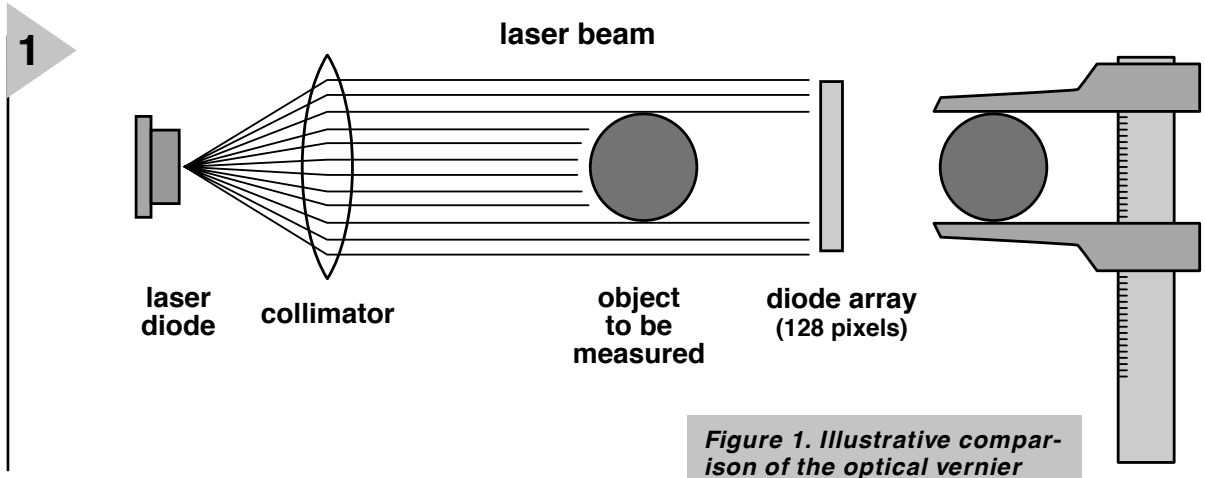


Figure 1. Illustrative comparison of the optical vernier calliper gauge and its mechanical counterpart.

LINEAR SENSOR ARRAY TSL401

Charge-coupled devices need several supply voltages and complex control signals, while their output signal requires additional analogue processing. In contrast, the Type TSL401 linear sensor array from Texas Instruments' provides a readily usable output signal, and needs only a single 5 V supply line and two logic signals. The functional block diagram of the sensor is shown in **Figure 2**.

The TSL401 consists of a 128×1 array of photodiodes and associated charge amplifier circuitry. The pixels measure 63.5 μm high by 50 μm wide with 63.5 μm centre-to-centre spacing and 13.5 μm spacing between the pixels.

Light energy striking a pixel generates a photocurrent that is then integrated. The amount of charge accumulated at each pixel is directly proportional to the light intensity on that pixel and the integration time. The integration time is the interval between two consecutive output periods.

A 128-bit shift register controls the output period of the device. An output period is initiated by the application of a high logic level to S_I for one leading (positive-going) clock edge. The logic 1 is clocked through a 128-bit shift register, in which one bit is associated with each pixel. When a given bit is high, the associated pixel signal is coupled to the analogue output (AO) through an output amplifier. When the bit goes low, the integrator is reset.

The output amplifier is a source follower that needs an external pulldown resistor. The source-follower configuration permits an analogue wired-OR hookup of multiple devices. When the device is not in the output phase, the output is in a high-impedance state. The output is nominally 0 V for no light input and 2 V for a nominal light intensity.

The TSL401 is intended for use in a wide variety of applications, including mark and code reading, optical character recognition (OCR) and contact imaging, edge detection and positioning, and optical linear and rotary encoding.

More detailed information on the sensor array is available on the Internet: **http://www.ti.com/sc/docs/folders/analog/tsl401.html**

CPLD INSTEAD OF MICROCONTROLLER

The sensor array may be controlled by a CMOS Programmable Logic Device (CPLD) instead of a microcontroller. A good choice for this purpose is the Type ispLSI1016 from Lattice (described in *EE*, November, 1994).

This device contains 64 macrocells, which makes it ideally suitable for simultaneously generating control signals for the array and providing an interface for connecting it to a computer. See **Figure 3**.

A dedicated programming unit is not needed, since the logic may be input directly into the CPLD via the parallel port of the computer.

Since the download cable also provides a link between the CPLD and the computer, the measurands may be sent directly to the computer. Before this can be done, however, the cable as well as the ispLSI1016 board need a few small modifications. Information on these is available on Lattice's Homepage: **www.latticesemi.com**

CONTROL LOGIC AND INTERFACE

The overall logic is in synchronous format: all registers are clocked centrally by a 16 MHz system clock. Asynchronous signals are integrated into the oscillator signal by bistables.

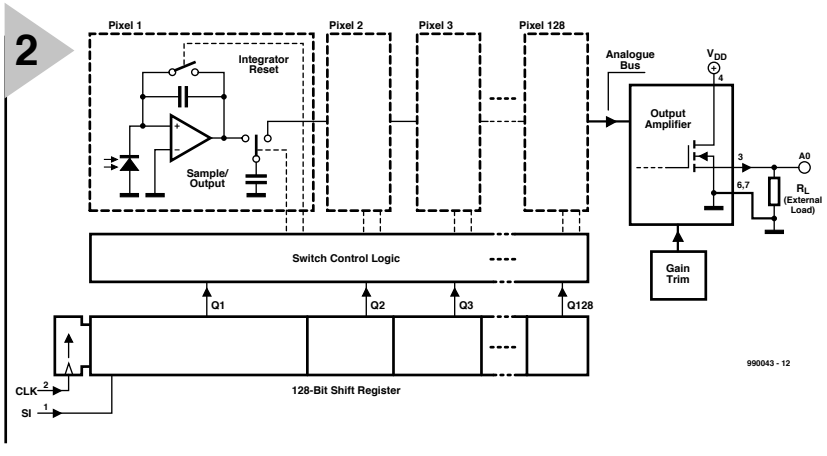
The 2 MHz pixel clock for the sensor array is derived from the system clock, so that a pixel clock period consists of eight phases. This means that the signals needed for processing the pixels may be synchronized with an accuracy of an eighth of the pixel clock period.

The logic signals in the ispLSI1016 are applied to modules contained in the CPLD as shown in **Figure 4**.

SYNCHRO

Control signals MODE and SCLK, with which the computer starts the serial reading of the data, are not in synchrony with the system clock. They are, therefore, synchro-

Figure 2. Functional block diagram of the Type TSL401 linear sensor array.



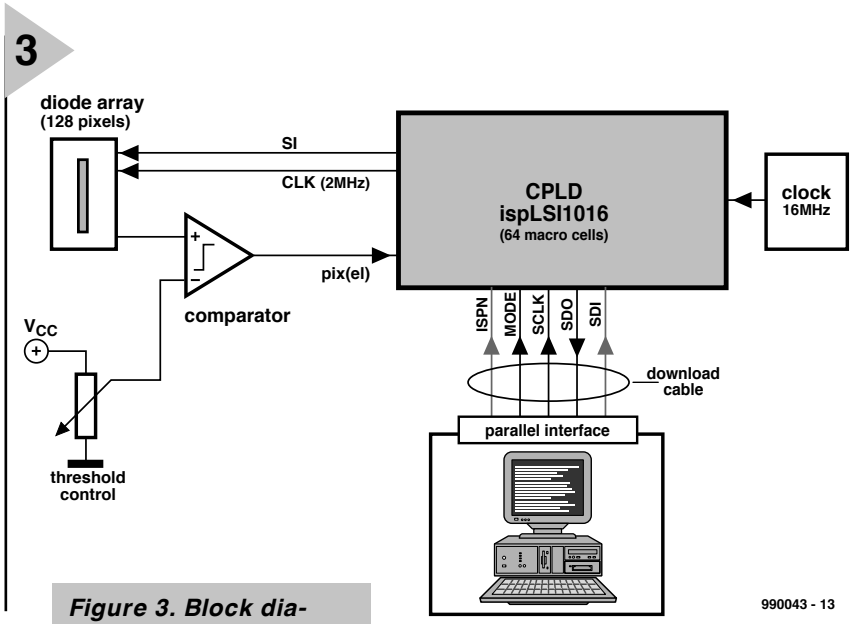


Figure 3. Block diagram of the electronic part of the vernier calliper gauge.

Figure 4. The requisite logic functions contained in the ispLSI1016 for sampling the measurand.

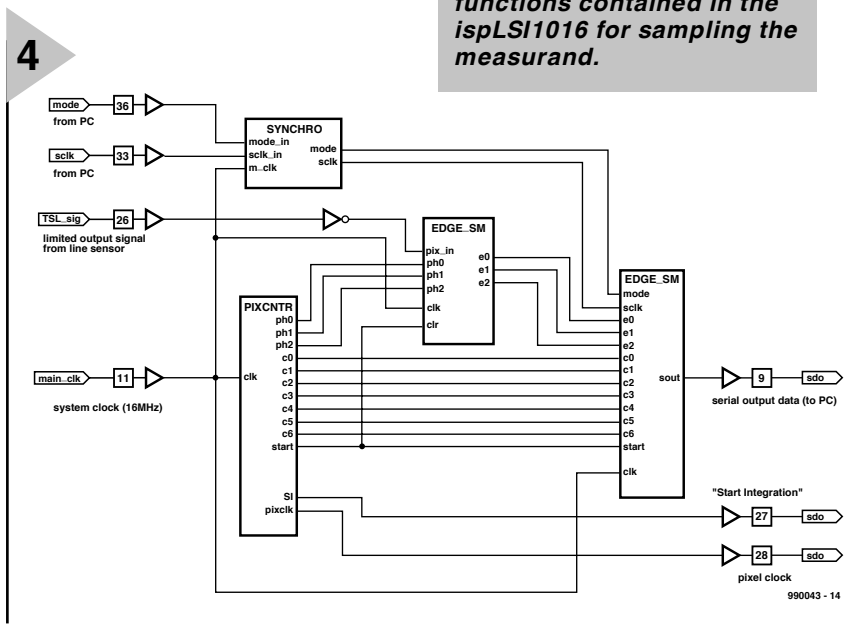
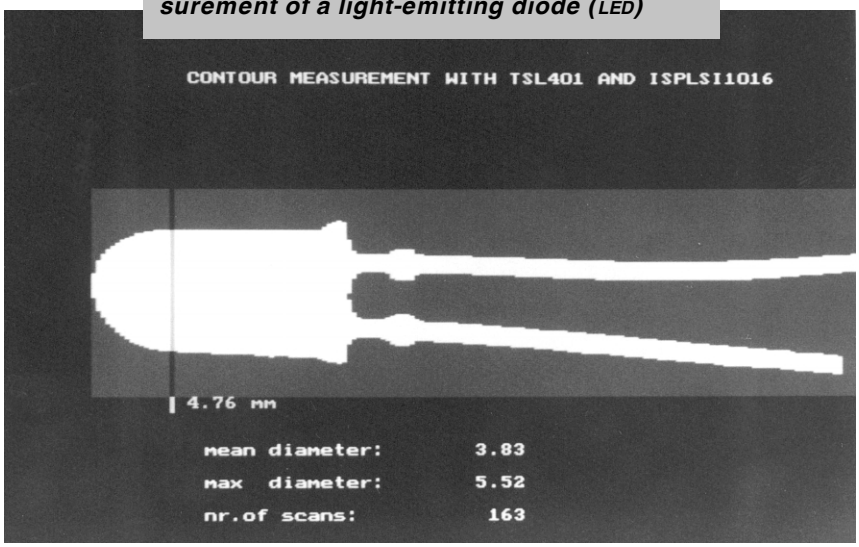


Figure 5. Screendump of the contour measurement of a light-emitting diode (LED)



nized with it before being applied to the remainder of the module.

PIXCNTR

The PIXCNTR module counts the number of pixels and generates control signals SI and PIXCLK for the sensor array. The array is read permanently at a pixel frequency of 2 MHz.

The module is based on a 10-bit counter that is clocked at 16 MHz. Bits C_0–C_6 form the real pixel counter, while bits ph_0–ph_2 divide a pixel period into eight intervals. The latter three bits are also used by the EDGE_SM module when a light/dark edge is detected to monitor the transient oscillation of the output signal of the sensor array pixel by pixel.

EDGE_SM

The video signal arriving from the sensor array is converted into binary form by a comparator (LM311) and then applied to an edge detector which recognizes light-to-dark or dark-to-light transitions.

The phase information of signals ph_0-ph_2 determines when the binary signal is sampled within the pixel clock period. This enables the transient response of the video signal to be allowed for. The edge counter (e_0-e_2) is increased by one for each edge; the counter state is passed to EDGE_BUF.

EDGE_BUF

The EDGE_BUF module assumes the state of the pixel counter at each new edge. Up to four edge positions may be stored.

Measurement of the edge positions is started by the control computer with signal MODE. After the measurement has been completed, the edge positions from the computer are read bit by bit via the parallel interface. The single data bits are clocked by SCLK and output via s_{out}. Measurement and data transfer follow each other in not fewer than two read periods of the sensor array, that is, 128 μs.

COMPUTER PROGRAM

The software for reading the measurement values is produced under DOS in Turbo Pascal. It is accessed directly at the relevant I/O register via the parallel port.

Although the logic design allows very rapid measurements to be carried out, in practice the speed of measurement is determined by the (relatively low) speed of port access during the data transmission.

Tests with a Pentium 166 produced measurement times of 192 μs in the case of two edges, and 256 μs in the case of four edges.

[990043]

multi-purpose infrared control

simple IR control systems for Sony audio equipment

It is now an established and fortunate fact that may hobbyists and programmers offer their knowledge, experience and expertise via the Internet. If you are sceptical about this statement, take a look at this website

http://www.czechin.com/minidisc/.

The main page at this url contains two interesting projects for those of you in possession of a PC and Sony equipment with infrared remote control options.

Under "My Old Projects" two items may be found that have been given the status 'freeware', which means that they are available in the so-called 'public domain'. 'TitleMD' points to a universal circuit consisting of a 555 IC, an IRED (infrared emitting diode) and a handful of capacitors and resistors. This circuit, which is connected to the PC's printer port (LPT), was designed by Stanislav Dosadil. Under PC control it generates a 38-kHz signal which is used to drive the sender diode. The lot should not cost you more than three pounds or so.

Using the DOS program called 'TitleMD.exe' (also found on the website and Windows 95 DOS box compatible), MiniDisc (MD) track titles may be automatically entered into the memory of a suitable MD player like the MDS-JE500. Because the source code of the 'MDTitler' program is also available on the website (Borland Pascal 7.0 for DOS), hobbyists may have a go at DIY improvements and extensions.

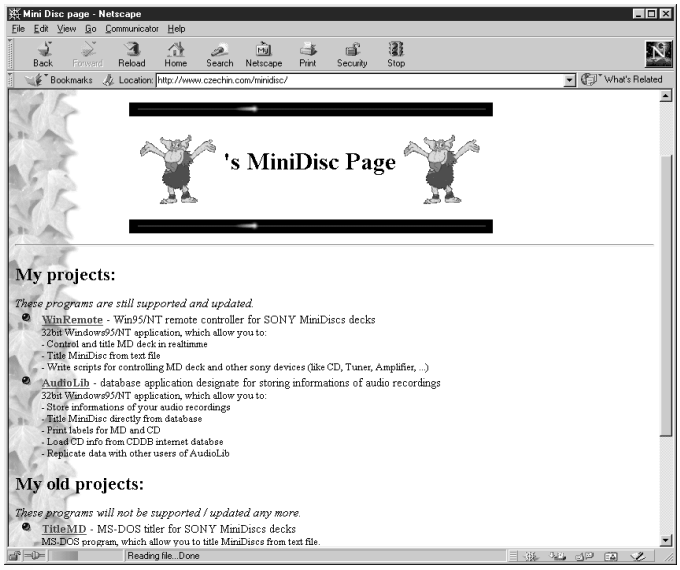
All clocked…

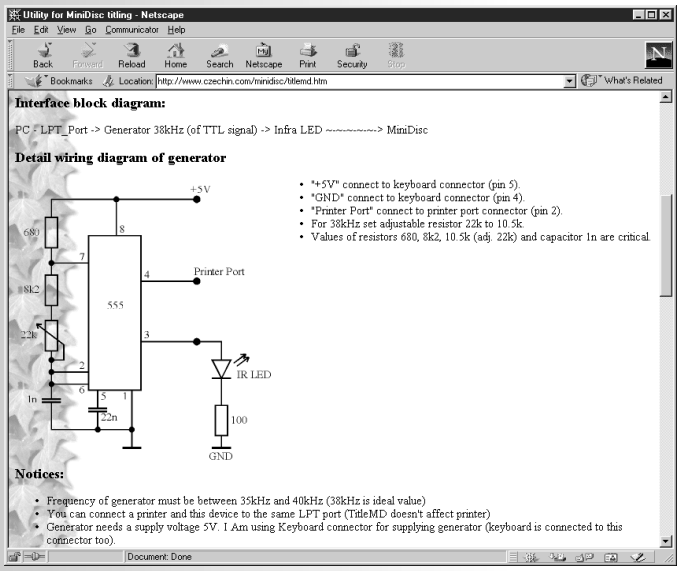
The same circuit has more capabilities, however. For example, the above website also contains a project called IRC (Universal Infrared Controller). Like MDTitler, IRC is a DOS program capable of driving the Dosadil hardware. The program may be used to transmit infrared control signals to MiniDisc players, CD players, amplifiers, tuners and other Sony equipment. The supplied configuration file has been prepared for functions on MD players, CD players, amplifiers and tuners. It can easily be extended by the user to include new functions. The only data you have to have available is the hexadecimal codes assigned to a particular function. That is not a problem because many codes for MD players, CD players, tuners, amplifiers, tape decks, DAT recorders, TV sets, video cameras, record players and laser disc players may be found at

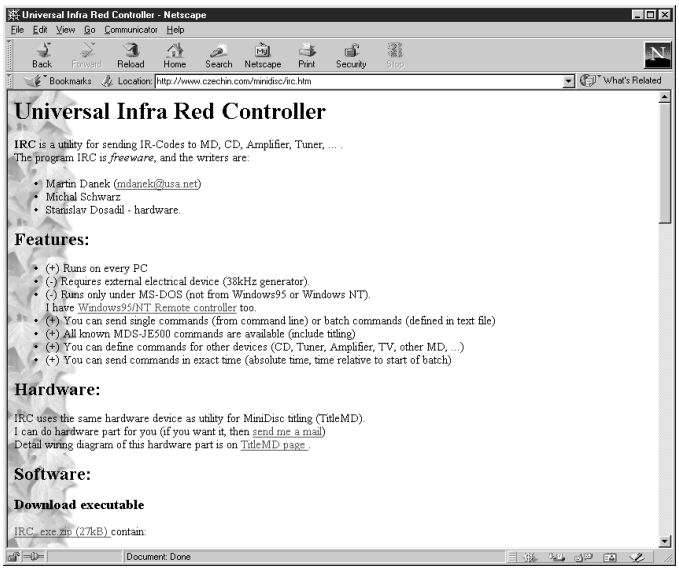
http://www.czechin.com/minidic/ircodes.txt

Using the built-in batch function you should be able to create script files, allowing a large number of commands to be executed in sequence. An internal timer function then ensures that the timing of all actions is properly managed. Synchronisation with the PC clock (date and time) is also provided.

(9945043-1)







2SC5171

Transistors
AF, driver

ELEKTOR ELECTRONICS

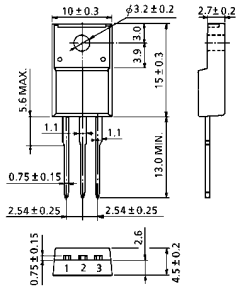
DATASHEET 5/99

2SC5171
Silicon NPN Epitaxial Transistor for Power Amplifier and Driver Stage Applications

Manufacturer
Toshiba

Features
➥ High Transition Frequency: f_T = 200MHz (Typ.)
➥ Complementary to 2SA1930

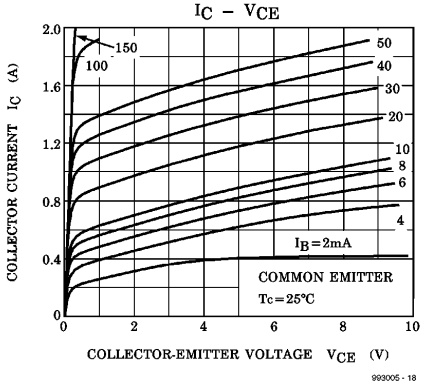
Application Example
Titan 2000 High-Power AF Amplifier,
Elektor Electronics February - May 1999.

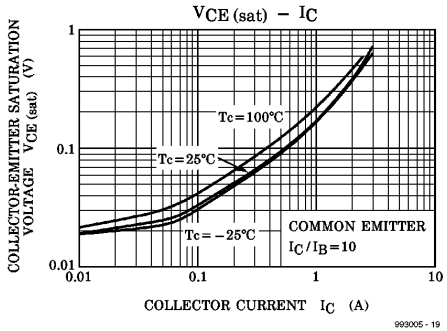


1. BASE
2. COLLECTOR
3. EMITTER

993005 - 17

MAXIMUM RATINGS (T_a = 25°C)				
CHARACTERISTIC		**SYMBOL**	**RATING**	**UNIT**
Collector-Base Voltage		V_{CBO}	180	V
Collector-Emitter Voltage		V_{CEO}	180	V
Emitter-Base Voltage		V_{EBO}	5	V
Collector Current		I_C	2	A
Base Current		I_B	1	A
Collector Power Dissipation	T_a = 25°C	P_C	2.0	W
	T_c = 25°C		20	
Junction Temperature		T_j	150	°C
Storage Temperature Range		T_{stg}	–55 to + 150	°C





2SA1930

Transistors
AF, driver

ELEKTOR ELECTRONICS

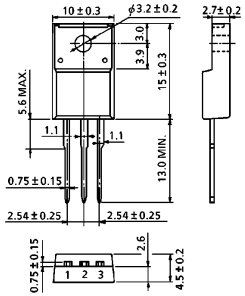
DATASHEET 5/99

2SA1930
Silicon PNP Epitaxial Transistor for Power Amplifier and Driver Stage Applications

Manufacturer
Toshiba

Features
➥ High Transition Frequency: f_T = 200MHz (Typ.)
➥ Complementary to 2SC5171

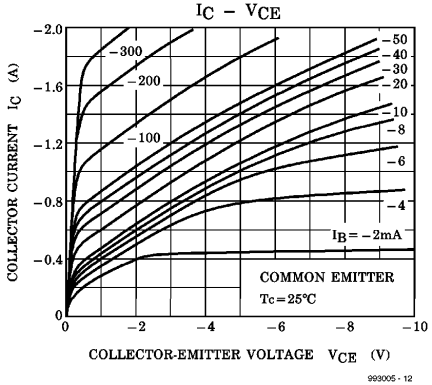
Application Example
Titan 2000 High-Power AF Amplifier,
Elektor Electronics February-May 1999.

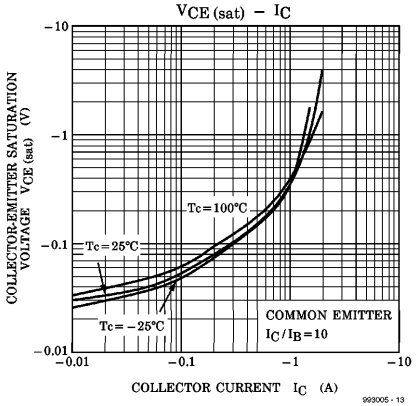


1. BASE
2. COLLECTOR
3. EMITTER

993005 - 11

MAXIMUM RATINGS (T_a = 25°C)				
CHARACTERISTIC		**SYMBOL**	**RATING**	**UNIT**
Collector-Base Voltage		V_{CBO}	–180	V
Collector-Emitter Voltage		V_{CEO}	–180	V
Emitter-Base Voltage		V_{EBO}	–5	V
Collector Current		I_C	–2	A
Base Current		I_B	–1	A
Collector Power Dissipation	T_a = 25°C	P_C	2.0	W
	T_c = 25°C		20	
Junction Temperature		T_j	150	°C
Storage Temperature Range		T_{stg}	–55 to + 150	°C





2SA1930

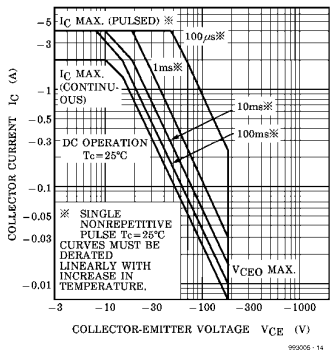
Transistors
AF, driver

ELEKTOR ELECTRONICS

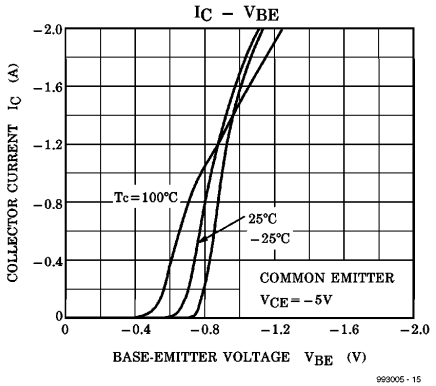
DATASHEET 5/99

ELECTRICAL CHARACTERISTICS (T_a = 25°C)						
CHARACTERISTIC	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Collector Cut-off Current	I_{CBO}	V_{CB} = −180V, I_E = 0	—	—	−5.0	μA
Emitter Cut-off Current	I_{EBO}	V_{EB} = −5V, I_C = 0	—	—	−5.0	μA
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	I_C = −10mA, I_B = 0	−180	—	—	V
DC Current Gain	$h_{FE(1)}$	V_{CE} = −5V, I_C = −0.1A	100	—	320	—
	$h_{FE(2)}$	V_{CE} = −5V, I_C = −1A	50	—	—	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = −1A, I_B = −0.1A	—	−0.24	−1.0	V
Base-Emitter Voltage	V_{BE}	V_{CE} = −5V, I_C = −1A	—	−0.68	−1.5	V
Transition Frequency	f_T	V_{CE} = −5V, I_C = −0.3A	—	200	—	MHz
Collector Output Capacitance	C_{ob}	V_{CB} = −10V, I_E = 0, f = 1MHz	—	26	—	pF

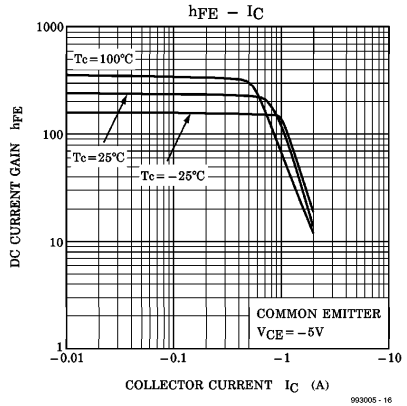
SAFE OPERATING AREA



I_C − V_{BE}



h_{FE} − I_C



2SC5171

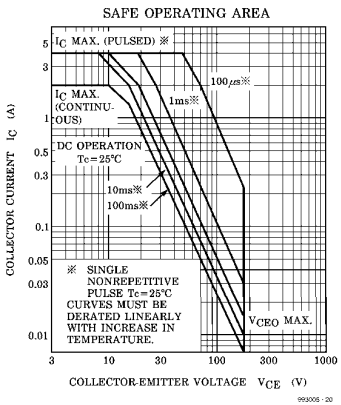
Transistors
AF, driver

ELEKTOR ELECTRONICS

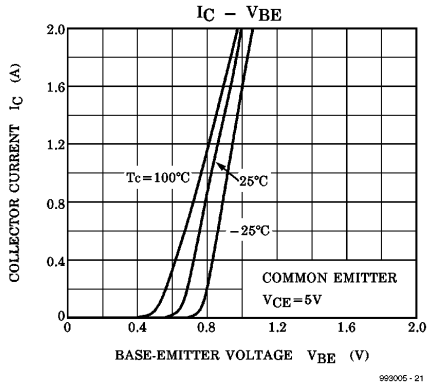
DATASHEET 5/99

ELECTRICAL CHARACTERISTICS (T_a = 25°C)						
CHARACTERISTIC	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Collector Cut-off Current	I_{CBO}	V_{CB} = 180V, I_E = 0	—	—	5.0	μA
Emitter Cut-off Current	I_{EBO}	V_{EB} = 5V, I_C = 0	—	—	5.0	μA
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	I_C = 10mA, I_B = 0	180	—	—	V
DC Current Gain	$h_{FE(1)}$	V_{CE} = 5V, I_C = 0.1A	100	—	320	—
	$h_{FE(2)}$	V_{CE} = 5V, I_C = 1A	50	—	—	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 1A, I_B = 0.1A	—	0.16	1.0	V
Base-Emitter Voltage	V_{BE}	V_{CE} = 5V, I_C = 1A	—	0.68	1.5	V
Transition Frequency	f_T	V_{CE} = 5V, I_C = 0.3A	—	200	—	MHz
Collector Output Capacitance	C_{ob}	V_{CB} = 10V, I_E = 0, f = 1MHz	—	16	—	pF

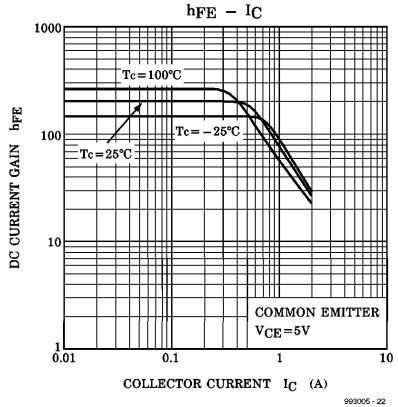
SAFE OPERATING AREA



I_C − V_{BE}



h_{FE} − I_C



induction lighting

economical lamps with a long life

It is not widely known that a new type of lamp was introduced in the 1980s: the induction lamp. The design of this lamp, which has no electrodes, ensures that its useful life is not less than 6000–60000 hours*. This means that the lamp, assuming it is on for six hours a day, will last for 3–25 years*. This article gives a brief description of the design.

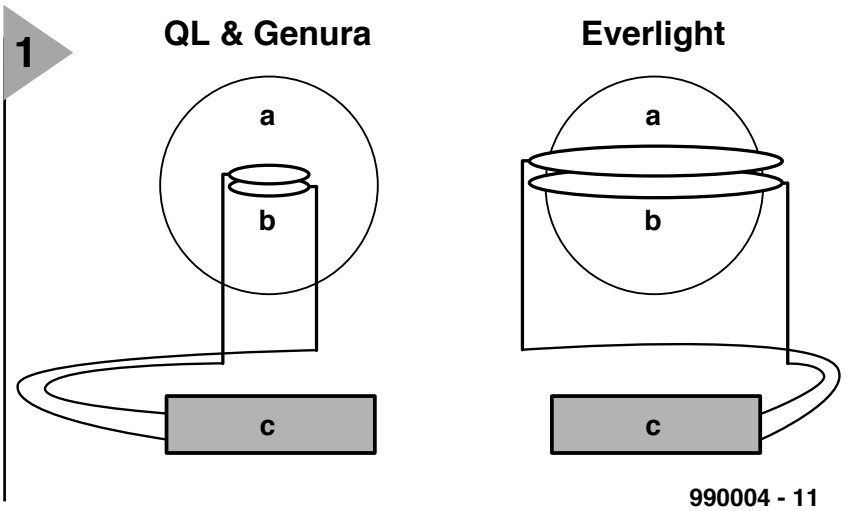


Figure 1. Basic design of an induction lamp. It is built around a discharge tube (a), an inductive-field generator (b), and an r.f. generator (c). There are a number of types on the market, among which the QL, the Genura, and the Everlight.

INTRODUCTION

In spite of it being virtually unknown to the world at large, the induction lamp system has been around since the mid-1980s. In the intervening years, many of its facets have been improved to make it a more practical product and the lamp is consequently now used more and more in industrial applications. No doubt, once it becomes more widely known, many householders will switch to it as well.

The first design, introduced in 1986 by Matshushita Electrical Works in Japan, was originally intended for the home market only. In 1991, Philips of the Netherlands announced a similar lamp, the QL lamp, and a few years later, General Electric launched its R80 Genura Retrofit induction lamp. Today, there are several other types as well, such as the E-lamp from Intersource Technologies, and the Solar 1000 from Fusion Lighting.

The Everlight lamp, the Genura Retrofit lamp, and the E-lamp, are low-power types, whereas the QL lamp is available in 55 W, 85 W, and 165 W ratings. The Solar 1000 lamp, rated at 1400 W, is clearly intended for heavy-duty applications. Nevertheless, all these lamps work on the same principle: an induced discharge in an evacuated tube.

BASIC DESIGN

An induction lamp system consists of three main elements: an evacuated discharge tube or bulb, an induction-field

* Depending on the type and manufacture of the lamp system.

This article is based on information from Philips Lighting and the article 'Elektrodenloze lampen' from International Lighting Review, no. 96/4

Photo: Philips Lighting

Figure 2. Photo of a practical QL lamp from Philips. The separate r.f. generator is linked to the bulb by a coaxial cable.

generator, and an r.f. generator.

The operating frequency of the r.f. generator is 2.65 MHz in the QL and Genura Retrofit lamps, 13.65 MHz in the Everlight and E-lamps, and 2.45 GHz in the Solar 1000 lamp. The latter system consists of an evacuated discharge tube, a magnetron, a waveguide and a microwave cavity.

The induction-field generator consists of an inductor on a ferrite core. The current flowing through the inductor generates a magnetic field that is magnified by the ferrite core. The magnetic field causes an electric field in the lamp, which generates a circular plasma current around the field generator to sustain the discharge. The system operates like a transformer, in which the inductor is the primary winding and the plasma in the lamp functions as the secondary winding.

The operation is virtually identical to that in a traditional fluorescent tube. The mercury atoms are excited by the discharge and emit ultraviolet photons. These photons are converted into visible light by the phosphor layer at the inside of the tube or bulb.

OPERATION

The basic design of the QL and Genura Retrofit lamps may be understood from the sketch at the left in Figure 1, and that of the Everlight from the sketch at the right. In both sketches the discharge tube is at (a). The electromagnetic field ignites the gas in the tube or bulb, which results in ultraviolet radiation. The current causing the electromagnetic field flows through the inductive-field generator (b). The r.f. generator at (c) is the electronic system that generates the r.f. signals that are converted into an electric field by the field generator. This is the circuit that in practice appears to determine the ultimate life of the lamp.

Figure 2 shows a practical QL lamp, although in normal use this is usually mounted in a suitable holder.

In the field generator in **Figure 3a**, the alternating current, I_p, in the primary coil induces a corresponding current at the same frequency, I_s, in the secondary coil. In the QL lamp system, the secondary coil is formed by the metal evaporated in the bulb.

In **Figure 3b**, the free electrons in the metal vapour are excited by the induced secondary current, which results in ultraviolet radiation. This radiation is converted into visible light by the phosphor layer on the inside of the bulb.(1: gas vapour atom; 2: visible light; 3: fluorescent powder).

Figure 3c shows the discharge tube of the QL lamp system in the shape of a sealed glass bulb that is filled with a noble gas at low pressure and a small quantity of vapourized mercury. (1: cavity; 2: fluorescent coating; 3: residual amalgam; 4: main amalgam; 5: lamp socket).

The external r.f. generator in **Figure 3d** generates an alternating current at a frequency of 2.65 MHz for the primary coil of the field generator in Figure 3a. (1: primary coil; 2: 40 cm coaxial cable; 3: 2.65 MHz oscillator; 4: mains voltage terminals; 5: pre-treatment; 6:filter; 7: r.f. generator.

LONG LIFE

Because the discharge tube has no electrodes, the life of the system is determined primarily by the associated electronics. The estimated average life quoted by manufacturers, that is, the time after which 50 per cent of the lamps still function correctly, is 10 000 hours for the Genura lamp; 15 000 hours for the Solar 1000 system; 50 000 hours for the E-lamp, and 100 000 hours for the QL lamp. Consumers, however, are more interested in the practical life span, that is, the period after which 80 per cent of the lamps is still in working order but the light emission has been reduced to 70 per cent. Generally, this is about 60 per cent of the estimated average life, that is, in the case of a QL lamp, about 60 000 hours.

INTERESTING FACTS

The shape of most induction lamps is similar to that of traditional incandescent lamps. This means that the light flux of these new lamps can be controlled much more effectively by reflectors than that of standard fluorescent lights.

As mentioned before, induction lamps are electronic products that gen-

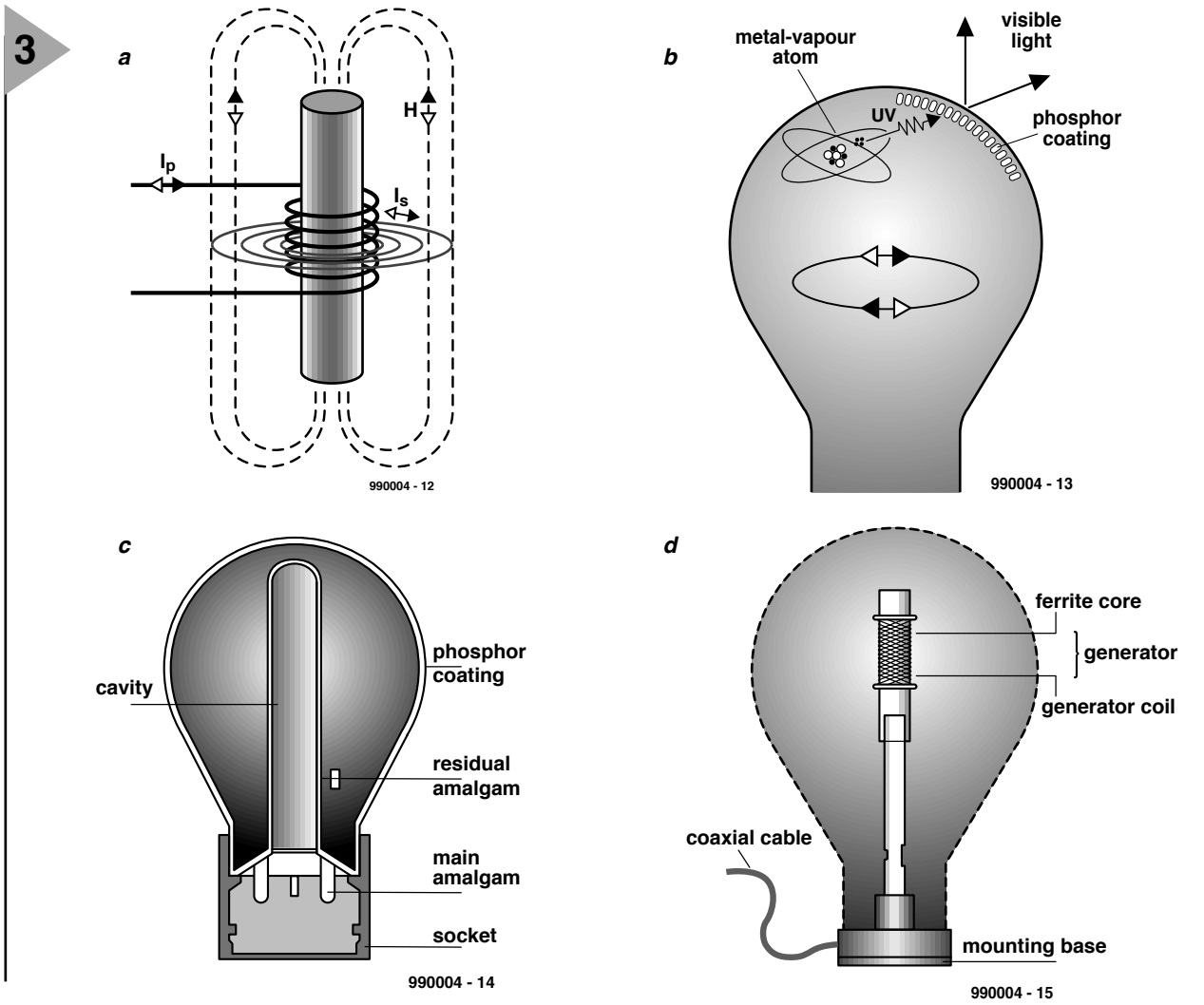


Figure 3. Four sketches to illustrate the operation of an induction lamp.

erate electromagnetic radiation. If these waves interfere with other signals, electromagnetic interference (EMI) may ensue. At present, there are few guidelines for interference suppression in the case of lamps rated at up to 25 watts. Until recently, higher power QL lamps used an effective but expensive holder to meet current radiation requirements.

A general complaint regarding induction lamps is that they are not available in higher powers. The Solar 1000 System, which is rated at 1400 watts, proves that the light flux is not a limiting factor.

The length of standard fluorescent tubes increases in direct proportion to the power rating. Because induction lamps are also fluorescent products, their light-emitting surface will also increase with the power rating. However, since induction lamps are normally bulb-shaped, their surface area will increase with with only the fourth root of the power.

Although none of the currently available induction lamps is suitable for use with a dimmer switch, this does not mean that the light produced by these lamps cannot be dimmed. Since the relevant electronics is integrated in the lamp system, it should be possible to implement dimmers in it.

NEW VARIANTS

The electromagnetic interference (EMI) has been reduced drastically in the latest generation of QL lamps. Provided they are properly earthed, these lighting systems meet the requirements of EN5501, EN55022, and FCC Part 15 Class B. This means that designers of suitable holders for these lamps need not worry about possible design limitations.

Also, the r.f. generator for use with the latest variants is about 30 per cent smaller than the previous generation. This means that the QL lamp can be integrated more readily in holders.

QL lamps are now available with powers up to 165 watts. A discharge tube only 13 cm (5 in) long can produce a luminous flux of 12 000 lm.

General Electrics has recently introduced a smaller version of its Genura lamp. Rated at 15 watts, this lamp produces a luminous flux of 700 lm.

The Endura system from Osram is rated at 150 watts and operates with (the relatively low) frequency of 250 kHz. It produces a luminous flux of about 80 lm/watt, that is, 12 000 lm.

CONCLUSION

The new generation of induction lamps combines the advantages of fluorescent lighting, such as low energy consumption, low heat production, variable colour (within reason), high efficiency, and long life, with the advantages of the incandescent lamp. Especially attractive is the round shape, which makes it much easier (and cheaper) to produce holders (sockets) than for the long neon tubes, and to replace standard incandescent lamps.

Owing to their current high price, induction lamps are at present used only in situations where the replacement of lamps is expensive: rooms with high ceilings, tunnels, theatres, street lights, and so on. The high initial investment is largely compensated by the very low maintenance costs.

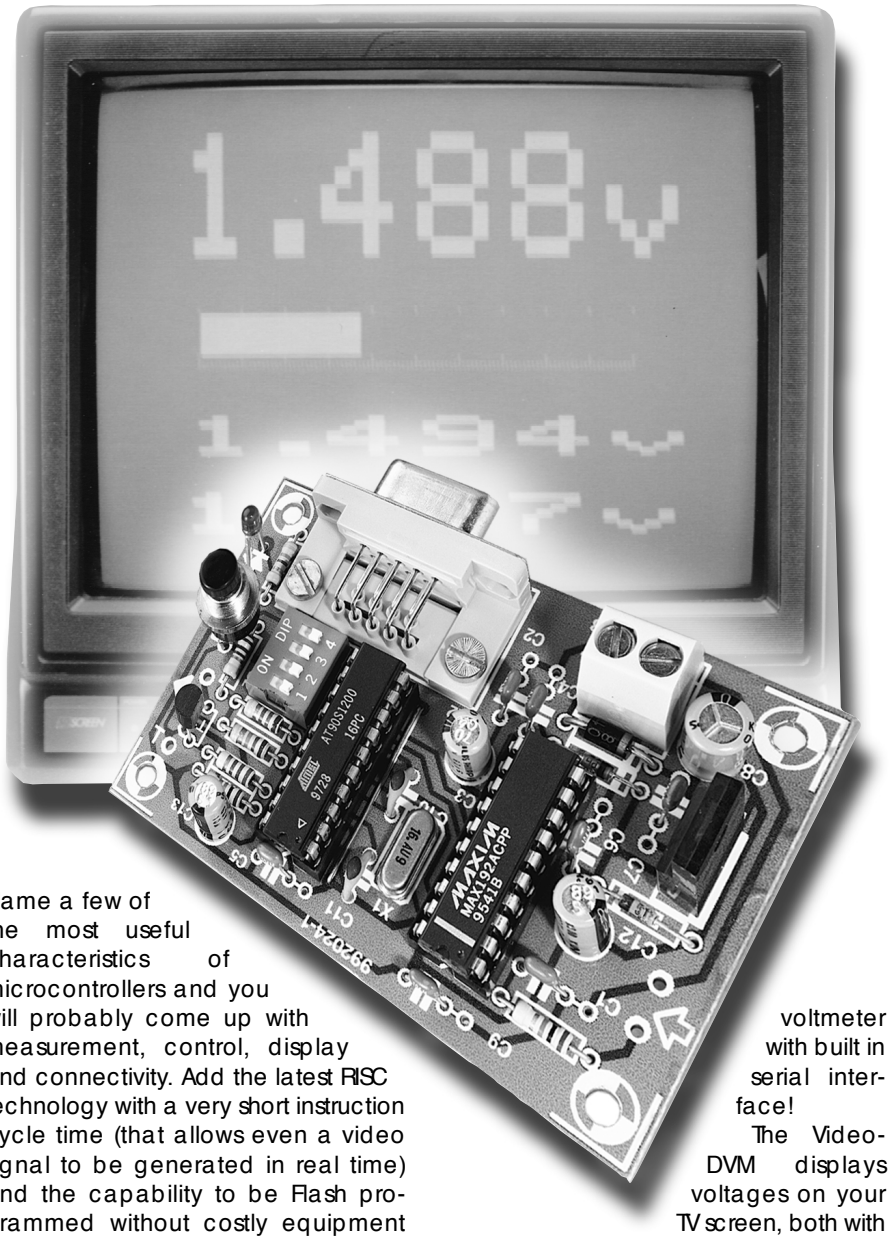
[990004]

Digital voltmeters are popular tools for anyone wishing to measure electrical voltages. The circuit described here is, we feel, unique because of its combined features. The DVM has two outputs, one serial and one for direct connection of a TV or a monitor.

Design by A. Ricci Bitti

video DVM

measurement values on monitor, TV or PC



Name a few of the most useful characteristics of microcontrollers and you will probably come up with measurement, control, display and connectivity. Add the latest RISC technology with a very short instruction cycle time (that allows even a video signal to be generated in real time) and the capability to be Flash programmed without costly equipment and — *voilà* — you have the Video-DVM, a cheap, funny, giant-size display voltmeter with built in serial interface!

The Video-DVM displays voltages on your TV screen, both with giant digits and analogue-bar; records maximum and minimum peak; it also sends measured data to a personal computer through a serial interface. Its block diagram is shown in **Figure 1**. Here are its main features:

- ✓ An analogue input capable to measure voltages in the range 0 to 4.096 V;
- ✓ A video display output capable to direct drive any ordinary TV set via the SCART (VCR) input;
- ✓ A serial data output, to log data on a personal computer;
- ✓ Needs only a single + 5V, 15 mA typ. supply.

With its big on-screen display, the Video-DVM is great to show to a large audience practically anything that can be converted to volts, from temperature in a serious physics experiment in the classroom to a *love-meter* for a party.

But the Video-DVM is a lot more than a funny toy. It is really cheap and easy to modify to suit your needs, letting everyone to experiment with video signals and data display. The programming itself meets the severe constraints of real time direct video synthesis, digital conversion, serial data timing, and reduced code size. The analogue to digital converter can be easily connected to a variety of sensors, or can be replaced with new code to display time or count pulses. Last but not least, thanks to its serial datastream the Video-DVM can also be used as a simple data logger.

All the hard work of interrupt-driven TV/monitor picture generation, serial data routines, ADC converter driving, etc. is ready-programmed, enabling anyone to modify the code in small steps to suit any specific need or brilliant idea.

In other words, building the Video-

DVM can be very instructive, a major characteristic in this day and age of hyper-specialized ICs that leave almost nothing to fantasy and exploration.

The hardware circuit

As you can see from the circuit diagram in **Figure 2**, the circuit is built around the new Atmel's AVR 90S1200 microcontroller and Maxim's MAX192 analogue to digital converter (ADC).

Despite to its 16-MHz clock, Flash program memory and internal EEPROM, the AVR is relatively cheap, and therefore ideally suited for hobbyists. What's more, all the software needed (including a powerful simulator) is available for free from Atmel's web site at *www.atmel.com*.

The chip can be reprogrammed at least 1,000 times in a flash, using one of the many programmers already available (some are advertised on Elektor's pages). The detailed flash programming protocol is available on the web site, too.

The chip has 32 bytes of RAM, 64 bytes of EEPROM, 512 words of program memory and an 8 bit timer. The instruction set is concise and very well balanced, and thanks to an Harvard RISC architecture even a complex task like the one described here is accomplished using no more than about 400 instructions.

The instruction cycle time is very short, enabling video signals to be built by software.

A simple two-bit asymmetrical DAC built around three resistors supplies the composite video signal at a standard level of 1 V_{pp} to the input of any TV set with a SCART connector or an AV (VCR) input. The serial datastream (ASCII data at 1200 baud, no parity, 8 data bits, 1 stop bit) is also generated by software. The level is TTL: most personal computers work with TTL levels as well as with standard RS232 levels, provided that the connecting cable is not too long. Because of this I thought a voltage converter like the MAX232 not necessary. If you want, you can add it externally; in that case you must invert the polarity, inverting the 'set bit' and 'clear bit' instructions in the code (the position is clearly marked in the listing).

All input pins have internal pullups and high current sink capacity, so the 'max-min clear' button and the three decimal point selection DIP switches or jumpers may be connected directly between the pins and ground.

An LED, flashing each time a measurement is completed, is connected to an output pin.

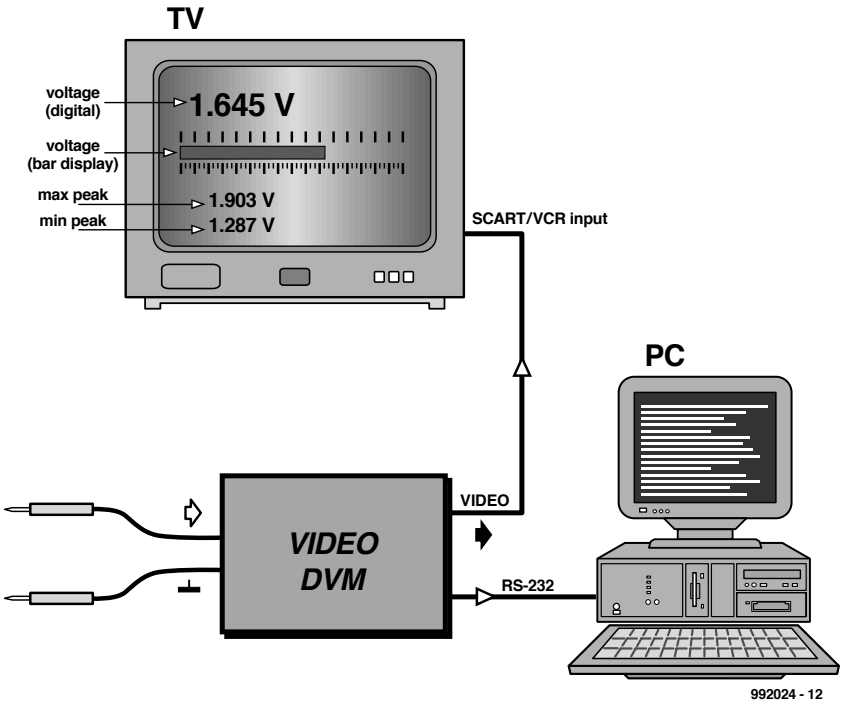


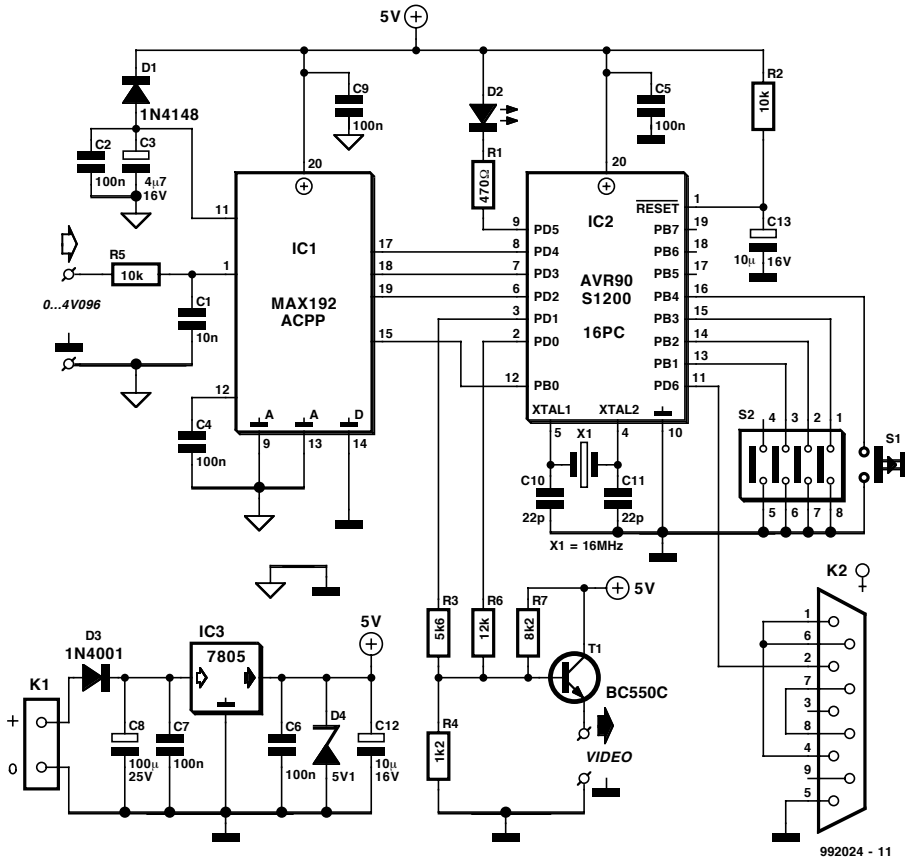
Figure 1. Bock diagram of the digital voltmeter with serial and video output.

The ADC concept

The voltage is read using a 10-bit serial ADC converter type MAX192ACPP with its own voltage reference set at 4.096 V. Technical details on this interesting chip may be found on the Datasheets in the April 1999 issue of *Elektor Electronics*.

Four I/O lines are needed for data transfers (Data input, Data output, Chip enable, Serial clock). Even if it is specified for 10 bits, the ADC supplies two

Figure 2. From theory to practice: a microcontroller and an A-D converter.



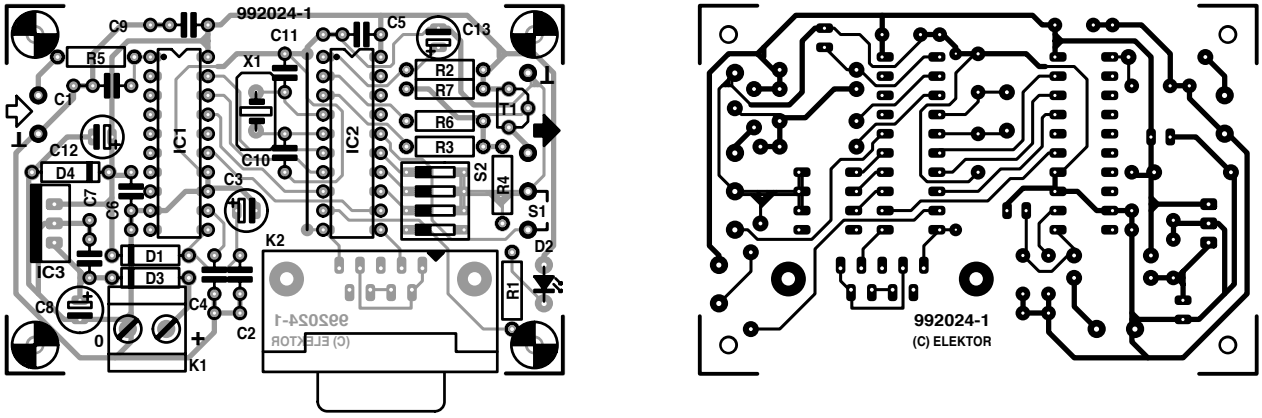


Figure 3. Printed circuit board design (board available ready-made).

COMPONENTS LIST

Resistors:
R1 = 470Ω
R2,R5 = 10kΩ
R3 = 5kΩ6
R4 = 1kΩ2
R6 = 12kΩ
R7 = 8kΩ2

Capacitors:
C1 = 10nF, ceramic
C2,C4-C7,C9 = 100nF, ceramic
C3 = 4μF7 16V radial
C8 = 100μF 25V radial
C10,C11 = 22pF
C12,C13 = 10μF 16V radial

Semiconductors:
D1 = 1N4148
D2 = LED, high efficiency
D3 = 1N4001
D4 = 5V1 400mW zener diode
T1 = BC550C
IC1 = MAX192ACPP
IC2 = AVR90S1200-16PC (order code)
IC3 = 7805

Miscellaneous:
S1 = pushbutton, 1 make contact
S2 = 3-way or 4-way DIP switch
X1 = 16MHz quartz crystal
K1 = 2-way PCB terminal block, raster 5mm
K2 = 9-way sub-D socket (female), angled pins, PCB mount
PCB, order code 992024-1

The CD-ROM 'μP/μC hard & software 97/98' (ISBN 90 5381-086-2) available from the Publishers contains the complete source code listing for this project. The file location is /Gb/03.

more 'sub LSB' bits: this means that 12 bits are effectively read from the ADC, although only 10 bits have the guaranteed precision. Nonetheless, I found these two extra bits very precise. All 12 bits are shown on the display, covering the range from 0.000 to 4.095 volts with direct reading in millivolts. Only one of the eight inputs available on the MAX192 is used, but the software driver is prepared to read any input you want. With minor changes, you can set up the Video-DVM to measure four voltages; three with digital display and one as an analogue bar.

Direct video synthesis

From the hardware point of view, the hardware involved in video synthesis is exceptionally simple: two output pins and three resistors, allowing for four signal levels to be generated (sync, black, white, light grey). From the software point of view, video synthesis requires a very fast instruction cycle (here, 62.5 ns) and a carefully timed, instruction-balanced, tweaked and manually optimised code.

In order to achieve proper generation of the complex video signal, a robust timing system is absolutely necessary. Even a single 16-MHz clock cycle (62.5 ns) delay is clearly visible on the display, so you have to think twice before putting down even a single instruction.

First of all, we have to choose a suitable timebase: choosing the raster line duration (64 μs) as time base let us to build the entire frame a line after another (the non-interlaced frame consists of 312 lines), as well as placing easily the horizontal sync pulse (a few microseconds at start of each video line) and the vertical pulse (a few lines at start of each frame).

The only timer available on the micro is capable of generating repetitive interrupts every 16 μs without the need of reloading; that is, four interrupts for every raster line.

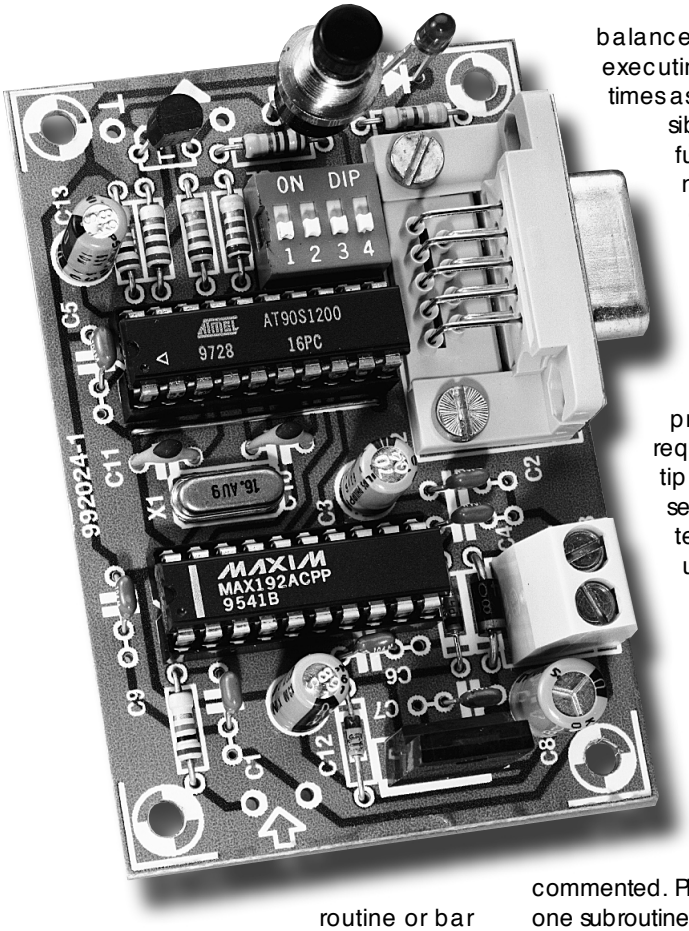
At each fourth interrupt we make a new video line: to do this, each time the interrupt routine is executed, a counter is incremented and every four interrupts we are (almost) at the start of a new line. "Almost", because we have to account for the time needed to service the interrupt routine upon interrupt request. This time is not constant, depending on the instruction being executed at the time of the interrupt generation. Some instructions have a longer execution time than others, so the interrupt service time can vary in an unpredictable way, distorting the display.

The best workaround I found for the problem is to put the micro in sleep mode just before the fourth, critical interruption occurs: the next interrupt will then wake up the micro with constant, known timing.

The two output pins are labelled CsyncBit (composite sync) and VideoBit. Pulling both Csync and VideoBit to logic-low, the video signal is at 0 volts (sync level). With only CsyncBit high, we get the black level; with both CsyncBit and VideoBit high, we get a white display.

Not surprisingly, all the video generation is based on the timer interrupt routine. Every fourth interrupt a new line is started with the sync pulse; then the repetitive timekeeping (counting of lines, serial communications) routines are executed. All this work is done so quickly that we have to add a delay loop to wait for the start of the visible portion of the video line.

At this point, a multiple jump structure is executed to determine what kind of line we are at. The jumps are based on line number (vertical position), so that the micro can decide if the current line will show the current voltage (in which case the character display routine is called), or the analogue bar (bar



routine or bar ruler routines), or small numbers showing the peak values (character display routines with reduced size parameter).

Of course, there is also a routine for blank lines in between. For blank lines, the interrupt routine simply ends, returning control to the main program. For display lines, the control is not returned until the entire line has been drawn with the appropriate graphics. For vertical retrace lines, the display is blanked and the sync polarity inverted.

At the end of display lines, or shortly after the third interrupt, the micro is 'frozen' using the sleep instruction, waiting for the fourth, time-critical interrupt.

During the 'timekeeping' interval at the start of each video line the serial data is output; with no more hardware timers available, the serial port is made in software. Every 13 horizontal lines a new bit is transmitted, achieving a baud rate of 1200: this is perfectly adequate given the small amount of data we have.

Data is sent as an ASCII string, terminated by a <CR> (ASCII 13) character. You can use a QBasic program, or any terminal program (like HyperTerminal supplied with Windows 95 or Terminal supplied with Windows 3.11) to collect the data.

All the video generation routines are carefully hand-tuned. Do not remove the NOPs from code, they are here to balance execution times! When executing branches, execution times associated with every possible path must be carefully considered. Fortunately for you, all the code needed to handle the video signal is ready made and works by itself under interrupt control.

Feel free to modify or add code to the main program to suit your requirements. Even the multiple jump structure that selects the display contents is not too difficult to understand, so you can easy build hundreds of different displays, with characters of any size or with multiple analogue bars.

All routines and variables have long names which should be self-explanatory. The code is heavily commented. Please remember that only one subroutine call is allowed at a time.

Custom fonts

You can redefine fonts to any shape you like; this is particularly useful for the measurement unit. instead of the volt symbol (V) you can display any other letter or shape that fits in a 8x5 pixel matrix. Font shapes are stored in EEPROM according to the definition file FONTS.INC. The file is automatically included during assembly and results are compiled to VIDEODVM.EEP; *do not forget to separately program the EEPROM once you have programmed the FLASH part.*

Fonts are stored rotated 90 degrees clockwise, into 5 successive bytes.

Building the circuit

All the components used are cheap and easy to find. The MAX192 has equivalents with the same data protocol with different resolutions.

If your ordinary distributor does not have the Atmel AT90S1200-16PC yet, because this component is relatively new, it can be requested at a number of Elektor's advertisers who also sell programmers for the Atmel flash micros.

The copper track layout and component mounting plan are shown in **Figure 3**. The link to the computer is made via a standard 9-way sub-D connector.

Very likely you will have your preferred sensorware connected to the inputs: be sure that the range never exceed 4.096 V or goes below 0 V, placing a series resistor (about 1k) and crowbar diodes if that range can be exceeded.

Once powered up, the flashing LED will tell you that the microcontroller is working just fine. The LED flashes once per conversion.

Now is the time to connect the Video-DVM to the TV set: for TVs equipped with a SCART connector the pins for video input are 20 (video) and 17 (ground). The TV must be disconnected from the mains while you insert the SCART plug.

Switch the TV to AV input mode using the remote control: older TV sets may not have this capability, in that case the AV input selection can be forced by pulling up the SCART pin 8: simply install a 1-kΩ series resistor from the pin to + 5-12V.

You can now fit the jumpers for the selection of the decimal point position **(Table 1)**, play around with various voltages to the ADC, verify the effect of the max-min clear button, or simply admire your new electronic toy for a while.

The last step is to connect the personal computer. Start the Terminal program in the Accessories folder (Windows 3.11) or the HyperTerminal utility (Windows 95). Set the connection to 1200 baud, no parity, 8 data bits, one stop bit (1200,n,8,1). The standard measurement range is from 0 up to 4.095 V. If a larger range is required, an attenuator should be added. One solution that comes to mind is to fit a resistor in parallel with C1. When higher input voltages are used, however, there is a real risk of the input of the MAX192 being damaged by wrong connections. In that case, the preventive measure is to fit a 5.1-volt zener diode across C1 and the resistor. A measurement range of 0 to 10 V is created, for example, by fitting a 6.9-kΩ resistance (5.6 kΩ fixed resistor plus 2.2 kΩ preset) across C1.

(992024-1)

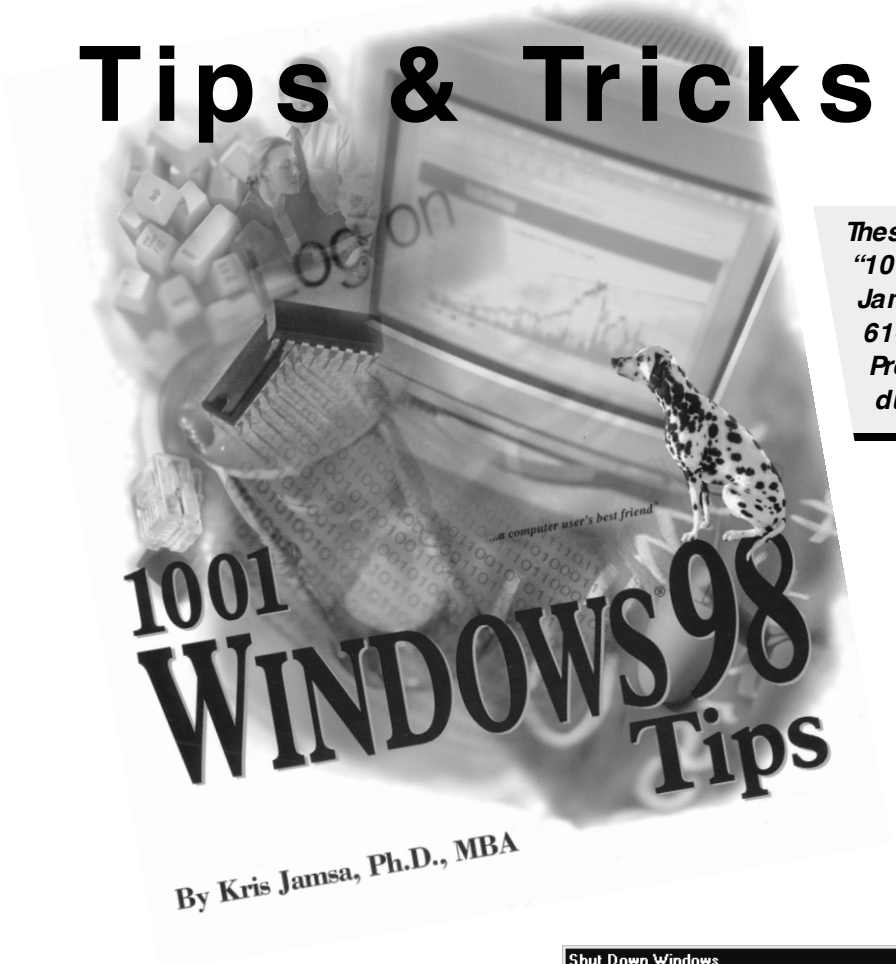
Table 1.
DIP switch settings (S2)

1	2	3	display
OFF	OFF	OFF	xxx.x
OFF	OFF	ON	xx.xx
OFF	ON	OFF	x.xxx
OFF	ON	ON	.xxxx
ON	OFF	OFF	xx.xx
ON	OFF	ON	x.xxx
ON	ON	OFF	.xxxx
ON	ON	ON	xxxx

This month we present a first selection of tips, trick, hints and kinks for advanced as well as novice users of the Windows 98 operating system. Take your pick!

By Kris Jamsa, Ph. D., MBA

Windows 98 Tips & Tricks



These tips were originally published in "1001 Windows 98 Tips" by Kris Jamsa, Jamsa Press, ISBN 1-884133-61-4. We are grateful to Jamsa Press for their permission to reproduce selected tips in this article.

A Faster Way to Restart Windows 98

When you select the Shut Down option, Windows 98 will display the Shut Down Windows dialog box, as shown in **Figure 1**, that you can use to shut down or restart your system.

Usually, when you select the Shut Down menu Restart option, Windows 98 will first reboot your computer and will then restart Windows 98. If, for example, you are restarting your system because you have installed new software, you can speed up the restart process by directing Windows 98 to restart itself without rebooting your PC. To restart only Windows 98 (without rebooting the PC), select the Start menu Shut Down option. Windows 98, in turn, will display its Shut Down Windows dialog box. Within the Shut Down Windows dialog box, click your mouse on the Restart option. Next, hold down the SHIFT key as you click your mouse on the OK button.

Figure 1. The Shut Down Windows dialog box.

Ending an Application Using a Local Reboot Operation

As you run programs within Windows 98, there will be times when a program simply won't run or when the program stops working (users describe this as "the program hangs" or the "program is hung"). If you think that a program is no longer working, try to end the program using "File, Exit" or "Close".

If you cannot end the program using normal steps, Windows 98 may be able to shut down by performing a "local reboot" of a specific program window. When you direct Windows 98 to perform a local reboot, Windows 98 will shut down only the program you select, and not the entire computer. To perform a local reboot within Windows 98, perform these steps:

1. Press the CTRL-ALT-DEL keyboard combination by first holding down the CTRL key, and then pressing down

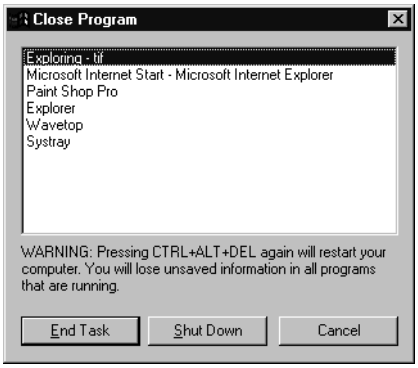


Figure 2. The Close Program dialog box.

Keyboard Combination	*Description*
WIN+ R	Displays the Start menu's Run dialog box
WIN+ M	Minimizes all open windows
SHIFT+ WIN+ M	Reverses a minimize all open windows operation by restoring all minimized windows to their original state
CTRL+ WIN+ V	Increases the speaker volume
SHIFT+ WIN+ V	Decreases the speaker volume
WIN+ F1	Starts the Windows 98 online help
WIN+ E	Starts Explorer
CTRL+ WIN+ F	Finds files and folders
WIN+ TAB	Cycles through Taskbar buttons
WIN+ BREAK	Displays the System Properties dialog box

Table 1. The Microsoft keyboard Windows-key shortcuts.

the ALT key, followed by the DEL (or DELETE) key. Windows 98, in turn, will display the Close Program dialog box, as shown in **Figure 2**. Usually, the name of the program you want Windows 98 to end will appear at the top of the list of program names within the Close Program dialog box.

2. Within the Close Program dialog box, click your mouse on the name of the program you want to end. Windows 98, in turn, will highlight the program name.
3. Within the Close Program dialog box, click your mouse on the End Task button to close the program.

Note: In some cases, Windows 98 may have trouble ending the program on its first try, and you may need to repeat these steps several times to end the program. Use a local reboot as a "last resort" to end a program. In most cases, after you end a program using a local reboot, you will lose any work you had performed within the program, but not yet saved.

Using SHIFT-DEL to Delete a File and Bypass the Recycle Bin

When you delete a file within Windows 98 (unless you delete the file from within an MS-DOS window), Windows 98 moves the file into the Recycle Bin, which provides you with the ability to later undelete the file. As you delete files, there will be times when you are sure you will never need a particular file's contents again, so there is no reason for Windows 98 to move the file to the Recycle Bin. In such cases, you can direct Windows 98 to delete the file from your system (and not use the Recycle Bin) by holding down your keyboard SHIFT key when you delete the file (which you can do either by pressing the DEL key or by clicking your mouse on an Explorer Delete button).

Shortcut Keys for the Microsoft Keyboard

If you are using a Microsoft keyboard or a keyboard that contains a Windows key, you can press that key to activate the Windows 98 Start menu. In addition, you can use the Windows key with the keyboard combinations **Table** 1 lists to perform other common operations.

Using the Explorer to Display Audio File Details

Audio files may differ in quality based on whether they use 8-bit or 16-bit quality, a high or low sampling rate, and whether they are stereo or monotone files. Using the Explorer, you can display specifics about an audio file, as shown in **Figure 3a**.

To display specifics about an audio file, perform these steps:

1. Within the Explorer, right-click your mouse on the audio file you desire. Windows 98, in turn, will display a pop-up menu.
2. Within the pop-up menu, click your mouse on the Properties option.

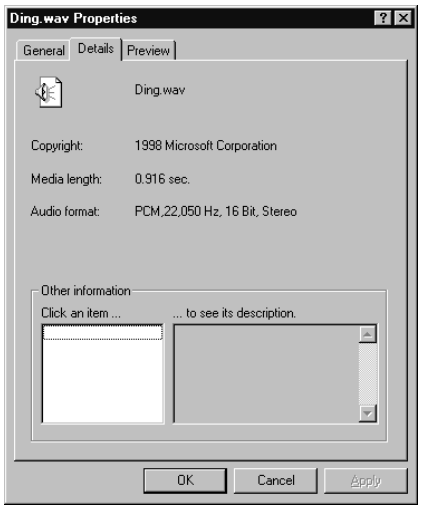


Figure 3a. Using the Explorer to display specifics about an audio file.

Windows 98 will display the audio file's Properties dialog box General sheet.

3. Within the Properties dialog box, click your mouse on the Details tab. Windows 98, in turn, will display the Details sheet which contains specifics about the audio file.
4. If you want to preview (hear) the current audio file, click your mouse on the Preview tab. Windows 98 will display the Preview sheet, as shown in **Figure 3b**.

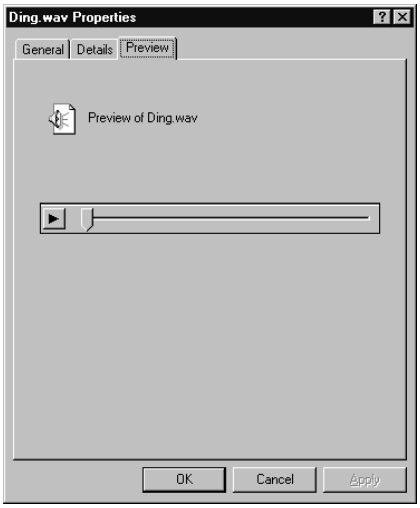


Figure 3b. Previewing an audio file.

Using the Windows Explorer to Display a Video File's Properties

Using the Windows 98 Media Player accessory you can play back video files within a window. Depending on the video's quality, the size of one video's window or the number of frames the video displays per second may differ from a second video. Using the Windows 98 Explorer, however, you can display specifics about a video file by performing these steps:

1. Within the Explorer, right-click your mouse on the video file you desire. Windows 98, in turn, will display a pop-up menu.
2. Within the pop-up menu, click your mouse on the Properties option. Windows 98 will display the audio file's Properties dialog box General sheet.
3. Within the Properties dialog box, click your mouse on the Details tab. Windows 98, in turn, will display the Details sheet which contains specifics about the video file as shown in **Figure 4a**.
4. If you want to preview the video file, click your mouse on the Preview tab. Windows 98 will display the Preview sheet, as shown in

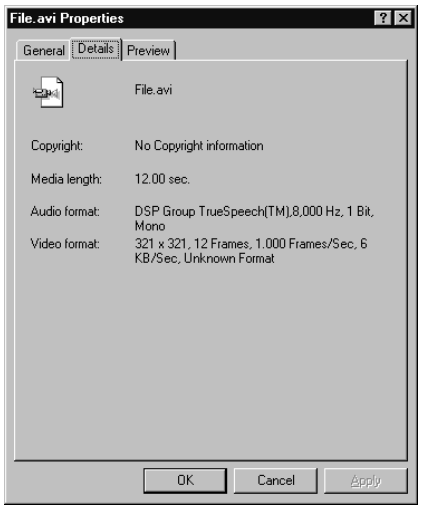


Figure 4a. Displaying specifics about a video file.

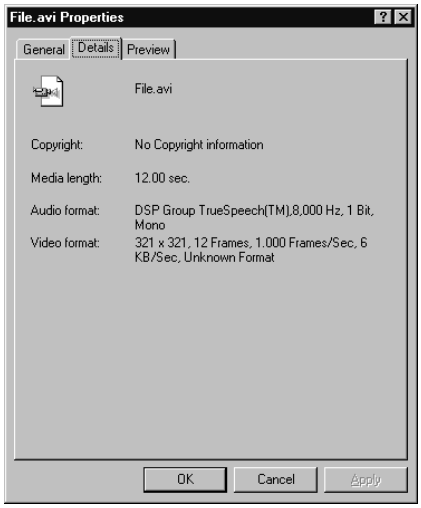


Figure 4b. Previewing a video file within the Explorer.

Figure 4b.

5. Within the Preview sheet, click your mouse on the Play button.

Network Protocols are Simply Rules Programs Must Follow to Communicate Over a Network

Networks let users share files and printers and exchange information using electronic mail. To perform such tasks, computers within the network must communicate with each other. For example, for one PC to copy a file from another PC across the network, the client PC must first tell the server the name of the file it wants to copy. Then, the server must send the file to the client, which requires additional communication. In general, the client will say "Ok, I'm ready, send me some data." The server, in turn, will say "Ok, here comes 500 bytes." After the client receives the data, it will tell the server "Ok, got it. Send me some more." By communicating in this fashion, the two PCs can exchange information across the network.

As you may have guessed, depending on the operation the two PCs are performing across the network, the messages they must exchange may become quite complex. As the programs exchange messages with one another, they follow a specific set of rules, or protocols.

In short, a network protocol might specify how fast the PCs exchange information or which PC goes first or second. When programmers create network software, they must follow the protocols to define their program's behavior. For example, when you surf the Web, your browser uses the hypertext transport protocol (HTTP) to request information from a Web server. Likewise, to download information from across the Web, you might use the file transport protocol (FTP). In each case, the protocol defines the rules the programs follow to communicate.

Across the Internet, most programs make extensive use of TCP/IP, the Transmission Control Protocol/Internet Protocol. Before you can use programs, such as your browser or chat program on the Internet, you must first install TCP/IP support within Windows 98. To add software support for a specific network protocol, such as TCP/IP, you will select the Protocol option from within the Select Network Component Type dialog box, shown in **Figure 5**, and then you will click your mouse on the Add button.

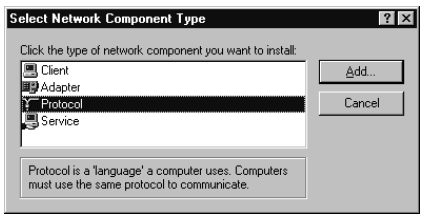


Figure 5. The Select Network Component Type dialog box.

The NetBEUI Protocol Lets Windows 98 Communicate with Windows for Workgroups

Within a PC network, some PCs may be running Windows NT, some Windows 98 or Windows 95, and some older PCs may be running Windows for Workgroups. To let such PCs communicate across a network, network administrators must install a myriad of network software programs. As you configure Windows 98 network settings, you may encounter the term *NetBEUI*, which stands for *Networking BIOS Extended User Interface* protocol. The NetBEUI protocol lets Windows 98 clients and servers communicate with network computers running Microsoft Windows for Workgroups, Windows NT, and Microsoft LAN Manager. For example, **Figure 6** shows the Select Network Protocol dialog box. As you can see, the NetBEUI protocol appears within the list of protocols Microsoft provides.

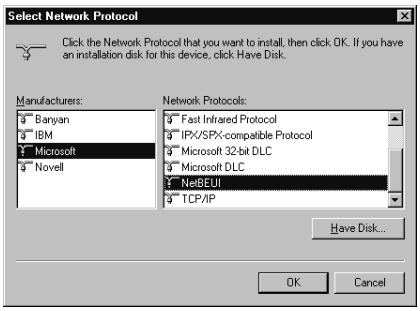


Figure 6. The NetBEUI protocol lets Windows 98 communicate with servers running Windows for Workgroups, Windows NT, or the Microsoft LAN Manager.

Understanding NDIS and ODI Network Standards

Just as there are many different PC, modem, and printer manufacturers, there are an equally large number of companies creating network cards and writing network software. Because such cards and software must work within a network which may use other manufacturer's cards and software, network hardware and software developers must follow a set of industry standards when they create a new device or write new programs. One such standard is the Network Driver Interface Standard, or NDIS, which defines how an operating system, such as Windows 98, will interact with a network device driver (the software that lets the operating system use the network card). Because Windows 98 complies with NDIS, you can use an NDIS-compliant network card within Windows 98. In a similar way, the Open Datalink Interface, or ODI, is a network standard developed by Novell and Apple. As you shop for network cards and software, make sure the card or software is compliant with the latest network standards. You will not select an ODI or NDIS option as you configure Windows 98 network operations. NDIS and ODI are standards your hardware and software developers follow so that Windows 98 can later interact with your network device.

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The basic principles of video processing with a PC were explained in the first part of this article. In this part, we look at how to go about editing a video clip using the PC, and we describe the features of inexpensive video editing systems. In this case we use the Adobe program Premiere 5.0 as an example. This widely-distributed program is often included with the video capture card. Even if you have a different program, this article will still be useful, since all video editing programs work in essentially the same way. You can thus easily adapt the descriptions here to your own program.

By Dr Martin Seiwert (Ecco Multimedia)

video processing on the PC (2)

part 2: using the video editor

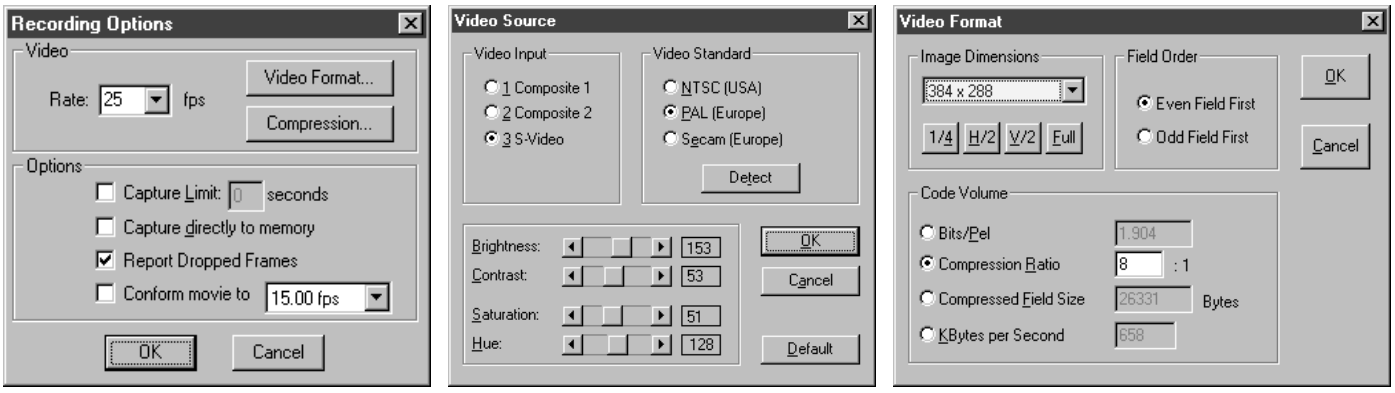


Figure 1. Setup menus for scanning in videos.

After all the scenes have been shot, it's time to start with the editing. All scenes that are to be included in the final product must be scanned into the computer. This requires the outputs of the video recorder or camcorder to be connected to the inputs of the video capture card. You will also need a special video editing program, such as Adobe Premiere (which we take as an example for the following descriptions). After starting the editing program, select 'Record' from the menu and then start the video recorder. You should then see the video imagery on the computer monitor and also on the control monitor (if present). If you do not, you have probably selected the incorrect input in the setup menu. The various possibilities are illustrated in **Figure 1**. Note that the actual contents of the screen menus depends on the particular video capture card used.

You can select the input in the Video Source menu, which also allows you to select the video standard. Most video capture boards can automatically detect the video format of the input signal. At the bottom of the Video Source menu you can see sliders for adjusting the brightness, contrast, colour saturation and hue. Before changing any of the default settings, make sure that your computer screen and/or control monitor are correctly adjusted. There is often a considerable difference between the appearance of the image on the computer screen and the control monitor (television set). Which should you choose? That depends on the intended use of the final product. If you plan to play it back to the video recorder for

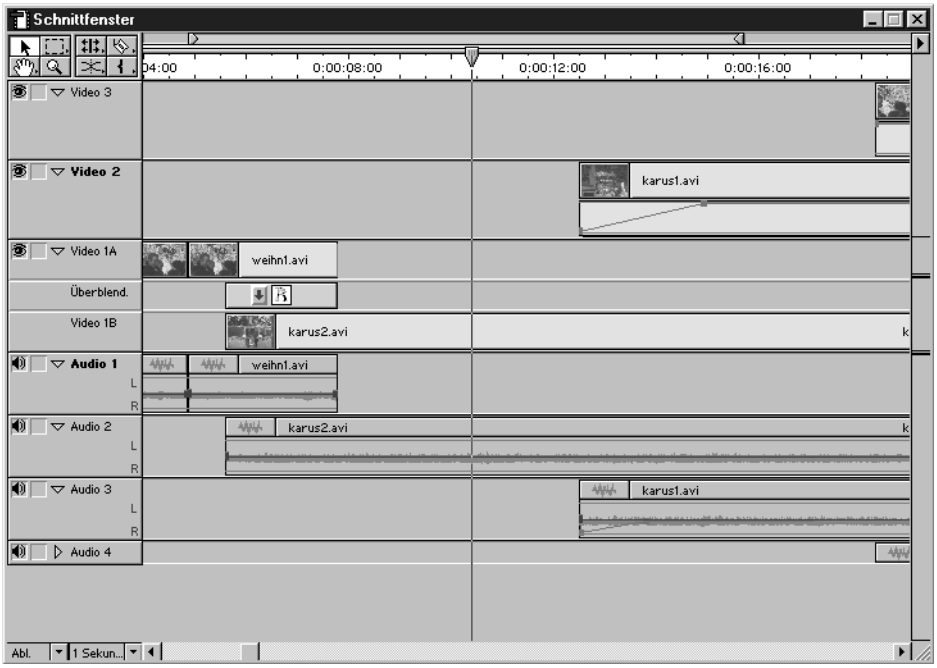


Figure 2. The editing window of the Premiere 5.0 program.

distribution via video cassettes, then you should go by the appearance of the image on the control monitor. If on the other hand you plan to use the video clip as a computer video or for a multimedia application, then the appearance of the image on the computer screen is what counts.
In the Recording Options window, you can select the recording format as well as the compression ratio or data rate. Here you should be guided by the requirements of your intended final product. For a computer video with (for example) 320 x 240 pixels, a 'one-quarter' resolution of 384 x 288 pixels is adequate. When selecting the compression ratio, you always have to make a compromise between the processing power of the PC and the picture quality. The higher the compression ratio, the more the quality of the imagery is degraded by compression artifacts, but increasing the compression ratio reduces the data rate and thus reduces the demands placed on the computer and the hard disk drive. The following are indications that the selected data rate is more than you system can handle:

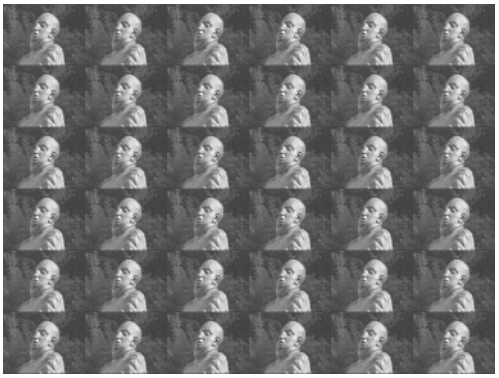
1. On completion of the scan, the video editor reports one or more missing frames ('dropped frames').
2. The playback of the scanned-in video is jerky: the sound track is normal, but the video 'freezes' briefly.

Remarkably enough, I have noticed with two different computers that playback is more critical than scanning. Data rates that work without any problems for scanning repeatedly result in jerky playback. If you plan to re-record the end product on a video recorder, you have no choice but to reduce the data rate to a value that results in problem-free playback, since the video recorder will naturally record every hiccup in the playback video. For computer videos, this is not a problem, since they will not be played back at the real-time rate.
Finally, you have to set up the sound track. You have to decide whether you want to have a sound track, and if so then you have to select the quality level for recording the audio signal. The recording level can be set either via the audio section of the video capture card or a separate sound card, depending on the particular video capture card that you use. If you use the sound card, then you can use any suitable audio program, such as the Windows Audio Recorder.
After all these selections have been made, the actual scanning process is refreshingly simple. Just start the video recorder and click on the Start button, and the video is scanned in. To stop scanning, click with the mouse or press the ESC key. A new window will be opened to display the scanned-in imagery, which can be checked and stored.

Editing

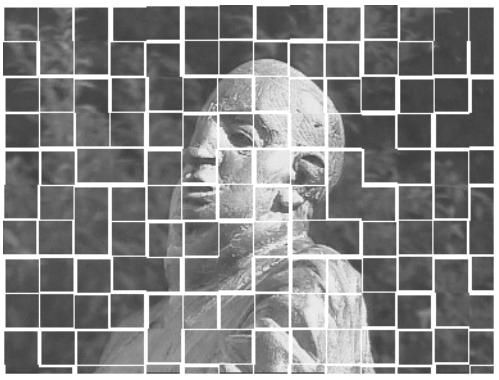
After all the scenes to be edited have been scanned in, you have to collect them together in the project window of the editing program. You can use the Import function for this, or drag and drop. The project window displays an overview of the collected scenes in the form of icons. You can select individual scenes and drag them into the editing window, arranging them according to your scenario. The editing window is constructed so that it largely mimics the traditional film editing technique with celluloid and scissors. You can 'cut' individual pieces of film with a knife, and you can use the mouse to arrange the pieces however you wish. 'Hard' cuts are thus made by simply pushing two pieces of film together in the editing window.
In addition to hard cuts, fade-overs are commonly used. For this purpose, the first video track is specially divided into the subtracks a and b. The film pieces for the fade-over are positioned on tracks 1a and 1b such that they overlap for the duration of the desired blend interval (see **Figure 2**). A large number of blend effects are available in the fade-over window, each illustrated by a small animation. All you have to do is to select the desired effect and drag it with the mouse to the editing window, dropping it in the overlap region between tracks 1a and 1b. In addition to the classical 'soft blend' and 'additive blend' effects, you can also choose from 'wipes' in various directions, as well as stripes and circular blends. There is also a series of attractive digital transitions, such as turning the page of a book, fade-overs

Original

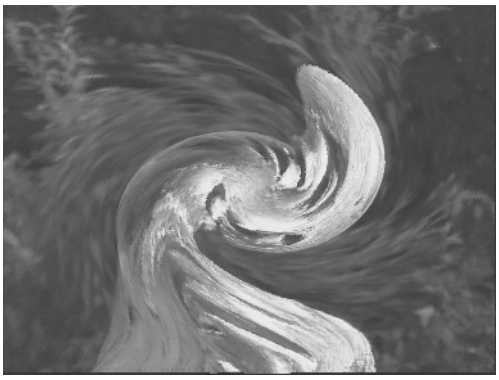


Replication

Wind effect



Tiled



Vortex

Waves

Figure 3. A few sample filters from the Premiere program. All filters can be made time-varying.

in small rectangles, 'whirlpool' and many more. If you have enough patience, you can even design your own transitions using the transition builder tool set.
To see how the fade-over looks, click on the time bar at the top of the editing window while pressing the ALT key. This causes the film to be displayed in the viewing window at the time corresponding to the location of the mouse pointer. By moving the mouse back and forth a bit, you can get an impression of how the transition works. You can judge it even better if you look at a preview. However, to do so you must first let Premiere calculate the effect over a selected time interval. The rendering time naturally is strongly dependent on the capabilities of the processor, the video capture card and the settings, but it will typically range between 10 to 60 times the length of the interval to be rendered. Once this is finished, you can view the transition in real time.

Filters

The term 'filter' is used collectively for all types of effects and processing that affect an individual piece of film. The classical filters are:

- ✓ brightness, contrast, saturation and hue correction;
- ✓ soft focus and edge enhancement;
- ✓ local contrast smoothing;
- ✓ black-and-white (monochrome) and
- ✓ mirror-image.

Other filters are familiar from photo-manipulation programs, such as:

- ✓ solarization;
- ✓ relief;
- ✓ lens distortion and lens reflection;
- ✓ ripple;
- ✓ crystallization and
- ✓ mosaic,

to mention only the most important ones. In contrast to photo manipulation, with the video editor these filters can be used in a timer-varying manner, which allows interesting effects to be produced. Gradually bringing a blurred image into focus, showing an artificial water surface with a variable amount of ripple, and simulating the focussing of the human eye with variable depth of field are only a few examples of the many possibilities.
In addition, there are also filters that are only applicable to video. These modify the time sequence of the individual frames. A simple example is reverse playback. One of these types of filters is the 'motion' filter, which allows the camera position to be changed (similar to an animation program). With this filter, you can add zoom and pan effects after the fact.

Transparency

Premiere allows up to 99 video tracks, and a time-variable degree of transparency can be individually set for each track. This effectively puts a complex video mixer at your disposition, with which you can create subtle fade-overs and effects using more than two pieces of film.
It is also possible to make certain parts of the image of a given film strip transparent, for example in order to present a speaker in front of an exotic background. For this purpose, the speaker is

first filmed standing in front of a uniformly-coloured background. Traditionally, this background is blue, so this effect is called 'blue screen'. However, any desired colour can be used. The selected colour can be defined in Premiere to be transparent, so that a film running in the background and displaying some imposing monument will be seen behind the speaker. The 'alpha channel', commonly used in photo-manipulation programs for making transparency masks, is also supported by Premiere.

Titles

Titles are generated in a special titling window, in the same way as in a vector drawing program. In addition to the fonts installed on the computer, you can use vector drawing elements such as straight lines, rectangles, circles and ellipses. Individual elements can be provided with shadows, and there is even a natural-appearing diffuse shadow effect with automatic alpha channel. Titles can be switched to transparent at the click of a button, so that they can be displayed in front of any desired background. Scrolling titles are also easily generated.

Limitations

The creative possibilities of affordable PC-based video editing software match the full scope of professional systems. You can give your imagination a free rein, and even very complicated effects can be realized (albeit not always directly).
The catch is the working speed. In order to properly assess a given effect, you have to view it in preview mode. This requires a certain amount of rendering time, which even for short scenes can easily amount to a couple of minutes. Of course, once a scene has been rendered it is saved, but only as long as no further changes are made within the working region. Unfortunately, fine tuning (such as adjusting the length of a fadeover) normally involves making a series of changes in a given region, requiring the scene to be rendered anew for each change. If you have to evaluate the results of editing a clip with a length of several minutes, the rendering time can easily be an hour or more.

Exporting the finished film

After the editing is complete, the film can be played back to a video tape. This is very simple: it works the same way as copying a tape from one recorder to a second one, except that here the PC takes over the role of the playback recorder.
However, if you want to use the finished film as a computer video, then the codec — the compression process — must be changed, as noted in the first part of this article. This is because the hardware of the video capture card in needed to play back the video in its standard form, and this hardware will naturally not be available to other users.
There is a whole series of codecs that can be used for this purpose. **Table 1** presents a summary of the available codecs, with their advantages and disadvantages. To change the codec, select the Export function in Adobe Premiere. You will see a series of selection windows, with which you can configure the many parameters of the video file to be generated. For a film clip of 5 minutes' duration, the rendering time for converting the codec will be several hours.

(990019-2)

Table 1. Summary of standard codecs

Video, or Microsoft Video 1
File formats: MOV and AVI
Advantages: fast calculation with good reproduction quality.
Disadvantages: requires a high data rate; otherwise the image quality suffers significantly. Colour space limited to 16 bits.
Recommended for test videos and videos to be played back from the hard disk. As a rule, not suitable for playback from CD-ROM.

Cinepak
File formats: MOV and AVI
Advantages: On average, good data quality, even with data rates suitable for CD-ROMs. Comparatively good colour reproduction. Suitable for older-model computers as well.
Disadvantages: requires more calculation time than Video. Large uniform-coloured patches are sometimes a bit unstable.
Recommendation: well suited to reproduction from CD-ROMs, especially if they are to be played back on older-model computers.

Intel Indeo
File formats: MOV and AVI
Advantages: On average, good data quality, even with data rates suitable for CD-ROMs. Suitable for older-model computers as well. Gives very good results for subjects with relatively little motion (such as a speech or presentation).
Disadvantages: requires more calculation time than Video. Disturbing colour distortions are sometimes visible in scenes with fast motion.
Note: various versions are available. The current version is 5.0, but Windows 95 and 98 come with only version 3.2.

MPEG 1
File format: MPEG
Advantages: Excellent reproduction quality in comparison to other codecs. The imagery appears to have television quality, even at data rates as low as 170 kB/s.
Disadvantages: the decoding is relatively computation-intensive, so only a 166-MHz Pentium MMX (or better) can achieve full-resolution reproduction. With older-model computers (100 MHz Pentium and below), videos using Cinepak or Intel Indeo will work better. A MPEG decoder (player) is part of the standard Windows package only since Windows 95, but there is a MPEG player available for Windows 3.1. As a rule, MPEG encoders are not included in the standard software complement of a video capture card and must be acquired separately. You can find a good summary of MPEG and MPEG software at the Internet site www.mpeg.org.

RLE (Run Length Encoding)
File format: AVI
Advantages: lossfree compression, relatively fast encoding.
Disadvantages: limited to 8-bit colour.
Recommendation: the restriction of the colour depth to 8 bits is too severe for normal videos, besides which the data compression does not work all that well for normal videos. However, this codec is an outstanding choice for cartoons and animations, where the limited colour depth does not matter.

Many hobbyists seem to harbour a desire to control stepper motors from a PC. Unfortunately, complete stepper motor interfaces that can communicate with a PC are pretty rare. In this article we present a compact circuit that can control unipolar stepper motors. The companion software is suitable for Windows, but it also supports DOS.

Design by Z. Otten

I²C stepper motor controller

a unipolar stepper motor under digital control

This design comes originally from the Dutch HCC Model Railroad Automation Users Group. They needed a simple interface to allow the smokestacks of model locomotives to be filled with a few drops of smoke liquid from a dispenser. This liquid produces a realistic plume of smoke as the locomotive thunders over the rails.
The mechanical actuation in this case is provided by an inexpensive four-phase stepper motor, scavenged from an old floppy-disk drive. The interface between the stepper motor and the serial port of the PC is constructed using standard components. A circuit trick is used to allow the serial port to support the I²C interface, which is a simple and efficient solution.
The necessary software has been developed in Delphi 3.0 and supports a number of basic commands, such as rotating left or right for a defined number of steps.

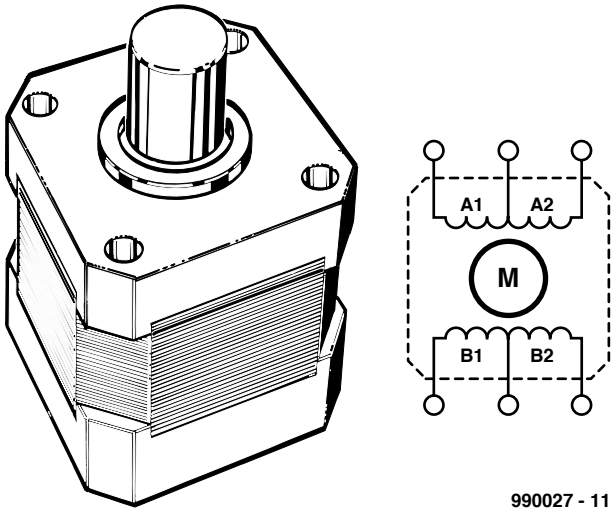


Figure 1. The basic design of a unipolar stepper motor.

Set by step

Stepper motors are DC motors which allow the amount of rotation of the shaft to be precisely controlled. A special interface is necessary for this — a stepper motor controller. As already mentioned, the present circuit is designed to work with four-phase, unipolar stepper motors. Such motors have centre-tapped windings, so that the magnetic field can be reversed without reversing the direction of current flow in the controller. The basic design of such a motor is shown in **Figure 1**. The four windings are activated in turn by a series of pulses, as shown in **Figure 2**. This causes the shaft of the motor to turn. The direction of rotation (left or right) depends on the order in which the pulses are applied to the windings, and the speed of rotation depends on the pulse repetition rate. In other words, the direction and speed of rotation of a stepper motor can be digitally controlled. Since the pulses overlap, the motor is never without power, so a separate brake is not necessary.
The DC resistance of the windings, and the resulting current flow, depends strongly on the particular model of stepper motor. This is equally true of the value of the operating voltage. To allow the controller to be used with a wide variety of stepper motors, the output stage is designed using TIP112 Darlington transistors. These can switch currents

up to 1 ampère. The motor voltage can range from 5 V to 25 V without presenting any problems to the controller, so that all commonly-available stepper motors can be used. This brings us to the circuit diagram of the controller, which is depicted in full in **Figure 3**. As you can see, it is a simple but effective design.

A simple controller

Since the output transistors are driven by a simple, repetitive set of waveforms, the logic circuitry can be made relatively simple. Only three ICs are used. IC2, a 74HC(T)193, is a binary counter that is driven by the clock signal generated by IC1 (PCF8574). A rising edge on pin 5 of IC2 (Count Up) increases the counter state by one, while a rising edge on pin 4 (Count Down) decreases the count by one. The Qa and Qb outputs (pins 3 and 2) thus count from one to four, which is precisely the four states that we need for the four phases of the motor drive. The IC following IC2 (IC3, a 74HC(T)155) is a 2-to-4 decoder. Only one of its four outputs is active at any given time, according to the binary code applied to its inputs. This information now has to be converted to the drive signals for the transistors. **Figure 4** shows how the control signals A, B, C and D are generated with the help of four NAND gates. High-level output signals from the NAND gates turn on the associated output transistors to apply power to the stepper motor.

You can use LS, HC or HCT ICs for IC2 and IC3. However, use only an HC or HCT type for IC4, since an LS type cannot provide an adequate amount of base current.

The I²C circuit is built in an unconventional manner. The heart of this circuit is formed by IC1, a PCF8574. Note that there is an alternative version available, the PCF8574A. These differ in the base address (40_H and 70_H, respectively).

The clock signal alerts the PC via the TxD line. Bidirectional data communication, as used on the SDA line, is implemented with the help of the CTS and DTR signals. Using the serial port for this interface is particularly attractive, since good support is available in software development environments such as Visual Basic and Delphi.

Resistors R4 and R5, in combination with diodes D1 and D2, serve to make the voltage at the serial port TTL-compatible. The combined CTS and DTR lines are connected to the SDA input of IC1, and TxD is connected to SCL. The base address of IC1 can be selected using jumpers JP1 through JP3. This allows up to eight such controllers to be connected in parallel to a single I²C bus. In theory, there are thus a maximum of (2 x 8 x 8) = 128 I/O lines (parallel connections) available. For this application, a single controller is (for the time being) adequate, and only three of its parallel connections are used. Output P0 of IC1 is used to drive a LED, while outputs P1 and P2 are used to supply the

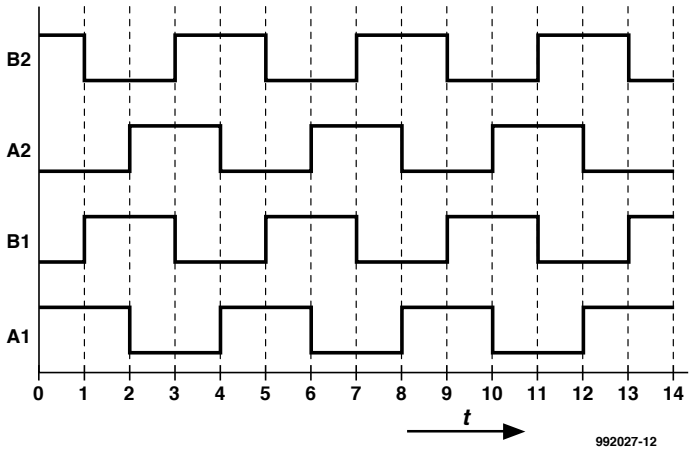
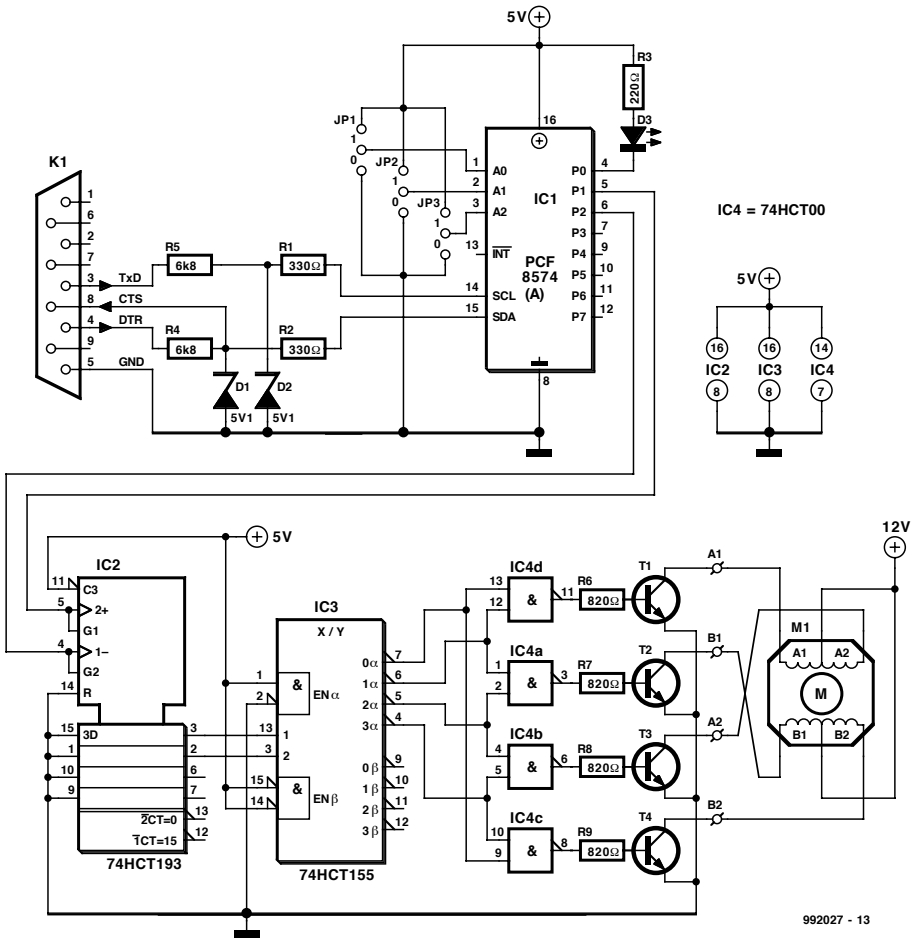


Figure 2. This timing diagram shows how a stepper motor must be driven to cause the shaft to rotate.

Figure 3. The schematic diagram of the stepper motor controller that is driven via the I²C port.



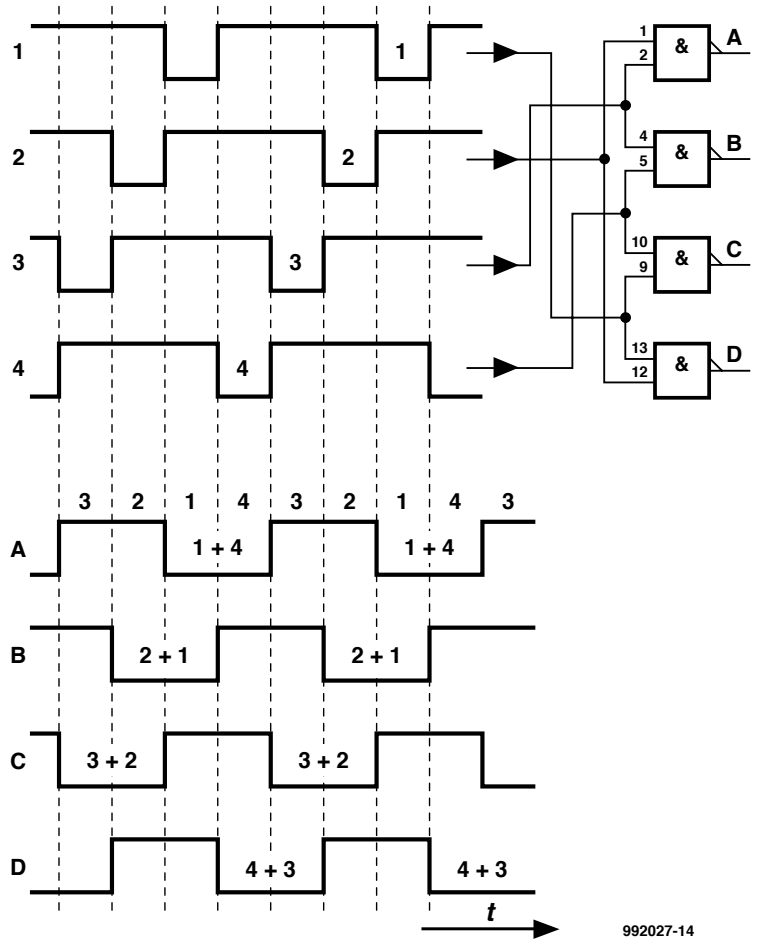
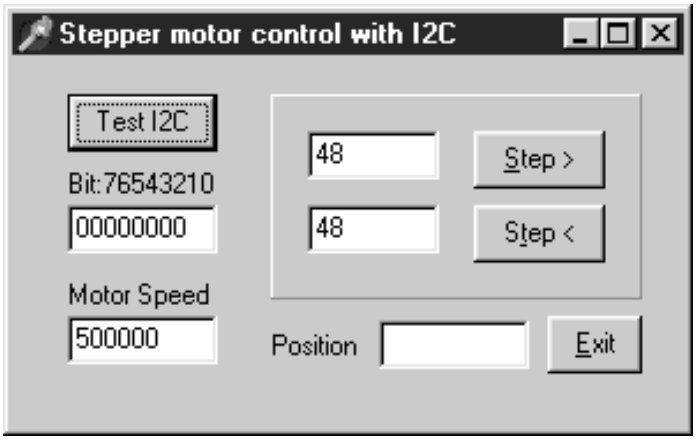


Figure 4. Here you can clearly see how the signals from the 2-to-4 converter are processed by the NAND gates to generate signals suitable for driving the output transistors.

left/right rotation control information for the motor.

The entire circuit operates from a 5 V supply voltage, with a current consumption of around 90 mA. Such a supply voltage can easily be arranged in a PC environment. The operating voltage for the motor depends on the type of motor used. Almost any type of DC power supply can be used to power the motor. The current consumption of the motor depends on the DC winding resistance, which can easily be measured with a multimeter.

Figure 5. Windows interface. The source code file is available on disk no. EPS 996014-1.



Bits and bytes

The software for driving the interface has been developed in Delphi 3.0 and can be used in combination with Windows 95/98. The driver can be readily used with other (possibly home-brew) software. It includes the routines needed to generate signals that comply with the I²C protocol, and to read data from and write data to IC1. Outputs P0–P7 of IC 12 can be directly loaded with an 8-bit value. If output P1 is set low and then high in turn, the motor rotates one step to the left. Similarly, output P2 can be used to make the motor rotate one step to the right.

The rate at which the control pulses are generated determines the rotational speed of the motor. The processing speed of the PC is a factor here; the faster the PC, the higher the maximum possible speed of the motor. To avoid problems due to this effect, a 'motor constant' is defined in the software. The value of this constant must be chosen so that enough pulses are generated in each time interval to allow the motor to reach the maximum desired speed.

The screen dump in **Figure 5** shows the user interface for the driver software (VPLS1.EXE). The left-hand portion of the window relates to the communication with the I²C interface, while the right-hand portion relates to the motor. Activating the button TestI2C should cause the LED on the controller to switch on. The status of the outputs P0 through P7 is displayed in a box; this represents the content of the binary status byte in IC1. The previously-mentioned motor constant can be read and modified via the box at the bottom. The remainder of the interface provides two pushbuttons that allow the motor to be stepped to the left or right by the indicated number of steps, plus a box that displays the current position of the motor (based on the number and direction of steps that it has executed).

Since stepper motors are most commonly used as part of a larger system, it is important that the driver software can be incorporated in other applications. The necessary software, including the source code, is thus available on a diskette from Readers Services (order number **996014-1**). This provides the tools you need to control stepper motors from your own applications.

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