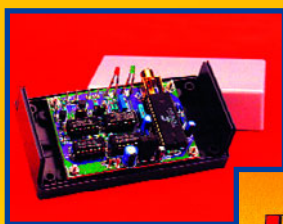


**ELEKTOR  
ELECTRONICS**

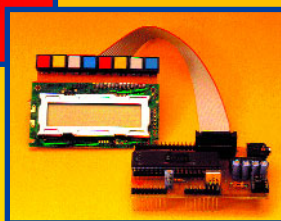
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- AVR evaluation system
- Linux: Windows alternative?

The art  
(science?)  
of fault-  
finding



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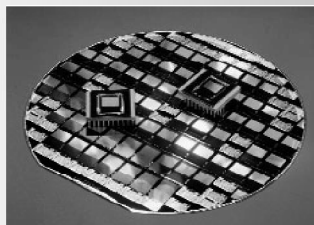
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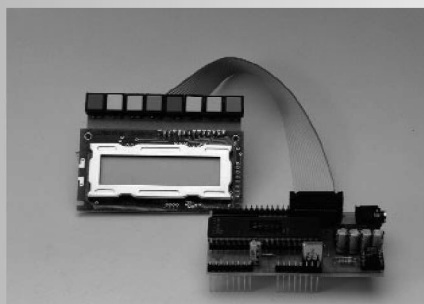
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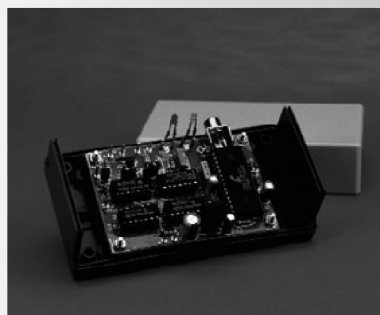
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# 418/433-MHz field-strength meter

Reliable data transmission using a radio link requires the transmitter signal to be received as clean as possible, and at sufficient fieldstrength.

Particularly inside buildings this is often problematic because of reflections and attenuation. The field-strength meter presented in this article is specifically designed for type-approved licence-exempt 418/433 MHz short-range signalling devices (SRDs), allowing the local RF fieldstrength to be measured, and receivers and transmitters to be installed in favourable positions.

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***range-test and equipment positioning aid for 70-cm SRDs***

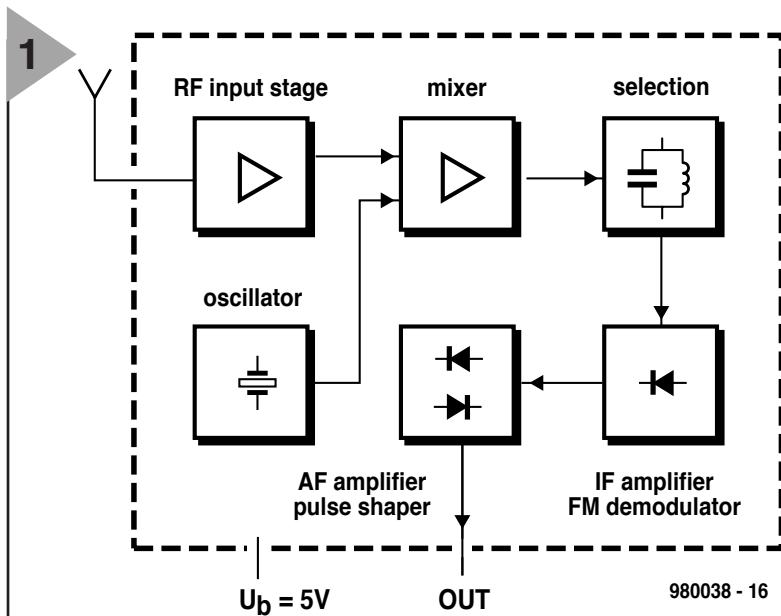
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## ***Main Specifications***

- Simple construction using few parts
- Simple to use
- Quantitative and qualitative evaluation of fieldstrength
- AM/FM modulation detection
- LED bar readout (dot mode)
- Compact construction with integrated antenna
- Battery operated

Based on an Application Note from Heiland Electronics



**Figure 1. Block diagram of the receiver module. This is basically a superheterodyne receiver with a SAW-stabilized local oscillator and an intermediate frequency of 10.7 MHz.**

The field-strength meter is based on a ready-made SRD receiver module with a factory-installed

output that supplies a voltage between 0.2 V and 1 V which is logarithmically-proportional to the RF signal strength at the receiver input. The receiver module type HE433/2R (UK: HE418/2R), by the way, is the same as the one used in the 418/433 MHz Control System described in last month's issue.

The pinning of the receiver module is shown in **Figure 2**. The receiver is capable of demodulating AM (amplitude modulation) and FM (frequency modulation) transmissions. For FM use, the AM output doubles as the signal strength (S meter) output, supplying a direct voltage which is logarithmically proportional to the level of the received RF signal. Also of good use is the 2.4-volt ( $\pm 100$  mV) reference voltage at pin 2 of the module. This voltage may be loaded with up to 1 mA. In the present circuit, it acts as a reference potential for an LED bargraph display.

## BARGRAPH READOUT

As you can see from the circuit diagram in **Figure 3**, the electronics consist of no more than a type-approved and licence-exempt SRD receiver module coupled to an LED driver IC type LM3916 (alternative: LM3914). This IC accurately converts a direct voltage applied to its input into LED scale units. Many of you will be familiar with the basic operation of the LM3914/16, because it is often used for bargraph LED readouts. Ten comparators compare the input voltage with discrete values supplied by a voltage divider. As you can see, the voltage to be divided is obtained from the refer-

ence voltage source. Each individual comparator output directly drives the associated LED. The scale of

the readout is linear in case of the LM3914, and logarithmic in case of the LM3916. The latter scale has dB steps as usually applied in VU (volume unit) meters. As indicated by the block diagram of the LM3916 (**Figure 4**), the internal potential divider is connected between the pins labelled RHI (pin 6) and RLO (pin 4). In the circuit of the fieldstrength meter these two pins are connected to an external voltage divider (R1, R2, R3, P1 and P2). This divider is supplied with the reference voltage from the receiver module (2.4 V), so that the internal reference voltage of the IC is not required here. This is in contrast with the standard application circuit of this integrated circuit.

The output labelled REFOUT (pin 7) is therefore only connected to ground via resistor R5. This resistor is needed because the load on the REFOUT pin determines the LED brightness.

The internal voltage divider pins, RHI and RLO, are taken to the wipers

of two preset potentiometers in the external voltage divider. In this way, the RHI and RLO pins receive adjustable voltage levels representing the upper and lower switching threshold, which define the range of the bargraph readout.

The measurement input of the LM3916, labelled SIG (pin 5), is not connected directly to the AM output of the SRD module, but via peak detector, D1-C2, and a level control, P3-R4. When a frequency-modulated transmitter is being received, the level at the AM output is virtually independent of the modulation signal. After all, the carrier level remains virtually constant when FM is used. In that case, the diode and capacitor have no function — the diode could be replaced by a wire link, and the capacitor could be omitted. The situation is different in case an AM transmitter is used because the demodulated signal then appears at the AM output of the receiver module. In that case, the diode-capacitor combination ensures that the peak value of the demodulated signal is taken as a measure of the fieldstrength. Preset P3 allows the signal voltage to be attenuated to some extent, enabling the scale factor of the LED bar to be set. Because pin 9 (MODE) of the readout driver is not connected, the LED bar is operated in 'dot' mode, in which only one LED lights at a time.

The circuit is powered by a 9-V battery in combination with a 5-volt fixed voltage regulator type 78L05 (IC1). Instead of a regular on/off switch, a push-button is used to power the instrument. After all, your in-situ fieldstrength readings should only take a few seconds at different locations.

Because the current consumption is modest at just 13 mA or so, the battery will have long life. Finally, diode D12 acts as a polarity reversal protection, and LED D14 as an on/off indicator.

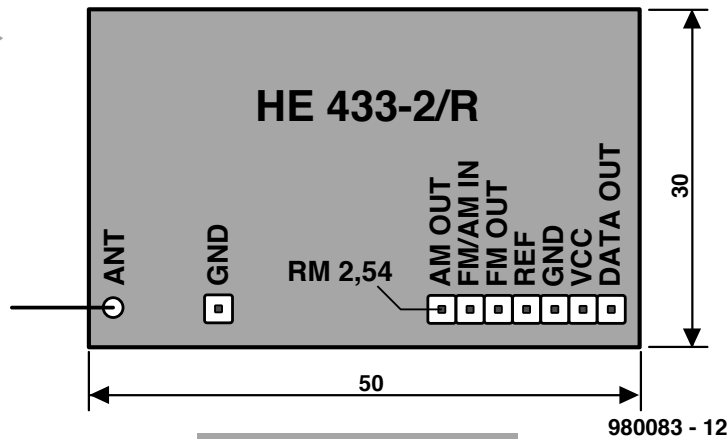
## CONSTRUCTION

Provided you stick to the component mounting plan shown in **Figure 5**, building the fieldstrength meter should not cause problems.

If you do not have an RF signal generator available for the final align-

## Technical Data

Receiver type:	SAW-stabilized superheterodyne receiver
Power supply:	9-V battery (IEC6F22)
Current consumption:	approx. 13 mA
Receiver frequency:	433.92 MHz
Range:	30-90 dB $\mu$ V
Intermediate frequency:	10.7 MHz
Modulation detection:	AM and FM
Temperature range:	0-50 °C
Size:	142 x 57 x 24 mm



**Figure 2. Pinout of the SRD receiver module from Heiland Electronic.**

ment of the instrument, only the cathode of diode D1 should be soldered — the anode terminal remains open as yet for direct voltage measurements. It is not possible to connect the module the wrong way around because its pinning matches the PCB layout. A different receiver module can only be used if it has an S-meter output supplying the same voltage range as the HE433/2R. Also, you have to take a serious look at the connections to the readout circuit, the readout range, the supply voltages, etc., and, of course, the final adjustments. Unfortunately, no SRD receiver modules other than the ones from Heiland Electronic could be tested for this design.

The printed circuit board fits exactly in the transparent case mentioned in the parts list. The board should not be

fitted in the case, however, until it has been adjusted.

The antenna connected to the receiver input is a straight piece of solid wire with a length of about 17 cm (see photograph).

### ADJUSTMENT

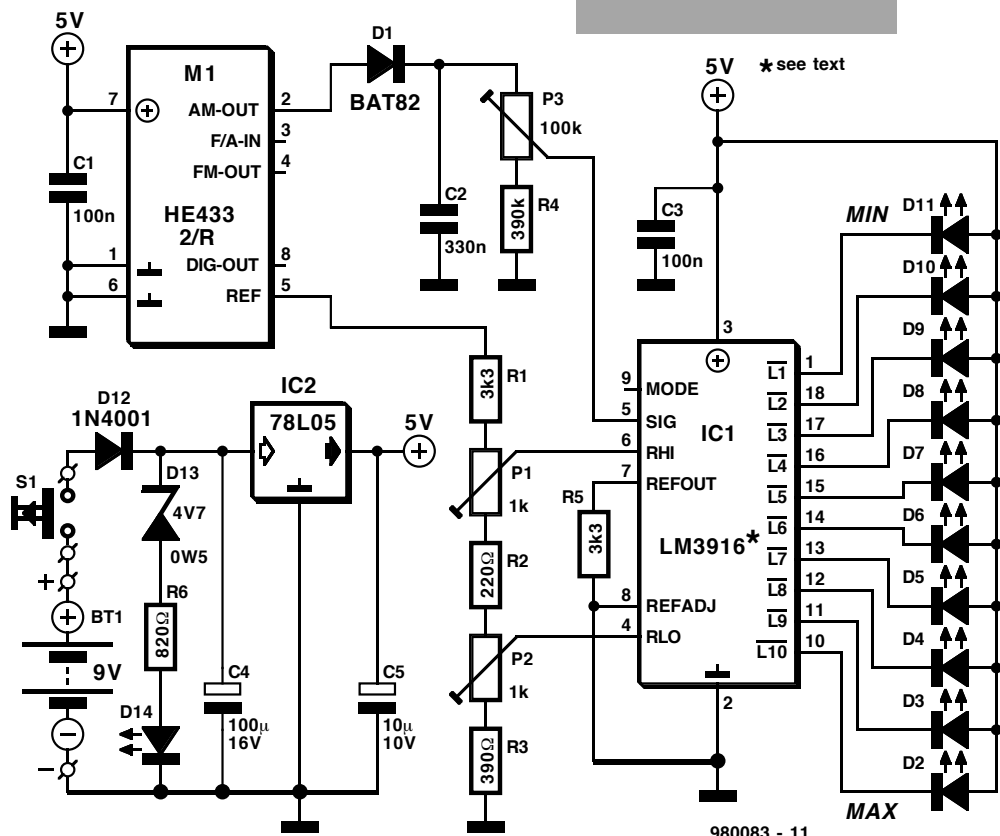
As already mentioned, there exists a logarithmic relationship between the local fieldstrength and the voltage level at the AM output of the receiver module. Using the linear LM3914, you therefore obtain an LED scale (dB scale) with a logarithmic range. The characteristic shown in Figure 6 illustrates the direct voltage at the AM OUT output (pin 2 of the receiver module)

as a function of the RF signal level (in dBm V) available at the antenna input. Because this characteristic was found to be repeatable on several modules we had on test, the possibility exist to enter dBm V marks on the curve, where the adjustment is carried out using direct voltages. This adjustment is the same for the LM3914 and the LM3916 — the only difference is the print around the readout.

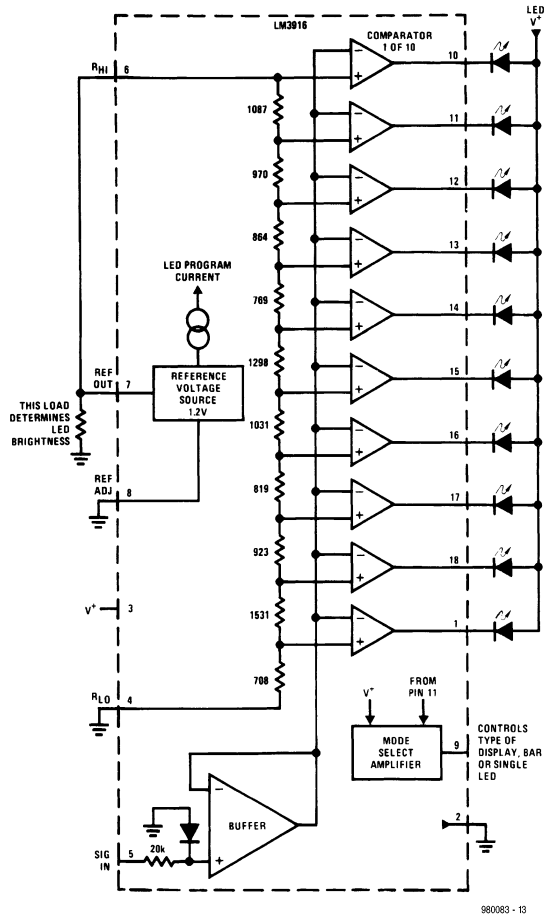
Connect the 9-V supply voltage to the board (LED D14 lights), short-circuit the push-button contacts, and first check the presence of the 5-V supply voltage at pin 7 of the receiver module. Next, see if the 2.4-V reference is present at pin 5 (normal tolerance: ±100 mV). If this value is correct, then the voltage at the wiper of P2 is set to 200 mV, and that at the wiper of P1, to 700 mV. Because of the loading of these two pins by the internal voltage divider in IC1 (between RHI and RLO), the two settings will interact to some extent. Consequently, the wiper voltages mentioned above will only be achieved by alternate tweaking of the two presets.

Next, connect the anode of D1 to the above-mentioned auxiliary voltage for the adjustment of P3 (scale factor). This helper voltage is best derived from the stabilized 5-volt supply line by means of a 3.9-kΩ series resistor and a 1-kΩ preset. The wiper

**Figure 3. Circuit diagram of the field-strength meter. The module has an AM demodulator output supplying a voltage which is proportional to the fieldstrength. This S-meter voltage is processed by a LED bargraph driver.**



4



**Figure 4. Block diagram of the LED driver type LM3916. It differs from the LM3914 and 3915 in respect of the values of the resistors in the internal voltage.**

SIG input (pin 5 of IC1). LED D7 (the one at pin 15 of IC1) should just go out, and LED D6 (at pin 14) should start to come on.

If you have a calibrated RF test generator available, its output is connected to the antenna input of the receiver module. Next, you set a generator output level of 45.5 dBm, which equals about 1.3 mV at the antenna input, or 60 dBμV across 60 Ω. D1 has to be soldered in place at this point, and P1 is adjusted to 530 mV at pin 5, as described above.

When the LM3916 is used, the scale shown in Figure 7 may be used, the divisions were established on the basis of field trials. The scale is shown at true size for convenient copying (for private and personal use only).

When the LM3914 is used, the LED scale has divisions of 5 dBμV per LED, allowing the respective values to be easily printed on the case.

**APPLICATIONS**

The fieldstrength meter is suitable for checking the operation of AM and FM transmitters operating at 418 MHz or 433 MHz, as well as for the evaluation of transmission paths, the absolute range of a certain transmitter, reception quality and the suitability of certain locations for a transmitter or receiver. Also of great importance is the ability to spot sources of interference, and the presence of foreign transmitter signals in the area normally covered by your own receiver system.

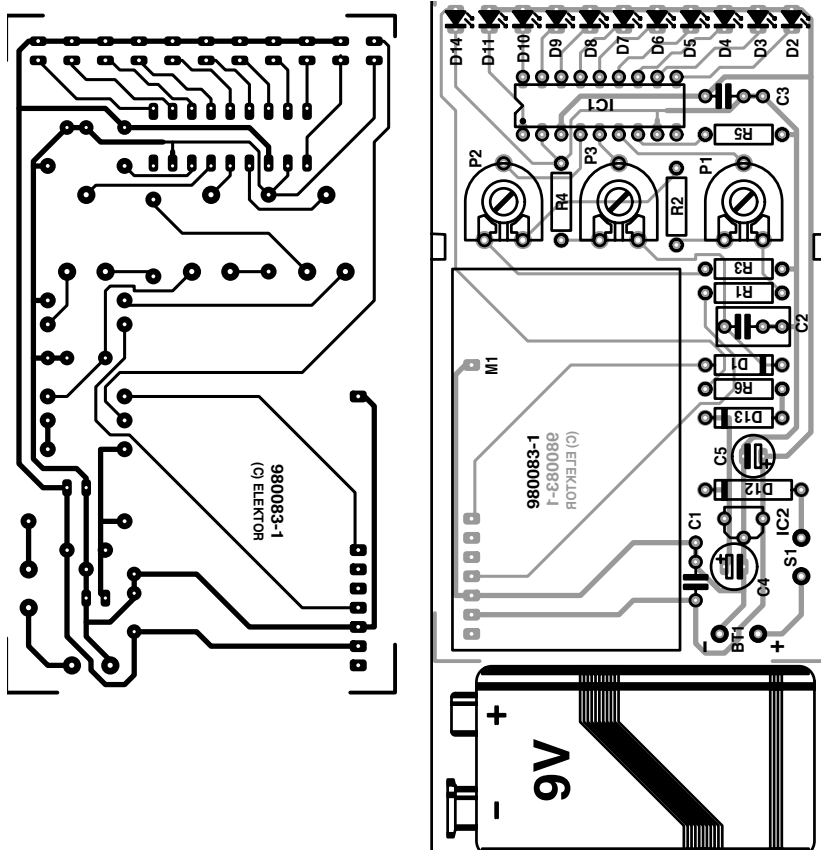
If, for example, you plan to implement a wireless data transmission system using SRD modules for the 70-cm band, the fieldstrength meter is installed at the planned receiver location, and the 'test' push-button is pressed. If the readout already shows an indication, that is, with your own transmitter switched off as yet, then another user is on the same frequency. Obviously, this signal may interfere with that to be picked up from your own transmitter. It is a simple matter to determine whether the interfering signal is AM or FM. In the case of FM, a fixed number of LEDs will light all the time. If an AM signal is picked up, the readout will show some variation.

**Figure 5. Single-sided printed circuit board designed for the instrument.**

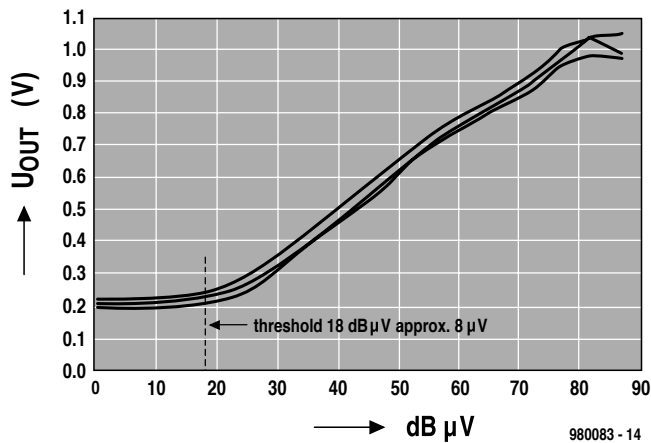
of the preset is then connected to the anode of D1, and a voltage of 0.75 V is set. According to the graph in Figure 6,

that direct voltage level corresponds to a fieldstrength of about 60 dBμV. Next, adjust P1 to a voltage of 530 mV at the

5







**Figure 6. Logarithmic characteristic of the S-meter output. The diagram shows the relation between the direct voltage at pin 2 of the receiver module and the RF signal voltage at the antenna input, measured on three modules of the same type.**

Weak interference from an AM transmitter is generally not a problem if you use FM yourself.

The fieldstrength meter also enables you to get an idea how often an interfering transmitter is actually on the air. When the off-air periods are sufficiently long, there should not be problems if your system is designed to perform measurements

and transmit the results at certain intervals. In that case, it will typically be sufficient if a temperature value is transmitted every minute or so.

For reliable reception of the kind of signals transmitted by approved SRDs for 70 centimetres, a field-strength of about 50 dB $\mu$ V is required, or about 360  $\mu$ V at the receiver input. In many cases, a small change in the

strength of about 50 dB $\mu$ V is required, or about 360  $\mu$ V at the receiver input. In many cases, a small change in the

## COMPONENTS LIST

### Resistors:

R1, R5 = 3k $\Omega$   
 R2 = 220 $\Omega$   
 R3 = 390 $\Omega$   
 R4 = 390k $\Omega$   
 R6 = 820 $\Omega$   
 P1, P2 = 1k $\Omega$   
 P3 = 100k $\Omega$

### Capacitors:

C1, C3 = 100nF ceramic  
 C2 = 330nF MKT  
 C4 = 100 $\mu$ F 16V radial  
 C5 = 10 $\mu$ F 10V radial

### Semiconductors:

D1 = BAT82  
 D12 = 1N4001  
 D2...D11 = LED red high efficiency  
 D14 = LED green high efficiency  
 D13 = 4V7/500mW  
 IC1 = LM3916 (LM3914) (see text)  
 IC2 = 78L05

### Miscellaneous:

BT1 = 9V PP3 battery with clip and wires  
 S1 = push-button 1x make  
 M1 = HE433 2/R\* (UK: HE418 2/R\*, see text)  
 Case: Heddic type 222\*  
 PCB, order code 980083-1 (see Readers Services page)

\* Manufacturer: Heiland Electronics, D-48351 Everswinkel, Germany. Tel. (+49) 2582 7550, fax (+49) 2582 7887.

## dB $\mu$ V, dB and dBm

Because the values involved may be considered (logarithmic) ratios rather than physical units, measuring and expressing relative signal levels, both RF and AF, is easier if the dB unit is consistently applied instead of, say, millivolts, microvolts or milliwatts. In principle, the dB (decibel) may be used to express the ratio of two (measured) values. For voltage and power ratios, the following basic equations apply for expressions using dB numbers (here, expressed as 'a'):

$$\text{Voltage ratio} \quad a = 20 \log_{10} (U1/U2)$$

$$\text{Power ratio} \quad a = 10 \log_{10} (P1/P2)$$

The really practical thing about this notation is that it makes calculations involving gain and attenuation figures much easier. Whereas gain and attenuation factors have to be multiplied to arrive at the overall gain or attenuation figure of a certain circuit or system, the same values expressed in dB are simply added or subtracted.

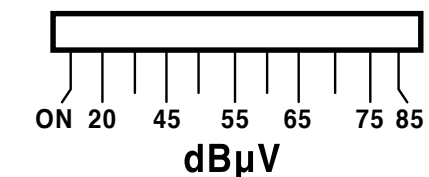
A value expressed in dB always expresses a ratio between two arbitrary voltage or power values. In RF technology, dB $\mu$ V and dBm represent two of the most popular reference units. The first is referred to 1  $\mu$ V, the second, to 1 mW. So, a level of 20 dBm means 100 mW.

To enable two dB $\mu$ V values to be compared to one another, the indication has to be based on one and the same impedance at which the voltages have been measured. In RF technology, the reference impedance is normally 50  $\Omega$ , 60  $\Omega$  or 75  $\Omega$  (the first is the most popular).

If you are interested in knowing the exact antenna voltage in  $\mu$ V, this value may be calculated using the above equation for voltages, by using the reference value 1  $\mu$ V for 0 dB $\mu$ V.

The same applies to power levels expressed in dBm, only then the equation for power ratios is used, and a reference level of 1 mW is assumed. Here, too, it makes no sense to compare values unless they refer to the same impedance. Converting from dBm to dB $\mu$ V and the other way around is no problem if the impedance, Z, is known. The relation between the three units is expressed by

$$P[\text{dBm}] = U[\text{dB}\mu\text{V}] - 10 \log Z[\Omega]$$



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**Figure 7. Suggested scale (actual size) for the LED read-out if the LM3916 is used.**



# digital cameras

## *how do they work?*

Digital cameras may not yet have captured the imagination of the consumer market (although most photographic retail outlets stock them), but with enhanced image resolution made possible by recent developments, and price falls they will take an increasing slice of the market over the next few years. Market research\* indicates that the digital camera market in the USA will grow from US\$240 million in 1997 to US\$ 930 by the end 2004. Europe, too, will see a dramatic increase in this market, although spending on cameras has fallen steadily over the past few years. This article takes a brief look at how a digital camera works.

By our Editorial Staff

\*Source: Frost & Sullivan



photo: Philips

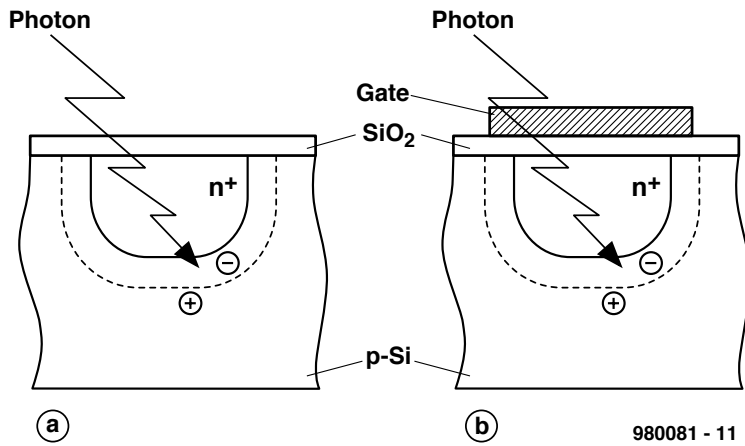
All the well-known names are active in the digital camera market: Agfa, Canon, Casio, Epson, Fuji, Kodak, Mustek, Olympus, Ricoh, but few produce models in each product segment. There is currently no clear market leader. Manufacturers are currently building up their product portfolios and concentrate on the increasing sophistication of the image resolution provided by their cameras. Prices in the consumer market at the time of writing (July 1998) vary from £200 to £700.

In terms of product types, the megapixel camera is leading the field. Ranking in second place is the

extended graphics adaptor type, followed by vertical grid array cameras and greater than megapixel types. Market researchers\* expect that the megapixel camera will retain its lead, followed by greater than megapixel types and extended graphics adaptors by 2004. The vertical grid array camera's market share will then have dropped to below 1 per cent. This article will concentrate on megapixel cameras.

### DEVELOPMENTS

Digital cameras are about to become a real force in the market. Owing to recent developments, manufacturers



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**Figure 1. Two photon-converting cells: (a) a metallurgical np-junction, and (b) a voltage-induced np-junction.**

are finally able to produce a digital camera that is cost-efficient, has

a reasonably storage capacity, and has a resolution that makes it suitable for a number of applications.

Although a breakthrough is in sight, developments are nowhere near at an end. Two years ago, the few digital cameras on the retail market had a resolution of about 280×340 pixels; today, some of the better-quality digital cameras have a resolution approaching one million pixels. Of course, compared with film, this resolution is low. A film has not less than 100 lines per millimetre, which means that a standard 35 mm film image has a resolution of some 2400×3600 pixels. It is expected that within a few years there will be digital cameras in the shops with a resolution of two million pixels, which is, of course, still significantly less than the 8.5 million of conventional film.

**TECHNOLOGY**

The technology that has made digital cameras possible comes partly from the semiconductor industry and partly from the film industry.

The semiconductor industry has developed compact, high-resolution image sensors, while the film industry has developed advanced compression algorithms, such as JPEG (Joint Photographic Experts Group), which are able to convert the enormous amount of data that form a picture into very compact files.

Today, microprocessors used in digital cameras are able without any difficulty to compress in a very short time a digital file of several Mbytes to some hundreds of Kbytes. These processors are complemented by memory cards that can store these data in semi-permanent form.

**LIGHT CONVERTER**

A digital camera needs a converter that transforms the light incident on the

lens into electrical signals. In most digital cameras this task is performed by a charge-coupled device-CCD.

A CCD is a semiconductor storage device in which an electrical charge is moved across the surface. Zeros and ones are represented, respectively, by the absence or presence of a charge. In most digital cameras, the charge transfer system, in which a charge is created by an impinging photon, is contained in MIS (metal insulated semiconductor) or MOS (metal oxide semiconductor) capacitors fabricated on a single crystal wafer.

Photons, which may be considered as elementary particles of light, pass through the lens of the camera on to the CCD. The energy contained in a photon is converted by the CCD into an electron/hole pair. If the total energy is sufficient, electrons may pass from the valence band to the empty (conduction) band. This causes a hole in the valence band. This charge movement reduces the amount of

energy contained in the incident photons by an amount equal to the energy difference between the empty and valence bands. This means that for a charge to be moved, the energy of the incident light must be greater than the forbidden band. In CCDs, this normally means that photons can create an electron/hole pair if their energy is greater than 1 eV (electron-volt) and their wavelength is < 1 μm. After this energy has been stored in the substrate, the negative electrons and positive holes must be separated. This is effected by applying an electric field across the substrate, whereupon the electrons are freed and the holes disappear into the substrate.

Unfortunately, it is virtually impossible to move a free electron since its energy is so tiny. Therefore, the energy, that is, the free electrons are gathered over a given period to make discrete packets of charge available. These packets are then moved to the output, for which a small capacitor is used.

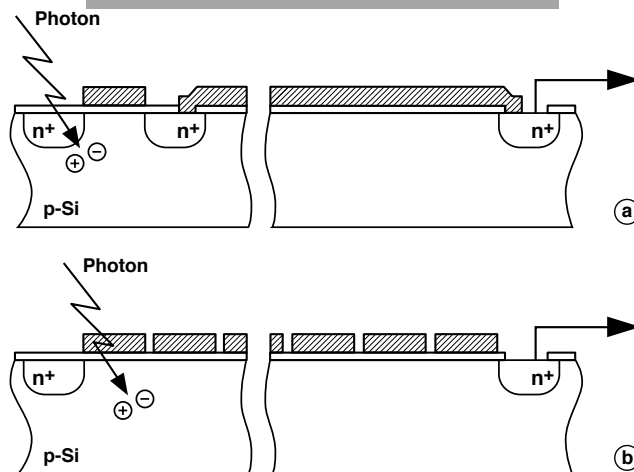
Figure 1 shows two variants of a photo-sensitive cell: in (a) a metallurgical n-p junction and in (b) a voltage-induced n-p junction. Both use a p-type substrate. The separation of holes and electrons is effected by an electric field across the n-p junction. When the field strength across the junction is reduced, the capacitance of the capacitor diminishes and the density of the charge carriers increases. This means that the sensitivity of the sensor can be adjusted with a control potential.

**CHARGE TRANSPORT**

The next link in the imaging chain is the transport of the packets of charge from the integrating sites towards the output of the device. There are two

ways of doing this: either with a MOS

**Figure 2. Read-out structure to connect the photodiode to the outside world: (a) a MOS switch, and (b) a CCD shift register.**



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switch containing a sense line or with a CCD shift register (see **Figure 2**). In both, the imaging cell or pixel consists of a photodiode constructed on a p-type substrate. The choice between a MOS switch with a sense line and a CCD shift register depends to some degree on the application. Both have their advantages and disadvantages. For the MOS switch with sense line, the fabrication technology is rather simple, but the switch connects the small capacitance of the pixel to the rather large capacitance of the sense line. This arrangement causes the signal-to-noise factor to be rather poor.

On the other hand, the technology for the CCD shift register is more complex in production and requires a clock to shift the packets of charge to the output capacitor via various intermediate capacitors. However, the charge packet taken from the small pixel capacitance is transferred to the small capacitance of the output diffusion and this results in an excellent signal-to-noise factor.

With reference to Figure 2, the conversion from a packet of charge to a voltage at the output pin of the imager is done in a classical way: sensing of the voltage changes on a floating  $n^+$ -region by means of a source-follower.

### IMAGER CONFIGURATIONS

So far, only the operation of a single imaging cell or pixel is explained. In practical applications, images can be built up in a one-dimensional path, for instance, facsimile, or in a two-dimensional configuration, for example, home video or



photo: Sony

camcorders.

### FRAME TRANSFER

Digital cameras use frame transfer (FT) CCDs, which are different from other types of CCD in the way imaging data are transported from the light-sensitive cell or pixel to the output. In FT-CCDs, MOS cells, that is, cells that use MOS capacitors, are used. Since the imaging elements, the light-sensitive sensor and the capacitors are fabricated in MOS technology, they can be, and often are, combined in a single design.

Each photo-sensitive CCD array is extended by a CCD shift register of equal length —

see **Figure 3**. The CCD shift register is shielded from any incident light, which means that it can be used as a buffer memory.

The cycle of operation is then as follows. In the mode in which light is registered, all cells are set to the integrating mode. One part of the CCD cells is connected to a high direct voltage, and another to a low direct voltage. In this mode, photons create a charge, which are gathered into packets. At the termination of a defined integration period (in a camera, this is the shutter time), the CCD shift registers ensure that their charge is stored in the light-immune part of the array. The charge transport takes place as quickly as possible to prevent mutilation of the data.

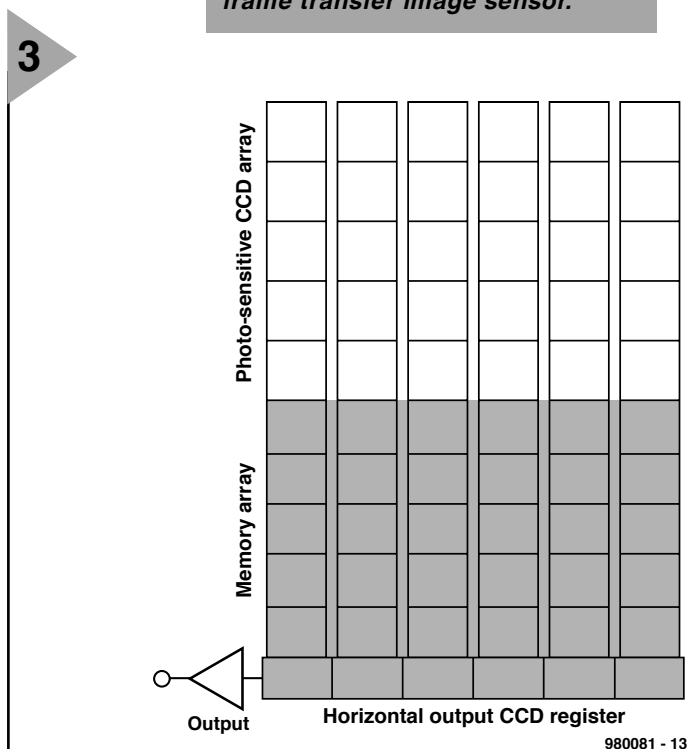
When all packets of charge have been transported, a start is made with reading the CCD. During this phase of the process, the packets of charge on one and the same horizontal line (but on different vertical lines) are clocked to a CCD output register, whereupon the packets are shifted to the output (parallel-to-serial conversion) and converted into a direct voltage. Once a line has been processed, the next one is clocked to the output register. This process continues until all lines have been read. The video signal is then available.

In principle it is possible for the photo-sensitive part of the CCD to be active while data are read from its light-immune part.

### COLOUR

Since all CCD cells react to incident light in a similar manner, the devices are suitable for black-and-white imaging only. For colour operation, the cells are combined with colour filters to

**Figure 3. Device architecture of a frame transfer image sensor.**

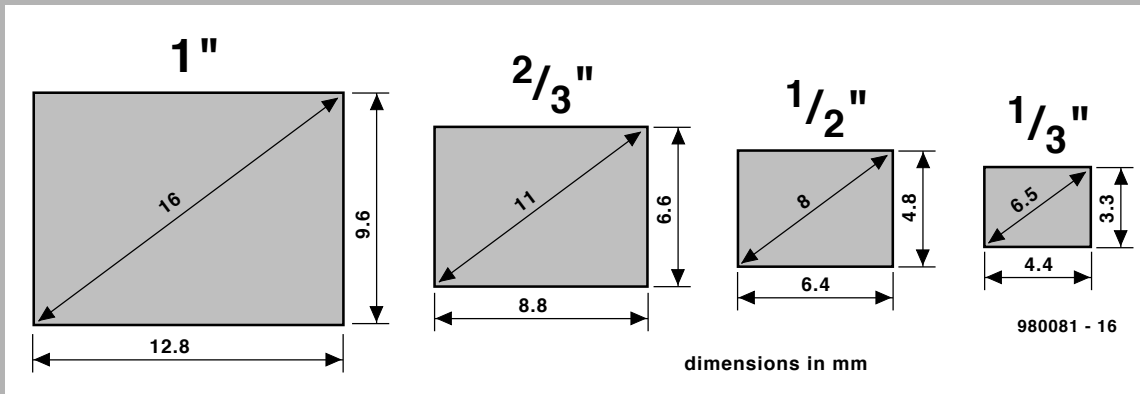


# ccd chip formats

The roots for describing the size of imaging sensors in inches go back to the time when there were only vidicons. A vidicon with a diameter of 1 inch (25.3 mm) had a rectangular, active window with a diameter of 0.6 in (16 mm). This format has been retained until today.

CCDs are available in various sizes: 1 in, 2/3 in, 1/2 in, and 1/3 in. Nowadays, 1 in chips are used rarely, whereas 1/2 in and 1/3 in types have experienced a constant growth in applications, mainly in the field of surveillance, miniature cameras, and home video cameras

Reducing the active sensor surface results in smaller pixels, eventually lowering the resolution. For most applications, a highly detailed picture is more important than the size of the CCD and thus more important than the size of the



camera. For instance, the Olympus C-1400L uses a 2/3 in CCD containing 1.4 million pixels. The horizontal resolution is 1280 pixels, and the vertical, 1024 pixels. Note that this deviates somewhat from the usual 4:3 picture ratio.

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make them react to the green, blue or red component of the incident light only. Since the human eye is more sensitive to green than to the other colours, there are more green-sensitive cells than red and blue ones.

The measured light intensity per cell is divided into 256 levels of brightness. In this way, each composite pixel gives 256<sup>3</sup> shades of colour, so that true colour operation is possible.

There are two types of CCD: one for video cameras and the other for film cameras. CCDs for video applications have rectangular cells and are filtered with cyan, magenta and yellow filters. Moreover, in these CCDs use is made of the fact that television pictures are built up from two halves (frames).

It might appear as if this type of CCD could also be used in film cameras, but this is not so because in the case of fast moving objects the difference between the two frames would be so large that serious distortion would ensue. Nevertheless, this type of CCD is easy and inexpensive to produce and it is therefore used in inexpensive digital film cameras. Up-market digital cameras use a CCD specially

developed for them: the progressive CCD.

## PROGRESSIVE CCD

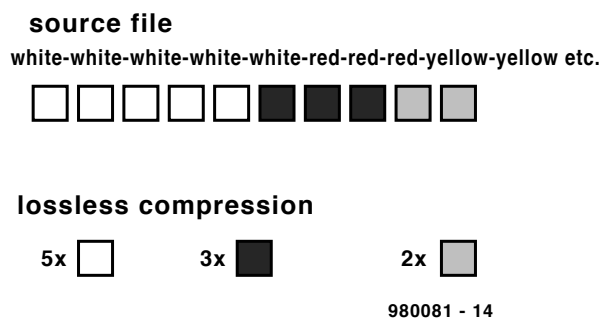
Progressive CCDs use square pixels which are filtered in the primary colours: red, green and blue (RGB). Moreover, each pixel is associated with only one primary colour. To ensure that a perfect image is constructed

with this arrangement, the camera is fitted with advanced software. The quality of this determines to a very significant degree the quality of the output image (picture). Finally, a progressive CCD captures the picture in one operation, that is, it does not use two halves (frames). Mutilation of fast moving objects therefore does not occur.



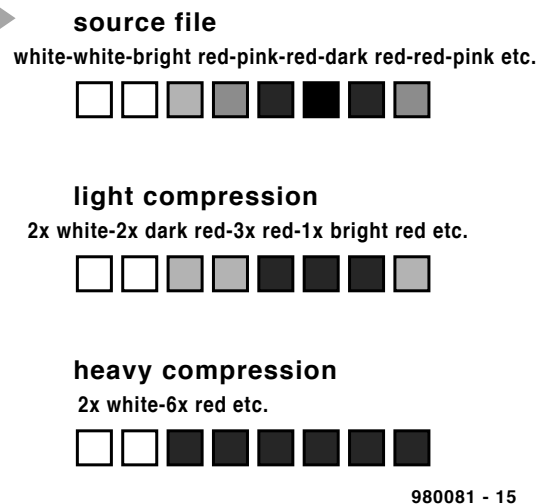
photo: Olympus

4



**Figure 4.** Picture data may be compressed lossless, for instance, by LZW compression as sketched.

5



**Figure 5.** Much more severe compression is possible if certain data can be made redundant. Illustrated is how the degree of compression determines the loss of detail.

To ensure optimum results from the CCD, taking account of various properties, the device has twice as many green-sensitive cells as red- or blue-sensitive ones.

It should be noted that in (good) digital cameras a separate sensor is used for each primary colour. The specified resolution does therefore conform to the actual number of sensors. It might be thought that each pixel is built up by three sensors, each reacting to a different primary colour. However, manufacturers have taken a different route by computing the desired colour data with the aid of refined algorithms. The colour information for each pixel is therefore the result of an arithmetic analysis in which the data of adjacent pixels are also taken into consideration.

## COMPRESSION

When the digital data representing a picture have been gathered, they are

compressed in the camera with the aid of a microprocessor. Of a picture consisting of  $1028 \times 768$  pixels, each pixel must be stored with a resolution of 24 bits. This is equivalent to 2.25 Mbyte of digital data. In other words, the internal memory of a camera, usually 2–4 Mbyte, would be able to contain only a few pictures.

The solution to this problem is an integral compression algorithm. A distinction must be made between lossless compression and redundant-bit compression. With loss-less compression, for instance, the TIFF (Tagged Image File Format) with LZW (Lempel Ziv Welch – a Unisys patent) compression, use is made of the data structure. Sequential series of identical information are clustered as shown in **Figure 4**, which results in a significant compression of data.

Much better efficiency is provided by redundant-bit compression, in which, as the name implies, data are

made redundant. In such compression algorithms, for instance, JPEG, use is made of the fact that the human eye can perceive only about 2000 shades of colour, which is appreciably fewer than the 16.7 million that are registered.

How such an algorithm analyses a series of colour shades and replaces it with a much more compact series is shown in **Figure 5**. The higher the compression, the more detail is lost and the poorer the quality of the reproduced image. Nevertheless, with the use of this kind of algorithm and without much discernible loss of quality, a 2 Mbyte file can be reduced to 100 Kbyte or less. The data so obtained may be stored in the internal memory or on the added memory card.

[980081]

## MOS or CMOS?

Currently, CCDs are produced in MOS technology, which has several disadvantages. For example, it is not suitable for energy-saving circuits, and it is a deviant production process.

The semiconductor industry pre-fers energy-saving CMOS technology and researchers are therefore working on the development of CCDs in this technology. Recently, it was announced that the first CMOS CCDs had been produced. This will, in time, bring down the price of CCDs and, perhaps more importantly, it will become possible to add intelligence to the device. For example, it will then be possible for the data of each and every pixel or cluster of pixels to be processed on the CCD.

Moreover, a single pixel may be accessed so that new functions, such as picture analysis, can be provided by the CCD.

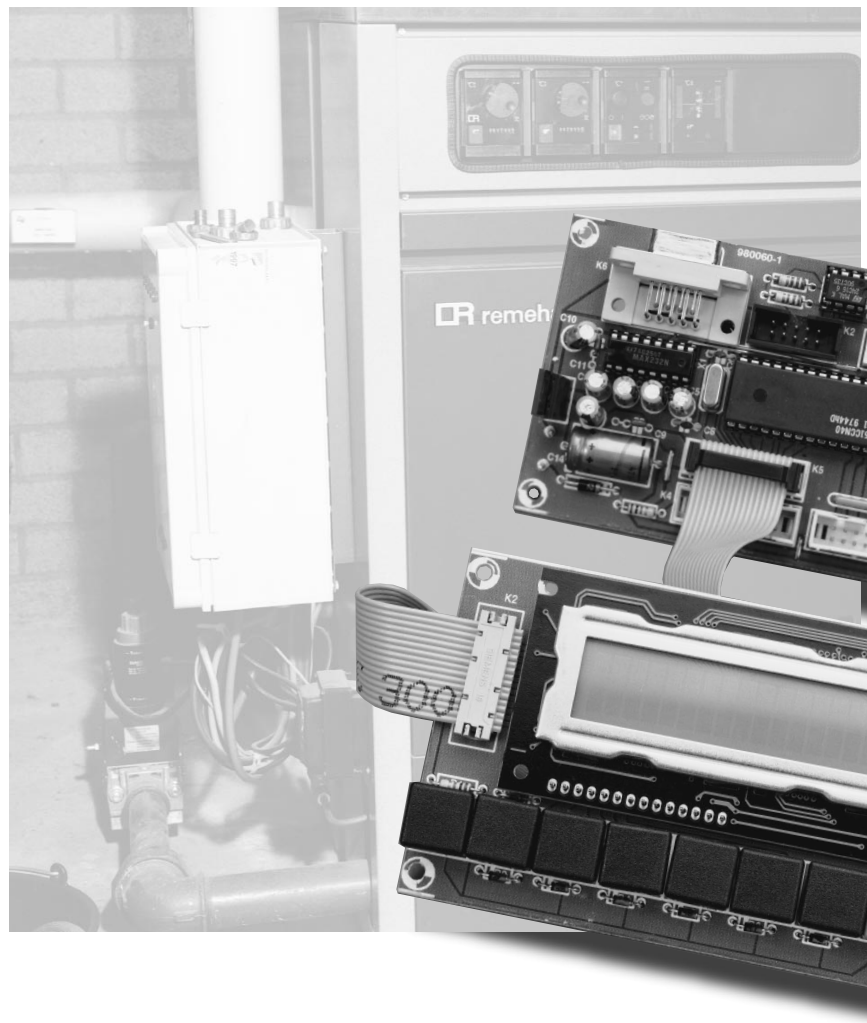
The Fraunhofer Institute for Microelectronic Circuits recently announced the design of a CMOS CCD with 120,000 imaging cells and associated logic circuits.

Another research institute has succeeded in developing a single-row photosensor 2048 pixels wide and an exposure-time range from 100 ns to 4 s. Each imaging cell in this design has its own read-out amplifier, a buffer and dark compensation. This enables the CCD to be used even at very low light intensities.

# versatile control system PLC87(A)

## *part 1: a PLC based on the Simatic S5 instruction set*

In the industry, there is no such thing as process automation without Programmable Logic Controls (PLCs). These systems are typically quicker and easier to program than just about any microcontroller circuit, and they also allow variables to be observed during program execution. The PLC87 and 87A boards described here are basically 8751 (or 87C550) based systems capable of executing Simatic-S5 oriented command sequences, the S5 command set representing a well-established industry standard.

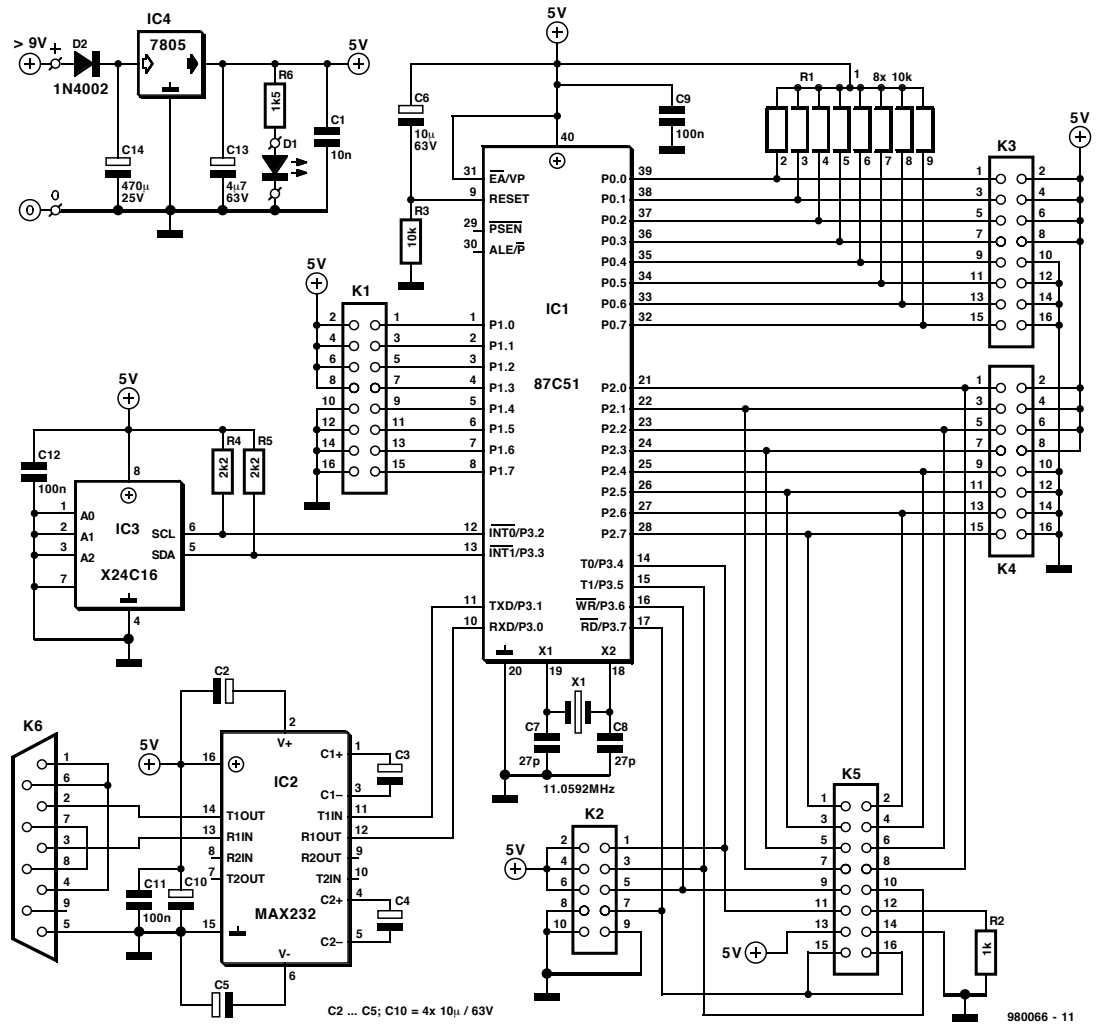


The PLC87 is a small plug-on board containing a microcontroller system that may be programmed like a traditional PLC. It also allows an LC (liquid crystal) display to be connected in a simple way. In addition to the microcontroller, an 87C51 or 87C550, the small single-sided board also contains a serial EEPROM and a level converter type MAX232. When the 87C51 is used, the PLC87 has 16 digital inputs and 12 digital outputs. When the 'analogue' version, the PLC87A, is built, the 87C550 controller is used, and the system

then has 10 digital inputs and outputs as well as 6 analogue/digital inputs available for your applications.

The PLC87 board is connected to the application circuit by way of four boxheaders. The LCD module has two lines of 16 characters, and is connected to another boxheader without the need for any additional hardware. If additional input keys are required, these may be connected to the multiplex inputs.

The PLC87 board processes a command sequence (CS) which is 'built' on

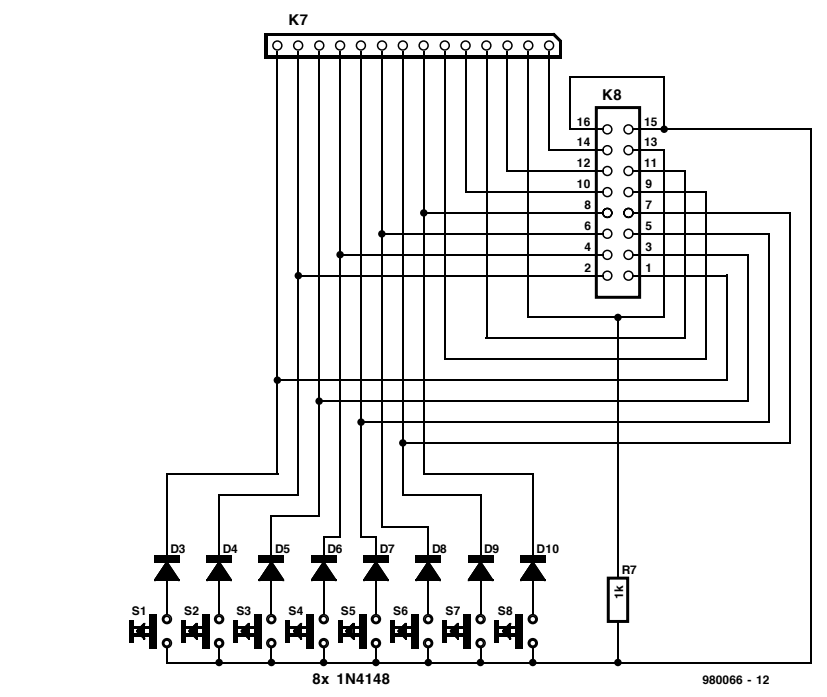


**Figure 1. The PLC87 is really no more than a small microcontroller system.**

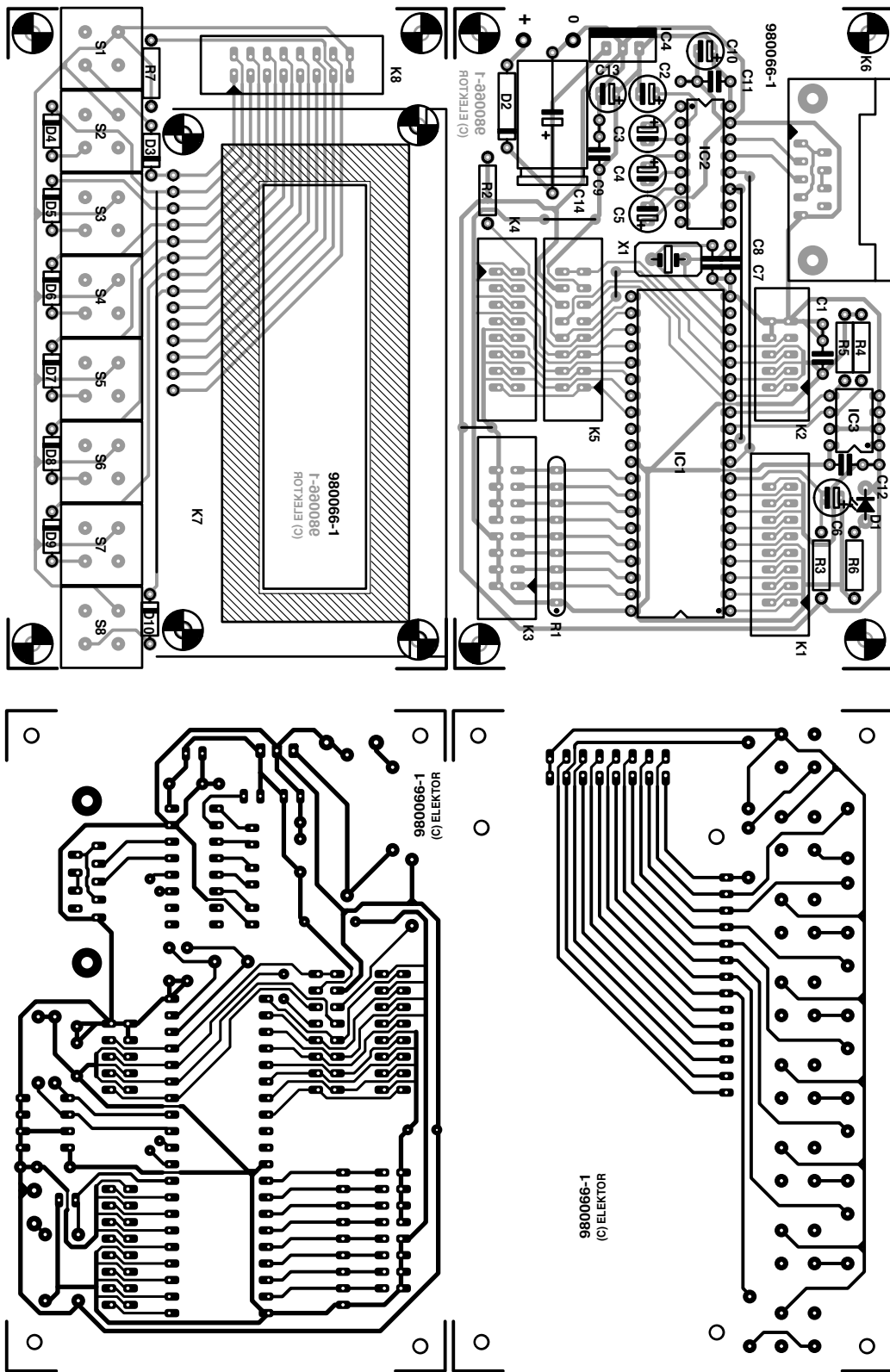
a PC using a special program called PLC87. The command sequence is actually the programming language of the PLC, and will be the subject of part 2 of this article, to be published next month. The CS mnemonics are transferred from the PC to the PLC87 by way of a serial link. The PLC87 program also allows the values of variables to be checked and modified. The same software is used for the analogue version PLC87A. The command sequence is heavily based on the Simatic S5 instruction set, to with added commands for display control and data logging. Program structuring is, however, not possible because that would exhaust the resources offered by the microcontroller. Also, the PLC87(A) is not suitable for fast events because the command sequence is marked by a relatively long cycle time.

The analogue version PLC87A enables you to capture temperatures and other measurement values from the 'real world'. The only difference with the all-digital PLC87 is the modified pinning of the control board. Any analogue input may also be configured as a digital input.

The PLC87(A) board may be the heart of a small system for machine



control, or a simple text output system if its LC display is used. Alternatively, you may want to use it to learn the basics of PLC programming, for example, to implement an intelligent heating control, a code lock, a garage door opener or even a simple datalogger. The PLC87 board may also be used to



**Figure 2.** Although the printed circuit board was designed to be as compact as possible, we managed to keep it single-sided.

design simple microprocessor circuits if you don't know the first thing about assembly-language programming. The only thing that will constantly seem to be in your way is the relatively slow program execution due to the serial EEPROM. Depending on the configuration, the pin assignment of the PLC

board is divided into control pins and signal pins, and input and output pins, by the software as shown in Table 1.

#### HARDWARE: FUNCTION, CONSTRUCTION AND TEST

The PLC87(A) is simple to build and test, after all, it is an ordinary 'minimum configuration' microcontroller system with the usual ingredients: controller with integrated ROM for the CS interpreter, an EEPROM acting as the

CS program memory, and a serial interface to establish the link to the PC. These sub-circuits are easily identified in the circuit diagram shown in Figure 1. The 87C51 controller exploits only a part of its port P3 for internal operations (EEPROM, serial interface) — all other port lines are freely available for PLC applications. The LC display and the input keys are wired to connector K5. Because the PLC87 inputs and outputs make direct use of the controller port lines, it should be noted that input signals are TTL compatible, and output signals can not be loaded too heavily. In general, it will therefore be necessary to add drivers to the controller port lines.

The few parts are quickly installed on the small printed circuit board which is single-sided. It is best to start with the smaller components like capacitors and resistors, and finish with the boxheaders and the integrated circuits. We recommend using sockets for the ICs. The copper track layout and component orientation aid of the board are shown in Figure 2.

Once the board is fully populated, it is wise to run a thorough check on the orientation of all electrolytic capacitors and integrated circuits. Then inspect the solder side of the board for dry joints and short-circuits caused by excess solder. If everything appears to be in order, you connect pin 20 to ground and pin 40 to the +5 V supply line. Launch the PLC87 program on the PC, and

establish the hardware connection between the PC and the PLC87 board. Once the right interface (COM port) has been selected, and ENTER is pressed in the ONLINE menu, the actual connection is made. If everything works so far, a menu pops up. Note that for first-time use the display has to be excluded in the CONFIG menu if it is not connected. If you forget to do this, the controller will not start properly, or simply 'hang'. If this happens, the only solution is to switch the



## COMPONENTS LIST

### Resistors:

R1 = SIL array 8x10 k $\Omega$   
R2,R7 = 1 k $\Omega$   
R3 = 10 k $\Omega$   
R4,R5 = 2k $\Omega$   
R6 = 1k $\Omega$

### Capacitors:

C1 = 10nF ceramic  
C2-C6,C10 = 10 $\mu$ F 63V radial  
C7,C8 = 27pF  
C9,C11,C12 = 100nF ceramic  
C13 = 4 $\mu$ F 63V radial  
C14 = 470 $\mu$ F 25V

### Semiconductors:

D1 = high efficiency LED  
D2 = 1N4002  
D3 = 1N4148  
IC1 = 87C51 (digital version, order code 986513-1) or 87C550 (analogue version, order code 986514-1)  
IC2 = MAX232CP (Maxim)  
IC3 = X24C16 (Xicor) or PCF85116-3 (Phillips) or M24C16-BN6 (SGS)  
IC4 = 7805

### Miscellaneous:

X1 = crystal 11.0592 MHz  
K1,K3,K4,K5 = 16-way boxheader  
K2 = 10-way boxheader  
K6 = 9-way sub-D socket (female), PCB mount, angled pins  
LCD module, 2 x 16 characters  
S1-S8 = presskey D6-C-90 (ITC) with cap BTN-ED6-90 (Conrad Electronics o/n 700622)  
IC sockets  
Solder pins  
PCB, order code 980066-1 (see Readers Services page)  
Disk, order code 986026-1 (see Readers Services page).

want to use. Save these settings.

By pressing F1 you will be able to obtain online Help for most menu options. In the Help windows, you can navigate using the arrow keys, and jump to references indicated by <....>. A press on Enter then takes you to this reference. You can leave Help by pressing the Esc key.

These are the main menu options:

### SETUP

The SETUP window opens the following options:

**COLOURS** menu colour selection.

**MOUSE** mouse speed setting.

**EXT PROGRAM** path, name and parameters of an external program that may be launched from this menu.

**COM** selection of COM port to be used with PLC87 board.

**PRINTER** printer selection

**SAVE SETUP** save selections made in this submenu, and the paths defined in the OPTIONS menu.

### OPTIONS

If you open the OPTIONS window, a menu list appears with the following entries:

**DIR** shows the contents of the current directory.

**PATH** defines the path followed to store command-sequence programs with the extension .S87.

**DOS SHELL** exit to DOS level (type *exit* to return to PLC87).

**EXT PROG** launch an external program as defined in the SETUP menu.

**QUIT** Leave PLC87, same as ALT-X.

### ONLINE

Once the link to the PLC87 board is up and running, and you select the *ONLINE* window, a options list appears on the screen. Of these options, STATVAR and READ PDS open sub-menus.

**START** execute command sequence in PLC87 board.

**STOP** stop execution of command sequence in PLC87 board.

**ERASE** erase command sequence in PLC87 board.

**STATVAR** interrogate/control variables.

**SYS-INFO** call up status of PLC87 board.

**READ PDS** read out Polling Data Memory.

**CONFIG** configure PLC87 board.

### ONLINE submenu: STATVAR

Here you can observe the status of variables in the PLC87 board *on-line*. To make use of this powerful option, simply type in the desired variable in the window (for example, MB1 or T5). The readout is launched by pressing F2. Three columns appear showing the value of the variable in decimal, hexadecimal and binary notation. Using the F3 key (con-

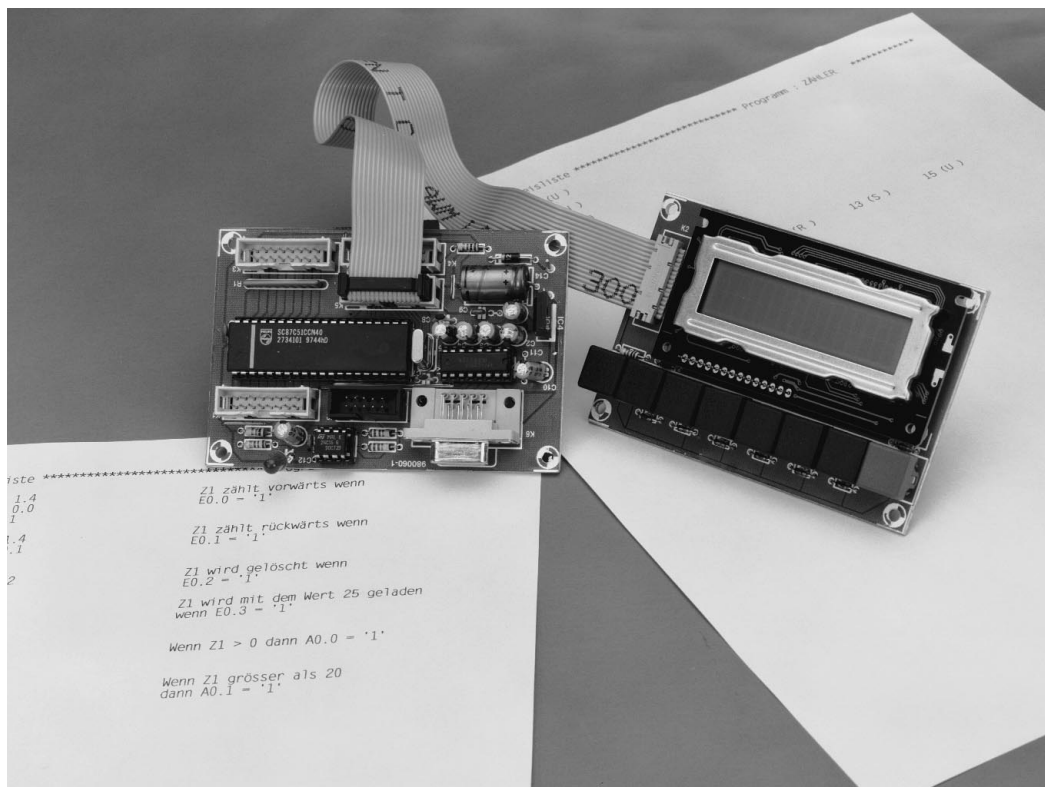
**Figure 3. Completed prototype and a command sequence on paper.**

PLC87 off, remove the EEPROM from its socket, start the PLC87 without the EEPROM, and only then insert the memory chip again.

## PC SOFTWARE PLC87

The DOS program PLC87 on the disk supplied for this project will also run under Windows 95. It creates, archives, modifies and debugs command sequences for the PLC87 board. Insert the disk (order code 986026-1) into your floppy disk drive and at the DOS prompt type *install*. The program will automatically install itself into the sub-directory c:\plc87, and can be launched from there by typing *PLC87*. For mouse support under DOS you start the program by typing *PLC87 +M*. No mouse support is available under Windows 95 because of possible conflicts. A list of options appears, and individual options may be selected in the usual way by means of the arrow keys (and Enter) or the underlined letter.

To begin with, you select the serial interface used to talk to the PLC87 board, the printer, and the colours you



trol) you can modify variables, bytes and words *on-line*. Before you can do so, you have to select the variable using the arrow keys. Note, however, that only flags and output bytes/words may be controlled in this way. Variables that may be controlled have a coloured background. Next, you have to press the *Tab* key to select one of the three columns, enter a new value, and transmit it to the PLC87 board by pressing *Enter*. Pressing the F4 key causes the variables displayed in the window to be cleared.

**ONLINE submenu: READ PDS**

The PDS (Polling Data Storage) is a cyclic memory with a capacity of 512 bytes in EEPROM. It is used for long-term storage of the variable states (values). When the PDS is read, the data are stored in a CSV (comma-space delimiter) file for further processing using, for example, Excel. Before reading in the file, you have to define the number of columns of the CSV file.

**PROGRAM**

If you open the window, a number of options are shown which allow the following operations to be carried out:

**NEW** clear program memory.

**LOAD FROM FD** load command sequence from disk into memory.

**SAVE TO FD** save command sequence on disk.

**LOAD FROM PLC** transfer command sequence from PLC87 board to program memory.\*

**SAVE TO PLC** transfer command sequence from program memory to PLC87 board.

**COMPARE** compare program memory and PLC87 board memory.

**PRINT** print program and cross-reference list.

The options marked with an asterisk (\*) only appear when the PLC87 board is already on-line.

**EDITOR**

The Editor is a simple word processor program that allows a command sequence (CS) to be written line by line. The CS program memory on the PLC87 board has a size of 1520 bytes, so that up to 1520 CS lines may be memorised. In general, however, commands will be longer than one mnemonic, so that the number of commands per CS. If a CS does not fit into the available memory, the program will report this during the download process.

Although the creating of the CS (PLC program) will be discussed in next month's second and last instalment, a few guidelines may already be mentioned. A CS line is divided into three columns. The editor program

PLC87 board		PLC87A board	
16 digital inputs 12 digital outputs		10 digital inputs 6 analogue/digital inputs	
16 timers (0.1-2550s, 4 functions) 8 counters 256 flags 1 flash pulse 1520 byte mnemonic memory 512 byte polling data memory		16 timers (0.1-2550s, 4 functions) 8 counters 256 flags 1 flash pulse 1520-byte mnemonic memory 512-byte polling data memory	
Both	Power Vcc +5V	GND Pin 40	Pin 20

**Table 1. Pin functions (independent of configuration):**

PLC87			
Outputs	A0.0-A0.7	Pin 1-8	(Port 1)
Inputs	E0.0-E0.7	Pin 39-32	(Port 0)
PLC87A			
Outputs	A0.0-A0.5	Pin 39-34	(Port 0)
Inputs	E0.6-E0.7	Pin 33-32	(Port 0)
Analogue inputs	AE0-AE5	Pin 3-8	(Port 1)
	E0.0-E0.5	(if AEx > 2.7 V)	
Reference voltage	Avcc/Aref+	Pin 1	
	Agnd/Aref-	Pin 2	
Standard configuration:			
Outputs	A1.0-A1.3	Pin 14-17	(Port 3)
Inputs	E1.0-E1.7	Pin 21-28	(Port 2)
Status configuration:			
(system Status display via pins)			
Outputs	A1.0-A1.1	Pin 14-15	(Port 3)
Inputs	E1.0-E1.7	Pin 21-28	(Port 2)
Status	AWL loaded	Pin 16	(Port 3)
	'RUN'	Pin 17	(Port 3)
Display configuration:			
LC display 2*16 connected			
Inputs*	E1.0-E1.7	Pin 21-28	(Port 2)
Display	D0-D7	Pin 21-28	(Port 2)
	Enable	Pin 16	(Port 3)
	R/W	Pin 15	(Port 3)
	RS	Pin 14	(Port 3)

\* Inputs 1.0-1.7 are only available as multiplex inputs. They use pin 17 as a common reference and may only switch it via a potential-free contact. The inputs must be mutually decoupled using a diode to pin 17.

supports column-oriented inputting of data. The individual columns have the following meanings:

- 1st column: branch markers (4 characters)
- 2nd column: directives
- 3rd column: comment (max. 40 characters)

The cursor defaults to the second column. To enter a branch (jump) marker, you first move the cursor into the left-hand column using *Shift-Tab*. The right-hand column (for your comment) can be reached by pressing the *Tab* key only. Once a line is complete, you finish it with *Enter*. Input in the left-hand and centre columns is in principle in upper case — lower case characters are

only allowed in the comment column. When the *Enter* key is pressed, the Editor checks the syntax of the CS lines and produces an error report when necessary. If the PLC87 board is on-line, the status of variables may be checked by pressing the *F2* key. Because the variable states are read out at random instants, they may not represent the actual values.

The main subjects of next month's instalment will be the creating of command sequence lists for the PLC87.

(980066-1)

# tachometer

## *for mopeds and (motor) scooters*

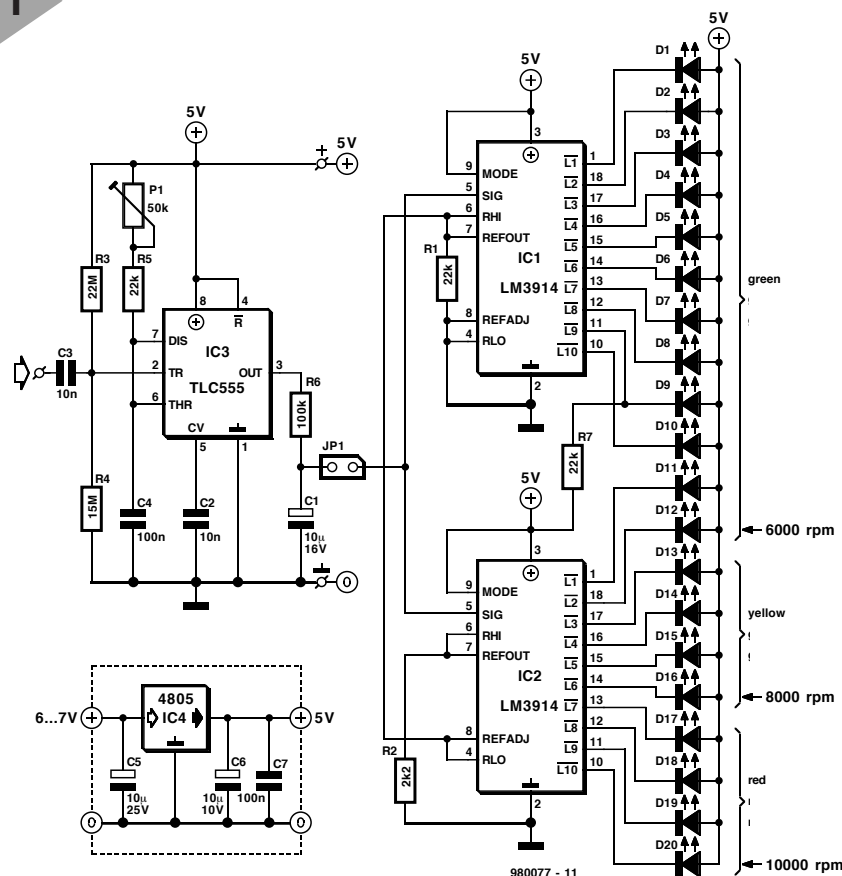
There are people who feel that every moped and motor scooter should be fitted with a tachometer (rev counter) as standard. There are others who find it a dodgy instrument since it tends to distract the rider's attention from the road. If you belong to the first category and have a scooter or moped without a rev counter, this article is for you. It describes a straightforward design of such an instrument that can be fitted to any model of moped or scooter.



Like many low-priced cars and motorcycles, mopeds and (motor) scooters tend not to have a rev counter fitted by the manufacturer, presumably on grounds of economy. However, such an instrument is relatively inexpensive and may be very useful, particularly on vehicles with manual gear change. For instance, the combined readings of the speedometer and tachometer give a good indication of whether the right gear has been selected. A falling reading on the rev counter is a sign to change down, while a rising one points to the need of changing up. Many riders who do not have the con-

venience of a rev counter argue that gear changing is done by ear, but the compulsory safety helmet does not always allow this: the sound insulation of some helmets is very good indeed! Best is, of course, to have an automatic gearbox, fortunately chosen by more and more riders. Second best is to build and fit the present tachometer.

The combined readings of speedometer and rev counter may also be useful in improving fuel consumption, but this implies that the power curve of the engine is known.



**Figure 1. The circuit of the tachometer consists of a pulse shaper, an integrating circuit, and a readout. The sensor is placed around the spark plug cable.**

**DESIGN**

There are various ways of constructing a tachometer, that is, the manner of its readout. Basically, there are three ways of achieving this: in figures via a seven-segment display, via an analogue scale consisting of light-emitting diodes (LEDs), or via a traditional moving coil meter with pointer.

The moving-coil type is the simplest construction, but is also vulnerable to shocks and vibrations. This makes it not really suitable for use on a moving vehicle.

A readout via a seven-segment display is highly accurate, but perhaps too sophisticated for use on a moped. The high accuracy is not needed and would make the design more complex than necessary.

An analogue (LED) readout is both simple and robust. It can make use of several types of control IC that enable an analogue voltage to be displayed on a bar of LEDs with only a few external components. If the bar consists of, say, 20 diodes, the readout is sufficiently accurate for most purposes.

The only other item that is needed is an electronic circuit with a sensor that provides pulses in proportion to the number of engine revolutions. These pulses are converted by the electronic circuit into an analogue direct voltage to drive the LED bar.

**SENSOR**

Ideally, the sensor should produce a pulse for each engine revolution and this is most easily achieved with the aid of an inductor (coil) to pick up the ignition pulses inductively. Since the voltage in the ignition pulses is fairly high, it suffices to construct the coil from 10–20 turns of insulated circuit wire around the spark-plug cable.

While the voltage level of the ignition pulses is fairly high, their shape varies appreciably. Therefore, the sensor is followed by a pulse shaper to transform the ignition pulses into stable, uniform count pulses. This ensures that random variations in the width and amplitude of the ignition pulses do not affect the readout.

**CIRCUIT DESCRIPTION**

The complete circuit diagram of the tachometer is shown in Figure 1. The pick-up coil (sensor) is linked to capacitor C<sub>3</sub>. This capacitor, in conjunction with resistors R<sub>3</sub> and R<sub>4</sub>, forms a differentiating circuit that narrows the ignition pulses into usable trigger pulses – an arrangement that prevents double triggering of the rev counter. The reshaped pulses are applied to the trigger input of monostable (multivibrator) IC<sub>3</sub>. This circuit outputs pulses whose width can be preset with P<sub>1</sub>.

The pulses output by IC<sub>3</sub> are integrated by a simple low-pass filter formed by R<sub>6</sub> and C<sub>1</sub>. This filter also removes any short-duration variations of the output which otherwise might make the readout unstable.

The LED readout is driven by two display drivers, IC<sub>1</sub> and IC<sub>2</sub>. These circuits are specially designed for this purpose and contain a reference voltage source and an accurate decade scaler.

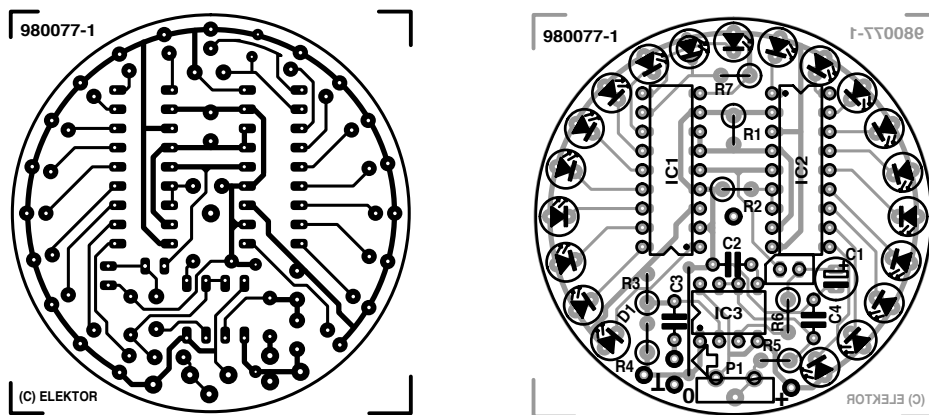
Each of the drivers can control a maximum of ten LEDs, so that the tachometer can use up to 20 diodes which gives a sufficiently accurate readout. Each of the LEDs represents about 500 engine revolutions. The

**Setting up**

*The pulse width of the output of the pulse shaper, and thus the drive voltage for the readout, can be set within a wide band with P1.*

*Calibrating the scale may be done in a number of ways: with another tachometer as reference, with a pulse generator, and also without any special equipment. This is possible by using the pick-up coil to sense the frequency of the mains voltage (in a safe manner!). This very stable signal at 50 Hz is excellent for calibration purposes, since it corresponds to 50×60= 3000 rev/min. So, if the proposed maximum of 10000 rev/min is adopted, P1 should be adjusted at 50 Hz so that D6 (3000 rev/min) lights.*

*An ideal source for the 50 Hz mains frequency is a demagnetizer for a cassette deck. The electric field radiated by this is readily picked up by the tachometer sensor. Never, never connect the input of the rev counter directly to the mains: this may be lethal and, even if you're lucky to survive, will destroy the tachometer.*



**Figure 2. Construction of the tachometer is straightforward when this printed-circuit board is used. It is available through our Readers' services.**

LEDs may be of different colours to create, say, a safe (green) range of revolutions of 500–6000 rev/min (D<sub>1</sub>–D<sub>12</sub>); a caution (yellow) range of 6000–8000 rev/min (D<sub>13</sub>–D<sub>16</sub>); and a danger (red) range above 8000 rev/min (D<sub>17</sub>–D<sub>20</sub>). Different ranges may, of course, be chosen to individual requirements.

Comparators are driven via each of the junctions of the scaler in the display drivers in such a way that every time the input voltage to the display driver increases the next comparator is enabled. The comparator outputs are capable of driving an LED directly.

The LED bar may be operated in the dot or bar mode. In the dot mode, pin 9 of the IC must be left open, and in the bar mode it should be linked to the positive supply rail. In the present application the bar mode is used.

#### Parts list

##### Resistors:

R<sub>1</sub>, R<sub>5</sub>, R<sub>7</sub> = 22 kΩ  
 R<sub>2</sub> = 2.2 kΩ  
 R<sub>3</sub> = 22 MΩ  
 R<sub>4</sub> = 15 MΩ  
 R<sub>6</sub> = 100 kΩ  
 P<sub>1</sub> = 47 kΩ (50 kΩ) preset

##### Capacitors:

C<sub>1</sub> = 10 μF, 16 V, radial  
 C<sub>2</sub>, C<sub>3</sub> = 0.01 μF, pitch 5 mm  
 C<sub>4</sub> = 0.1 μF, pitch 5 mm

##### Semiconductors:

D<sub>1</sub>–D<sub>13</sub> = low-current LED, green  
 D<sub>14</sub>–D<sub>16</sub> = low-current LED, yellow  
 D<sub>17</sub>–D<sub>20</sub> = low-current LED, red

##### Integrated circuits:

IC<sub>1</sub>, IC<sub>2</sub> = LM3914  
 IC<sub>3</sub> = TLC555

##### Miscellaneous:

JP<sub>1</sub> = 2-terminal 2.54 mm pin strip and pin jumper (Maplin)  
 Enclosure: Conrad Type 842230-55 (see text)  
 Sensor: see text  
 PCB Order No. 980077 (see Readers' services towards the end of this issue).

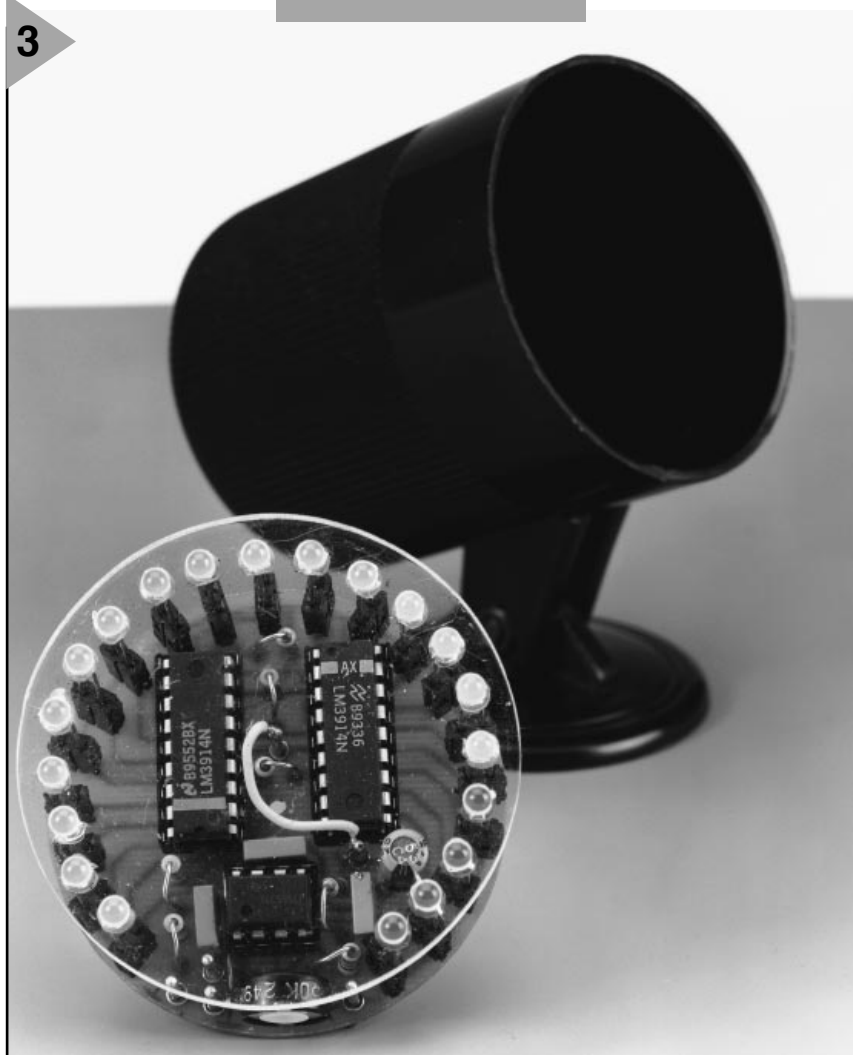
#### POWER SUPPLY

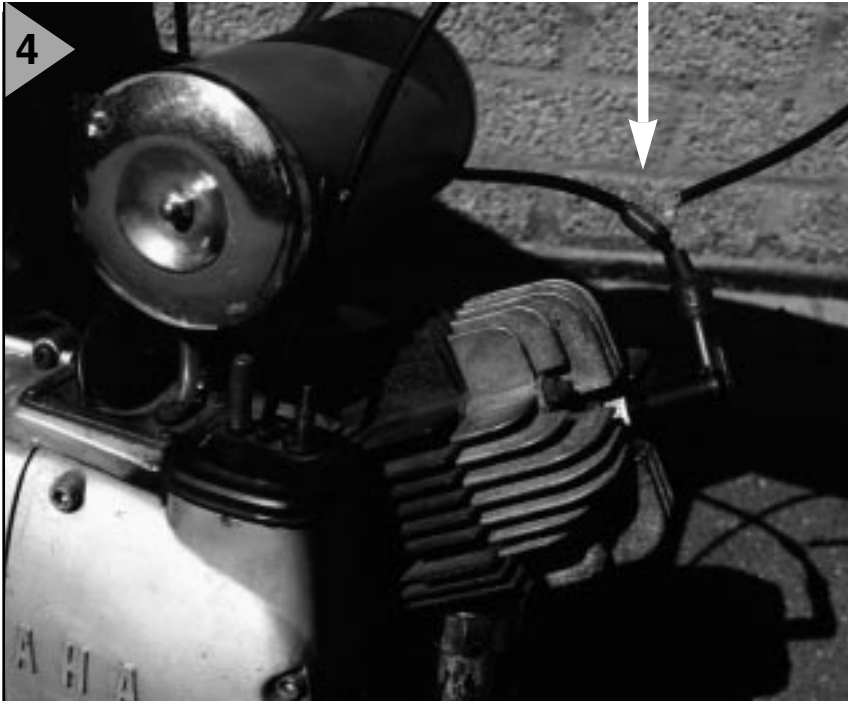
The tachometer needs a power supply of 5–6 V. The supply rails should be stable, which

means that the circuit cannot be connected directly to the battery terminals of the moped or scooter. A stable supply is obtained by the use of a 5 V regulator between the battery and the rev counter as shown in Figure 1. Since the voltage at the battery terminals is only about 6–7 V, the regulator must be a low-drop type such as the 4805: a standard 7805 will not do!

It is also possible to power the tachometer independently by a pack of

**Figure 3. The completed board in the Conrad enclosure mentioned in the text.**





**Figure 4.** This photo clearly shows how the pick-up coil is wound (25 turns) around the ignition cable.

four series-connected chargeable or dry 1.5 V batteries (AA= HP7= LR6 or C= HP11= LR14). A regulator is then, of course, not needed. The life of such batteries is lengthened by using the display drivers in the dot mode (in which pin 9 of the devices is left open).

#### CONSTRUCTION

The electronics is best built on the printed-circuit board shown in **Fig-**

**ure 2.** It is generally agreed that a circular readout is to be preferred and this is why the 20 LEDs have been arranged in a circle on the board. In view of the sparsity of components, populating the board is simplicity itself if the circuit diagram and the parts list are followed carefully.

Pin strip and jumper JP<sub>1</sub> enables the circuit to be checked on completion of the construction. During such

a check, the jumper should be removed.

When pulses are applied to capacitor C<sub>3</sub>, it should be possible to vary the low direct voltage at the terminal of JP<sub>1</sub> linked to junction R<sub>6</sub>-C<sub>1</sub> with P<sub>1</sub>. If this is so, the pulse shaper operates correctly.

When a variable direct voltage at a level of a few volts is applied to the other terminal of JP<sub>1</sub>, one of the display diodes should light.

Forming the pick-up coil around the spark plug cable (10–20 turns of thin insulated circuit wire) should not present undue difficulties. The coil should be linked to the input pin of the tachometer via insulated stranded circuit wire.

In some areas it may be possible to obtain a round enclosure to house the rev counter. A suitable one is produced by Conrad (Germany) and may be available from our regular advertiser Stippler Elektronik via another regular advertiser, Viewcom Electronics. The model number of the enclosure is given in the parts list.

[980077]

**DC-DC  
Step-Up Converter**

January 1999, 980073

Electrolytic capacitors C4 and C9 are shown with the wrong polarity in the circuit diagram,

Figure 1. The relevant PCB layout is all right.

**Portable  
Sound-Pressure Meter**

January 1998, 970085

The text alongside Figure 5 should be changed to read:

Measure the potential  $U_{REF1}$ , across pins 4 and 7 of IC2 and then connect a voltmeter across pins 4 and 7 of IC3.

**Tachometer**

October 1998, 980077

In the parts list and the circuit diagram, the value of R1 should be corrected to read 2.2 k $\Omega$ .

# faultfinding

## *art or science?*

Faultfinding, or trouble shooting, is an art to some and a science to others. Some people never get the knack of finding a fault or short-coming readily, whereas others seem to have divine guidance when it comes to locating one. For those who find faultfinding an almost impossible and tedious task, this article gives a number of hints to make the process a little easier. It also describes a randomly chosen actual case.



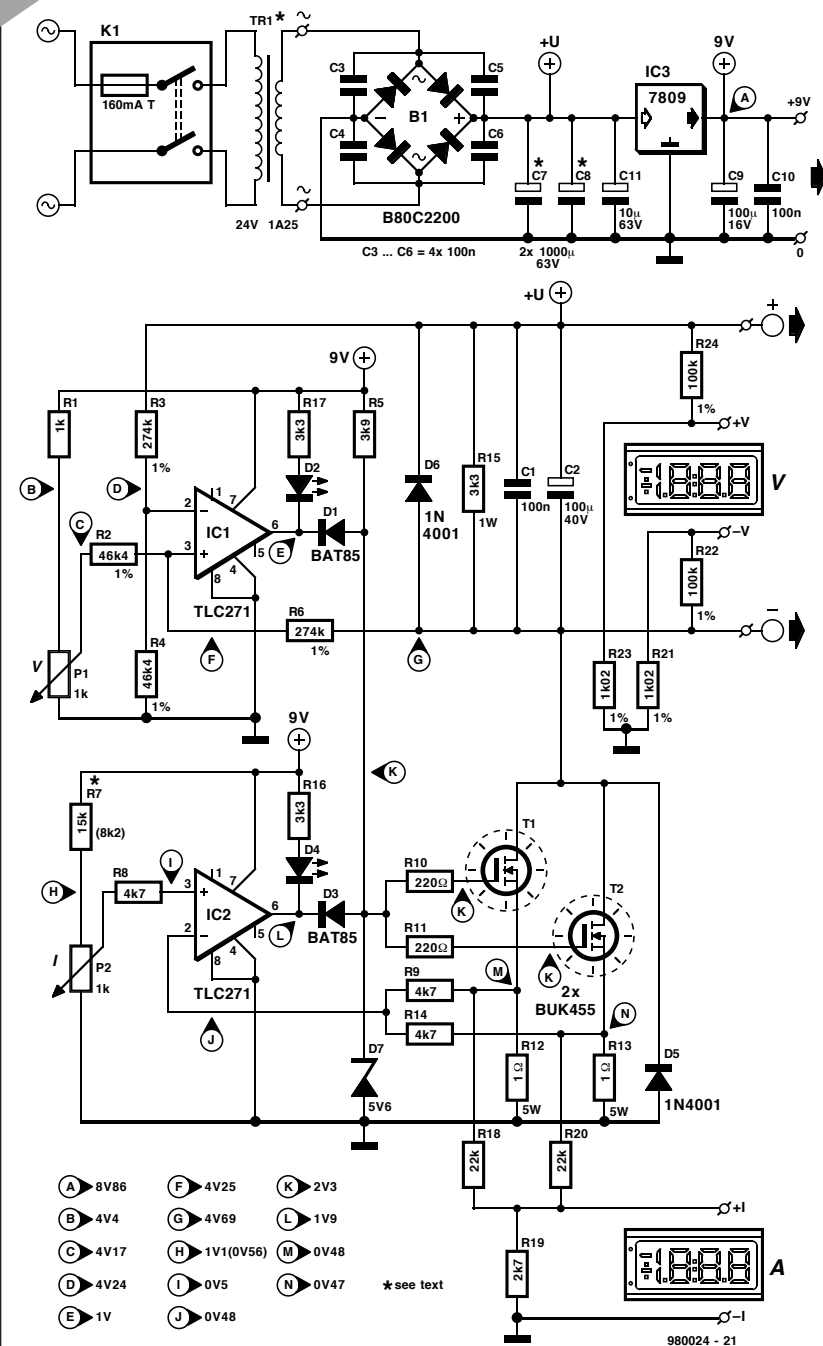
No matter how much care is taken in the construction of an electronic circuit, there is always the possibility that it will not work in the first instance. If that happens, stay calm. This is important. There are constructors who cannot accept that they may have made an error or that something unforeseen has happened. They are unnerved by such a situation and start doing all sorts of thing without considering the matter calmly. This is wrong.

Take your time to check the completed printed-circuit board (PCB) or

surface-mount assembly (SMA) systematically and thoroughly on the basis of the circuit diagram, the component layout drawing and the components/parts list.

Are all components and parts fitted in the right place? Errors often happen in the case of small resistors and capacitors. Are all integrated circuits, electrolytic capacitors and diodes fitted with correct orientation? Have the positive and negative supply lines been interchanged? Is there evidence of any dry joints? Is there a short-circuit





**Figure 1. The circuit diagram of the 'variable power supply' published in our March 1998 issue.**

caused by a tiny bead of solder between the tracks of the board?

Have all wire bridges been soldered in place? This is often a cause of malfunctioning of newly built equipment.

Admittedly, all these questions may seem irrelevant and the answers obvious, but it is a proven fact that about three quarters of all faults are caused by small errors in construction. The other quarter is normally caused by a component that has given up the ghost during soldering. It is very rare for the fault to lie with the design of the circuit or its adjustment.

When the construction has been checked carefully and the circuit still

malfunctions, a more thorough investigation is necessary. To start

with, all voltages, particularly those indicated on the circuit or wiring diagram, should be checked with a good multimeter. It is normally advisable to start at the output of the circuit.

It is virtually impossible to give general rules for measuring the various voltages and currents in a circuit. There is too great a variety of designs and layouts. It is undoubtedly much more instructive to describe a possible procedure on the basis of a practical malfunctioning equipment, in this case a power supply.

## PROCEDURE

The 'variable power supply', published in the March 1998 issue of *Elektor Electronics*, was built by one of our own employees, who could not get it to work and called in the help of our Central Design Department.

The trouble was that the unit provided an output voltage, but that this could not be regulated. The unit had been inspected thoroughly but nothing untoward had been found.

### Initial inspection

The completed board was removed from the unit and given a thorough going-over on the workbench in comparison with the circuit diagram (Figure 1).

It appeared that a few small mistakes had been made by the constructor. The first of these concerned IC<sub>3</sub>, which was a 12 V type instead of a 9 V type. This is not entirely correct, but it cannot be the cause of the malfunction. Also, R<sub>1</sub> was found to have a value of 100 Ω instead of 1 kΩ. This is an instance of careless work, but, again, cannot result in a non-variable output.

All this did not bring us closer to the root of the trouble, and it was therefore time to apply voltage to the board. This was done carefully using a variable power supply connected across C<sub>7</sub>-C<sub>8</sub>. The output of the supply was increased slowly while the ammeter was watched intently. Nothing untoward happened, however. At a supply output of 25 V the output of the board was measured and proved to be 25 V. So far, so good. However, turning P<sub>1</sub> made no difference to the output which remained stable.

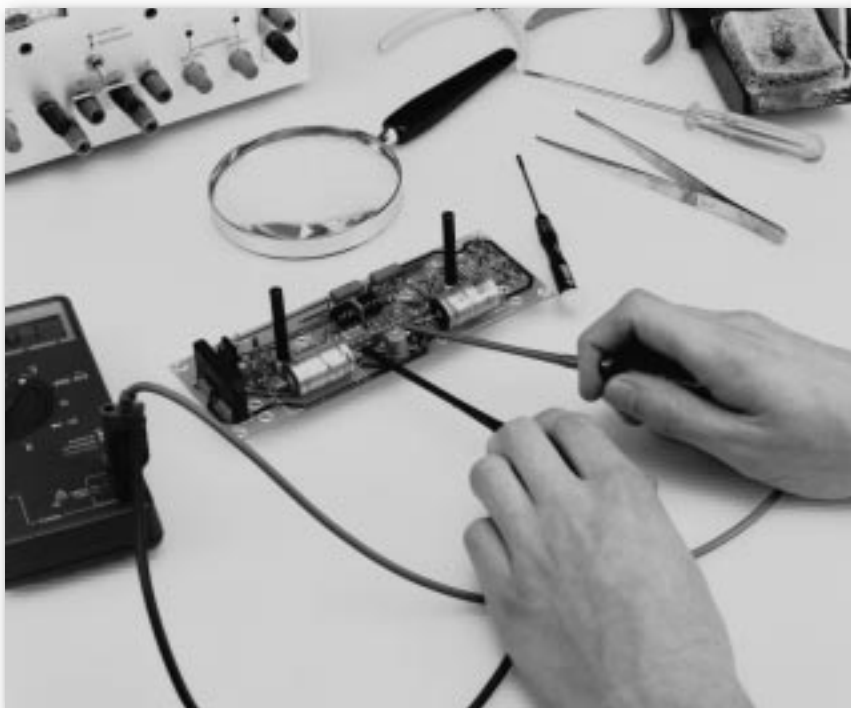
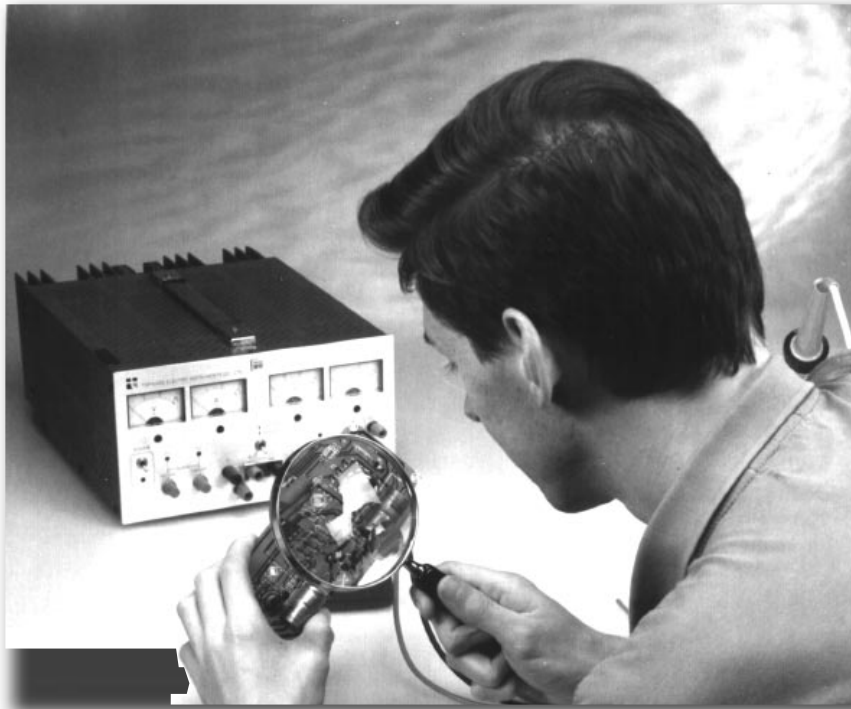
### Measurements

Since in the previous inspection transistors T<sub>1</sub> and T<sub>2</sub> passed the voltage from input to output, but nothing else, the question arose whether these FETs were connected properly or whether they were perhaps faulty. Their terminals were therefore checked with a digital multimeter. The drain and source voltages were low and about equal, which seemed to be all right since the output voltage was maximum. Also, the potential difference between gate and source was 5-6 V, indicating that the FETs were conducting (a lower difference would have been sufficient). So, how was it possible that the FETs were driven into full conduction by the control circuit, although they should be cut off with P<sub>1</sub> set to minimum.

### Backwards

To find the cause of the high control voltage, the gate potential of T<sub>1</sub>-T<sub>2</sub> was traced from back to front.

The potential at the cathode of



zener diode  $D_7$  was measured and found to be almost exactly the zener voltage, which is, of course, correct. This potential is derived from the 9 V auxiliary supply via  $R_5$  and the design of the unit is such that it can be lowered via  $D_3$  by reducing the current with  $P_2$  or via  $D_1$  by reducing the voltage with  $P_1$ .

Since the voltage setting was clearly the culprit, this branch was traced back further by measuring the potential at the cathode of  $D_1$  (test point E). This potential was found to be much too high: about 8 V. This indicated that something was not quite right with the

circuit around operational amplifier  $IC_1$ . This device was overdriven, defect or it had no connection to earth. Again, a number of possible causes.

#### Locating the fault

Once it was known that the error was somewhere around  $IC_1$ , it could be located more accurately. For this purpose, the voltages at all pins, not the socket, of the op amp were measured (carefully). This ensured that a faulty socket or a broken track would not cloud the issue. The measured values were written down so that they could be evaluated. Pin 7: 8.9 V; pins 4 and 8: 0 V; pin 3: 5.2 V; pin 2: 3.6 V.

Pin 7 is linked to the auxiliary positive supply line, so 9 V is correct. Pins 4 and 8 are linked to the negative auxiliary supply line, so 0 V is also correct. If this potential were different, it would indicate something not quite right with the earth connection of the op amp, whereupon this might act in a totally unpredictable manner.

The voltages at pins 2 and 3 were quite different, which, since these are the inverting and non-inverting inputs of the op amp, could not be right. (By definition, these voltages should be equal or very nearly so). This explained why the output of the op amp was high: the non-inverting input potential was higher than that at the inverting input, so that the output voltage was nearly equal to the supply voltage.

#### The net closes

It was clear that the cause of the malfunction lay in the inequality of the input voltages of  $IC_1$ .

The requisite voltage at pin 2 was calculated readily since it is determined by potential divider  $R_3$ - $R_4$  and the supply voltage. Since the supply was still 25 V, the potential at test point D had to be  $46.4/(46.4 + 274) \times 25 = 3.62$  v. This was virtually identical to the measured voltage, which is correct.

So, the voltage at pin 3 remained as the only possible culprit. It will be seen from the circuit diagram that this voltage arrives from the wiper of  $P_1$ . And, indeed, when this potentiometer was turned, the voltage at pin 3 varied, but remained higher at all times than that at pin 2. It was not surprising, therefore, that the circuit did not function correctly.

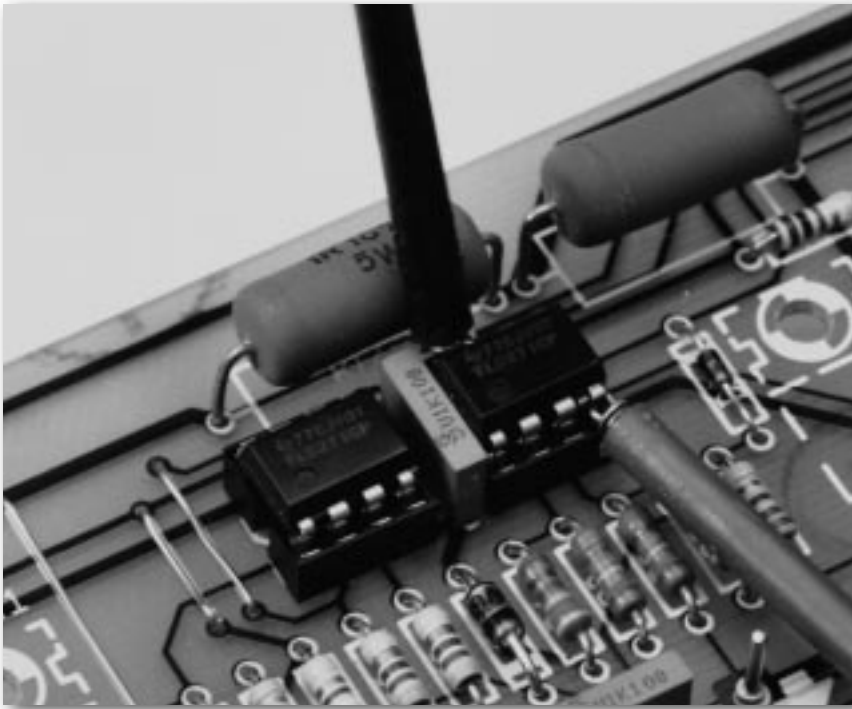
#### That's it!

The potential at test point G was the same high output voltage that was not affected by adjusting the potentiometer. However, the potential at test point C, that is, the wiper of  $P_1$ , varied between 4 V and 5 V, although it should have been 0 V with the wiper fully anticlockwise. This indicated a faulty potentiometer and, indeed, when it was replaced by a new one, the regulation of the unit worked fine.

#### Another problem

For completeness' sake, the action of the current limiting circuit was also tested. For this purpose, a 10  $\Omega$ , 10 W resistor was connected across the output terminals and the output voltage set to few volts with  $P_1$ . Subsequently, the current limit was slowly turned to a lower level with  $P_2$ . At a given level,  $D_4$  lighted and the output voltage dropped back. All perfectly in order.

However, just when the tests were about to be terminated, it smelled as if something somewhere in the unit was



getting too hot and it was found to be the FETs, although these were mounted on a correct heat sink. It was found that this heat sink was cool and the FETs hot. On close inspection it

was discovered that the FETs were not in close contact with the heat sink. Were the screws tightened sufficiently? Yes; in fact, they could not easily be undone. Once the FETs were removed

from the heat sink, it was found that owing to careless drilling and deburring, the FETs could not be fastened close to the heat sink. Once the holes were deburred, and the FETs reinstalled (with heat conducting paste), all was found to be in proper order.

#### **Finally**

The foregoing shows that the number of possible causes of a malfunction is great. Our engineer had never found a defect potentiometer in this type of equipment. The malfunctioning of the heat sink was also a rare occurrence.

It also shows that what was said at the beginning of this article is invariably true: that a completed board may at first sight look in perfect order, but on close inspection prove to have been finished, in some instances, in a careless manner. Also, in the case considered, there were two components with incorrect rating. There was nothing wrong with the circuit diagram nor with the component layout.

[980089]

# clipping indicator

## *for compact disc*

A little while ago a reader wrote to say that he had found overdrive on some of his compact discs.

This sort of news comes of course like a thunderbolt since it is assumed by most people that compact discs are examples of the quality of today's digital technology.

The first reaction to such an allegation is one of outright disbelief or at least scepticism. Moreover, it has been alleged by other readers that several producers have admitted (sic!) to overdriving, that is clipping, of CDs at the request of the relevant artists. Be that as it may, it was reason enough to design an indicator to bring overdrive to light and help the consumer in his/her quest not to buy flawed CDs\*.

\*It should be noted that overdrive on a CD is not a legal reason for asking your money back.

Designed by T. Giesberts

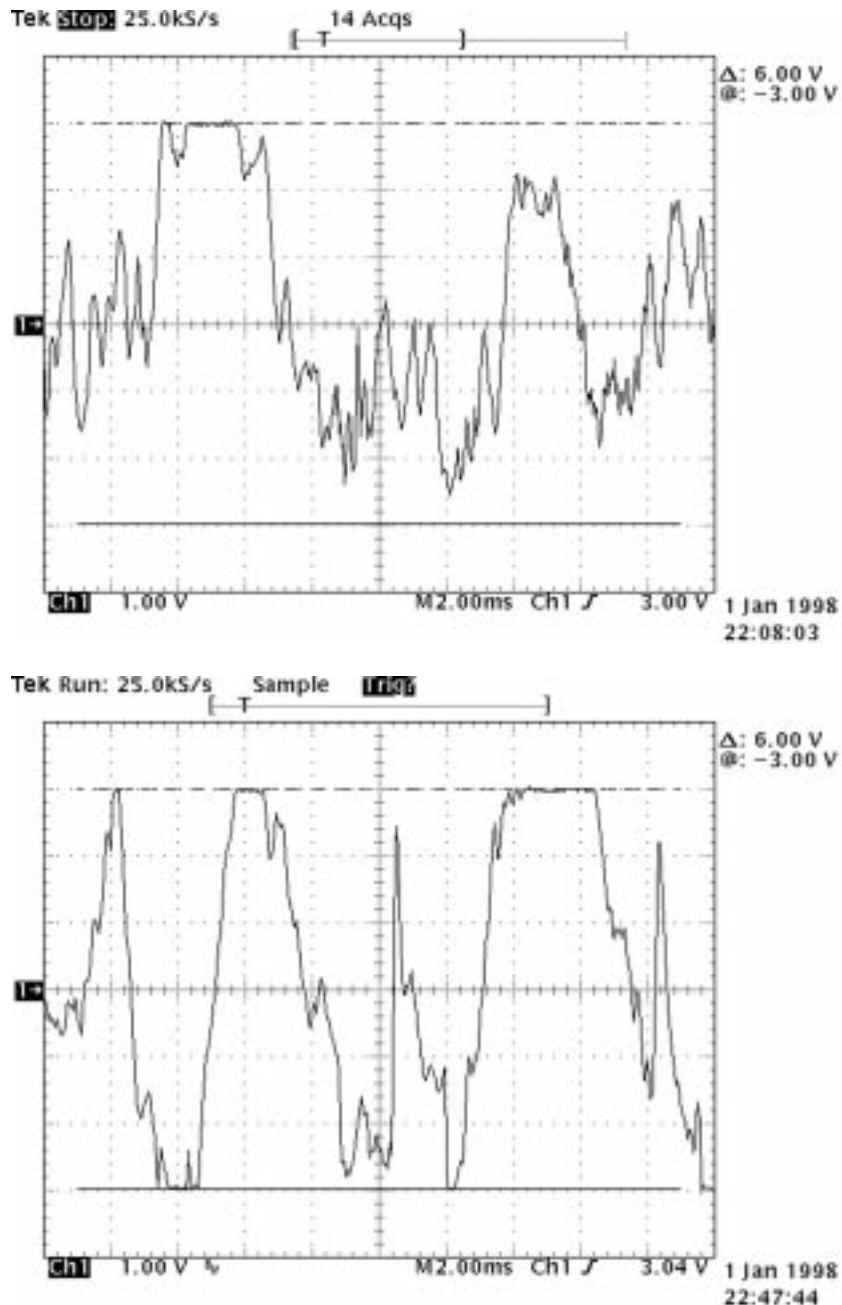


Most people will not believe that there are CDs that are overdriven by the producer: they generally assume that manufacturers know what they are doing and supply discs that are technically correct within the confines of modern digital technology. If the experiences of some of our readers are accepted, this may not always be true.

One reader wrote to say that he had noticed that some CDs in his collection sounded 'less than perfect' and others even 'downright poor'. Since he thought that his ears were playing him tricks, he decided to check the level

with a VU (visual unit). To his surprise he found that the level varied around 0 dB. A surprise, indeed, for the level on a CD should reach 0 dB only during very brief peaks in the signal. The average signal strength should be not less than 6 dB and preferably 10–12 dB below 0 dB.

In view of these findings, our reader decided to take his investigation a little further and connected an oscilloscope to the output of his CD player. This showed that on certain CDs the signal was clipped; on one or two, the clipping led to 'audible distortion'. Fig-



**Figure 1. Two clear cases of overdrive allegedly measured on modern compact discs (Sony Music 099748 393227/1996 and 099748 698421/1997).**

Figure 1 shows a few examples (not necessarily the worst!).

Apart from leading to distortion, clipping also results in another phenomenon. Since the average signal strength is too high, the dynamic range of the music is reduced, so that the reproduced sound is much too flat, which can easily lead to 'listening fatigue'.

### COINCIDENCE?

Could these findings be coincidence? It is hard to say, but evidence from other readers and our own measurements seem to indicate that there are CDs on which the signal has been purposely overdriven. [The allegation by another reader that two producers admitted to him that they sometimes used overdrive on CDs at the request of the relevant artists seems far-fetched – because it would be contrary to their

commercial acumen – but not impossible. Also, the reason given by these producers that they 'dared not go against the wishes of these artists' seems highly suspect. No artist is bigger than a bona fide recording studio. Editor].

### DETECTION

What can the consumer do to avoid buying a flawed disc? After all, a CD cannot be repaired or enhanced. Overdrive used in the recording studio cannot even be eradicated during manufacture of the disc.

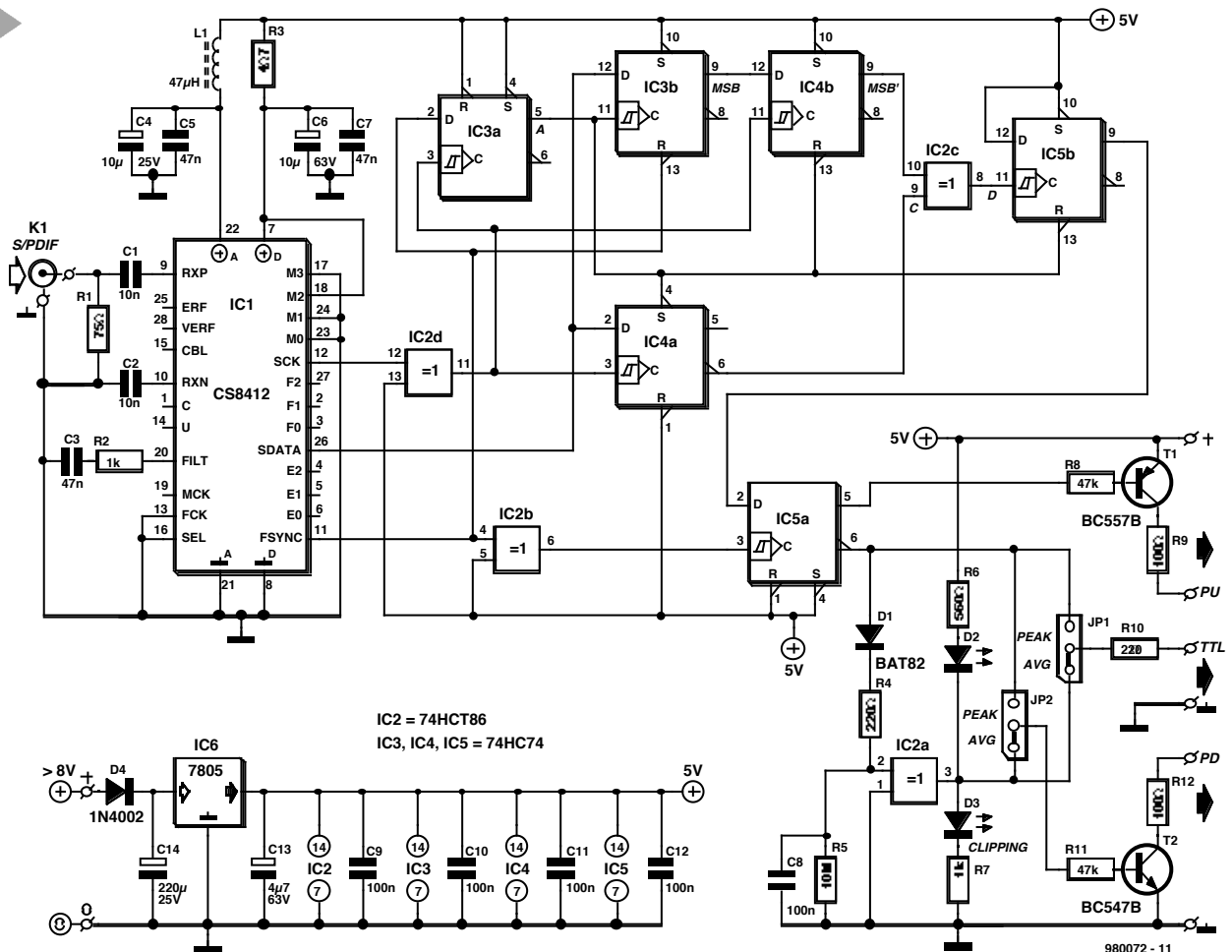
The only thing a consumer can do is not to buy the suspect CD. But how is he/she to detect that a certain CD suffers from overdrive? Listening to it

at the retailer's premises normally does not indicate anything awry, but

once it is played on a good-quality installation at home a deficiency may come to light.

The solution appears to be a small portable indicator that can be taken to the retailer, assuming that it is possible to connect it to the retailer's playback equipment.

What should the indicator react to? It is clear that on a good-quality CD the 0 dB level will be reached only during short high-signal peaks. If the 0 dB level is sustained for more than a fraction of a second, there may be reason to be suspicious. Consequently, the indicator is designed so that an LED lights when two or more samples



**Figure 2. The circuit of the indicator consists of an integrated digital audio interface receiver and a number of gates and bistables forming the signalling section.**

of the signal reach the peak value. The probability that some clipping that occurs is great. When the LED lights only once or twice per track, it must be assumed that this is caused by a couple of strong signals. If it lights more often, or it remains on for longer than a second, there is something not quite right.

To make a possible error indication as clear as possible, two LEDs are used: the green one lights as long as all is well, and the red one when there is something amiss. For those who have not the patience to keep an eye on the LEDs during the entire time the CD is played, there is an optional facility for connecting a counter module. This shows how many times during the playback clipping may have occurred.

In the design of the indicator it was assumed that the studio recording was transferred 1:1 to the manufactured compact disc.

### CIRCUIT DESCRIPTION

The circuit diagram of the indicator is shown in **Figure 2**. Audio socket K<sub>1</sub> is for linking the indicator to the digital output of the CD player.

The relevant data are retrieved from the S/PDIF<sup>†</sup> signal with the aid of

IC<sub>1</sub>, an integrated interface receiver Type CS8412 (see Data Sheets elsewhere in this issue). This circuit can handle virtually all current sampling frequencies. The serial audio data (SDATA) are read with the aid of a bit-clock and a word-clock (SCK and FSYNC respectively). The output of the IC is set to a special format (normal mode FMT 4: M<sub>0</sub>=M<sub>1</sub>=0; M<sub>2</sub>=1 M<sub>3</sub>=0) in which a clock pulse follows each audio sample, irrespective of left or right.

The audio data are coded in 2s complement. To check whether a peak value has been reached, the MSB (most significant bit) must be inspected and compared with the remaining bits. In the case of digital minimum and maximum values, all remaining bits must be the opposite of the MSB. The minimum and maximum values are checked with an XOR function.

### Gates & bistables

The comparing and indexing of the bits is carried out by a number of gates and D-bistables. The timing diagram of the most important signals is shown in **Figure 3**.

At the start of a new sample, a clock

signal is generated exclusively for the MSB in D-bistable IC<sub>3a</sub>-IC<sub>3b</sub>. The FSYNC signal is clocked into IC<sub>3a</sub> by the inverted bit-clock (IC<sub>2d</sub>). The output of IC<sub>3a</sub> (signal A) forms the clock for the MSB.

The clock input of IC<sub>3b</sub> goes high in the middle of the MSB, after which the bit is held for the duration of the audio sample (pin 9 of IC<sub>3b</sub>).

To ensure that the MSB is applied to comparator IC<sub>2c</sub> simultaneously with the next bit, it is clocked again in D-bistable IC<sub>4b</sub>.

The remaining bits are clocked by IC<sub>4a</sub>. Since signal A is applied to the S-input of this bistable, the inverted output remains low until the first of the remaining bits is clocked (signal C).

Use of the inverted output ensures that all bits there have the same level as the MSB if and when a minimum or maximum value is reached. If the level is not the same, IC<sub>2</sub> goes high at a certain moment, which causes IC<sub>5b</sub> to be clocked. This means that the output of IC<sub>5b</sub> is high when there is neither a minimum nor a maximum value.

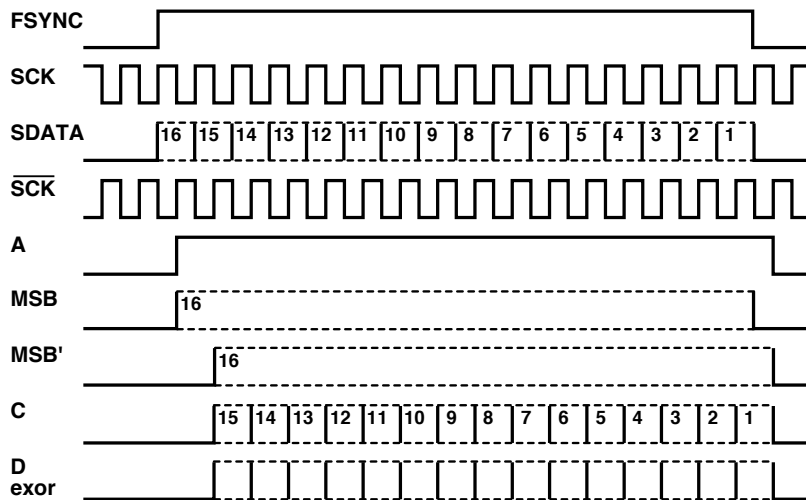
So as to enable the actual state of each sample to be determined, most bistables, including IC<sub>5b</sub>, are reset by signal A. Before this happens, the sta-

tus of IC<sub>5b</sub> for each sample is clocked to IC<sub>5a</sub> by the FSYNC signal inverted by IC<sub>2b</sub>. Since IC<sub>5a</sub> is not reset by signal A, the data transferred to it are retained. Pin 6 of this bistable therefore remains low as long as there is no sample that contains a minimum or maximum value. If a peak value does occur, pin 6 briefly goes high.

Converting the change in level at the output of IC<sub>5a</sub> into a usable optical indication is not too difficult. The design basis was to make a (red) LED (D<sub>3</sub>) light for about one second if two or more consecutive samples reach peak value. Time constant R<sub>4</sub>-C<sub>8</sub> averages a number of samples, while the discharge time of C<sub>8</sub>, determined by R<sub>5</sub>, results in an afterglow of about one second. The potential across C<sub>8</sub> is buffered by IC<sub>2a</sub>. The indication

3

Figure 3. Timing diagram of the most important signals in the indicator.



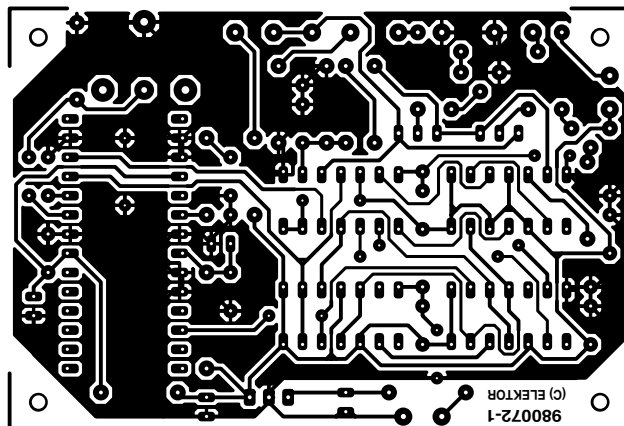
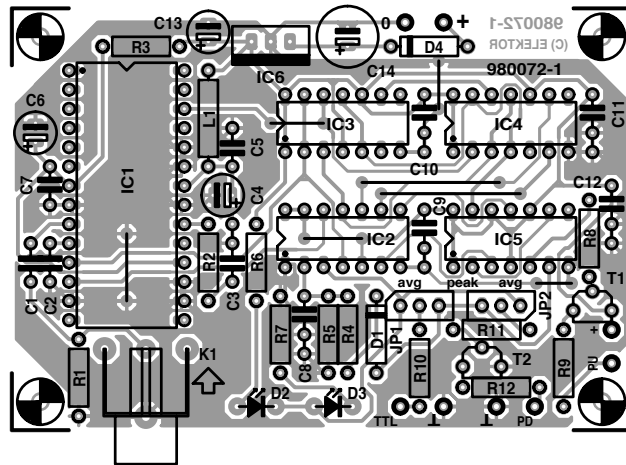
980072 - 13

becomes much clearer by the addition of a second (green) LED (D<sub>2</sub>). The light-up behaviour of this diode is the

opposite of that of D<sub>3</sub>, so that when clipping occurs there is a distinctive change of colour.

Figure 4. The printed-circuit board for the indicator makes construction child's play.

4



Parts list

Resistors:

- R<sub>1</sub> = 75 Ω
- R<sub>2</sub>, R<sub>7</sub> = 1 kΩ
- R<sub>3</sub> = 4.7 Ω
- R<sub>4</sub>, R<sub>10</sub> = 220 Ω
- R<sub>5</sub> = 10 MΩ
- R<sub>6</sub> = 560 Ω
- R<sub>8</sub>, R<sub>11</sub> = 47 kΩ
- R<sub>9</sub>, R<sub>12</sub> = 100 Ω

Capacitors:

- C<sub>1</sub>, C<sub>2</sub> = 0.01 μF, ceramic
- C<sub>3</sub> = 0.047 μF
- C<sub>4</sub>, C<sub>6</sub> = 10 μF, 63 V, radial
- C<sub>5</sub>, C<sub>7</sub> = 0.047 μF, ceramic
- C<sub>8</sub>-C<sub>12</sub> = 0.1 μF
- C<sub>13</sub> = 4.7 μF, 63 V, radial
- C<sub>14</sub> = 220 μF, 25 V, radial

Semiconductors:

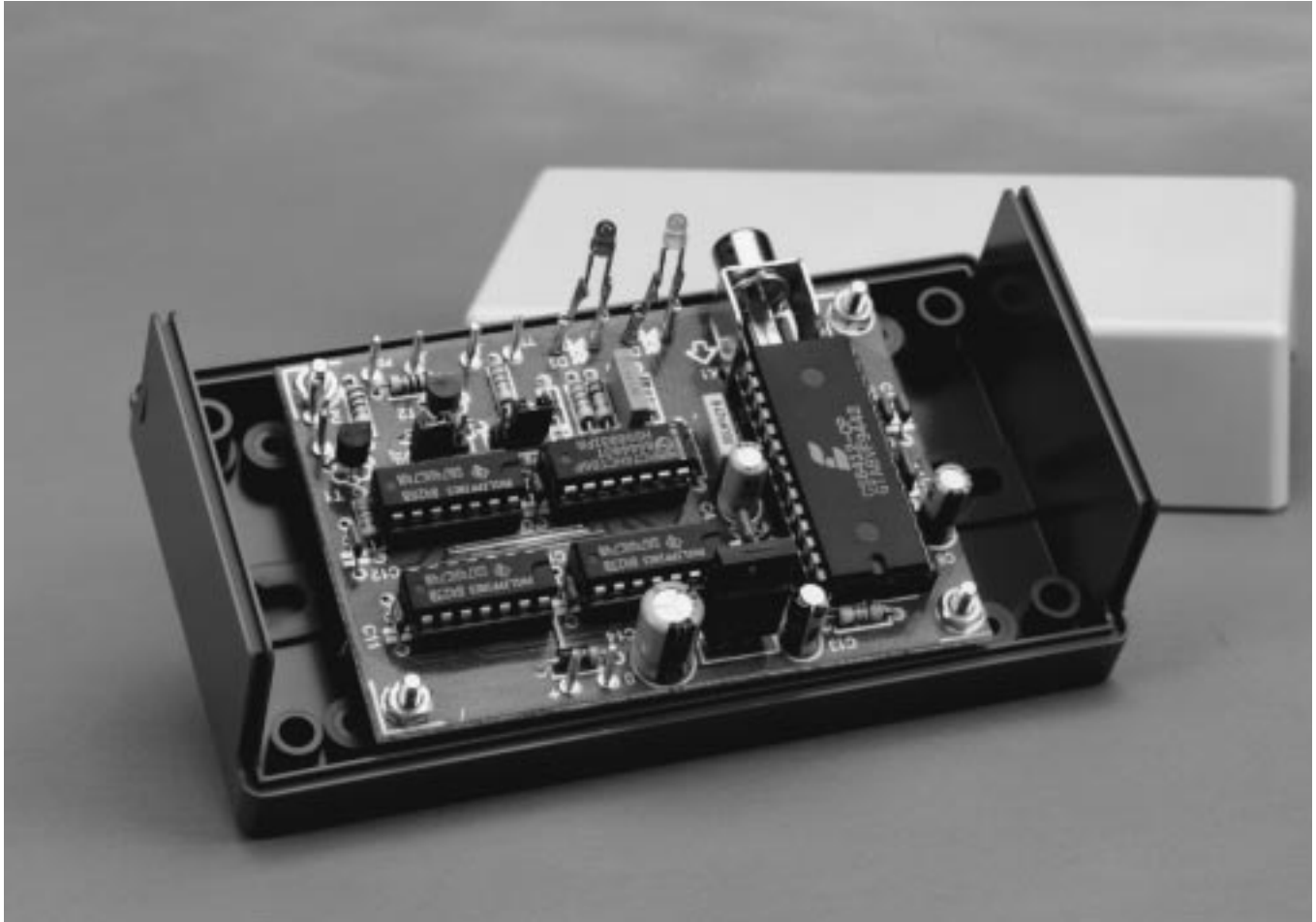
- D<sub>1</sub> = BAT82
- D<sub>2</sub> = LED, green, high efficiency
- D<sub>3</sub> = LED, red, high efficiency
- D<sub>4</sub> = 1N4002
- T<sub>1</sub> = BC557B
- T<sub>2</sub> = BC547B

Integrated circuits:

- IC<sub>1</sub> = CS8412 (Crystal Semiconductor)
- IC<sub>2</sub> = 74HCT86
- IC<sub>3</sub>, IC<sub>4</sub>, IC<sub>5</sub> = 74HC74
- IC<sub>6</sub> = 7805

Miscellaneous:

- L<sub>1</sub> = choke 47 μH
- JP<sub>1</sub>, JP<sub>2</sub> = 3-way, 2.54 mm pin strip and pin jumper (Maplin)
- K<sub>1</sub> = audio connector (male) for board mounting
- Enclosure 120 × 65 × 41 mm (L × W × H), e.g., Bopla 430 (available from Phoenix 01296 398355)
- PCB Order no. 980072 (see Readers Services towards the end of this issue)



**Figure 5. Photograph of the completed prototype indicator board.**

### COUNTER OPTION

As mentioned earlier, there is provision for linking a counter module to the indicator to show the number of times that clipping has occurred over a given period. There are three outputs: TTL, pull-down (PD), and pull-up (PU), so that almost any current type of module can be used.

Owing to the averaging by  $R_4$ - $C_8$ , the output remains active even when brief interruptions occur. If, however, the output of  $IC_5$  is used, count pulses are obtained for all discrete samples or strings of them. Both facilities may be used thanks to  $JP_1$  and  $JP_2$ . This arrangement gives a choice at the TTL or PD output of either an averaged count of the number of times clipping has occurred or a count giving the peak value.

In practice, peak counting may be a little too severe, since normally nothing much happens when the peak sig-

nals just reach the 0 dB level. The averaged count is a more realistic measure of the number of clipping occurrences. A drawback of the averaged count is that the toggling of  $IC_{2a}$  may cause high-frequency pulses that may adversely affect fast counter modules. However, most modern modules are immune to these pulses and in any case the risk can be removed by connecting a  $1\ \mu\text{F}$  capacitor across the counter input.

### CONSTRUCTION

The indicator is best built on the PCB shown in **Figure 4**. Populating the board with reference to the components list and the circuit diagram should not present any undue difficulties. Sockets should be used for the ICs. Mind the the polarity of the electrolytic capacitors and diodes. Note that  $D_1$  must be of the type specified

in view of the permissible leakage current.

Since the circuit provides for a 5 V regulator,  $IC_6$ , a mains adaptor with an output of not less than 8 V may be used as power source. The circuit draws a current of about 25 mA. This low current also facilitates the use of a 9 V battery if portable use is desired. A dry battery will give some 10 hours operation.

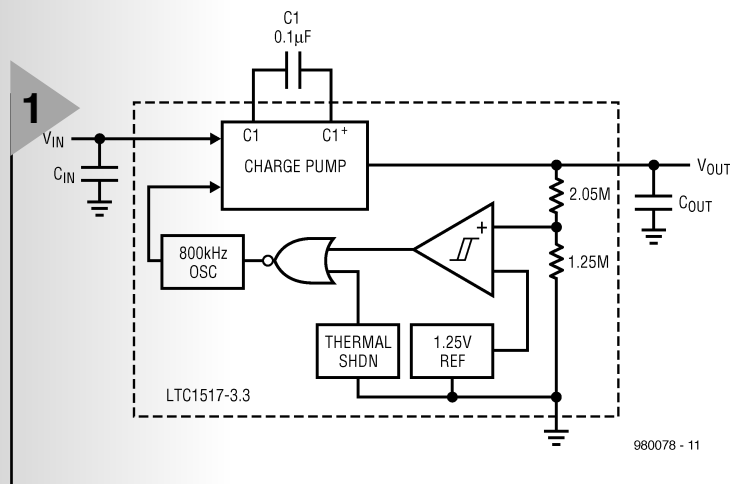
For portable use it is, of course, essential that the circuit is housed in a small, neat enclosure such as that specified.

[980072]



# compact 3.3 V charge pump converter

*in 5-pin SOT-23 package*



**Figure 1. Block diagram of the LTC1517-3.3. Capacitor C<sub>1</sub>, which forms part of the charge pump, is the heart of the circuit.**

As more and more circuits are powered by battery, there is a growing need for voltage converters that can derive a stable 3.3 V supply from a wide range of input voltages. This need may be met by Linear Technology's LTC1517-3.3 and LT1517-5 d.c.–d.c. converters

**GENERAL DESCRIPTION**

The LTC<sup>®</sup>1517-3.3 is a micropower charge pump d.c.–d.c. converter that produces a regulated 3.3 V output from an input voltage range of 2–4.4 V. Extremely low operating current (typically 6 µA with no load) and low external parts count (one 0.1 µF flying capacitor and two small bypass capacitors at input and output) make the part ideally suited for small, light-load, battery-powered applications. The total printed-circuit board area of the application circuit in **Figure 2** is only 29 mm<sup>2</sup>.

The LTC1517-3.3 operates as a burst-mode™ switched-capacitor doubler to produce a regulated output. It has thermal shutdown capability and can survive a continuous short-circuit between output and ground. The device is available in a 5-pin SOT-23 package.

With an input voltage of 2 V and an output current of 0.1–10 mA, the efficiency of the LTC1517-3.3 is 80%.

There is also a 5 V variant of the IC: the LTC1517-5. This IC provides a regulated output of 5 V from an input voltage range of 2.7–5 V. The maximum output current is 20 mA.

<sup>®</sup> LTC and LT are registered trademarks of Linear Technology Corporation.  
<sup>™</sup> Burst Mode is a trademark of Linear Technology Corporation.

**TECHNICAL DESCRIPTION**

The block diagram of the LTC1517-3.3 is shown in Figure 1. The IC uses a switched-capacitor charge pump to boost  $V_{IN}$  to a regulated output of  $3.3\text{ V} \pm 4\%$ . It achieves regulation by sensing the output voltage through an internal resistor divider and enabling the charge pump when the divided output drops below the comparator's lower trip point, which is set by  $V_{REF}$ .

When the charge pump is enabled, a 2-phase non-overlapping clock controls the internal charge pump switches. Flying capacitor  $C_1$  is charged to  $V_{IN}$  on phase 1 of the clock. On phase 2 of the clock,  $C_1$  is in series with the input and connected to the output via an internal switch. This sequence of charging and discharging the flying capacitor occurs at a free-running frequency of 800 kHz (typical) and continues until the divided output voltage reaches the upper trip point of the comparator.

Once the output is back in regulation, the output is back in regulation, the charge pump is disabled. This method of bursting the charge pump on and off enables the LTC1517-3.3 to achieve a high efficiency at extremely low output loads.

A typical application diagram is shown in Figure 2.

**CAPACITOR SELECTION**

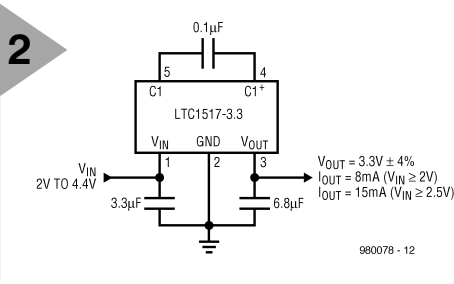
For best performance, it is recommended that low ESR (equivalent series resistance) capacitors be used for both  $C_{IN}$  and  $C_{OUT}$  to reduce noise and ripple. The  $C_{IN}$  and  $C_{OUT}$  capacitors should be either ceramic or tantalum and have a capacitance of not less than  $3.3\ \mu\text{F}$ . Ceramic capacitors will provide the smallest size for a given capacitance.

If the input source impedance is very low ( $< 0.5\ \Omega$ ),  $C_{IN}$  may not be needed.

Ceramic capacitors with values of  $0.1\ \mu\text{F}$  or  $0.22\ \mu\text{F}$  are recommended for flying capacitor  $C_1$ . Lower values may be used in low  $I_{OUT}$  applications.

**OUTPUT RIPPLE**

Normal operation of the LTC1517-3.3 produces voltage ripple on the  $V_{OUT}$  pin. This output voltage ripple is needed for the parts to regulate. Low frequency ripple exists owing to the hysteresis in the sense comparator and



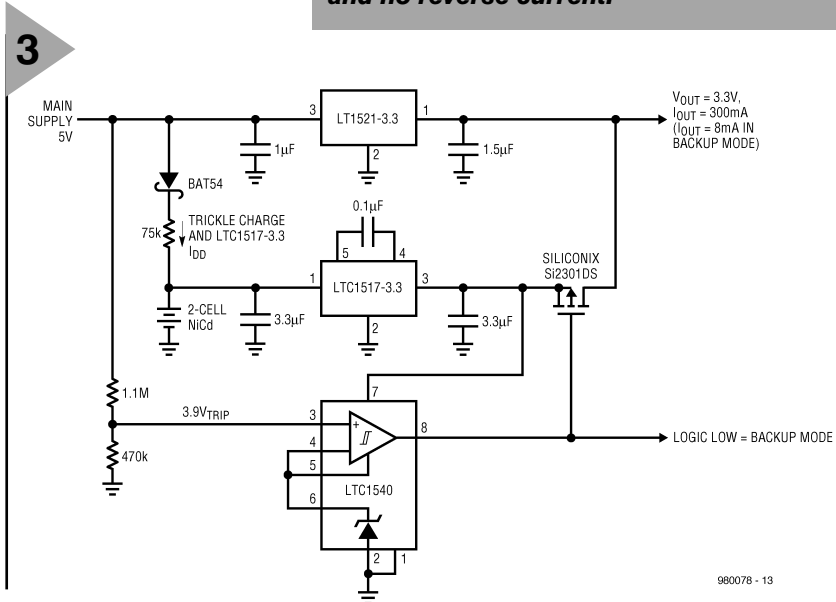
**Figure 2. Diagram of the standard application of the LTC1517-3.3. Apart from the IC, only three capacitors are needed.**

propagation delays in the charge pump enable/disable circuits. High frequency ripple is also present, mainly from the equivalent series resistance (ESR) of the output capacitor.

Typical output ripple with  $V_{IN} = 2.5\text{ V}$  under maximum load conditions is 75 mV peak-to-peak with a low ESR output capacitor of  $3.3\ \mu\text{F}$  (minimum recommended  $C_{OUT}$ ). For applications

temperature exceeds about  $160\ ^\circ\text{C}$ . The charge pump is re-enabled when the junction temperature drops to about  $145\ ^\circ\text{C}$ . The LTC1517-3.3 will cycle in and out of thermal shutdown indefinitely without latchup or damage until the short-circuit is removed from the output.

**Figure 3. Diagram of a low-power battery backup supply with automatic switchover and no reverse current.**



requiring  $V_{IN}$  to exceed  $3.3\text{ V}$  or for applications requiring less than 75 mV peak-to-peak ripple, a  $6.8\text{--}10\ \mu\text{F}$   $C_{OUT}$  capacitor is recommended. Slight further decreases in output ripple can be achieved by using  $C_{OUT}$  capacitors larger than  $10\ \mu\text{F}$ .

**PROTECTION CIRCUITS**

During output short-circuit conditions, the LTC1517-3.3 will draw a current of 40–150 mA from the input, causing a rise in junction temperature. On-chip thermal shutdown circuitry disables the charge pump when the junction

**ANOTHER APPLICATION**

The diagram in Figure 3 shows an application of the LTC1517-3.3 that illustrates what an important role the IC can play in a power supply with integral buffer circuit. When in this circuit the input voltage fails, the logic circuits are automatically switched to the backup mode. In that mode, the MOSFET conducts and the LTC1517-3.3 ensures a continued  $V_{OUT}$  derived from two NiCd buffer batteries.

[980078]

# refrigerator economizer

## *for older models*

If your refrigerator is still one of the old types with an 'automatic defrost' system, this economizer can help you reduce your electricity bills. These old models are provided with a small heating element to prevent icing up, but in general this is at best inefficient and adds unnecessary kilowatt-hours. The circuit described in this article limits the number of defrost cycles in such a way that your electricity bills are reduced without an increase in ice formation.



It is a fact of nature that humidity tends to condense on the coldest part of a space (think of single-glazed windows in cold weather). This also happens in a refrigerator. The coldest spot in this is easily recognized by the formation of ice. This icing hinders the heat conversion and so lowers the efficiency of the system. In modern fridges the on and off switching of the compressor motor is timed so that ice is never a problem: it can defrost naturally, i.e., without a heating element. Many older models, however, are provided with an 'automatic defrost' facility, which consists of a small heating element. As soon as the compressor motor of such a refrigerator is switched off, the heating element is switched on

to melt the ice.

This is, of course, an inefficient system: first the air is cooled and then it is heated.

Since the heating element invariably is on for longer than necessary, it is possible in many cases to lower the energy consumption of the fridge without affecting the efficacy of the defrost facility.

### **FIRST ...**

Before you start building the economizer, make sure that it can be used with your fridge.

A diagram of the electrical circuit of a typical fridge is shown in **Figure 1**. A heating element, A, with an electrical

resistance of about three kilohms is in series with the compressor motor, C. Thermostat B short-circuits the heating element when the compressor is to operate. This setup is shunted by door switch D in series with the interior light.

A multimeter is needed to find out whether your refrigerator is suitable for use with the economizer.

- Unplug the refrigerator cable from the mains socket outlet.
- Set the thermostat control to zero.
- Make sure that the door of the refrigerator is closed.
- Measure the resistance between the L(ive) and N(eutral) pins of the mains socket terminating the refrigerator cable. The resistance should be about 3 k $\Omega$ ; if it is much more, exceeding 1 M $\Omega$ , the refrigerator has no heating element and the economizer cannot be used.

### POWER REQUIREMENTS

A refrigerator with an auto defrost facility, and connected to the mains supply, needs power at three different levels.

- When the compressor motor is working: about 150 watts (W).
- When the compressor motor is off and the heating element is on: about 15 watts (W).
- When the compressor motor is off and the heating element and the interior light are on: about 30 watts (W).

When the refrigerator is disconnected from the mains supply by the economizer, it may happen that:

1. The refrigerator needs power at a level of more than 15 W. This may be because the thermostat wants to switch on the compressor motor. In this case, the economizer must reconnect the refrigerator to the mains supply.
2. The refrigerator needs power at a level of less than 30 W. This indicates that only the heating element is required to be on. The economizer then does not reconnect the refrigerator to the mains supply.

### CIRCUIT DESCRIPTION

The circuit diagram of the economizer is shown in **Figure 2**. When the refrigerator is connected to the mains supply, the current drain is measured by the potential difference, p.d., across resistor R<sub>9</sub>. If this is in accord with the current drawn by the heating element and the interior light, the output of op amp IC<sub>1b</sub> is low during part of the positive half-cycle of the voltage. If the current is considerably larger since the compressor motor is on, op amp IC<sub>1c</sub> is on for part of the positive half-cycle of

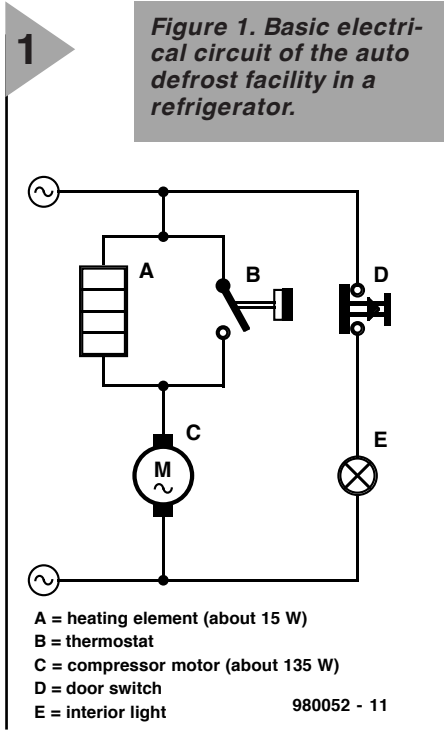
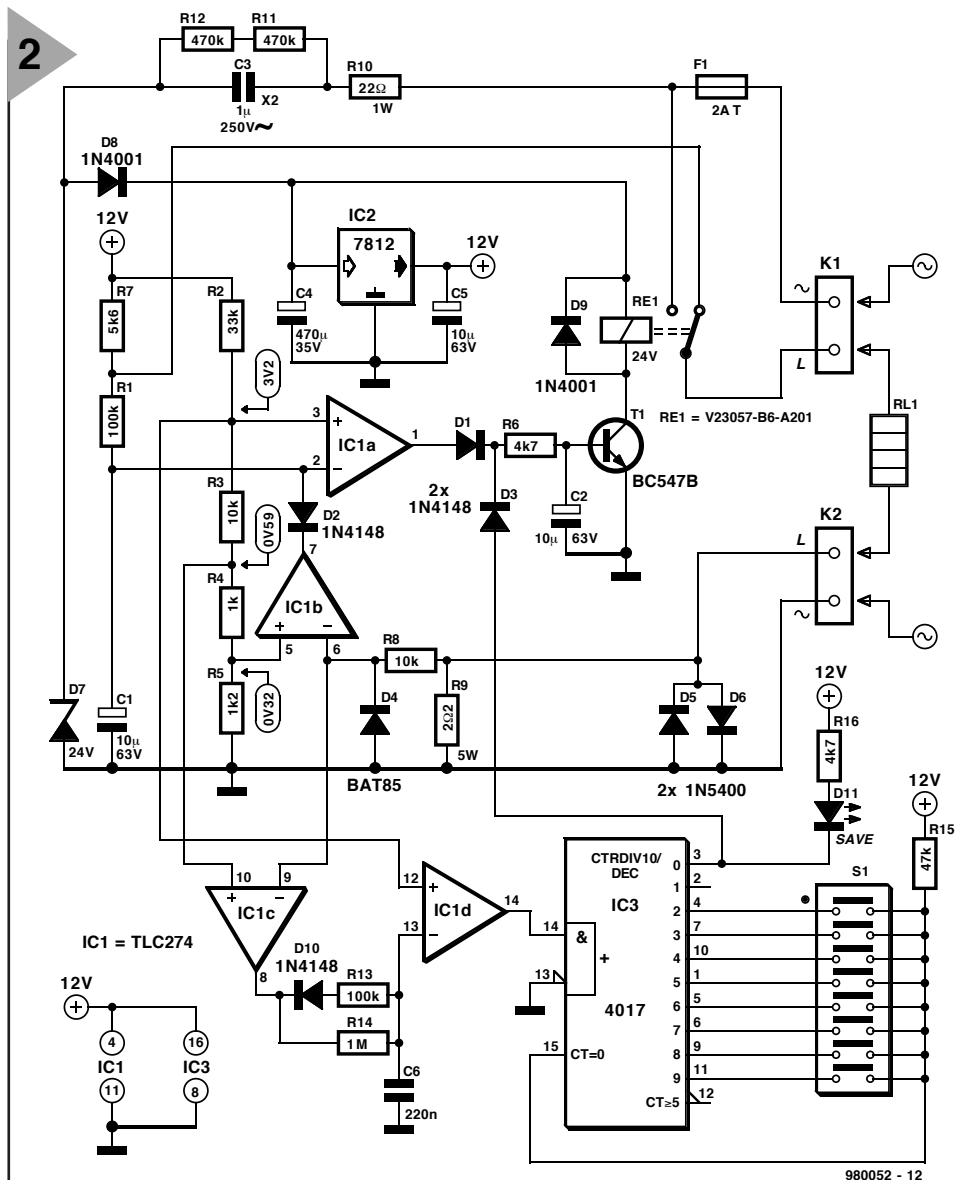
the mains voltage.

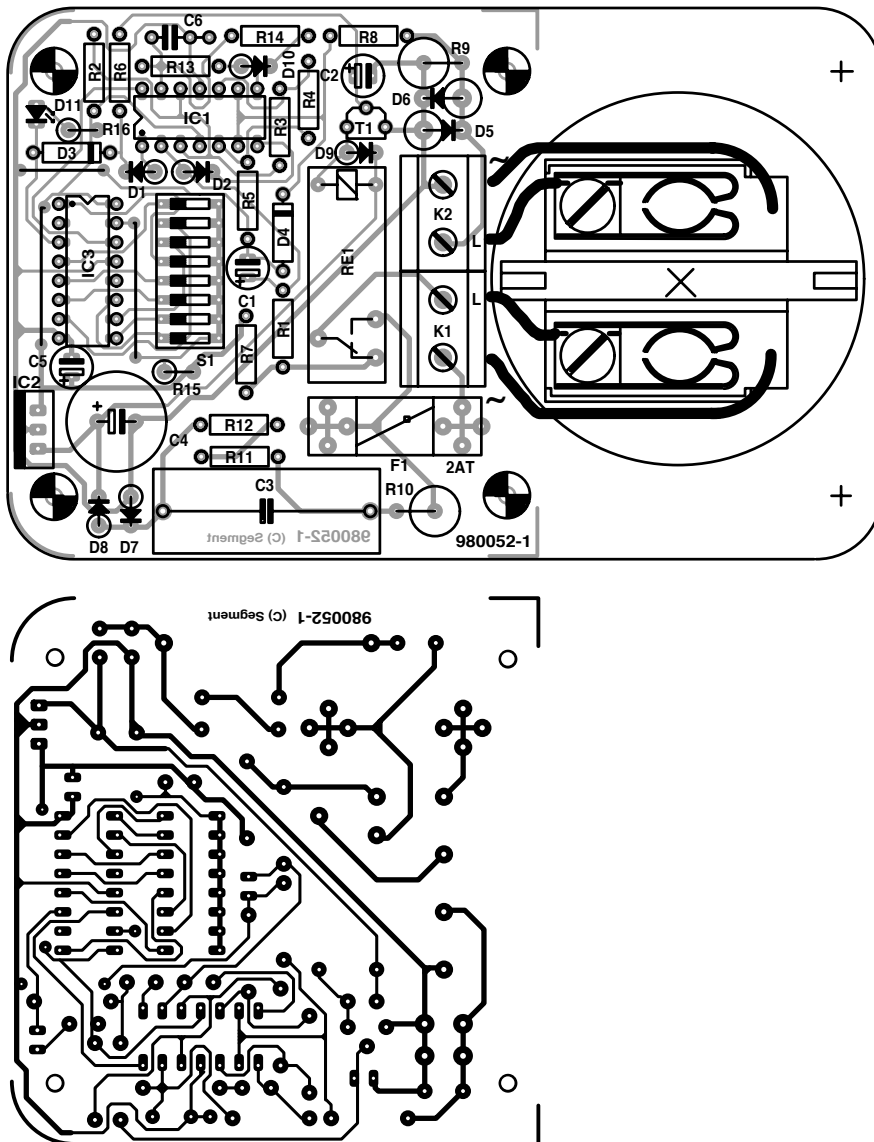
In the quiescent state, when relay Re<sub>1</sub> is not energized, the refrigerator is linked to the 12 V supply line on the economizer via resistor R<sub>7</sub>. The fridge and this resistor then create a potential divider, which provides a simple means of detecting whether the interior light or the compressor motor is switched on.

When the resistance of the refrigerator becomes low, the refrigerator is switched on by IC<sub>1a</sub> via T<sub>1</sub> and relay Re<sub>1</sub>. This results in a p.d. of more than 320 mV across R<sub>9</sub>. The relay remains energized until the load diminishes (interior light or compressor motor off).

When the compressor motor works, the p.d. across R<sub>9</sub> is large enough to

**Figure 2. Circuit diagram of the economizer. It is linked directly to the mains supply, so that great care must be taken in testing it.**





**Figure 3. The printed-circuit board for the economizer is available ready made – see Readers Services towards the end of this issue.**

drive IC<sub>1c</sub> on in the rhythm of the mains voltage. The consequent negative pulses at the output of the op amp cause capacitor C<sub>6</sub> to be discharged via D<sub>10</sub>. The trailing edge is inverted and enhanced by IC<sub>1d</sub>. In this way, the state of counter IC<sub>3</sub> is then increased by one for every trailing edge. When the compressor motor stops, C<sub>6</sub> is recharged via R<sub>14</sub>.

When the state of counter IC<sub>3</sub> is zero, that is, when output Q<sub>0</sub> is high, the relay remains energized. Every time the compressor motor is working, the next output of the IC goes high. When the output whose DIP switch is closed becomes high, the counter is reset. It will be seen that the setting of the switch determines after how many times the compressor motor has been on a defrost cycle is initiated. Since at least one 'motor on' cycle must be ignored (otherwise there would be no

economizing), output Q<sub>1</sub> is not linked to a DIP switch. Diode D<sub>11</sub> indicates when the heating element is not on.

Diodes D<sub>1</sub> and D<sub>3</sub>, in conjunction with T<sub>1</sub> and network R<sub>6</sub>-C<sub>6</sub>, form an OR gate, so that T<sub>1</sub> may be switched on by IC<sub>1a</sub> or IC<sub>3</sub>.

A 24 V supply voltage is derived from the mains voltage by network R<sub>10-12</sub>-C<sub>3</sub>. This supply line is stabilized by zener diode D<sub>7</sub>, and subsequently dropped to 12 V by regulator IC<sub>2</sub>. Various reference voltages are derived from the 12 V line by potential divider R<sub>2</sub>-R<sub>5</sub>.

Diodes D<sub>5</sub> and D<sub>6</sub> protect op amp against high voltages at the input and also limit the dissipation in R<sub>9</sub>.

#### CONSTRUCTION

**WARNING.** Constructors in the United Kingdom must ensure that the circuit earth is NOT linked to the mains earth which, by Regulation, must be permanently connected to the refrigerator. If the two earths were linked, the Neutral line would be short-circuited to the mains earth.

**CAUTION.** It will be noted that the

**economizer circuit works directly from the mains supply, which means that it must be housed in a double-insulated enclosure.**

The economizer is best built on the printed-circuit board in **Figure 3**, which is available ready made – see Readers Services towards the end of this issue. Depending on the enclosure used, it may be necessary to round the corners of the board with a file as shown. **Figure 4** shows the prototype board in its enclosure.

Solder all components on the board as indicated, but do not yet fit IC<sub>1</sub> and IC<sub>3</sub> into their socket. Connect the finished board to the mains supply and measure the voltages at the points indicated in Figure 2. *Take great care since the full mains voltage is present on the board. Use an insulated workbench if at all possible.* It is convenient to leave one probe of the multimeter permanently connected to the circuit earth (NOT the mains earth!).

When all voltages correspond with those indicated on the circuit diagram, disconnect the circuit from the mains.

#### Parts list

##### Resistors:

R<sub>1</sub>, R<sub>13</sub> = 100 kΩ  
 R<sub>2</sub> = 33 kΩ  
 R<sub>3</sub>, R<sub>8</sub> = 10 kΩ  
 R<sub>4</sub> = 1 kΩ  
 R<sub>5</sub> = 1.2 kΩ  
 R<sub>6</sub>, R<sub>16</sub> = 4.7 kΩ  
 R<sub>7</sub> = 5.6 kΩ  
 R<sub>9</sub> = 2.2 Ω, 5 W  
 R<sub>10</sub> = 22 Ω, 1 W  
 R<sub>11</sub>, R<sub>12</sub> = 470 kΩ  
 R<sub>14</sub> = 1 MΩ  
 R<sub>15</sub> = 47 kΩ

##### Capacitors:

C<sub>1</sub>, C<sub>2</sub>, C<sub>5</sub> = 10 μF, 63 V, radial  
 C<sub>3</sub> = 1 μF, 250 V a.c., Class X2  
 C<sub>4</sub> = 470 μF, 35 V, radial  
 C<sub>6</sub> = 0.22 μF

##### Semiconductors:

D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, D<sub>10</sub> = 1N4148  
 D<sub>4</sub> = BAT85  
 D<sub>5</sub>, D<sub>6</sub> = 1N5400  
 D<sub>7</sub> = LED, 5 mm, high efficiency  
 T<sub>1</sub> = BC547B

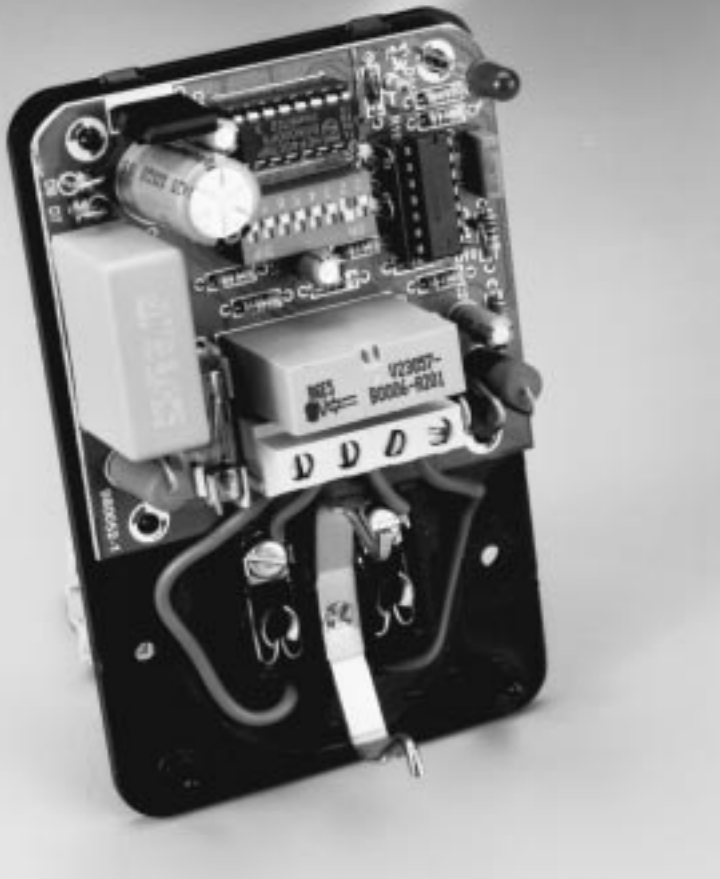
##### Integrated circuits:

IC<sub>1</sub> = TLC274CN  
 IC<sub>2</sub> = 7812  
 IC<sub>3</sub> = 4017

##### Miscellaneous:

K<sub>1</sub>, K<sub>2</sub> = 2-way terminal block, pitch 7.5 mm  
 S<sub>1</sub> = octal DIP switch  
 Re<sub>1</sub> = 24 V relay for board mounting  
 F<sub>1</sub> = fuse, 2 A, slow  
 Enclosure as appropriate (see text)  
 PCB Order no. 980052 (see Readers Services towards end of this issue)

4



**Figure 4. Photograph of the finished board in its enclosure with the lid removed. Great care must be taken when testing it.**

the thermostat control, when the diode should light. When this is so, the remainder of the economizer may be checked. When the refrigerator door is opened, the interior light must come on. When the door is being closed, the click of the relay changing state should be heard clearly.

It is not possible to say which setting of S1 is the most propitious for each and every case. As a guide, open all switches so that the counter is reset, and close S1.8. If this results in icing up after a while, the economizing action is too drastic. Open S1.8 and close S1.7. If this still leads to icing up, open S1.7. and close S1.6. and so on until there is no icing up.

[980052]

Open all DIP switches, except S<sub>1.1</sub>. Insert IC<sub>1</sub> and IC<sub>3</sub> into their respective sockets. Connect the refrigerator to the relevant terminals and reconnect the

circuit to the mains supply. Briefly open and close S<sub>1.1</sub>.

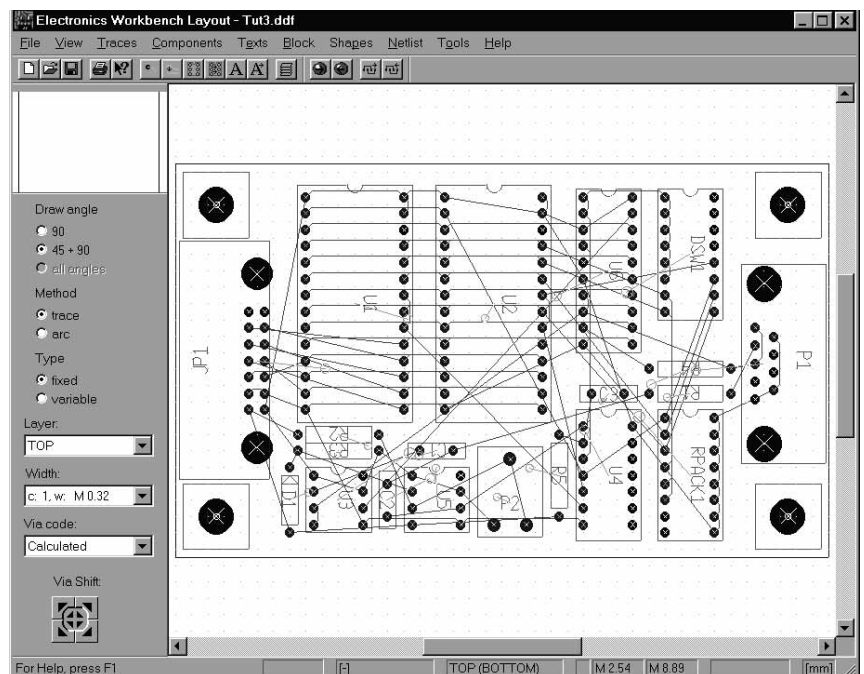
When all is well, D11 remains off. Turn on the compressor motor with

ELEKTOR		
240V~	50Hz	
No. 980052		
F = 2A T max. 220VA		

## Electronics Workbench Layout

*simulation program starts to design PCB layouts*

Electronics Workbench (EWB), the user-friendly simulation program, has been extended with a new, powerful, program for the design of printed circuit boards. The new program, like the basic simulation software, is marked by ease of control. Circuit diagrams from EWB may be exported to the PCB layout program without any trouble whatsoever. Next, the components are simply dragged to the desired positions on the board.



Many electronics enthusiasts will agree that by virtue of its simple user interface and clearly structured menus, 'Electronics Workbench' paved the way towards simulation of analogue and digital circuits using the computer. Despite their user-friendly setup, the current versions of EWB offer the same functionality as many simulation programs aimed at the professional market. These days, a clear trend becomes visible of suppliers of simulation software and PCB layout programs extending the functionality of their products. The Canadian company Interactive Image Technologies, too, has been looking for ways to 'widen' its product in an attempt to enable designers to cover the largest possible range from circuit design to the final PCB layout phase, all using the computer, of course. But how does

one extend a program for simulation of electronic circuits? Well, the most likely candidate is a circuit board layout utility. The new program 'EWB Layout' we received for reviewing is the result of close co-operation between Interactive and Ultimate Technology. Users of 'Ultiboard' software will not fail to notice lots of similarities between their program and the fledgling from Interactive.

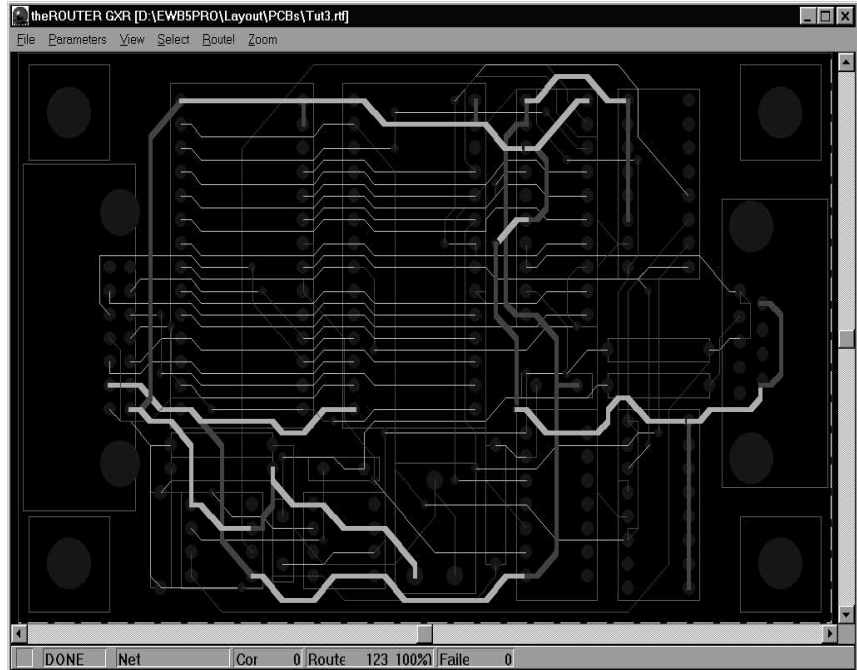
Interactive has succeeded in integrating its new PCB layout program into the EWB suite. Having drawn the circuit diagram and put it through the circuit simulation phase, you are ready to export the lot to the PCB design program. You are instantly presented with a board. Beside it appear all components that make up the simulated circuit, and their interconnections. All you have to do is drag these compo-

nents to the desired position on the board, and then leave the real work to the autorouter. In this way, even inexperienced users can make a PCB layout in no time at all. We put EWB Layout through its paces by presenting it to an unsuspecting person without any previous experience in PCB designing. In less than half an hour, he came up with a circuit diagram and a matching PCB design!

Of course, the layout program has much more to offer than the rather simple operations mentioned above. The program contains a library with over 4,000 footprints, and recognises the right footprint for all 10,000 components stored by EWB. With the aid of the internal editor, the user is capable of creating new component shapes, or modify existing shapes. Multilayers are possible up to 32 layers. Two interactive autorouters provide formidable assistance when it comes to dividing the PCB tracks. All sorts of PCB shapes are allowed, up to a size of 50x50". Some other features that may be mentioned here: interactive editing, real time design rule check, track density histograms, blind and buried via's, re-route while move, and user-defined pads.

The program supports a number of plotters and printers, and is capable of saving files in foreign formats like DXF, Gerber and Excellon.

EWB Layout only runs on Windows 95 or NT PCs. Although Interactive indicates a 486 PC with 8 Mbytes



of RAM as a minimum requirement, it would seem unwise to use anything older or slower than a 200 MHz Pentium, if only to be able to work comfortably.

EWB Layout comes in three versions: *EWB Layout Professional* with a maximum of 2,000 pins (price £995); *EWB Layout Power Professional* supporting unlimited pins (price £1995) — both intended to complement EWB EDA or PRO — and the low-cost version for private use called *EWB Layout Personal Edition* (price £299). The latter

version has slightly reduced functionality (fewer footprints, max. 500 pins, and only one autorouter). These three versions are shortly to be complemented with an Educational version. All prices are exclusive of VAT.

(985065-1)

In the UK and Ireland, contact Adept Scientific plc, 6 Business Centre West, Avenue One, Letchworth, Hertfordshire SG6 2HB. Tel: (01462) 480055, fax: (01462) 480213. Email: ewb@adeptscience.co.uk. Internet: <http://www.adeptscience.co.uk>.





CS8412

# ELEKTOR ELECTRONICS

**DATASHEET 10/98**
**Integrated Circuits  
Special Applications, Audio**
**CS8412  
Digital Audio Interface Receiver**
**Manufacturer**

Cirrus Logic, Inc. Crystal Semiconductor Products Division, P.O. Box 17847, Austin, Texas 78760, U.S.A. Homepage: www.crystal.com.

**Features**

- Monolithic CMOS receiver
- Low-jitter, on-chip clock recovery, 256x Fs output clock provided
- Supports: AES/EBU, IEC958, S/PDIF, & EIAJ CP-340 professional and consumer formats
- Extensive error reporting
  - repeat last sample on error option
- On-chip RS422 line receiver

**Application Example**

Digital Clipping Indicator, *Elektor Electronics* October 1998.

**Description**

The CS8412 is a monolithic CMOS device which receives and decodes audio data according to the AES/EBU, IEC958, S/PDIF & EIAJ CP-340 interface standards. The CS8412 receives data from a transmission line, recovers the clock and synchronisation signals, and de-multiplexes the audio and digital data. Differential or single-ended inputs can be decoded.

The CS8412 de-multiplexes the channel, user, and validity data directly to serial output pins with dedicated output pins for the most important channel status bits. Audio data is output through a configurable serial port that supports 14 formats. The channel status and user data have their own serial pins and the validity flag is OR'ed with the ERF flag to provide a single pin, VERF, indicating that the audio output may not be valid. This pin may be used by interpolation filters that provide error correction.

**Pin Descriptions**
**Power Supply Connections**

**VD+** **Positive Digital Power, pin 7.**  
Positive supply for the digital section. Nominally

+5 volts.

**VA+** **Positive Analog Power Supply, pin 22.**  
Positive supply for the analogue section. Nominally +5 volts.

**DGND** **Digital Ground, pin 8.**  
Ground for the digital section. DGND should be connected to the same ground as AGND.

**AGND** **Analog Ground, pin 11.**  
Ground for the analogue section. AGND should be connected to the same ground as DGND.

**Audio Output Interface**

**SCK** **Serial Clock, pin 12.**  
Serial clock for SDATA pin which can be configured (via the M0, M1, M2 and M3 pins) as an input or output, and can sample data on the rising or falling edge. As an output, SCK will generate 32 clocks for every audio sample. As an input, 32 SCK periods per audio sample must be provided in all normal modes.

**FSYNC** **Frame Sync, pin 11.**  
Delineates the serial data and may indicate the particular channel, left or right, and may be an input or output. The format is based on M0, M1, M2 and M3 pins.

**SDATA** **Serial Data, pin 26.**  
Audio data serial output pin.

**M0, M1, M2, M3** **Serial Port Mode Select, pins 23, 24, 18, 17.**  
Selects the format of FSYNC and the sample edge of SCK with respect to SDATA. M3 selects between eight normal modes (M3=0) and six special modes (M3=1).

**Control Pins**

**VERF** **Validity + Error Flag, pin 28.**  
A logical OR'ing of the validity bit from the received data and the error flag. May be used by interpolation filters to interpolate through errors.

AD22100

# ELEKTOR ELECTRONICS

**DATASHEET 10/98**
**Integrated Circuits  
A-D Converters**
**AD22100\*  
Voltage Output Temperature Sensor with Signal Conditioning**
**Manufacturer**

Analog Devices, One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A. Homepage: www.analog.com

**Features**

200°C Temperature Span  
Accuracy better than  $\pm 2\%$  of Full Scale  
Linearity better than  $\pm 1\%$  of Full Scale  
Temperature Coefficient of 22.5 mV/°C  
Output Proportional to Temperature  $\times V +$   
Single Supply Operation  
Reverse Voltage Protection  
Minimal Self Heating  
High Level, Low Impedance Output

**Applications**

HVAC Systems  
System Temperature Compensation  
Board Level Temperature Sensing  
Electronic Thermostats

**Markets**

Industrial Process Control  
Instrumentation  
Automotive

**Application Example**

PLC-87 Board, *Elektor Electronics* October 1998.

**General Description**

The AD22100 is a monolithic temperature sensor with on-chip signal conditioning. It can be operated over the temperature range  $-50^\circ\text{C}$  to  $+150^\circ\text{C}$ , making it ideal for use in numerous HVAC, instrumentation and automotive applications.

The signal conditioning eliminates the need for any trimming, buffering or linearization circuitry, greatly simplifying the system design and reducing the overall system cost.

The output voltage is proportional to the temperature times the supply voltage (ratiometric). The output

swings from 0.25 V at  $-50^\circ\text{C}$  to +4.75 V at  $+150^\circ\text{C}$  using a single +5.0 V supply.

Due to its ratiometric nature, the AD22100 offers a cost-effective solution when interfacing to an analogue-to-digital converter. This is accomplished by using the ADC's +5 V power supply as a reference to both the ADC and the AD22100 (See Figure 2), eliminating the need for and cost of a precision reference.

\* Protected by U.S. Patent Nos. 5030849 and 5243319.

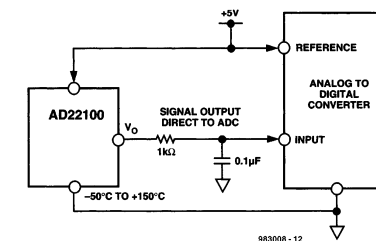


Figure 1. Simplified block diagram.

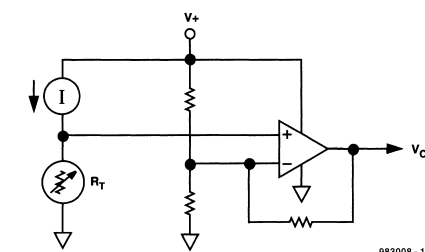
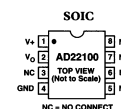
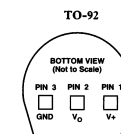


Figure 2. Application Circuit.



Pin Configurations  
TO-92  
SOIC

983008-13

**Ordering Guide**

Model/Grade	Guaranteed Temperature Range	Package Description	Package Option
AD221001 KT	0°C to 100°C	TO-92	TO-92
AD22100 KR	0°C to 100°C	SOIC	SO-8
AD22100 AT	-40°C to +85°C	TO-92	TO-92
AD22100 AR	-40°C to +85°C	SOIC	SO-8
AD22100 ST	-50°C to +150°C	TO-92	TO-92
AD22100 SR	-50°C to +150°C	SOIC	SO-8
AD22100 Chips	+25°C	N/A	N/A

 Specifications ( $T_A = +25^\circ\text{C}$  and  $V_+ = +4\text{V}$  to  $+6\text{V}$  unless otherwise noted)

Parameter	AD22100K			AD22100A			AD22100S			Units
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
TRANSFER FUNCTION	$V_{\text{OUT}} = (V_+/5\text{ V}) \times [1.375\text{ V} + (22.5\text{ mV}/^\circ\text{C}) \times T_A]$									
TEMPERATURE COEFFICIENT	$(V_+/5\text{ V}) \times 22.5$									mV/°C

**TOTAL ERROR**

Initial Error $T_A = +25^\circ\text{C}$		$\pm 0.5$	$\pm 2.0$		$\pm 1.0$	$\pm 2.0$		$\pm 1.0$	$\pm 2.0$	°C
Error over Temperature										
$T_A = T_{\text{MIN}}$		$\pm 0.75$	$\pm 2.0$		$\pm 2.0$	$\pm 3.7$		$\pm 3.0$	$\pm 4.0$	°C
$T_A = T_{\text{MAX}}$		$\pm 0.75$	$\pm 2.0$		$\pm 2.0$	$\pm 3.0$		$\pm 3.0$	$\pm 4.0$	°C

**Nonlinearity**

$T_A = T_{\text{MIN}}$ to $T_{\text{MAX}}$			0.5			0.5			0.5	% FS <sup>1</sup>
--	--	--	-----	--	--	-----	--	--	-----	-------------------

**OUTPUT CHARACTERISTICS**

Nominal Output Voltage										
$V_+ = 5.0\text{ V}$ , $T_A = 0^\circ\text{C}$		1.375								V
$V_+ = 5.0\text{ V}$ , $T_A = +100^\circ\text{C}$		3.625								V
$V_+ = 5.0\text{ V}$ , $T_A = -40^\circ\text{C}$					0.475					V
$V_+ = 5.0\text{ V}$ , $T_A = +85^\circ\text{C}$					3.288					V
$V_+ = 5.0\text{ V}$ , $T_A = -50^\circ\text{C}$								0.250		V
$V_+ = 5.0\text{ V}$ , $T_A = +150^\circ\text{C}$								4.750		V

**POWER SUPPLY**

Operating Voltage	+4.0	+5.0	+6.0	+4.0	+5.0	+6.0	+4.0	+5.0	+6.0	V
Quiescent Current		500	650		500	650		500	650	μA

**TEMPERATURE RANGE**

Guaranteed Temperature Range	0		+100	-40		+85	-50		+150	°C
Operating Temperature Range	-50		+150	-50		+150	-50		+150	°C

PACKAGE	TO-92, SOIC			TO-92, SOIC			TO-92, SOIC			
---------	-------------	--	--	-------------	--	--	-------------	--	--	--

<sup>1</sup> FS (Full Scale) is defined as that of the operating temperature range, -50°C to +150°C. The listed max. specification limit applies to the guaranteed temperature range. For example, the AD22100K has a nonlinearity of  $(0.5\%) \times (200^\circ\text{C}) = 1^\circ\text{C}$  over the guaranteed temperature range of 0°C to 100°C.

**U User Bit, pin 14.**  
Received user bit serial output port. FSYNC may be used to latch this bit externally.

**C Channel Status Output, pin 1.**  
Received channel status bit serial output port. FSYNC may be used to latch this bit externally.

**CBL Channel Status Block Start, pin 15.**  
The channel status block output is high for the first four bytes of channel status and low for the last 16 bytes.

**SEL Select, pin 16.**  
Control pin that selects either channel status information ( $\text{SEL}=1$ ) or error and frequency information ( $\text{SEL}=0$ ) to be displayed on six of the following pins.

**C0, Ca, Cb, Cc, Cd, Ce Channel Status Output Bits, pins 2-6, 27.**  
These pins are dual function with the 'C' bits selected when SEL is high. Channel status information is displayed for the channel selected by CS12. C0, which is channel status bit 0, defines professional ( $\text{C0}=0$ ) or consumer ( $\text{C0}=1$ ) mode and further controls the definition of the Ca-Ce pins. These pins are updated with the rising edge of CBL.

**CS12 Channel Select, pin 13.**  
This pin is also dual function and is selected by bringing SEL high. CS12 selects sub-frame 1 (when low) or sub-frame 2 (when high) to be displayed by channel status pins C0 and Ca through Ce.

**FCK Frequency Clock, pin 13.**  
Frequency clock input that is enabled by bringing SEL low. FCK is compared to the received clock frequency with the value displayed on F2 through F0. Nominal input value is 6.144 MHz.

**E0, E1, E2 Error Condition, pins 4-6.**  
Encoded error information is enabled by bringing SEL low. The error codes are prioritized and latched so that the error code displayed is the highest level of error since the last clearing of the error pins.

Clearing is accomplished by bringing SEL high for more than 8 MCK cycles.

**F0, F1, F2 Frequency Reporting Bits, pins 2-3, 27.**  
Encoded sample frequency information that is enabled by bringing SEL low. A proper clock on FCK must be input for at least two thirds of a channel status block for these pins to be valid. They are updated three times per block, starting at the block boundary.

**ERF Error Flag, pin 25.**  
Signals that an error has occurred while receiving the audio sample currently being read from the serial port. Three errors cause ERF to go high: a parity or biphas coding violation during the current sample, or an out of lock PLL receiver.

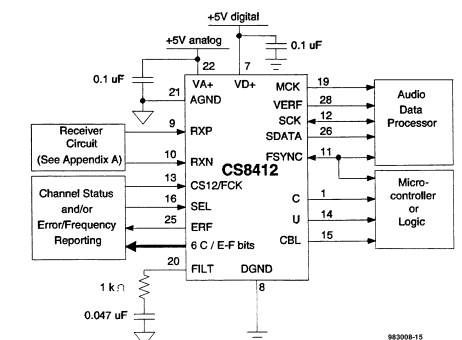
**Receiver Interface**

**RXP, RXN Differential Line Receivers, pins 9, 10.**  
RS422 compatible line drivers.

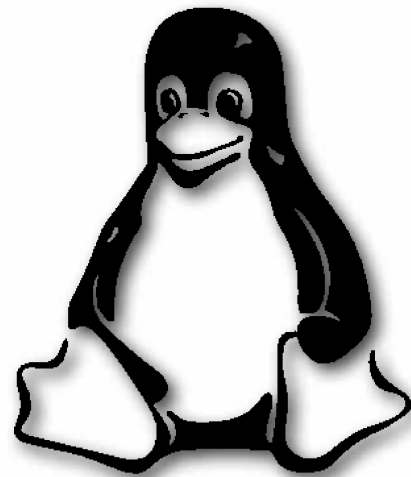
**Phase Locked Loop**

**MCK Master Clock, pin 19.**  
Low jitter clock output of 256 times the received sample frequency.

**FILT Filter, pin 20.**  
An external 1kΩ resistor and 0.047-μF capacitor are required from the FILT pin to analog ground.


**CS8412, Typical Connection Diagram**

Microsoft Windows looks poised to reign supreme as the operating system for PCs used at home and in the small office. Competition is weak, other manufacturers having given up or left the market after a short death struggle. And yet, there is hope. An operating system called Linux appears to be a good alternative for Windows. In stark contrast with Microsoft Windows, Linux is the fruit of own users.



# Linux — a Windows alternative?

## Red Hat Linux 5.1 with simplified installation

The rapid evolution of the personal computer (PC) over the past fifteen years or so was not just due to sensational hardware developments, but also to the availability of complex software. In this way, the PC slowly became the user-friendly machine for a galaxy of applications.

Today, the Windows operating system is used on more than 90% of all

PCs in the world. Actually, that is a positive point because a single operating system (or 'platform') promotes the compatibility of software, and urges hardware manufacturers to develop and supply Windows drivers for their products. On the other hand, competition keeps the market alive. Unfortunately, there are not many suppliers of graphics user interfaces (we're not tal-

king about Mac computers here, as they represent a different category). Gone are the days when advanced PC users could mention four or five suppliers of DOS systems!

Fortunately, there are a few alternatives left. Of these, Linux is probably the best known. But why go for another operating system than Windows? Two important reasons can be mentioned: first, Linux is much cheaper than Windows (including the associated applications); second, Linux is much more stable than Windows 95/98 or NT, and that is why many Internet servers and network computers run under Linux.

### What is Linux?

For years, Unix has been among the most popular operating systems for larger computer systems. Unix has slowly become available for almost any type of processor, and is marked by its modular structure, and the fact that it is almost entirely written in C. These two aspects make it easy to extend or modify Unix as required.

In 1991, Linus Torvalds from Finland wrote a simple computer operating system resembling Unix. He based his work on Minix, which was fairly well known at the time, and called it Linux.

Over the past couple of years, thousands of programmers around the globe worked on improving and extending Linux. As we write this, Linux is an

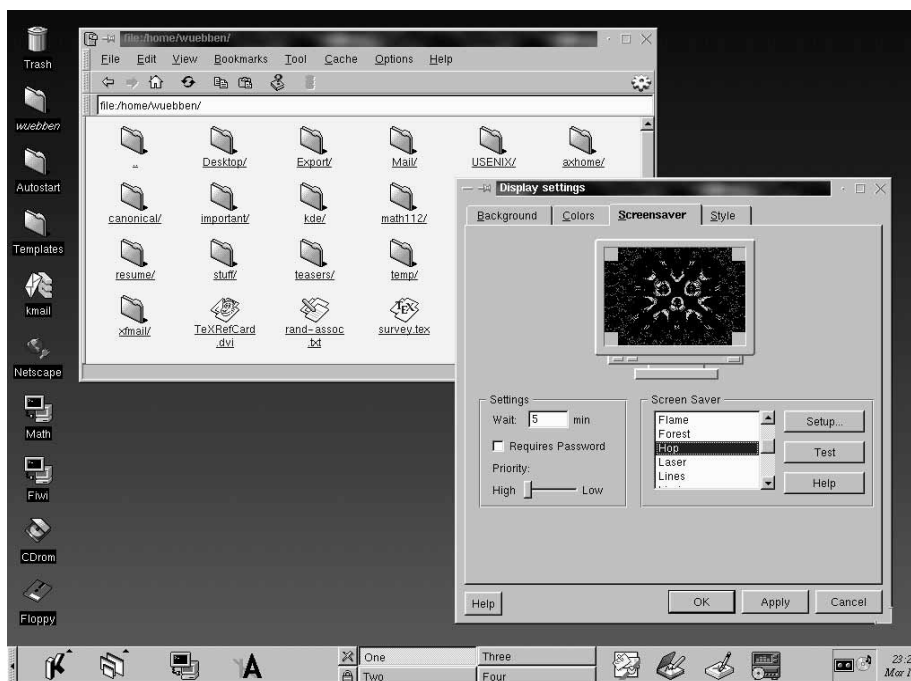


Figure 1. KDE is a typical Linux window manager.

up-to-date computer operating system with support for lots of different hardware products. Meanwhile, there are Linux versions for many different computers, including Intel-compatible PCs, and Alpha and Sun SPARC workstations.

You may wonder what makes Linux so fascinating that lots of programmers around the world keep contributing to it. The most likely answer is that Linus Torvalds insisted on the price tag for Linux: *free of charge*. In practice, this was arranged by means of so-called GNU public licencing. Although all modules that make up Linux, as well as all applications, may be sold at cost by any company or programmer, they are always obliged to supply the source code files with the product. Next, the users of these products are free to make modifications to the program, or extend it, and offer the result to others.

It is almost incredible that an extremely complex software application like an operating system can be made by so many people working at different locations around the globe. Thanks to the global communication possibilities offered by the Internet, organised groups of programmers mainly concentrate on the larger parts of the operating system. Even if programs are only in an early beta stage, they are made available so that other Linux users can help to improve and debug the program.

To keep things in control, Linus still has the final say about any important change to the kernel (i.e., the software core of Linux).

Several distribution points may be found on the Internet where the Linux operating system may be downloaded free of charge. Although there are companies that will make a charge for their distributing Linux on CD-ROM, the price is either modest, or largely determined by the printed manual and the amount of support the user is entitled to receive.

You may wonder what 'distribution' entails. Because Linux is basically a collection of small programs and modules, it is pretty hard for the average user to assemble these into a fully working Linux system. A Linux distribution is a program package with an installation section that ensures that the right modules, settings and programs end up on your PC. In the past, the complex structure of Linux was a serious stumbling block for many computer users wishing to experiment with this interesting operating system. That situation has been improved considerably, and the current distributions are so good that they are capable of automatically

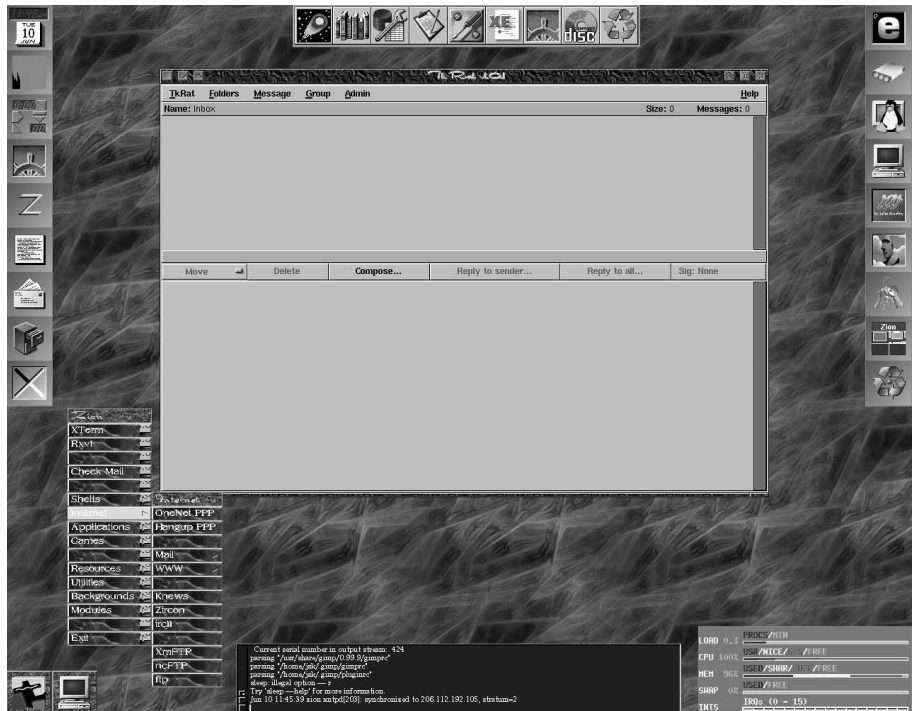


Figure 2. The Afterstep desktop not only looks impressive, it is also easy to use.

recognising nearly all computer components during the installation. In fact, a minimum amount of user action is required to arrive at a correctly working system. Some of the best known distributions include Red Hat Linux, Caldera Open Linux, Debian GNU/Linux and S.u.S.E. Linux.

## X-windows

Inside the Linux fraternity, the need was felt to have a graphics user interface which was comparable to Microsoft Windows. The result was the X-windows system developed in co-operation with DEC and the MIT. The aim was to create a graphic system which was equipment- as well as system-independent, freeing the programmer from the burden of ensuring that his/her program be compatible with any system or hardware. In the mean time, X11 has evolved into a global standard.

In addition to this basic system, a number of other window managers were developed. Running under X11, they take care of all display and display updating functions. Some of the better known are Motif, Open Look, Fvwm95 and KDE. The latter in particular has become pretty popular lately, the final version, 1.0, being available as we write this. KDE offers nearly all features Windows users have grown accustomed to, and that is, of course, crucial for any PC owner contemplating the move from Windows to Linux.

## Applications

Good as an operating system may be, it is worthless without application programs. During the past couple of years, a large number of fine programs were written for Linux. For example, all utilities you need to set up an Internet server come free of charge with almost any distribution. However, if we look at 'ordinary' programs for use by everyone, the choice is limited because Linux is mainly used by people with a basic interest in programming and other technical matters. These days, office computer users have grown accustomed to the luxury and ease of use of program suites like Microsoft Office. Fortunately, Linux is also developing into that direction. There are already a couple of good Office-like packages like Applixware Office Suite and Star Office. The latter is even free of charge and very well suited to home and SOHO use.

The Canadian company Corel has announced Linux versions of an increasing number of its products, while WordPerfect Corp. products are already available. Of course, we should not forget to mention that Netscape Communicator is available in a Linux version. This is crucial for the very backbone of Linux: communication using the Internet.

PC games written to run under Linux are few and far between. Apparently, there are no PC game makers as yet willing to develop Linux-compatible products, probably because of the



Figure 3. The new Red Hat Linux version 5.1 is easy to install, also for beginners.

enormous cost. None the less, the PC gaming market has a tremendous potential. Maybe this situation will change for the better in the near future.

Drivers are essential for the proper controlling of all kinds of peripheral devices. Although there are suitable Linux drivers for most standard equipment around, you should not expect have instant access to a driver for the very latest model of, say, a laser printer. This requires (1) a Linux user willing and able to develop the driver, and (2) a manufacturer willing to part with all information necessary for this to be done. In the mean time, you will have to make do with a standard driver.

Corel estimates the total number of Linux users at about 7 million. Most users appear to be in the USA, although Germany and the UK also have a fair number.

## Getting started with Linux

Although there are many enthusiastic stories about Linux in the computer press, an unsuspecting Windows 95 user moving to Linux is sure to feel left out in the dark initially, and has to discover that the lights will not come on until a vast amount of Linux literature has been studied (complete handbooks are available on the Internet).

The migration from Windows to Linux may be compared to a Windows user forced to sit in front of a Macintosh computer. Despite a certain similarity in the graphics 'shell' and the mouse con-

trol, the change is radical, requiring quite some getting used to.

After the installation of Linux, which is quite simple thanks to the modern distributions (we will revert to this below), the computer is restarted, and a kind of DOS prompt appears on the screen as you may remember it from 10 years ago. The obvious question is then: what do I do now?

Linux has a very extensive command set, but all commands have different names than under DOS. What's more, they have a different effect, and lots of extra options. So it would seem wise to have a list of frequently used commands available.

The strict network structure of Linux will strike single users as very odd. There is no way to avoid logging on to the system. Depending on your status as a user you are allowed to make use of certain features. Obviously, as the sole user of the PC you can double as the system operator (called 'root' in Linux), who has access to all levels.

The DOS/Windows user will also have to get used to the totally different structure of his/her PC. All drive (station) letters have disappeared, and there is just one directory tree which includes everything (hard disks, CD-ROM drives, floppy disk stations, etc.). Moreover, removable media like floppy disks and CD-ROMs have to be dealt with in a quite different way. Because Linux employs a cache memory for all available storage media, you will have to inform the system when, for instance, a

CD-ROM is removed from the CD-ROM drive. This is done by means of a 'mount' and 'u(n)mount' command.

If you would like to work in a more Windows-like environment, that is fairly simple to achieve. By means of a Start command (usually startx), X-Windows is launched, and most tasks can be carried out using the mouse, as you learned to do under Windows.

Some thought is also required when switching off a PC running Linux. Because the cache has to be emptied first, and all running programs properly terminated, it is necessary to run the shutdown command before you actually switch off the PC. Fortunately, the keyboard combination CTRL-ALT-DEL no longer causes the computer to be reset just like that. After pressing this key combination, Linux first closes all applications and then tells you that the PC can be switched off.

## Red Hat Linux 5.1

To illustrate the installation of Linux, we decided to use the latest version 5.1 from the American company Red Hat. This particular distribution is known for its simple installation.

Red Hat Linux is available in different versions. There is, for example, a set of six CD-ROMs (Red Hat Power Tools) for about £20 containing the latest Red Hat Linux version for different processors, all source code files and a large number of Linux applications. Documentation is not supplied in book form but as a file on the CD-ROMs.

If you are new to Linux, it may be better to obtain the CD-ROM set with handbook, a number of bonus programs and extensive support, all at the price of about £30. The book provides good coaching with the installation of Linux, while support (by email) for the same installation is available for a period of 90 days. A separate disk makes installing Linux very easy.

First you have to ensure that a hard disk partition of 0.5 Mbytes is available for Linux. This is required because Linux employs its own file system (although a DOS partition may be used, this will cause Linux to be slowed down). Don't worry about what will happen to Windows, because the relevant part on the hard disk remains untouched as long as you do not change the partitioning system.

After booting the PC from floppy disk (or direct from the CD-ROM), all main components that make up your PC are, in principle, identified by the installation program. Next, you are taken through a number of menus in which to choose

the keyboard, language, etc. After a number of other prompts you arrive at the partitioning section. Two options are available: the fairly Spartan 'fdisk' (the same name as used for the DOS program) and the more extensive Disk Druid written by Red Hat. The latter program has a very clear structure. You indicate where Linux is to sit by creating a couple of Linux partitions in a free section of the hard disk. The minimum partitions you have to make are a swap partition (say, 50 MB), a root partition (/) for configuration files etc., and a user partition (/usr) for all other software. The user partition obviously takes up the largest part of the available disk space.

Once the marked partitions have been formatted, a list appears showing programs that have to be installed. The main programs have been activated already, and Windows users will find it worthwhile to select all X-window programs. Initially, you will not need any of the 'development' software — this may be added at a later time. Once the selections have been made, the computer is busy for a few minutes installing all programs.

Next, the installation program detects the mouse type connected to the PC, whereupon a configuration module is started for the Xfree86 server, the Windows-like program. Most graphics cards are automatically recognised, but you have to enter the highest refresh frequencies for the monitor yourself. If autodetection is not successful, then there is always the possibility of doing the settings by hand.

After the network configuration, which is not normally required for single users, the clock is set. Then the services are set that Linux has to launch automatically. Finally, you are asked to look at the printer setting and selection.

The next action on your part is entering a password for the root — this is necessary to be able to enter the Linux system as the main user, after the operating system has started.

The next part of the installation is crucial because it involves the boot manager and the Linux start program called LILO (Linux Loader). This program is normally written to the root sector of the hard disk, and enables the user to choose between different operating systems which may be available on the hard disk.

For instance, the LILO may be configured so that Linux is automatically started a few minutes after the PC is powered up. If, during that period, you type, say, 'win' (or any other name you may have entered in LILO), Windows will be launched. So, depending on what you want to do on the computer, you can make your selection and start the operating system you feel is better suited to the task on hand.

Finally, then, the moment has come for the PC to be restarted. After a few dozen messages on the screen the Linux version appears, and you are prompted to log on. For the impatient among you, we will tell what to do without too much reading in the manual: type 'root' to log on, and then enter the password you supplied during the

installation. Once you are 'in' the system, you can type commands or launch programs.

As you will soon find out, a number of things have to be configured at this point, and you even have to report yourself the system as an ordinary user. All this, and more, you will easily find out for yourself after using Linux for some time, and, of course, reading the manual. (Ex-)Windows users will like to know that the command 'startx' takes them to the X-Windows level of Linux.

We reckon none of this is too difficult for the reasonably advanced computer user. Once you know what to enter with the various menus that pop up during the installation, the total configuration will take less than half an hour.

The new Red Hat Linux distribution is marked by a superb installation procedure during which most hardware is automatically recognised. Even inexperienced users will be able to install Linux, provided he/she sticks to logical thinking. The manual is a fine product, and much more extensive than the one supplied with version 5.0. It provides a step-by-step description of the installation procedure, comes up with lots of useful tips for beginners and advanced users. There are also notes on important matters like Glint, Control Panel and RPM. Furthermore there is an overview of all programs that come with this distribution of Linux, as well as an 'FAQ' reference section listing frequently asked questions and answers. Finally, should you remain stuck with a problem you are unable to solve, help is available from a team of specialists at Red Hat (but only if you have the version with 90-days support).

In conclusion, *Elektronics* readers who like to experiment with PCs and change lots of system settings are well advised to have a serious look at the Linux operating system. Linux represents a totally different world with a galaxy of possibilities!

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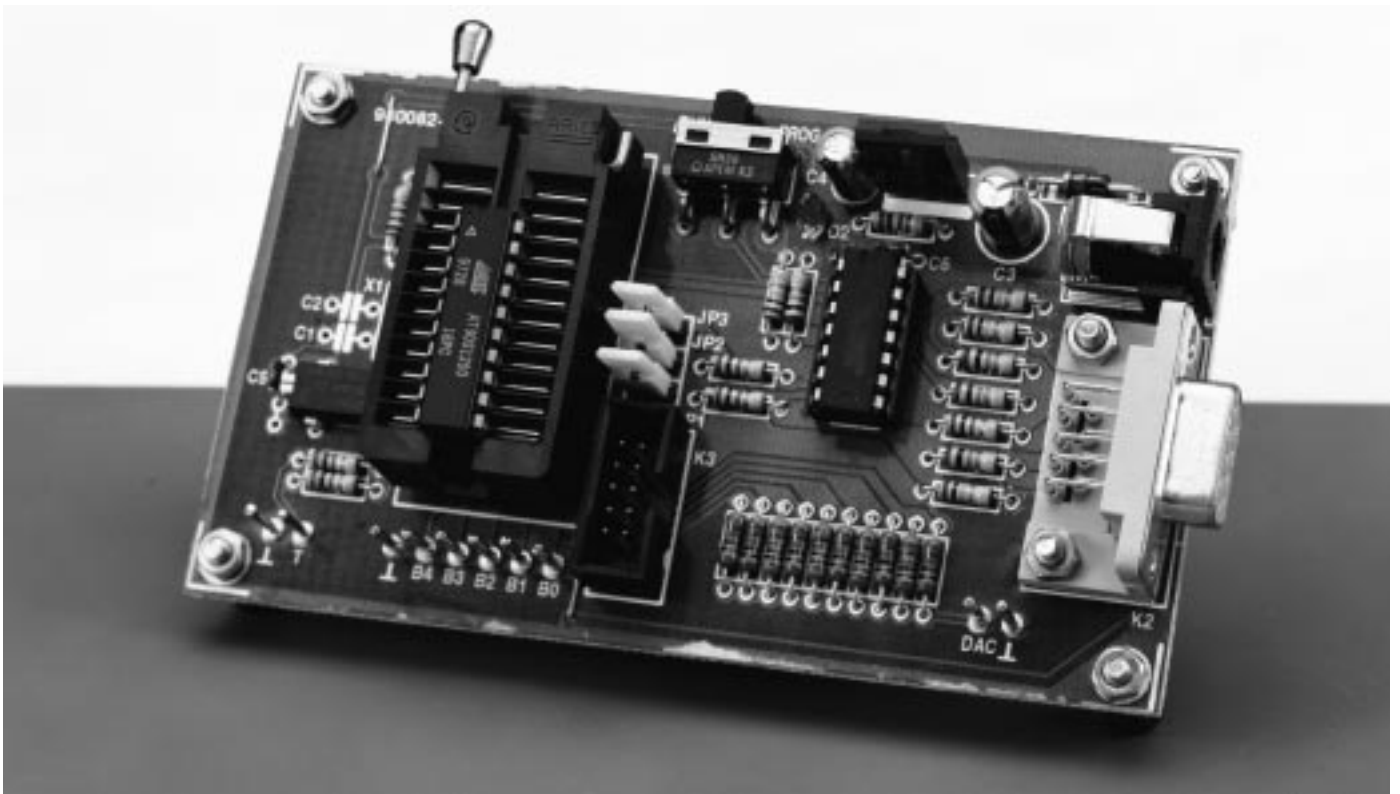
Figure 4. The window-manager FVWM2 is supplied standard with Red Hat Linux.

Atmel's AT90S1200 AVR-RISC 8-bit RISC processor has been available for some time now, and is generally recognised as a very fast device. The price, too, is good at less than £3 even in the hobby market. So, substituting a couple of logic ICs (and their sockets) by an AVR device may already pay off. The most interesting aspect of this processor is, however, that it features a serial interface with direct access to the on-chip memory. The general concept of the AVR processor was already discussed in our January 1998 magazine. The present article aims at showing some more practical applications of the 90S1200, using easy to obtain hardware and software.

Design by Dr. M. Ohsmann

# AVR-RISC evaluation system (1)

experiment with Atmel's latest RISC processors



To give its new AVR processor family a head start, Atmel has made quite a few software utilities available free of charge on their web site. There is, for

instance, a complete assembler (for DOS as well as Windows) and a simulator. The relevant datasheets and software documentation are also free for

downloading. So, if you want to familiarise yourself with these new processors without committing yourself to hardware for the time being, our advice is



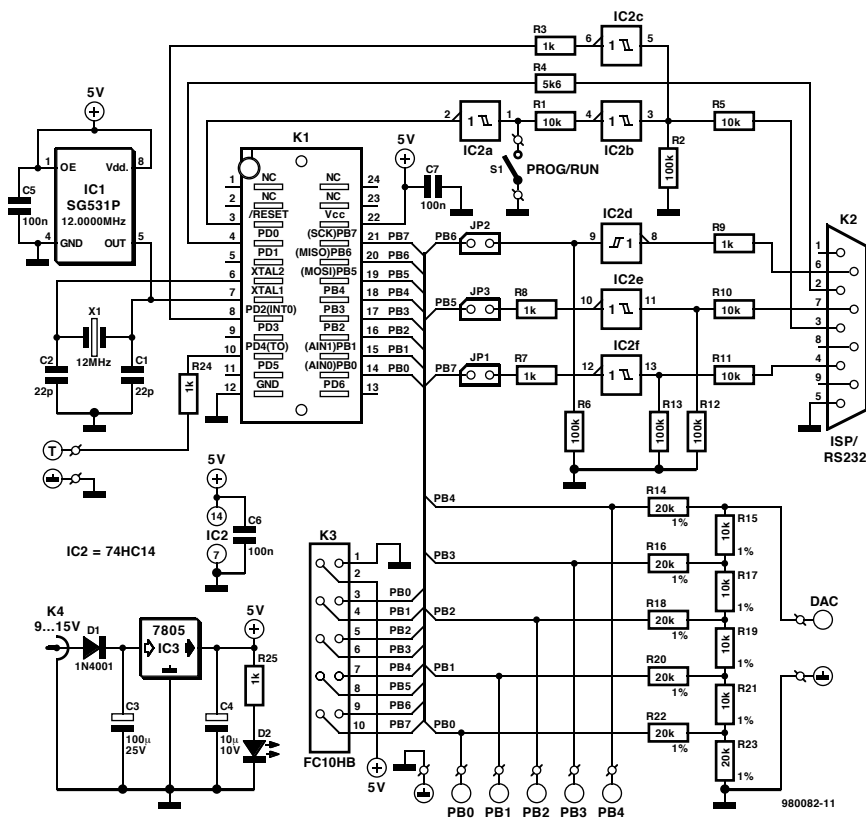


Figure 1. Circuit diagram of the AVR evaluation system.

to go to [www.atmel.com](http://www.atmel.com), where you will find lots of interesting stuff, including

- an assembler for the Atmel AVR family;
- a simulator for the AVR family;
- example programs illustrating:
  - simple arithmetic
  - EEPROM use

### Evaluation system

Atmel also has available a demonstration board and the associated control software. Unlike the above mentioned software and documentation, this material is not free of charge. Because *Bektor Electronics* magazine constantly aims at addressing the active (i.e., soldering) electronics enthusiast, we started to develop our own experimenting system for the AVR-RISC processors. The circuit diagram is

shown in Figure 1. Actually, the circuit consists of no more than a six-fold (hex) Schmitt trigger which translates the signals at the serial PC-RS232 interface into levels that can be processed by processor's serial interface, which is neither RS232 compatible nor asynchronous. Then there is a switch that enables you to change from "software download" to "run program", and a quartz crystal or crystal oscillator module which generates the processor clock signal. If you foresee applications requiring high accuracy (for example, frequency or time measurements), the best choice is the oscillator module (fitted in a socket). In that case, only the oscillator IC1 is mounted, while X1, C1 and C2 are simply omitted. With less critical applications, a simple crystal is, of course, the more economical option. If you intend to program lots of processors, then it is advisable to use a

ZIF (zero-insertion force) socket. That's it! Because of the simplicity of the circuit, it may even be built on a piece of veroboard or general-purpose stripboard. A more elegant solution is, however, to use the PCB shown in Figure 2.

### Serial download utility

To enable programs generated by the Atmel Assembler to be loaded into the processor, you need special download software. Because the author was unable to find a suitable program on the Atmel web site, he came up with his own solution. The resulting program and its source code file (written in Pascal) is available on a disk with order code 986020-1. This disk, and the software picked from the Atmel web site then forms a complete package, and you are ready to get started.

### Example programs

A good way to learn about micro-processor programming is to test fully functional programs, and then modify and extend them. In case of newly released processors, the decisive factor is often whether or not a supply of ready-made 'modules' is available. Such modules may relieve you from the burden of writing, say, your own character input/output routines, to mention but one example. The project disk contains a fair number of such modules (see Table 1), which should help to unburden beginners, allowing them to concentrate on more essential matters in the learning process. Unfortunately, a full discussion of all modules on the disk is beyond the scope of this article. Those of you who are interested in the programming details are referred to the commented source code files on the disk, and to the file XAVR.DOC which presents an overview of available programs, complete with concise descriptions and application examples. In this article, we present just a few of the many ideas that may be realized using the AT90S1200. Our aim is to pick out those applications in which speed is the decisive factor. After all, a fast beast like the AVR-RISC processor is by no means required to switch a lamp on and off every few seconds! You will not find such applications in this article. By contrast, you will learn, for instance, how various clock signals may be derived from a 10 MHz source. Such an application is surely too much to ask of an 8051, while the AT90S120 can manage!

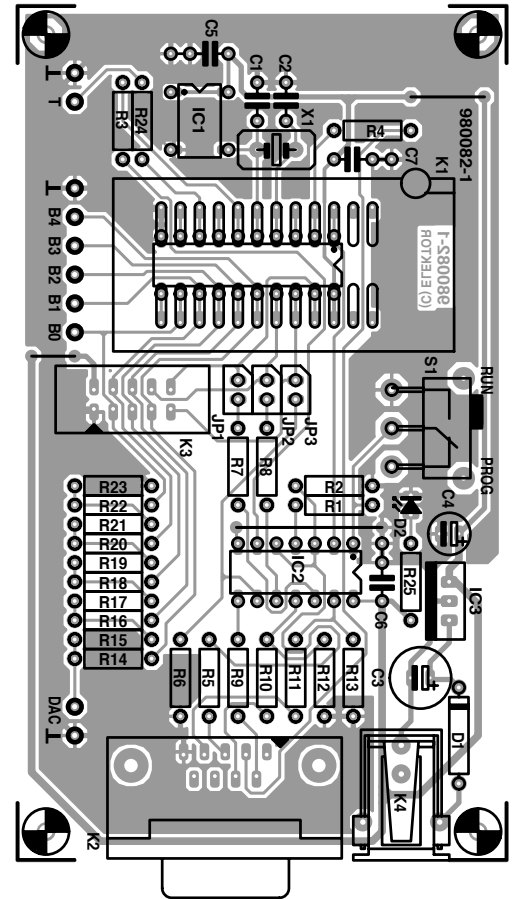
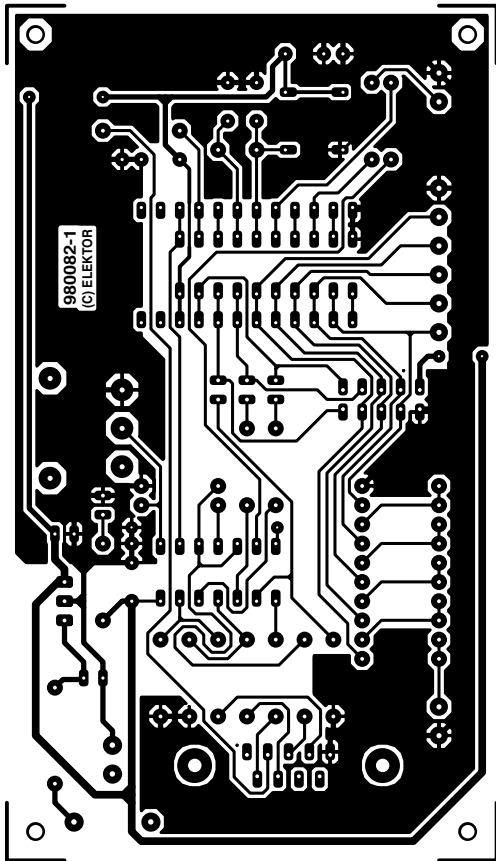


Figure 2. Single-sided printed circuit board (available ready-made).

## One instruction every 66ns: applications

The AT90S1200 may be operated at a clock frequency of up to 16 MHz. Because most instructions are executed within a single clock pulse, it is possible to execute instructions at a rate of 16 million per second. So, if you want a certain routine to be executed one million times in one second, the relevant program section may have a length of 10 to 16 instructions. Using this number of instructions quite a lot can be done. Of course, at the hardware level only, who can imagine a Windows program with a length of just a few tens of bytes?

A really fast processor may often be used when economising on the number of digital ICs while the speed is not so high as to necessitate the use of expensive programmable logic. The great thing about such a microcontroller is that you have access to an army of registers, and to an accumulator capable of doing sums! Those of you who have ever attempted to make programmable logic do simple calculations will appreciate this facility.

## AT90S1200: a quick overview

Mainly because of its RISC architecture, the structure of the AT90S1200 processor remains wonderfully simple. Figure 3 provides an overview. The section we are particularly interested in is an array of 30 8-bit registers that may be used to perform calculations and store results. Then there are two

input/output ports (Port B and Port D) of which each pin is individually addressable as an input or an output. Program execution runs under the control of the central clock frequency which may be any value between 0 and 16 MHz. In addition, there is an interrupt control system and a small 8-bit timer/counter. The complete description of the AT90S1200 covers about 50 pages,

Table A

; semicolon used as comment delimiter

```
.def sum=20 ; use .def to assign symbolic names to registers
mov r2,r3 ; copy contents of register R3 to R2
ldi r17,r123 ; load register r17 with 123
add r20,r21 ; register r20 becomes sum r20+ r21
adc r20,r21 ; register r20 becomes sum r20+ r21+ carry
sbi PORTB,2 ; set port B line 2
clr r27 ; clear r20 to 0
bme loop ; jump to loop when not zero
sbrs r20,2 ; skip if bit in register set
; skip next instruction when bit 2 of r20 is set
```

and interested readers are strongly advised to obtain it from the Internet or the local Atmel distributor. For now, a few programming examples to get used to the AVR controller:

## Simple digital word generator

Because the AT90S1200 is capable of working at any clock frequency between 0 Hz (static operation) and 16 MHz, it is perfect for use as a generator for complex signal patterns, all based on just one central clock frequency. Normally, such a generator is built using counter modules and decoders, and the resulting circuit can become quite complex because a lot of additional components may be needed to keep the effect of glitches under control. At frequencies below 16 MHz is it, however, perfectly possible to employ a RISC processor. For example, the pulse pattern shown in Figure 4 is created with the aid of the processor.

### COMPONENTS LIST

#### Resistors:

- R1,R5,R10,R11 = 10kΩ
- R2,R6,R12,R13 = 100kΩ
- R3,R7,R8,R9,R24,R25 = 1kΩ
- R4 = 5kΩ
- R14,R16,R18,R20,R22,R23 = 20kΩ 1%
- R15,R17,R19,R21 = 10kΩ 1%

#### Capacitors:

- C1,C2 = 22pF ceramic (see text)
- C3 = 100μF 25V radial
- C4 = 10 μF 10V radial
- C5,C6,C7 = 100nF ceramic

#### Semiconductors:

- D1 = 1N4001
- D2 = LED red high efficiency
- IC1 = SG531P12.0000MHz EPSON (Eurodis), see text
- IC2 = 74HC14
- IC3 = 7805

#### Miscellaneous:

- X1 = 12MHz see text
  - K1 = 24-way Aries 0.3-0.6inch (Farnell)
  - JP1,JP2,JP3 = 2-way jumper
  - S1 = slide switch, 1x changeover, PCB mount
  - K2 = 9-way SUB-D socket
  - K3 = 10-way boxheader (optional)
  - K4 = mains adapter socket, PCB mount
- PCB: order code 980082-1, see Readers Services page.  
Disk: order code 986020-1, see Readers Services page.

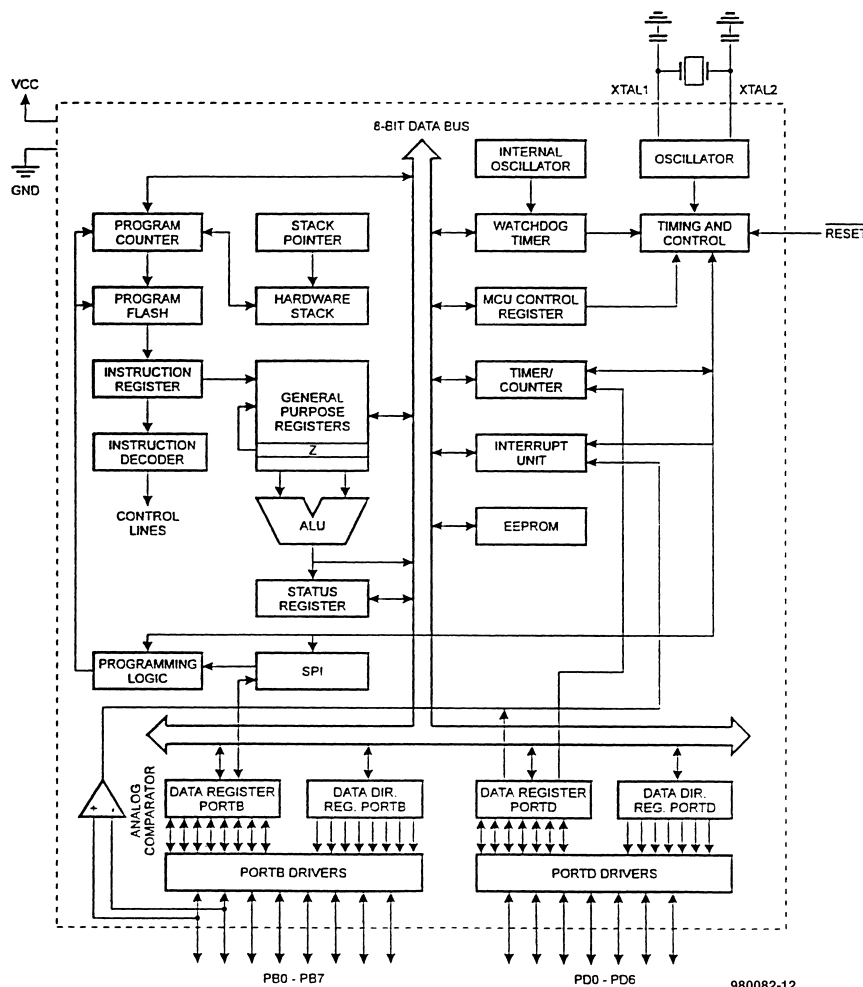


Figure 3. Atmel AT90S1200 processor architecture.

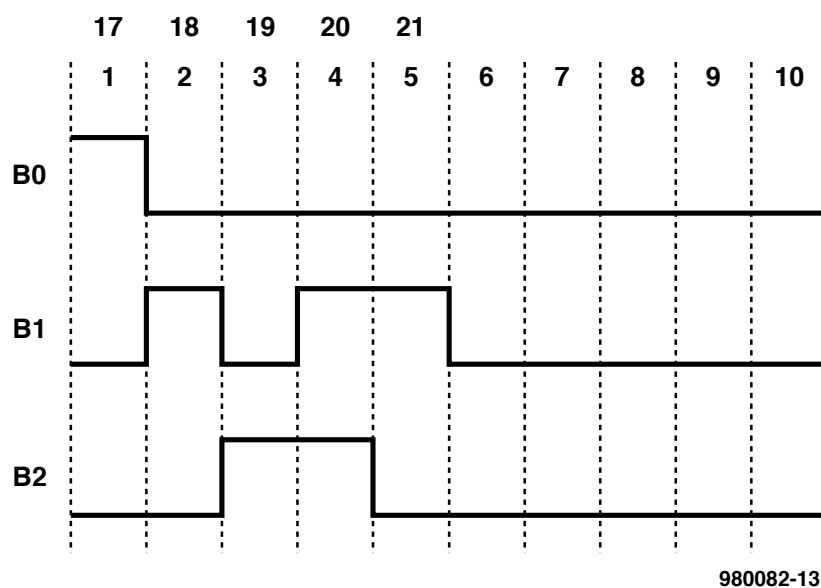


Figure 4. Because of its speed, the Atmel controller is capable of generating complex digital patterns at frequencies well over 10 MHz.

## PC programs

SER90	program download utility for evaluation board. Pascal source code file included on disk.
V24COM	V24 serial communication program. Pascal source code file included on disk.
AVRASM.EXE	AVR assembler (DOS version). Included by courtesy of Atmel UK.

## AT90S1200 example programs

File	Function
XSEROUT1	output characters via RS232, 9600 bits/s
XHEXOUT1	output registers via RS232, hex format
XHEXOUT2	output all 32 registers (dump) via RS232
XDECOUT1	output 24-bit values (0-16777215), decimal format, via RS232
XSERIN	Input characters via RS232, 9600 bits/s
XFMES1	frequency measurement up to 5 MHz, 1s gate, RS232 output, decimal, at 9600 bits/s
XTIMES1	time measurement, 1 ms to 8 s, 0.5 ms resolution, RS232 output, 9600 bits/s
XNCO1	numerically controlled oscillator, output 77.5 kHz using 12 MHz crystal
XNCO2	numerically controlled sawtooth generator, programmable via RS232
XFRQDIV1	divide by N scaler, N programmable via RS232
XPATGEN1	simple 8-channel pattern generator
XPATGEN2	simple 8-channel pattern generator, patterns adjustable via RS232
XDIV625	divide by 625 scaler, non-overlapping pulses

6 clock cycles, and then wait exactly 428376233 cycles for the game to commence again. All you need for this function is a counter capable of keeping track of the necessary number of clock cycles. Four registers in the processor, spanning a total width of 32 bits, and a couple of addition instructions are sufficient for this purpose. No soldering is required when the number of cycles has to be changed for whatever reason. All you have to do is change a few constants in the program, and that's it. This kind of flexibility is simply not available in traditional wired logic, and very expensive in programmable logic (in particular, development tools).

The collection of example programs found on the project diskette includes a simple pattern generator that reads its pattern information from the serial interface (via XPATGEN2.EXE and XPATGEN2.PAT).

(980082-1)

Next month's second and final installment will continue with programming examples including frequency dividers, numerically controlled oscillators (NCOs), time measurement and frequency measurement.

Table 1. Contents of the project disk (order code 986020-1).

gram listed in Figure 5 (XPATGEN1.ASM). The program is short and its operation boils down to loading registers r17 through r22 with the desired signal combinations. Next, a loop is used to output the values on Port B at maximum speed. This program may be modified in many ways. For instance, by including delay loops you can create signals with very long periods, which are timed at crystal accuracy, or synchronous with the clock signal. You should not find it too difficult to modify the program so that the signal shape does not change during the first

Figure 5. This little program generates the pulse sequence shown in Figure 4.

Figure 5

```

; XPATGEN1.ASM
; simple pattern generator

.include "1200def.inc"

        ldi r16,$0FF        ; set output B to totem-pole
        out DDRB,r16

        ldi r17,0b0001     ; set patterns into registers
        ldi r18,0b0010
        ldi r19,0b0100
        ldi r20,0b0110
        ldi r21,0b0010
        ldi r22,0b0000

LOOP:   out PORTB,r17      ; output each register to PORT
        out PORTB,r18
        out PORTB,r19
        out PORTB,r20
        out PORTB,r21
        out PORTB,r22
        nop                ; two extra cycles
        nop
        rjmp LOOP         ; this also takes 2 cycles

```

Lots of advanced joystick units are available in the computer shops for pretty realistic control of various flight simulator programs. Builders of model aircraft will fail to appreciate this approach, being used to the control sticks on their R/C transmitters. The circuit shown here enables modellers to continue using these transmitters for over-the-air control of a flight simulator running on a PC.

Design by U. Hartog

# R/C interface for PC flight simulator

## THE solution for the true modeller



Microsoft and other suppliers of PC peripherals have been successful at producing joysticks whose 'feel' comes pretty close to that of the control sticks in a real plane. In fact, the realism of these joysticks is such that the next thing PC gamers will want is an imitation cockpit! Regrettably, that seems to be

a long shot as we write this. For now, we will have to content ourselves with very high quality joysticks like the SdeWinder.

Over the years, model builders around the globe have grown accustomed to their own way of controlling aircraft: by control sticks that allow the

model to be flown in all directions. Unfortunately, the R/C modeller fraternity is simply overlooked by the marketing departments of joystick manufacturers. So, out of doors the R/C modeller controls his plane in a different way than in front of the PC, and that, as we see it, is not good if he wants to improve his flying skills.

The circuit presented here can change this undesirable situation. The circuit not only promotes the use of the familiar control sticks, it also allows the flight simulator to be controlled over the air, that is, with the R/C transmitter in your hands.

So put on your cap and your sunglasses, switch on your R/C transmitter, and take off...

### Interfacing

Converting the receiver unit normally installed in the model in such a way that it can be connected up to a PC requires quite a few changes to the electrical signals. After all, such a receiver normally drives a set of servo motors with pulse-width modulated digital signals. These signals, in turn, control analogue actuators like the rudder and ailerons. The control of the PC is entirely different in this respect. Normally, a pair of potentiometers is used for the analogue part of the control,

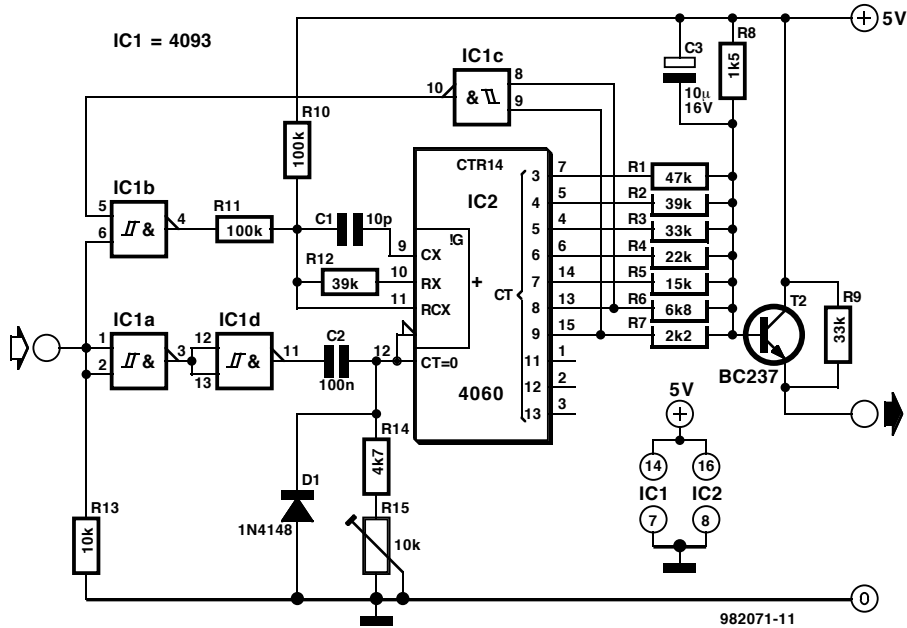


Figure 1. Circuit diagram of the interface designed to convert servo signals into an analogue signal whose level and timing can be recognised by the gameport on the PC.

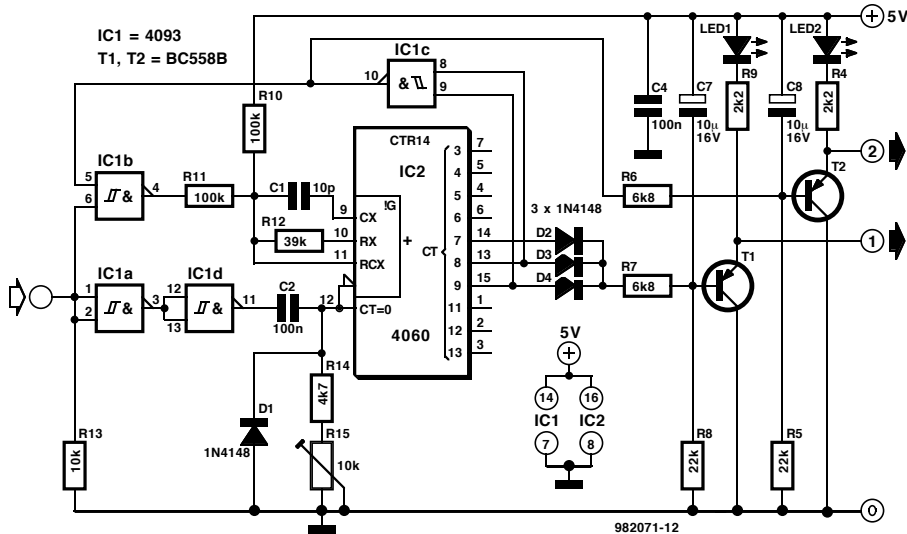


Figure 2. The Fire buttons are also simulated. This circuit is a bit simpler than that of the analogue interface, mainly because it has no D-A converter.

and a number of digital signals for the fire buttons.

For optimum control of the flight simulator, for instance, *Microsoft Flight Simulator 98*, we need:

- \* Up
- \* Down
- \* Left
- \* Right
- \* Two 'Fire' buttons

Because each of these signals will have to be applied to the PC gameport in analogue and/or digital form, such an interface will be unknown to model builders. So, some electronics has been thrown in to give the signals the proper shape and level. The circuit is designed such that four digital signals can be generated in addition to the usual four analogue signals. What more can the budding pilot aspire to have?

Figure 1 shows how the analogue signals are created. The digital servo signal reaches the circuit and appears at the inputs of IC1b and IC1a. The output of IC1d supplies the buffered signal. Via a monostable multivibrator consisting of C2, R14, R15 and D1, this signal is used to reset a counter type 4060. The reset input of the 4060 is pulled high on the rising edge of the input pulse. When the monotime has elapsed, the counter is enabled again. The component values in the monostable circuit result in a reset pulse with a length of 1 ms. Although R15 allows the pulse length to be accurately adjusted, it can be left at mid-travel because this setting is not all that critical. All IC outputs are pulled low during the reset pulse. However, when the input signal is at logic 1, both inputs of IC1b are also at 1, so that the oscillator in the 4060 is enabled. Here, the oscillator operates at about 200 kHz. No counting takes place, however, as long as the reset input is activated.

After the monotime of about 1 ms, the oscillator pulses are duly counted, and a 7-bit binary code appears at the output of IC2. In the quiescent state, when the pot is at mid-travel, the servo pulse has a length of about 1.5 ms. Depending on the position of the control stick on the transmitter, the pulse length varies between 1 ms and 2 ms. For the present circuit, the result is that the measurement is actually limited to the parts of the servo pulse that are longer than 1 ms.

The binary output code is converted into a direct voltage by a D/A converter built from discrete components. The component values used here result in a direct output voltage range of 2 V to 4 V. In practice, this can be relied upon to give adequate results. This variable direct voltage simulates the signal at the wiper of the pot fitted in a joystick. The oscillator may be halted by feeding back the digital output signal from IC2 to IC1b. Disabling the oscillator may sometimes be necessary when the discriminator circuit is (yet) out of alignment. If the setting is much shorter than 1 ms, the counter can shoot past its highest state causing the output voltage to return from 4 V to 2 V — an unpredictable result. As soon as counter state 96 is reached, the output of IC1c drops low, and the oscillator is halted. The output voltage remains 'frozen' and the output remains stuck at the high level of about 4 V. Once the circuit is properly adjusted, this circuit will not be actuated, and the oscillator stops as soon as the servo pulse is over. The counter state remains frozen until a

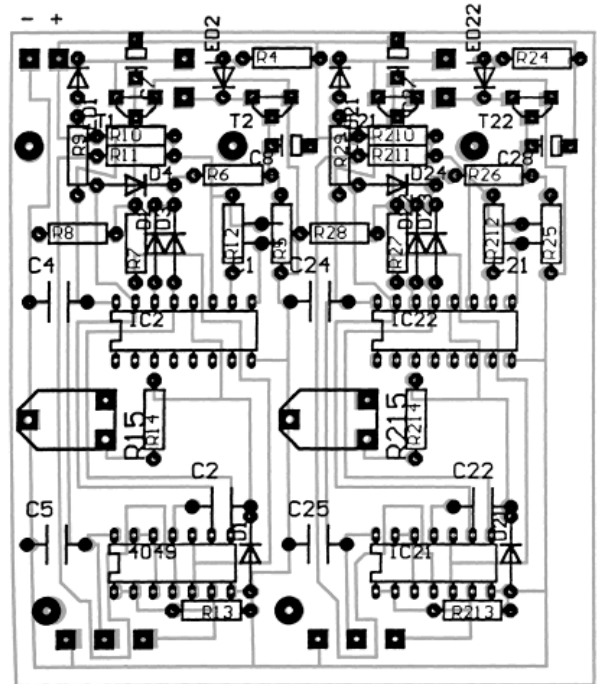
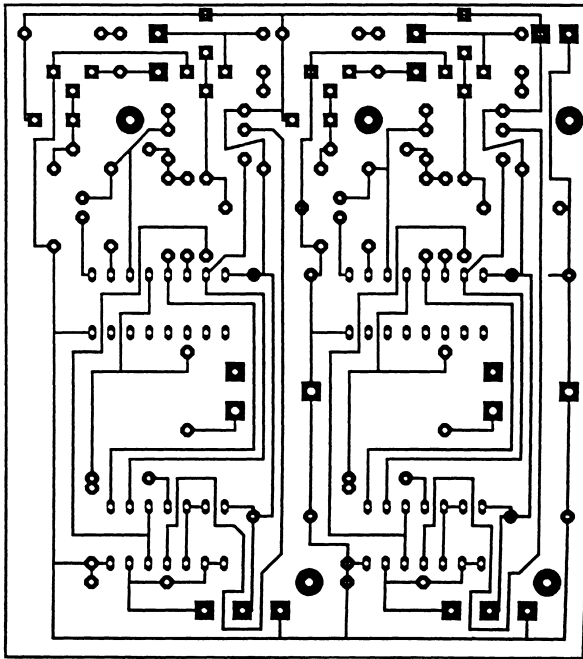


Figure 3. Copper track layout of the analogue interface board. This board contains all electronics to simulate four potentiometers (two control sticks). Board not available ready-made.

new servo pulse appears at the input. A kind of feedback is also applied in the interface that generates the digital output pulses (Figure 2). At a servo pulse length of 1 ms, output 1 is activated, or output 2 with longer pulses. Here, too, the pulse length needs to be examined. When the reset time of 1 ms

has elapsed, the counter starts to operate again. The first 15 clock pulses have no effect on the outputs connected to diodes D2, D3 and D4. The output level of IC1c is then high, and T2 is switched off. Transistor T1, on the other hand, is allowed to conduct, and LED D1 lights up. If a counter state between 16 and 31 is reached, the base of T1 is pulled high via D2. Both T1 and T2 are then off, and neither of the two fire buttons is active. When the counter state becomes 96 or higher, both inputs of IC1c are logic high, allowing T2 to start conducting. The second fire button is then active. In this simple manner, the tolerances in the pulse lengths are ironed out.

### Printed circuit board

Building this project is made pretty easy by the PCB designs submitted to us by

the author. One board is reserved for the analogue section, and one board for the digital section. The copper track layouts and component overlays of the analogue board are shown in Figure 3, those of the digital board, in Figure 4. Making your own PCB from this artwork should not be too difficult if you have the right equipment and tools.

The completed boards may be assembled in a sandwich construction to make a compact unit.

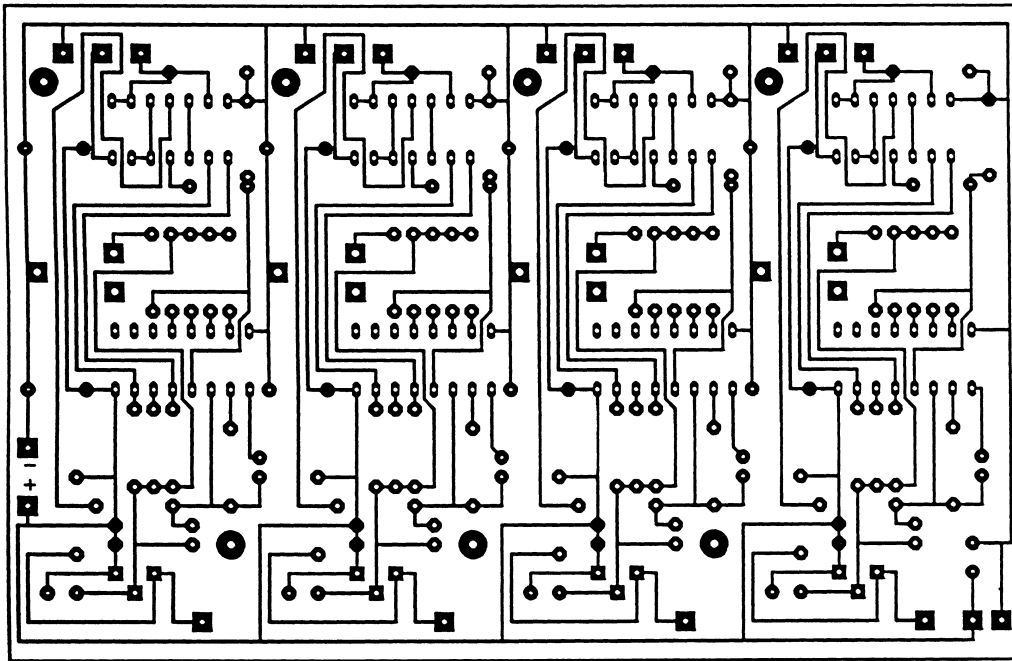
The construction we think should not cause too many problems, mainly because there are no critical sub-circuits. Simply fit all the parts in accordance with the component overlay and set the presets to the centre of their travel. Because the PCB layout is pretty dense, you have to work carefully and use a solder iron with a small tip. Note that the components are consecutively numbered on the PCB. The first analogue interface contains components as used in the circuit diagram. The second one has an extra '2' before each component reference number. Likewise for interfaces 3 and 4, which have a '3' and a '4' affixed, respectively.

It will be clear that the value of R1 is the same as that of R21, R31 and R41. This method of numbering the parts is also applied with the digital interface.

### Ten wires

The circuit does not need a separate





Ladies and gentlemen this is your captain speaking. We are ready for take-off. On behalf of the crew: we wish you a pleasant flight.

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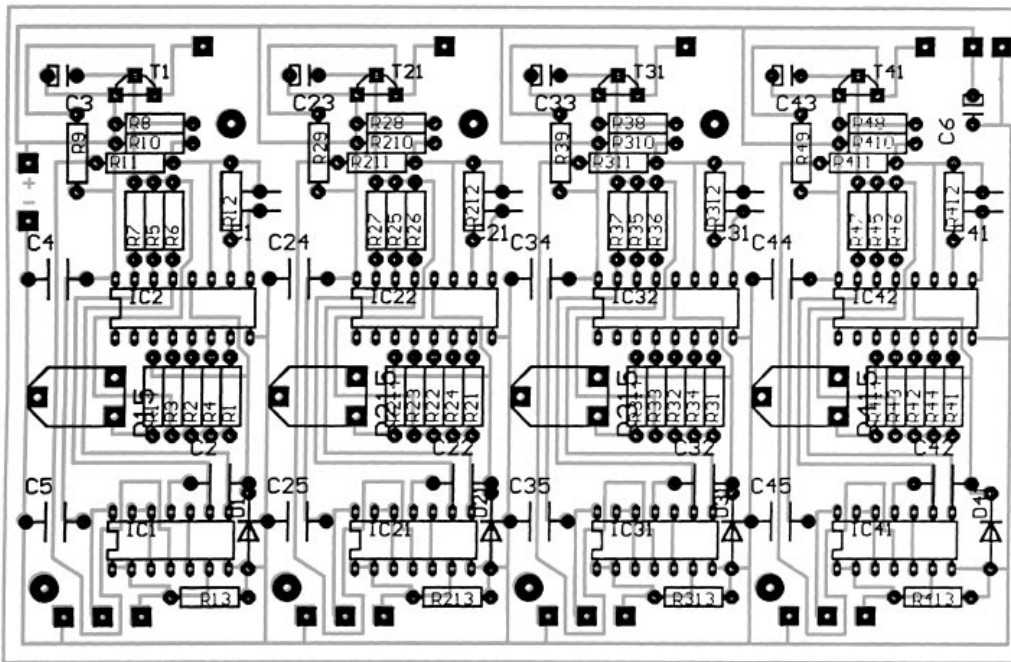


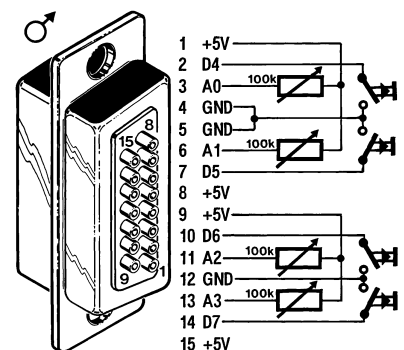
Figure 4. Copper track layout of the digital interface board. Board not available ready-made.

power supply because its supply voltage may be 'stolen' from the game port on the PC. So, make sure you have two extra wires available in the connecting cable, and tap the necessary supply voltage from the port. The pin allocation of the gameport connector shown in Figure 5 will help you find the relevant signals and voltages.

The servo connections on the receiver module may be wired directly to the corresponding inputs on the interface board. No new connectors have to be bought, or wires cut.

Depending on the number of channels supported by the transmitter/receiver combination, a total of four fire buttons and four analogue outputs are available. On the board, the outputs are clearly labelled, so that the necessary electrical connections are quickly and easily made.

Figure 5. Pinout of the 15-way gameport connector on your PC. Use this diagram as a reference to connect up the interfaces.



982071 - 13

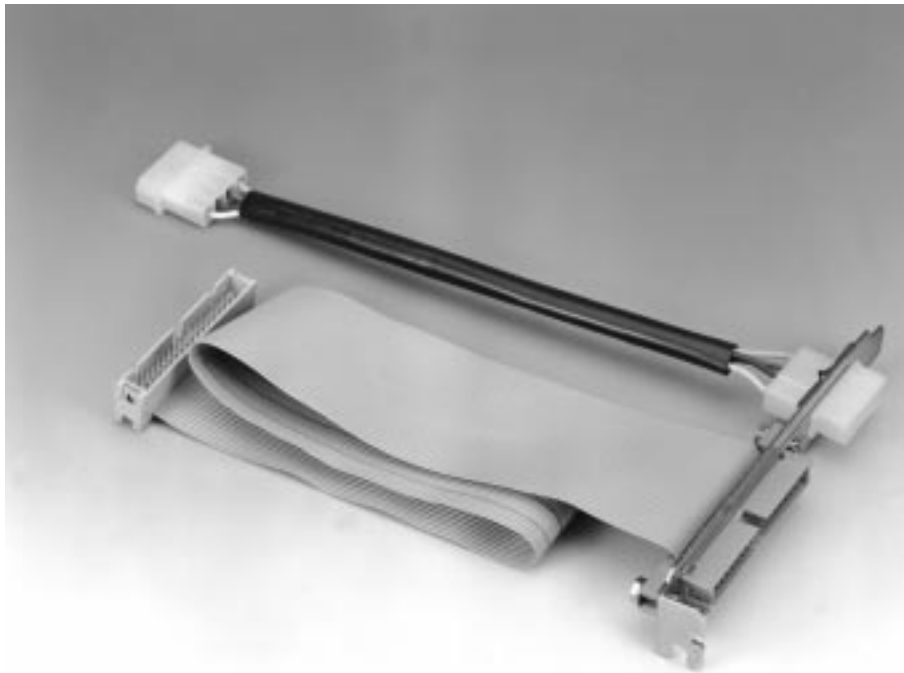


Tape streamers are used not only to secure data, system software, but also to transfer large files from one computer to another. This article describes a simple adapter that allows an internal tape streamer unit to be used as an external back-up device. The adapter employs a modified slot bracket and the PC's internal floppy disk controller.

Based on an idea by H. Flohr

# external port for tape streamer

connects to floppy-disk controller



External backup devices are not only harder to obtain than their internal counterparts, but also more expensive. What's more, they are usually slower than internal versions, mainly because data to be copied to and from the tape travels by way of the parallel (printer) port. If it is no longer possible to fit an internal tape drive in a PC, you may want to consider fitting the unit in an empty floppy-disk drive case, and use the streamer as an external unit. This solution is economical, quick and straightforward, although it does require

a direct connection to the floppy disk controller unit.

Our reader Mr. Flohr came up with an equally simple and practicable solution. He suggests using a slot bracket in which a clearance is cut that allows a 34-way flatcable to be passed. The flatcable is fitted with connectors at both ends. At the side of the bracket, a connector with a flange is used, and at the controller side, one without a flange. The connectors supplied by 3M are perfectly suitable for this application.

The coupling connector on the bracket leaves sufficient room for the power supply plug. Unfortunately, we are not aware of disk drive power plugs with a flange, so that this assembly will have to be secured by a small support bracket, or suitable glue. Alternatively, a completely different plug/socket combination may be employed. Whichever system you decide to use, make sure it is effectively polarized to prevent wrong connections with disastrous results!

(982061-1)