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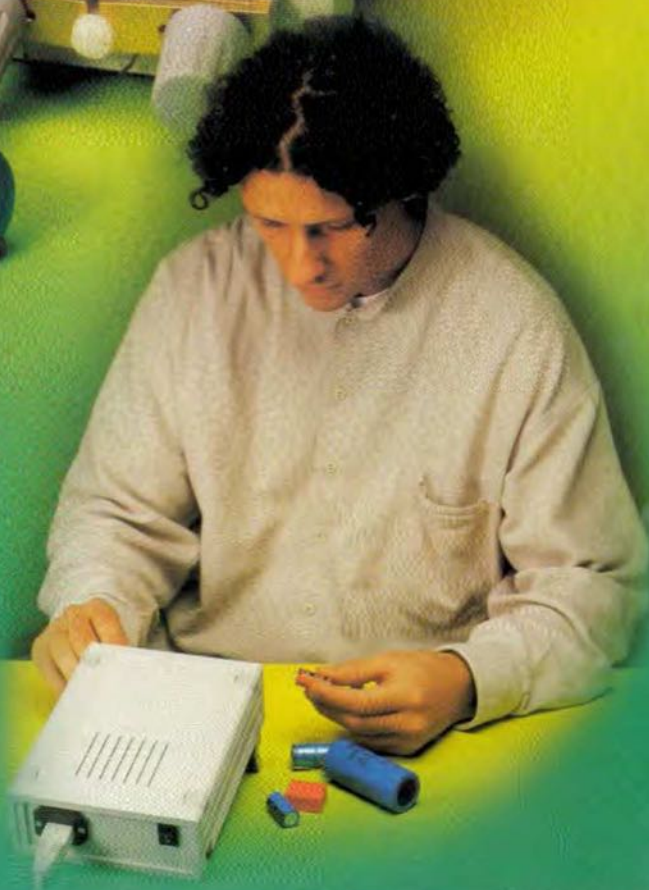
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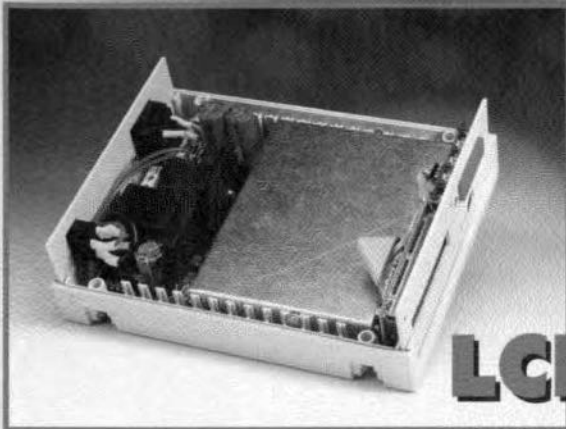
30
LCR meter

36
measuring
with a
PC multimeter

22
PIG-controlled
home alarm system

CONTENTS

Note: Subscribers will find in this issue a
special full-colour poster on PC connectors.

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NETWORK COMPUTERS, THE ISDN, COMPUTER MEMORIES AND INTERNET PROBLEMS

COMPUTER MEMORIES

The recent news that memory prices have been sent soaring because producers in South Korea have slashed their production of DRAMs (dynamic random access memories) by more than a third is not all that surprising. The trouble with this kind of memory is that it has become too complicated.

Until recently, the device that held down the speed of PCs was the microprocessor. Today, a modern microprocessor such as Motorola's PowerPC is so fast that the rest of the PC cannot keep up with it. Future microprocessors such as the P7 will make the situation even worse.

The device that slows down these modern PCs is the DRAM, which is used to store commands and data while the microprocessor does its number crunching. It is not the DRAM's capacity (up to 64 Mb) but the rate at which data can be stored into it and retrieved from it.

A DRAM, in contrast to the much more expensive SRAM (static random access memory), uses only one transistor per memory cell. Since each cell stores one data bit, a modern DRAM needs to contain only 64 million transistors. However, the network interconnecting all these transistors causes interference, timing problems and noise. These in turn limit the rate at which data can be input and output.

To increase the rate, that is, to increase the volume of data transferred in a given time period, the channel width may be increased, allowing more bytes to be transferred simultaneously, or the clocking speed can be stepped up.

Traditionally, designers have tended to increase the channel width (to as much as eight bytes). Now, however, a small Californian chip company, Rambus, has approached the problem in a different way: the manner in which a DRAM interfaces with the outside world. To do this, their designers have altered the device's layout by replacing the network of signalling lines by a bus in which all the leads are parallel and of the same short length. This enabled them to increase the clock. In their design, the channel width is one byte, but the byte rate is 600 MBps. and they reckon that this rate can be increased by 200 MBps per year. Since the rate can also be doubled by adding a second bus, Rambus's designers hope to have production models that transfer data at a rate 1.6 GBps by 1999.

The design has so impressed Intel, the world's largest chip maker, that its microprocessors will from 1999 onwards be configured to work solely with the Rambus design.

The new configuration should enable realistic 3-D graphics to be used on a PC. Just refreshing a PC's screen when it is running such graphics may require 500 MB per second. So, even with the new device, a third of its capability is needed to run the screen. And that is before considering PCs start equipped with a DVD (digital video disk) drive that will replace the CD-ROM drive in a few years' time. (Think of what size of memory will be required to decompress and present a full-length movie on one of these new discs).

ISDN

The Integrated Services Digital Network – ISDN – has evolved owing to the problems associated with analogue telephony systems. There are considerable advantages that can be gained by changing to a system that will allow the end-to-end transfer of information in a digital manner. Once such a transition has been made, the advantages are:

1. Greater reliability due to the use of ISDN.
2. Faster access speed due to the introduction of *dual tone multi frequency* (DTMF) dialling instead of pulse dialling.
3. Computer access to the system which gives rise to the concept of *computer-integrated telephony* (CIT), where the power of the computer can be combined with the communications power of the ISDN.
4. By introducing CIT, many new services such as video, data and Group 4 high-speed facsimile can be introduced into the telephony system in a truly integrated manner.

For reasons of economy, the service has to be compatible with analogue systems and had to be introduced in an evolutionary manner. Thus, voice signals are processed in analogue-to-digital converters (ADCs) and digital-to-analogue converters (DACs) to be carried over the new system by *pulse-code modulation* (PCM).

Two classes of service are offered. A basic rate access (BRA) which most subscribers will use, known as 2B+D (B = bearer, D = diagnostic), and consisting of two 64 kbps (kilobits per second) voice and data channels, plus one 16 kbps digital signalling channel making a total of 144 kbps. The former is circuit-switched, while the latter is packet switched.

The second, more costly, service is known as primary rate access (PRA), and consists of 30B+D channel groupings in Europe (CCITT standard, 32 channel multiplex and 23B+D (Bell standard, 24 channel multiplex) in North America, giving total signalling rates of 2.048 Mbps (Megabits per second) (E1/T2) and 1.544 Mbps (T1) respectively.

Thus, the D channel forms a *common signalling channel* using the CCITT Common Channel Signalling System C7. Domestic and small business users use BRA, while large users with Private Automatic Branch Exchanges (PABX) use PRA.

The CCITT has developed a set of recommendations, individually prefixed by the letter *I* and collectively know as the *I series*, which cover such ISDN related topics as the ISDN concept and associated principles, overall network aspects and functions, user-network interfaces and inter-network interfaces.

The 1200 and 1300 series of CCITT recommendations respectively describe the services and network capabilities provided by an ISDN , while the 1100 series provide general recommendations for ISDN.

An ISDN *bearer service* is defined as a service to the customer which allows him the capability for information transfer between ISDN access points according to CCITT standards. An ISDN *teleservice*, on the other hand, is defined as a service which allows the customer complete capability for communications with another user of the service, according to protocols established by CCITT.

Memorable Dates

On 2 April 1872, Samuel Morse, American inventor of the telegraphic morse code, died aged 80 in New York City. He was borne on 27 April 1791.

On 6 April 1965, the communications satellite Early Bird was launched by the USA.

On 9 April 1968 Concorde made its maiden flight.

On 10 April 1849, the safety pin was patented by American Walter Hunt.

On 12 April 1961, the first manned space flight took place (Yuri Gagarin in Vostok I).

On 14 April 1629, Christiaan Huygens, the Dutch scientist, was born at The Hague.

On 15 April 1955, Albert Einstein, American scientist, died at Princeton.

On 22 April 1661, the Royal Society was constituted by Royal Charter.

On the 28 April 1874, Guglielmo Marconi, physicist and radio pioneer, was born in Bologna, Italy.

On 29 April 1913, the zip fastener as we know it was patented by Gideon Sundback of New Jersey.

Equipment and line plant installed today will, during the next decade or so, be expected to handle an increasing proportion of non-voice services during its lifetime. These non-voice services can be expected to rise from around 22% of subscribers today to as much as 50% by the year 2000.

In the UK, British Telecom's ISDN-2 provides two B channels each operating at 64 kbps and one D channel at 16 kbps. The B channels cater for voice and data but may be parallel configured with the use of appropriate terminal equipment to provide a single 128 kbps channel. The D channel is primarily used for signalling between the terminal and the network, but in some applications can also be used to carry packed switched data.

The BT Basic Rate Access (BRA) service was started in the late 1980s but formally launched in February 1991 and is available from System X local exchanges. From 1992, all business users requesting an additional business line (or asking for two new business lines) from BT will automatically have access to ISDN-2 via a network termination (NT) adaptor.

Several manufacturers, such as IBM and ICL, can supply ISDN PC adaptor cards which have been approved specifically for the UK.

The next stage of development in the evolution of the ISDN is the provision of services such as high-speed data transmission and high-resolution television. Unfortunately, such services require very high bit rates and consequently demand excessive bandwidths within the transmission medium.

To illustrate this point, a minimum bit rate of about 2 Mbps is considered appropriate for high-speed data and document transmission, whereas for high-definition TV (HDTV) a minimum rate of 140 Mbps is considered necessary. To accommodate these new services, subscribers' access lines will require comparably wide bandwidths.

Within the transit network, however, special coding techniques can be employed in order to reduce the cost overhead associated with wideband long distance transmission. For video telephony and video conferencing, it is then possible to reduce the transit network bit rate to around one third of that

present within the subscriber's access lines.

The Deutsche Bundespost is currently planning a nationwide wideband satellite system based on ITT System 12 exchanges which will switch data at a rate of 1,920 Mbps. Other data services operating at this rate will undoubtedly become operational within the very near future in several other European countries.

ISDN can be expected to have a major effect on the introduction of wide area networks (WANs) which are currently used primarily as a means of interconnecting remotely sited local area networks (LANs). The ISDN is eminently suited to this same task but offers improved reliability together with reduced capital costs and overheads. Hence, provided that an ISDN is in existence at each site, the need for a WAN can be eliminated.

NETWORK COMPUTERS

Some of the world's largest computer companies – Oracle, Sun Microsystems and IBM – maintain that within a few years network computers (NC) will have taken over almost half the world market at the expense of the PC. (A network computer relies entirely on the software and data available from a network). It will be interesting to see whether they will be proved right.

Originally, their claim was based on the low cost of the NC as compared with that of a PC: about $US500. However, production models now on the market cost nearer $US1000. Now the reasons for buying an NC instead of a PC are given as the much lower lifetime cost of the network computer and increased employee productivity (since users no longer have to tinker with their PC and can no longer play games on it). Also, learning to use an NC is almost certainly easier than a PC. (What happens to user distraction when the NC is connected to the Internet is anybody's guess).

The arguments for the NC are strong, indeed. Pundits reckon that they will replace mainframe terminals and telephones in the office and offer inexpensive, easy-to-use devices attached to TV receivers at home. They base their forecasts

on the fact that there are upwards of 30 million mainframe terminals that need updating and being provided with the means of connection to the Internet. Also, a large proportion (some say as much as a quarter) of the 200 million PCs are being used merely as terminals.

In the home, the NC is likely to be of greatest interest in the USA, where most households have two or more TV receivers and two telephone lines (an NC will occupy one TV receiver and one telephone line). But, no doubt, it will eventually come to households in Europe and other parts of the world as well. Already, in the UK many people have two TV receivers and two telephone lines (both are getting cheaper in real terms all the time).

INTERNET PROBLEMS?

The Internet is an amateur network run largely by volunteers and used by many professional organizations worldwide. In spite of the hype about on-line shopping, there are few companies that make a profit from selling via the net. Most publishers do not charge for access to their web sites (have a look at *The Times* or *Newsweek*.

The trouble is that companies in general do not sell to consumers but to each other. It is reckoned by Forrester Research, an American market research organization, that in three years' time business-to-business deals on the Internet will be worth almost $US70 billion (as against $US500 million in 1996), and consumer retailing about $US7 billion.

It appears that on-line shopping for individuals has to compete with the social pleasures of the real thing, whereas business buyers merely want the right product at the right price.

[975027]

digital thermometer

with RS-232 interface

It would be all too easy to describe the DS1620 as a simple temperature sensor: in the present circuit, the device doubles as a thermometer with a wide temperature range, and a programmable thermostat with switching outputs and hysteresis. The DS1620 is coupled to a PIC microcontroller which is programmed to store the digitized temperature, send it to an RS-232 interface, and show it on a bright LED display.
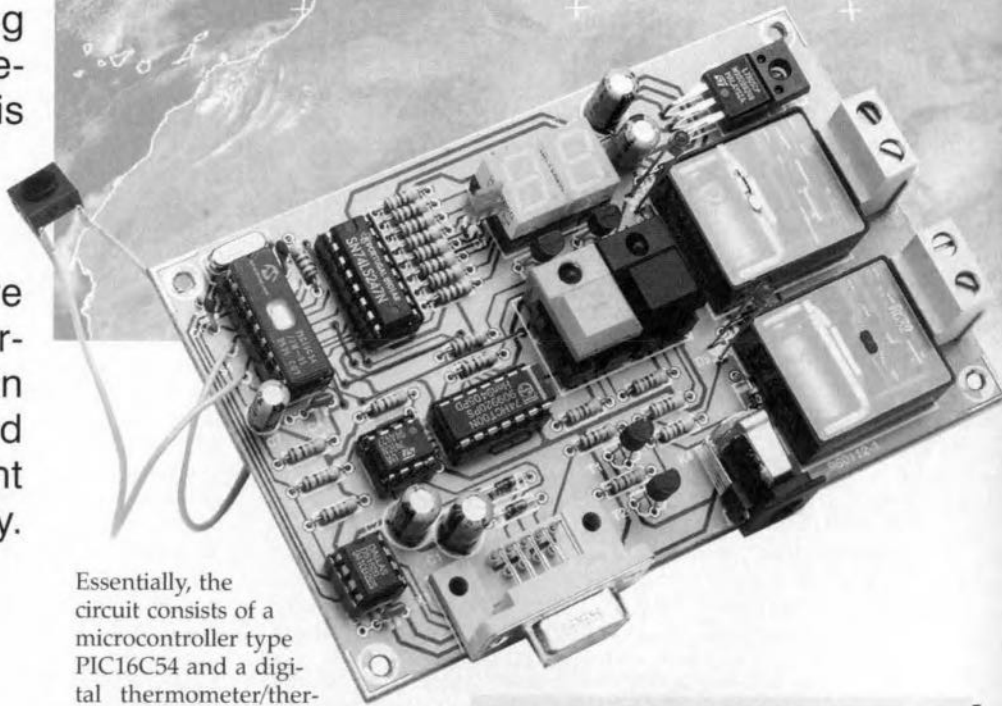
Essentially, the circuit consists of a microcontroller type PIC16C54 and a digital thermometer/thermostat IC type DS1620 from Dallas Semiconductor. Depending on the programming of the microcontroller, a plethora of functions and applications is available. Here, the main task of the microcontroller is to look after the serial data traffic with the sensor. The main additional functions provided by the microcontroller program are: in-circuit programming of the temperature switching threshold, storing the minimum and maximum measured temperature, periodic outputting of measurement values

Specification

Thermometer
✔ Two-digit display
✔ Adjustable range from −40 to +80 °C
✔ Error smaller than 0.5% (−10 to +80 °C)
✔ Adjustment-free
✔ Min/Max function
✔ RS-232 output, temp. in steps of 0.5 K

Thermostat
✔ Upper and lower switching levels freely adjustable
✔ Two relay outputs, 5 A, 2 x c/o

Design by G. Stippler

via a simple RS-232 interface, and, last but not least, indicating the temperature on a two-digit LED display. Moreover, the present circuit enables any DS1620 chip to be programmed for stand-alone as a thermostat (i.e., without a CPU).

THERMOMETER AND THERMOSTAT IN ONE IC

Figure 1 illustrates that modern temperature sensors such as the DS1620 consist of more than just an integrated *temperature sensor*. As you can see, the DS1620 contains a series of functional groups which allow many applications to be realized without complex and extensive peripheral circuitry.

The DS1620 has two modes of operation. In **stand-alone mode**, the sensor IC operates as a simple thermostat, requiring the upper and lower temperature limits (switching levels) to be programmed, along with a couple of other parameters, before it can be used. The parameters are stored in a non-volatile memory, where they are safe against any interruption of the supply power. In theory, this mode allows the DS1620 to be employed without any additional external components (well, except a supply). In practice, drivers (buffers) may be useful at

Table 1. DS1620 Command Overview

Value (Hex)	Command	Description
0C	Write Config	Write configuration data into Config Register
02	Write TL	Write low temperature limit into TL Register
01	Write TH	Write high temperature limit into TH Register
AC	Read Config	Read configuration data from Config Register
A2	Read TL	Read low temperature limit from TL Register
A1	Read TH	Read high temperature limit from TH Register
AA	Read Temp	Reads last measured temperature from Temperature register
EE	Start Convert T	Start temperature measurement
22	Stop Convert T	Stop temperature measurement

Table 2. Configuration Byte Structure

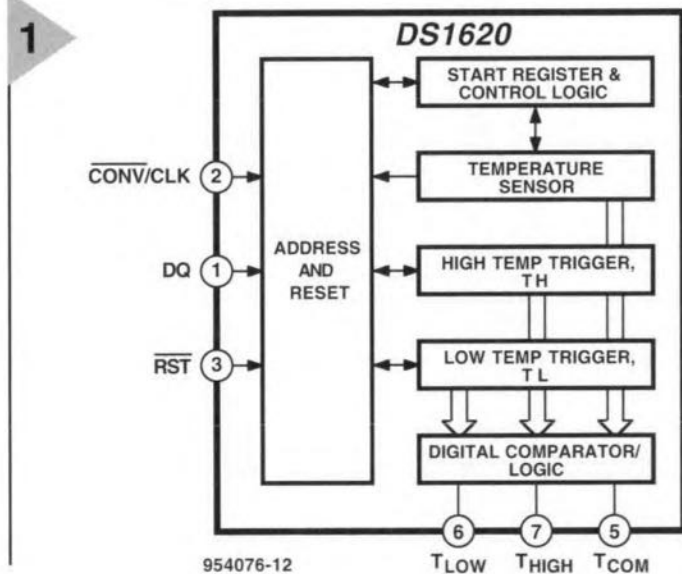| Bit 8	DONE	Zero: conversion active, One: conversion done
Bit 7	THF	Temperature-High Flag goes to 1 when the limit is equal to, or exceeds, the temperature, and remains at 1 until the memory location is overwritten with a zero, or the supply power is switched off.
Bit 6	TLF	Temperature-Low Flag goes to 1 when the limit is equal to, or smaller than, the temperature, and remains at 1 until the memory location is overwritten with a zero, or the supply power is switched off.
Bit 5, 4, 3		no function
Bit 2	CPU	Zero: Stand-alone mode, Pin 2 = $\overline{CONV}$ with $\overline{RST}$ zero at the same time; One: 3-wire mode with CPU, Pin 2 = CLK. CPU bit stored in EEPROM.
Bit 1	1SHOT	Zero: continuous temperature measurement; One: single temperature measurement controlled by $\overline{CONV}$ (START Convert T), then return to stand-by state. Wait 10 ms after writing to EEPROM.

Figure 1. Internal organization of the DS1620 thermostat/thermometer IC.

the outputs, as well as relays, overvoltage protectors, acoustical or optical alarm actuators, or opto-isolators. Such devices are also used in the present circuit.

The measured and digitized temperature is compared by a section called *digital comparator/logic*. The comparison is against two limits called *high temp trigger* (TH) and *low temp trigger* (TL). Depending on the actual situation, the comparator output actuates

one of three outputs: TH when the temperature exceeds the upper limit, TL when the temperature drops below the lower limit, and TCOM, which couples TH and TL to give a hysteresis function.

The $\overline{RST}$ connection has no func-

tion in this mode, and is held at 0V. A negative pulse at pin2 ($\overline{CONV}$) causes a temperature measurement to be started, while a continuously low level at the $\overline{CONV}$ pin selects permanent operation as a thermostat.

In **3-wire mode** the DS1620 may be coupled to a microcontroller. Only this mode allows the IC registers to be accessed by reading and writing. The $\overline{RST}$ terminal is the active-low reset input of the chip; CLK, the clock input, and DQ the port through which data may be read or written. A data transfer via the DQ port consists of two bytes. The first, the protocol byte, identifies the meaning of the data of the second byte. As shown in **Table 1**, three write commands are available, and four read commands. Furthermore, the last two commands enable a temperature measurement to be

Table 3. Temperature/data relation

Temperature	Digital Value		
	MSB	LSB	hexadecimal
+125 °C	0 1111 1010		00FA
+25 °C	0 0011 0010		0032
+0.5 °C	0 0000 0001		0001
0 °C	0 0000 0000		0000
-0.5 °C	1 1111 1111		01FF
-25 °C	1 1100 1110		01CE
-55 °C	1 1001 0010		0192

2

A ▶ 8V6
B ▶ −7V
C ▶ −9V4
D ▶ 5V
E ▶ 0V
F ▶ 0/5V
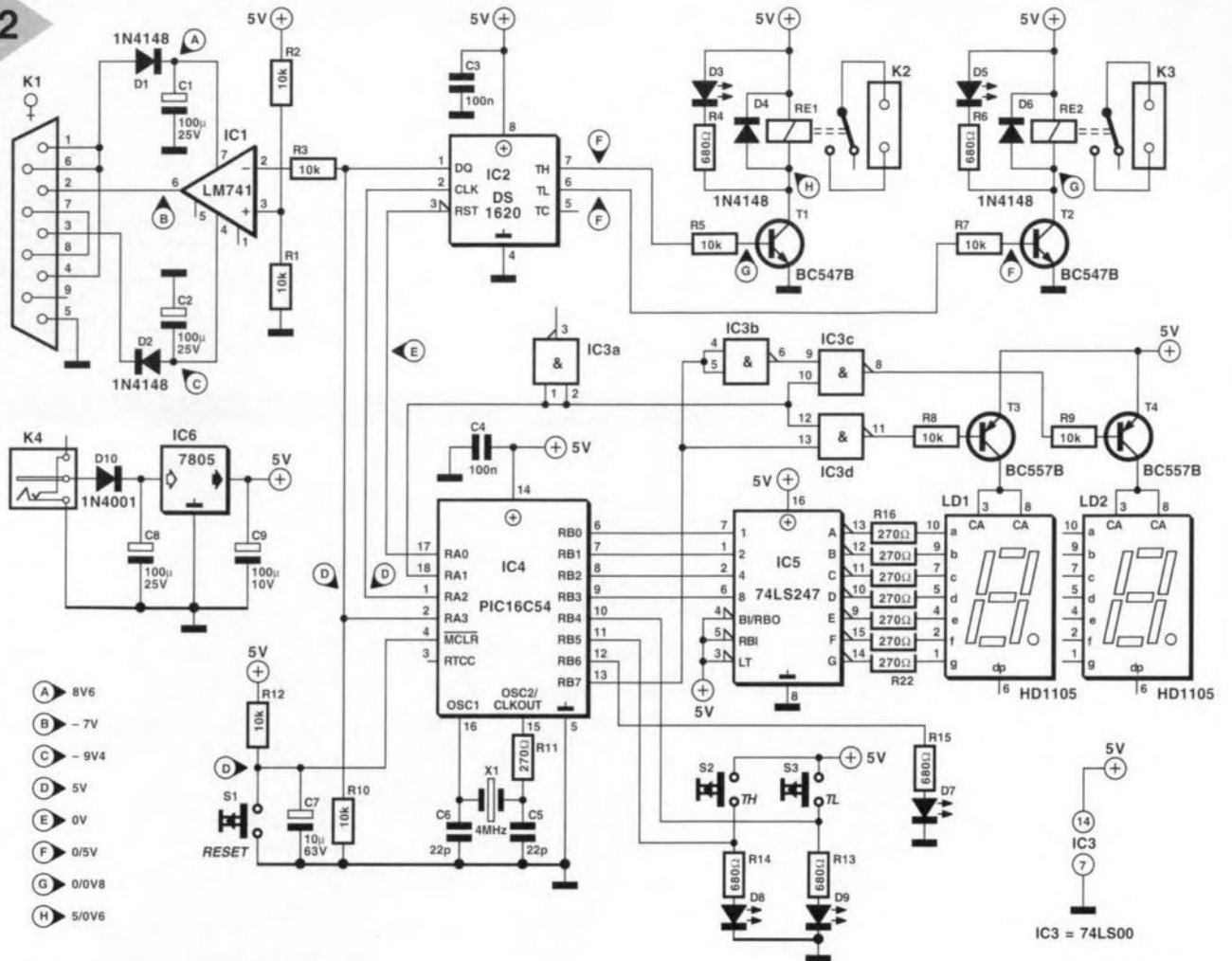G ▶ 0/0V8
H ▶ 5/0V6

960112 - 11

Figure 2. The digital thermometer/thermostat is controlled by a PIC microprocessor.

started or stopped, without the need for a second byte to follow the protocol byte.

The configuration byte in the register called *status register & control logic* has special significance. Bit 2 of this byte, the CPU-bit, determines whether the DS1620 operates in stand-alone mode or 3-wire mode. In fact, the CPU-bit determines the function of pin 2: $\overline{CONV}$ or CLK. The other bits of the configuration byte describe the status of the DS1620, and are only of interest for read operations. Their exact meaning is given in **Table 2**. Because a measurement range of − 55 °C to +125 °C means that 360 discrete temperature

steps have to be displayed, a resolution of nine bits is required. According to the protocol byte, all commands that concern input or output of a temperature have nine instead of eight bits, and are transmitted LSB-first. The relation between temperature and transmitted data is shown in **Table 3**. The value rises from 0000_H at 0 °C to $00FA_H$ at 125 °C. The negative part of the range is output as a two's comple-

Table 4. *Temperature Acquisition in BASIC*

```
300 CLS:CLOSE:DEFINT A-Z:FALSE=0:TRUE=NOT FALSE:DEFSNG T:ON ERROR GOTO 460
310 XOFF$=CHR$(19):XON$=CHR$(17)
320 OPEN "com1:1200,n,8,1" AS #1                    '1200 Baud, no parity, 8 data bits, 1 stop bit
330 OPEN "scrn:"FOR OUTPUT AS #2                    'screen as file
340 LOCATE ,,1:PAUSE=FALSE
350 B$=INKEY$:IF B$ <> "" THEN PRINT #1,B$;
360 IF EOF(1) THEN 350                              'check input if no characters
370 IF LOC(1) > 128 THEN PAUSE=TRUE:PRINT #1,XOFF$; 'buffer > half full
380 A$=INPUT$(LOC(1),#1)                            'read buffer contents
390 TEMP=ASC(A$):HG=TEMP AND &H80:MINUS=TEMP AND &H40:TEMP=TEMP AND &H3F
392 IF HG=128 THEN TEMP=TEMP+.5
396 IF MINUS=64 THEN TEMP=TEMP* -1
420 PRINT "Temperature: ";:PRINT USING "###.#";TEMP;:PRINT " degrees C at ";:PRINT TIME$
430 IF LOC(1) > 0 THEN 370
440 IF PAUSE THEN PAUSE=FALSE:PRINT #1,XON$;
450 GOTO 350
460 REM Error processing
470 RESUME
480 END
```

ment: $-0.5\,°C$ corresponds to $01FF_H$. The lowest temperature that can be measured, $-55\,°C$, then produces an output value of 0192_H. In this arrangement, the ninth bit (MSB) becomes the sign bit.

THE PIC
MICROCONTROLLER

The measured value is to be transmitted via the RS-232 interface as an 8-bit dataword. A complete cycle starts with a read access to the nine bits of the temperature register of the DS1620. This happens so fast (approx. 100 kHz) that the RS-232 interface (set to 1200 baud) does not respond. Next, CLK goes high, causing the DQ output to switch to the high-impedance state. The value read is shortened to eight bits, and subsequently transmitted via the RS-232 interface, using the protocol: 1200 baud, no parity, 8 databits, 1 stop bit. The syncopation to eight bits causes the measurement range to be reduced to -40 to $+80\,°C$. The order of the databits is also changed: the first seven bits indicate the temperature (in whole degrees centigrade), where bit 7 acts as the sign bit ($+$ or $-$). The eighth bit is the half-degree bit. The simple GW-BASIC terminal program shown in **Table 4** uses these values to compute the corresponding temperature between -40 and $+64\,°C$ at a resolution of $0.5\,°C$, and sends it to the PC display together with the current time. Extending the temperature range to $+80\,°C$ is relatively easy by processing the double function of bit 7, which is at logic 1 at temperatures below $0\,°C$ and above $63\,°C$. If bit 7 changes from 0 to 1, the software should be able to interpret the trend to tell which of these temperatures is being measured.

INTERFACES

Disregarding, for the moment, the DS1620 and the microcontroller, then it is fair to claim that nearly all components that go into the present thermostat/thermometer are part and parcel of some kind of interface.

The physical structure of the RS-232

Figure 3. PCB artwork.

COMPONENTS LIST

Resistors:
R1,R2,R3,R5,R7-R10,R12 = 10kΩ
R4,R6,R13,R14,R15 = 680Ω
R11,R16-R22 = 270Ω

Capacitors:
C1,C2,C8 = 100μF 25V radial
C3,C4 = 100nF
C5,C6 = 22pF
C7 = 10μF 63V radial
C9 = 100μF 10V radial

Semiconductors:
D1,D2,D4,D6 = 1N4148
D3,D5 = LED
D10 = 1N4001
D7 = LED, rectangular model
T1,T2 = BC547B
T3,T4 = BC557B
IC1 = LM741
IC2 = DS1620 (Dallas Semiconductor)
IC3 = 74HCT00 or 74LS00
IC4 = PIC16C54, programmed, order code 966501-1
IC5 = 74LS247
IC6 = 7805

Miscellaneous:
K1 = 9-way sub-D socket, PCB mount, angled pins
K2,K3 = 2-way PCB terminal block, pitch 7.5mm
K4 = mains adaptor socket
S1 = Push-button, make contact
S2,S3 = Digitast press-key with internal LED
Re1,Re2 = Siemens V23127-A1-A101 (6V) or V23127-A8-A101 (5V)
X1 = 4MHz quartz crystal
LD1,LD2 = HD1105 (Siemens)
Enclosure: size approx. 145x95x34mm (Pactec)
PCB and programmed PIC: set order code 960112-C (see Readers Services page)
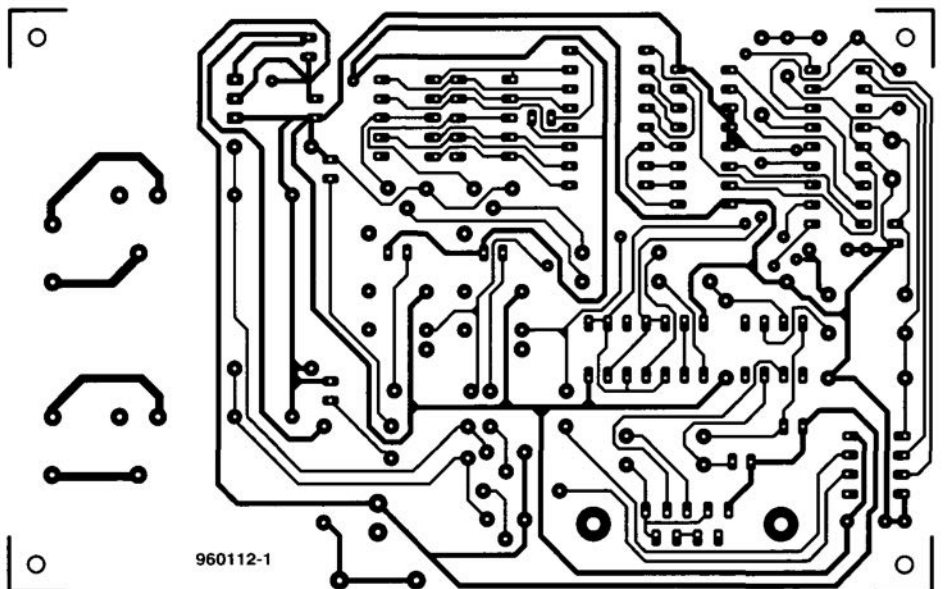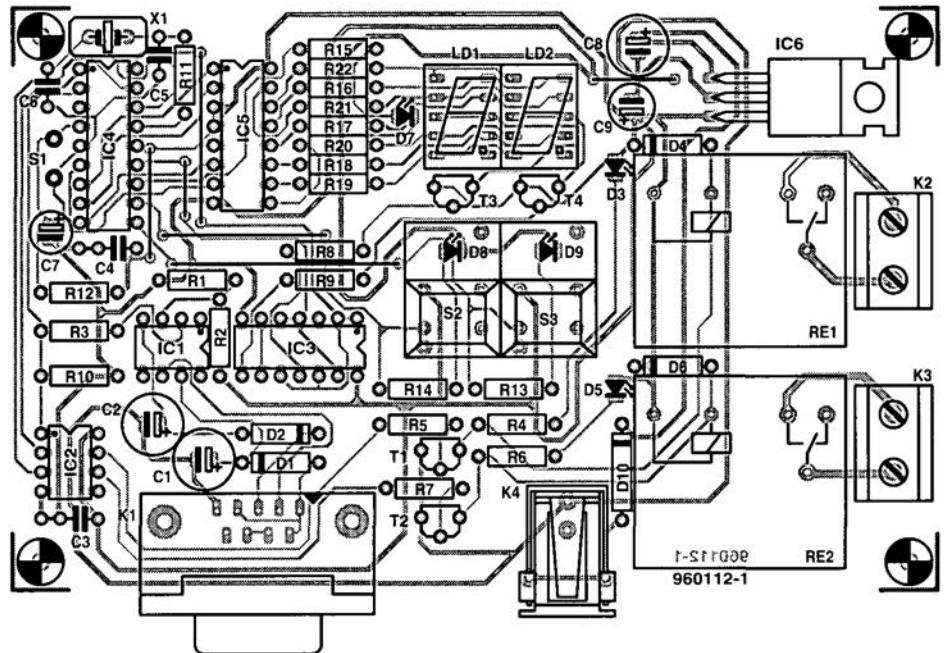
interface is both simple and unusual. Even the familiar MAX232 which would be expected here was considered a superfluous luxury. Because the interface has a transmit path only, and does not make use of a return channel, the simplest of all ICs, the LM741, is adequate for our purpose. The positive supply voltage of the IC is derived from the DSR line on the RS-232 interface, while the negative bias is obtained from the inactive transmit line, RxD. The non-inverting input of IC1 being held at a potential of 2.5 V, the output will swing between the two extreme RS-232 voltage levels in accordance with the databits supplied by the PIC. This creates a simple serial link without a special symmetrical supply.

Returning to the PIC, port lines RB0-RB3 drive a two-digit display via a 4-bit-to-7-segment decoder (IC5). The display is multiplexed via port RB7, IC3, T3 and T4. The sign is handled by
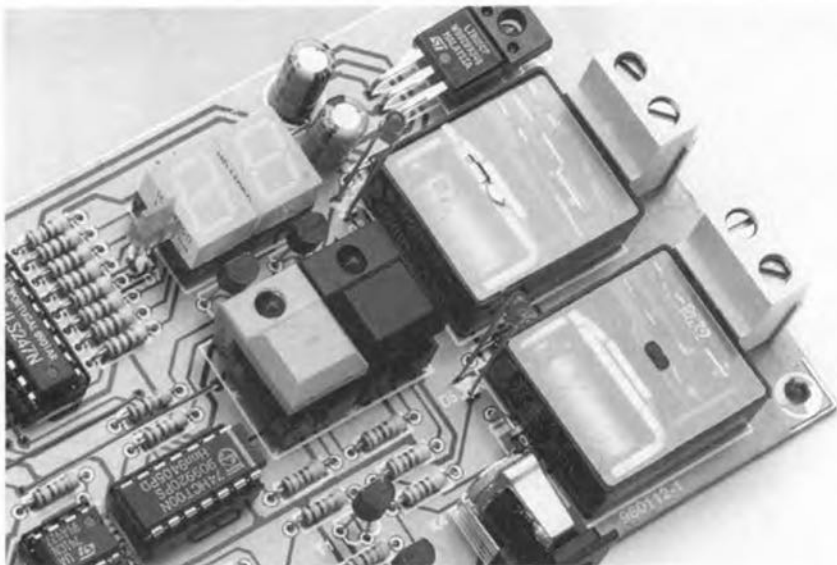
port RB6 which controls a rectangular-face LED, D7. This indicator is fitted to the left of the displays, and indicates a minus sign when lit.

The two relays are controlled by the thermostat outputs on the DS1620, with the help of drivers. The relays may switch loads up to 5 A. The type indicated in the parts list is a 6-volt relay. A better alternative, although harder to find, is the corresponding 5-volt version (V23127 A8 A101), also from Siemens. The status of the LEDs is indicated by LEDs D3 and D5.

The TC (hysteresis) terminal is not used here. If you need it for switching purposes, however, simply give it a driver and a relay just as the TH and TL outputs.

OPERATION

The operator controls and indicator elements of the thermostat are the three push-buttons, Reset, TH and TL, and the integral LEDs, D8 and D9, in the

latter two switches. The LEDs have double and even triple functions, however.

- When the circuit is switched on, the display first reads 00 for few seconds, then the first measured temperature appears.
- Keeping the TH key pressed for a while causes the integral LED to light, and the value representing the upper temperature limit to appear on the display.
- Release the key; the LED will continue to light, and the highest temperature measured since resetting the circuit is displayed for a few seconds.
- To program a new upper limit, keep TH pressed, and step to the desired value by repeatedly pressing the TL key. At a setting of 80 °C, the display jumps to – 40 °C. If the desired value is reached, keep the TL key down, release TH, and then TL. The new

value is then programmed, and will remain on the display for a few seconds. If you do not press TL, the old value is retained.
- The lower switching limit is changed likewise, with the functions of the TH and TL keys interchanged, of course.
- To clear the min./max. memory, or set it to the current temperature, press TH and TL simultaneously. This action is recommended when the unit is first switched on, because the minimum value displays 00 until the first frost occurs.
- To switch the DS1620 to thermostat mode, keep the TL key pressed while you press the Reset key. In this way, the CPU-bit in the status register is changed. Also, the controller enters the sleep mode, reducing the current consumption to that of the LEDs and the relays. Pressing Reset again switches on the thermometer function again. The display will then read '00' initially.

It is recommended to first decide on the actual application you have in mind for the thermostat even before you start buying components. If it is required that the circuit remains fully operational even at very low temperatures, then parts with an extended temperature range specification should be purchased. The PIC controller supplied by the Publishers (see Readers Services page) is programmed for a temperature range of – 40 to +85 °C. Purchasing parts for the project becomes easier if you expose the circuit to temperatures below 0 °C in thermostat mode only, when most of the circuitry is 'asleep'.

Populating the large and clearly laid out printed circuit board should not cause undue difficulty. The track layout and component mounting plan are shown in **Figure 3**. Like the PIC controller, the board is available from the Publishers. Start by fitting the six wire links on the board, so that these are not forgotten later. Sockets may be used for all ICs, but do bear in mind that they may cause problems in humid or very cold conditions. The LEDs, displays and press-keys are fitted at the same height, so that they rise above the other parts (in particular, the PCB terminal blocks and the connectors).

Having finished the work on the board, give it a thorough visual inspection. If everything appears to be okay, you may connect a 9-V mains adaptor to K4 (watch the polarity). Next, check the presence of the +5 V supply voltage on all IC supply pins (directly on the IC pins, not at the solder side of the board). Assuming that '00' is being displayed, the current consumption of the circuit amounts to about 80 mA. If the display remains dark, you should first check whether the programmed PIC operates properly. Pin 13 (RB7) should supply a rectangular signal with a repeat rate of 1.6 ms. This is the display multiplexing signal. Next, use an oscilloscope to check for oscillator activity at pin 15 of the PIC (the measured level should be about 2 V). A properly working PIC supplies clock pulses at 5-second intervals on pin 1 (RA2). The DS1620 responds to these clock pulses by issuing data at pin 1 (DQ). This is readily traced with a digital oscilloscope, but not so, unfortunately, with an analogue scope or a DVM.

If everything works, the circuit may be fitted into a weather-proof case. A few ventilation holes, protected against water ingress, may be drilled near the sensor ICs.   (960112)

Note: datasheet extracts of the DS1620 may be found in the January 1997 issue, pages 69/70.

PIC-controlled home alarm system

Simple to build thanks to microprocessor control

These days, if you want to protect your home and valuables, you can't avoid installing a clever and reliable alarm system. The circuit described here complies with both requirements. Thanks to the use of a microcontroller at the heart of the system, a wide range of commercially available burglar detectors may be incorporated in a simple 2-wire cable loop.
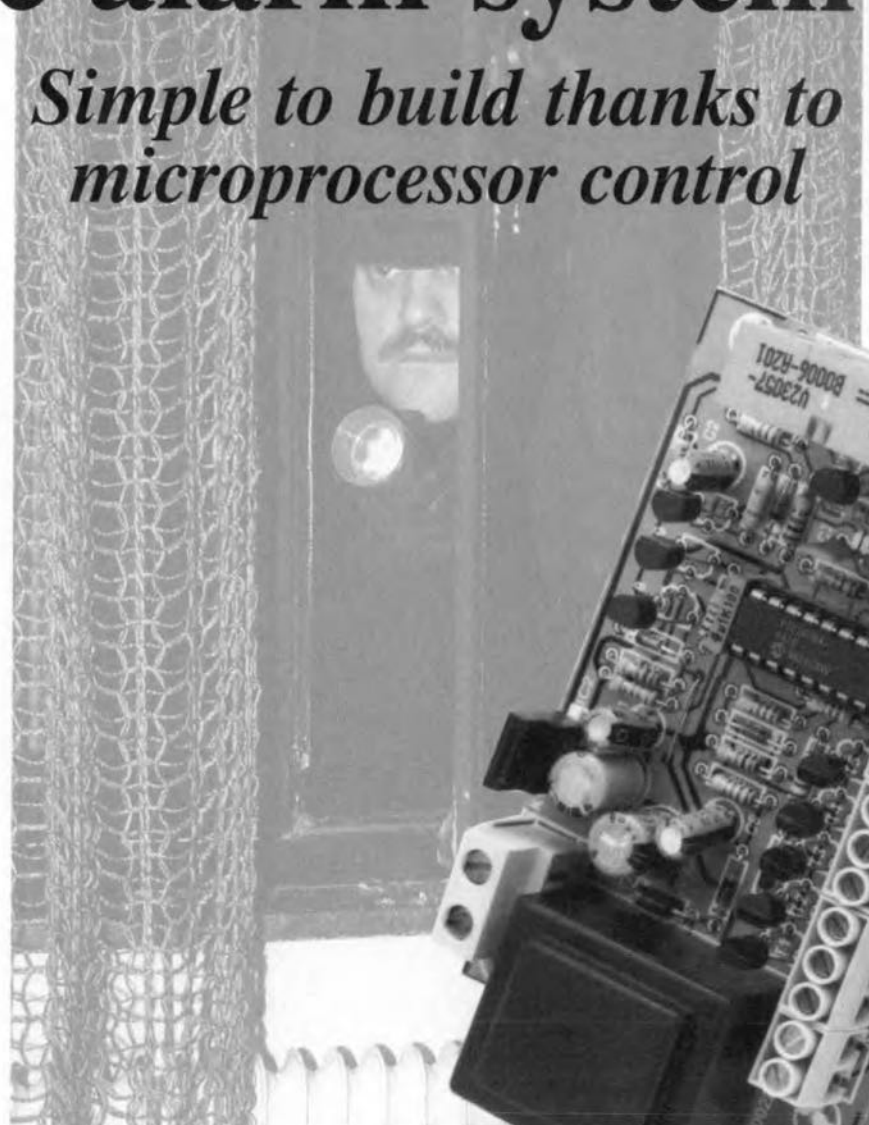
Specifications

Processor:	PIC16C84
Arm delay:	60 seconds
Interface:	2-wire current loop
Detector types:	break (series connection)
Number of groups:	5
Output:	relay
Alarm time:	1 minute
Indicators:	2 LEDs on control unit
	1 LED with each detector
Power supply:	mains

Design by P. de Bruyn

Burglars and intruders may be typified by their habit of entering homes or premises at undesirable times and using undesirable methods to get inside. Fortunately, it is this 'unique' characteristic that makes their criminal activities relatively easy to detect. As a matter of course, a security system to ward off burglars requires some electronics, and that is our field *par excellence*.

The elementary structure of the home alarm system is shown in **Figure 1**. The sensors (detectors) fitted on to doors and windows are standard types which should be available as spares from any hardware or department store. In most cases, you will be looking at magnetically-operated switches consisting of a small magnet and a reed switch. These units are suitable for fitting on to doors and/or windows. In the present circuit, the sen-

sors are included in a current loop (10 mA), which is broken (interrupted) as soon as the distance between the magnet and the reed switch exceeds a certain value. That happens when a protected door or window is opened, and it is usually a reason for setting off the alarm.

The use of current loops gives the circuit a high degree of immunity against noise that may be induced in the cables.

The microcontroller applied in the circuit offers some distinct advantages over a circuit built from discrete components. The switch-on procedure, for example, is particularly user-friendly, and the total complexity of the circuit is considerably reduced.

An important difference between the present design and conventional home alarm systems lies in the fact that

the circuit discussed here only responds to detectors changing from the 'open' to the 'closed' state. Consequently, a window may be left ajar (but locked), so that the current loop is actually broken. The window is not included in the alarm system until it is closed (when the current loop is closed also). So, you may still air the house by opening windows on a warm summer day, and not set off the alarm.

The alarm switches on a relay for about one minute when an alarm condition occurs. The relay may be used to actuate an external sounder or indicator, say, a flashing light or a siren, but also a 'silent alarm'. When the minute has elapsed, the circuit resets itself and performs an automatic restart. The occurrence of an alarm condition is stored in its memory. When the circuit is switched off with the on/off switch or the door switch, the LED starts to flash rapidly to signal that an alarm condition has been recorded.

PRACTICAL CIRCUIT

The circuit diagram of the home alarm system is shown in **Figure 2**. The various connections of the detector groups which are to be fitted on to or into the objects to be protected are shown in **Figure 3**, along with the wiring of the door switch and the on/off push-button(s). Note that the diode connected in series with the detectors is reversed with respect to the diodes connected in series with the push-button and the switch. The reason for this arrangement will be discussed further on.

The door switch should be mounted inside the lock in the front door, in such a way that the switch is closed when you lock the front door. In this way, the alarm is automatically switched on if you close and lock the front door. The on/off push-button may be mounted near other exterior doors, for example, the back door. These on/off buttons enable the alarm to be switched on and off independent of the door switch.

The heart of the alarm system is a PIC processor type PIC16C84. All features of the system have been implemented in a compact program which is stored in the processor's internal ROM memory. The PIC processor is supplied ready-programmed by the Publishers.

When power is applied to the cir-

cuit, network R1-C1 provides a delayed pulse at the master clear (MCLR) input of the PIC (pin 4). The pulse ensures that the processor does not start until defined logic levels are present at all points. The R-C combination consisting of R15 and C7 is responsible for the clock signal. A relatively expensive quartz crystal is not required here because the oscillator frequency is rather uncritical in the present application.

The alternating voltage supplied by the transformer's secondary winding is applied to input RB4. Series resistor R14 provides the necessary current limiting, while two internal protection diodes clip the peak excursions of the positive and negative half-cycles to safe levels. On the one hand, this provides the processor with an accurate 50-Hz reference frequency. On the other hand, this signal plays an important role with the evaluation of the detection circuit. During the positive half of the alternating voltage at the secondary of the transformer (when pin 10 of IC1 receives a logic high level), the circuit which arranges the operation of the alarm system (on/off switch and door switch) is read out. During the negative half-cycle (pin 10 logic low) the detector circuit is read out. Thanks to this

approach, the door switch, on/off switch and the detectors (sensors) may be connected at any location where one of the five detection loops is available.

THE DETECTION CIRCUIT

The sketches in **Figure 4** serve to unravel the seemingly complex structure of the detection circuit. The main cause of the complexity is the fact that the alternating voltage determines which part of the circuit is operational.
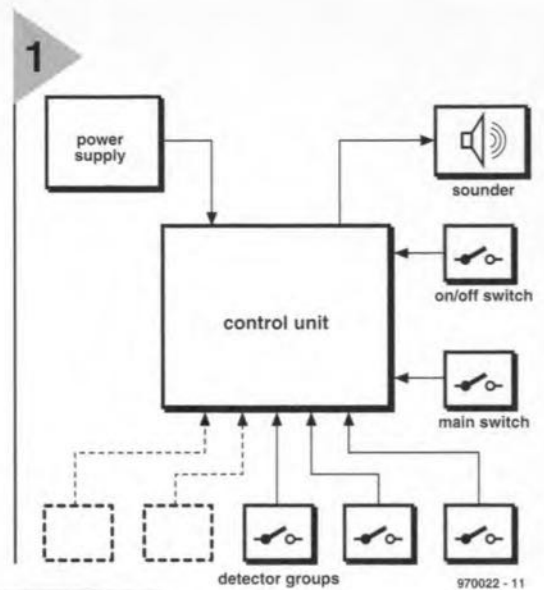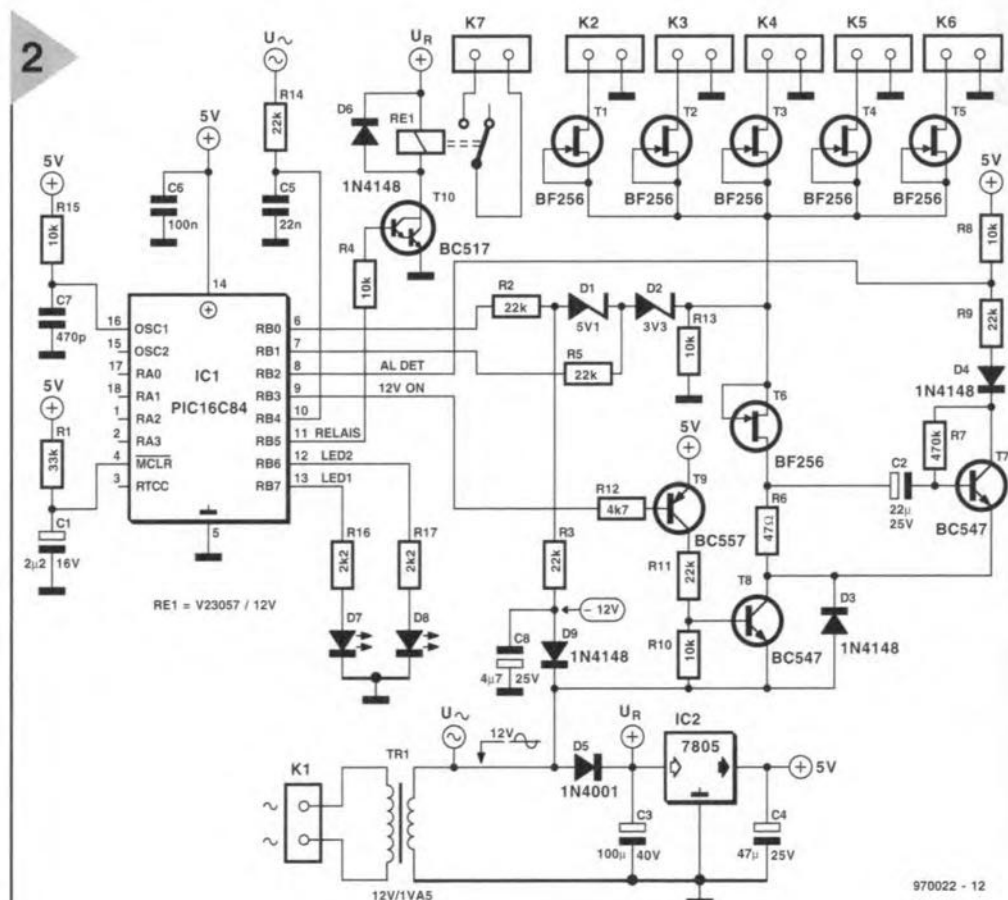

Figure 1. Block diagram of the home alarm system. The main parts are the power supply, the microprocessor with its two-wire interface, the individual detectors and the switches.

970022 - 11

Figure 2. From theory to practice. Thanks to the use of a PIC processor, the control unit remains a fairly compact circuit.

RE1 = V23057 / 12V

970022 - 12

3

one detector | two detectors

a

1N4148 | 1N4148

K | K

b | c | 4V7

on/off switch | door switch

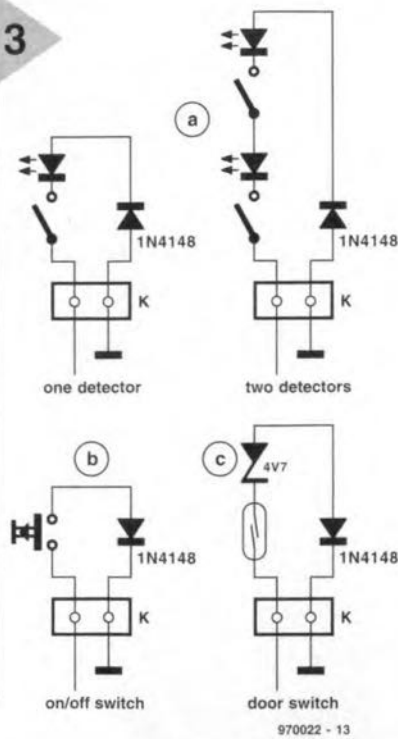1N4148 | 1N4148

K | K

970022 - 13

Figure 3. The control unit allows an on/off push-button, a door switch and sensors to be connected. These drawings show the circuit configurations of the various options. Note that the series diode with the detector circuits is reversed with respect to the one with the push-button/door switch.

Let's start by looking at the circuit which reads out the detectors. For the simplicity's sake, we will only consider connector K2 in the following discussion. The states of the connected detectors are read out (evaluated) during the **negative half cycle** of the transformer's secondary voltage. One side of the transformer winding is connected to the ground terminal of K2. During the negative half-cycle, this terminal represents the point with the most positive potential, so that a current flows from this point to the other side of the transformer winding. When the microprocessor switches on the alarm, transistors T9 and T8 are switched on by the logic level supplied by output RB3. Diode D3 is then effectively short-circuited. FET T6 also acts as a short-circuit with this direction of the current. The upshot is that a constant current (set to 10 mA by T1) flows through the LED and the closed door switch, causing a constant voltage across resistor R6. In the non-actuated state, the small base current through T7 causes a low level at PIC input line RB2 (AL-DET). If a detector input is opened (alarm condition), the current through R6 drops by 10 mA. This results in a negative pulse being applied to the base of T7, causing the transistor to be switched off briefly. RB2 goes high temporarily, which signals that the actuator(s) should be energized. The drawing in **Figure 4a** indicates the current flow in this situation.

The evaluation of the on/off push-button state and the door switch takes place during the **positive half-cycle** of the transformer secondary voltage. Transistor T6 then acts as a current source, and T1, as a short-circuit (see **Figure 4b**). In this situation, current flows via D3, R6 and current source T6, through the circuit consisting of the on/off push-button and the door switch. Because a zener diode is incorporated in series with the door switch, the voltage across R13 becomes dependent on the position of the switches. If the door switch is closed, the voltage is higher than 5.3 V. If the on/off switch is then pressed, this voltage drops to about 0.6 V. When both switches are open, the voltage across R10 rises to more than 10 V.

Zener diode pair D1-D2 acts like a voltage filter. If the door switch is closed (circuit active) and the on/off push-button is open, the 5.3-V voltage keeps PIC input RB6 logic low, while a logic high level is applied to RB1. To a PIC processor, a voltage level of 1.5 V already means a logic 1. If the on/off button is pressed (by the user switching the alarm on or off), the voltage across R3 drops to 0.6 V, and RB0 as well as RB1 'see' a logic low level at the respective inputs.

Returning to the practical side of things, terminal blocks K3 through K6 allow a detector as well as an on/off push-button to be connected. Up to four detectors may be connected in series, each with its own LED. In this way, it becomes very

Detectors, push-button and door switch

Suitable detectors may be found in hardware and electronics stores. These detectors may be neatly fitted on window frames and door frames. If you want the alarm system to be invisible, you may have to resort to making your own detectors. Fortunately, that is relatively simple. Use a chisel to make a small notch in the door frame or windows frame, and seat the reed switch and the connection wires. Next, drill a hole in the door or window, exactly opposite the location of the reed switch, and insert a small magnet. Fill the holes with painter's putty, allow to dry, cover with paint, and you have your invisible detector.

An on/off is best fitted near the front or back door, in such a way that it not visible to intruders. If you want, you may use a key lock for this purpose, but do remember that the switch is then normally off. Closing it briefly then actuates the alarm, or switches it off. Users of a key lock are well advised to fit a detection LED of a detection circuit near the key lock.

The door lock switch may be made by cutting a small part from the night bolt to make room for a small magnet which is secured with strong glue. At the side of the door frame, you then fit a reed contact which responds to the magnet.

COMPONENTS LIST

Resistors:
R1 = 33kΩ
R2,R3,R5,R9,R11,R14 = 22kΩ
R4,R8,R10,R13,R15 = 10kΩ
R6 = 47Ω
R7 = 470kΩ
R12 = 4kΩ7
R16,R17 = 2kΩ2

Capacitors:
C1 = 2µF2 16V radial
C2 = 22µF 25V radial
C3 = 100µF 40V radial
C4 = 47µF 25V radial
C5 = 22nF

C6 = 100nF
C7 = 470pF
C8 = 4µF7 25V radial

Semiconductors:
D1 = zener diode 5V1/0.5W
D2 = zener diode 3V3/0.5W
D3,D4,D6,D9 = 1N4148
D5 = 1N4001
D7,D8 = LED
T1...T6 = BF256
T7,T8 = BC547
T9 = BC557
T10 = BC517
IC1 = PIC16C84-04/P, programmed, order code 976501-1
IC2 = 7805

Miscellaneous:
K1 = 2-way PCB terminal block, pitch 7.5 mm
K2-K7 = 2-way PCB terminal block, pitch 5mm
Re1 = 12-V PCB relay, e.g., Siemens V23057-B2-A201
Tr1 = PCB mains transformer 12V/1VA5, e.g., Monacor VTR1112, Block VR1112, Velleman 1120018
Enclosure: 120x65x40mm, e.g. Bopla E430
PCB and programmed PIC, set order code 970022-C
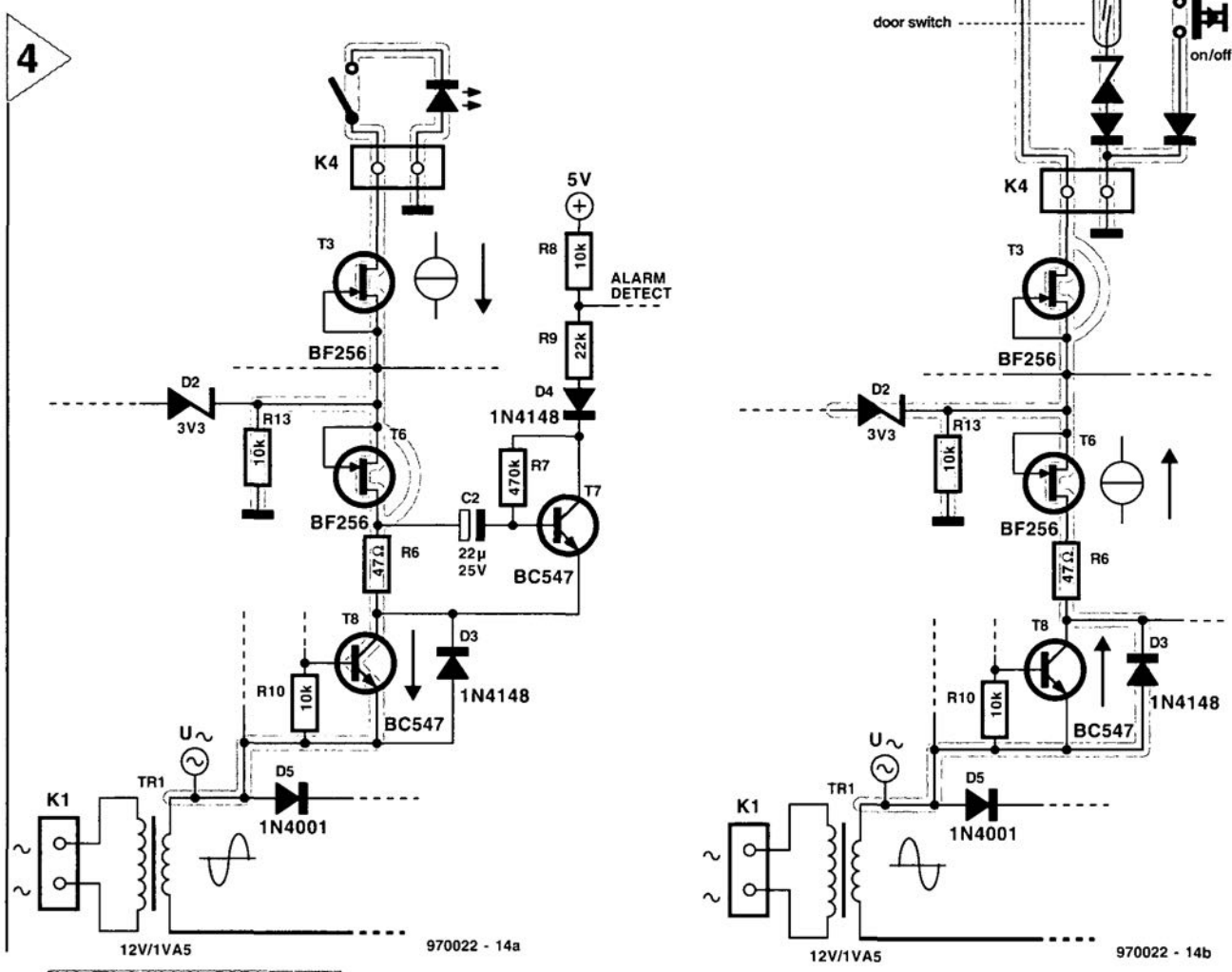Programmed PIC only: order code 976501-1

4

5V
ALARM DETECT

970022 - 14a

970022 - 14b

Figure 4. These two circuit diagrams illustrate the way in which the state of the switches and the detectors is evaluated.

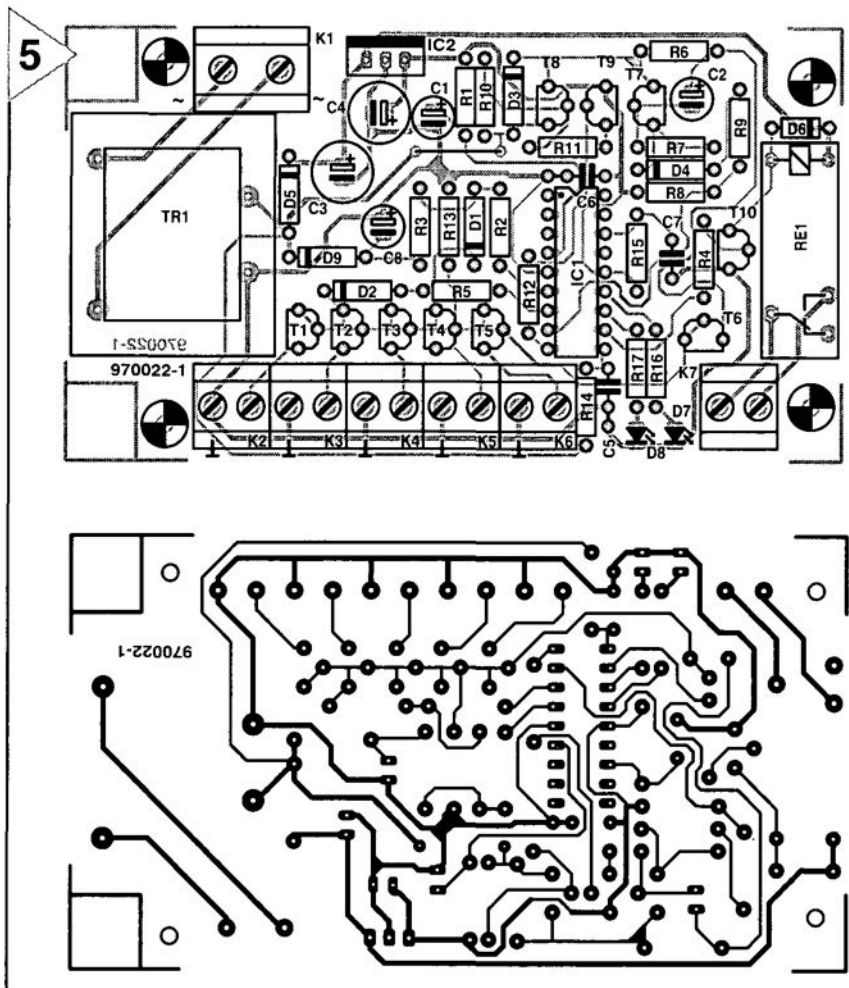simple to mount an on/off push-button in several locations.

By switching T8 on and off in a pulsating manner, the microcontroller ensures that the LEDs connected in series with the detectors start to flash, indicating the 'stand-by' mode of the alarm system. If T8 conducts all the time, the LEDs light continuously, indicating that the alarm is armed. In this way, the processor is able to provide a simple, clear indication of the alarm state at any location having a sensor device.

STOP THIEF!

All LEDs will light after you switch on the power supply. LED D8 will flash

Figure 5. Copper layout and component mounting plan of the PCB. Board available ready-made from the Publishers.

970022-1

for about one minute, this indicates the time you have available to leave the room or the home after the switching on of closed alarm circuits. D8 will light continuously once this actuation delay has elapsed. From then on, the system is fully armed, all sensors are checked all the time, and the alarm will be actuated if one of the detectors is opened from the closed state. If an alarm condition is detected, the internal relay will be energized for about one minute. Next, the circuit is reset, and the power-on delay is observed for one minute. Next, if the alarm is switched off via the on/off push-button, LED D8 starts to flash rapidly if an alarm condition arose in the mean time. In all

there's little that can go amiss. All components, including the mains transformer, are fitted on to the compact board. Before you start soldering, remove the marked areas in the corners of the board, at the side of the mains transformer. This is necessary if you want to mount the completed board into the Bopla case type E430. To prevent connection errors, it may be useful to use coloured terminal blocks for K1, K2-K6 and K7, or mark the terminal blocks with a felt-tip pen.

Be sure to fit the electrolytic capac-

Voltage regulator IC2 dissipates very little heat, so that a heat-sink is not required.

Because the mains voltage is present at several points in the circuit, the printed circuit board has to be fitted in an all-ABS case before it is connected to the mains. For further information regarding electrical safety with home construction projects, read the information on the relevant page elsewhere in this issue.

Next, the circuit is ready for testing. As you can see in Figure 3, there are three types of circuits which may be connected to the terminal blocks (detectors, on/off push-button and door switch). In the test phase, connect at least one detector, one on/off push-button and one door switch with associated LED and diode to one of the connectors. In case you encounter problems, start by checking is the presence of the 5-V supply voltage at pin 14 of IC1. Also check the ground connection at pin 5, the presence of a 50 Hz signal at pin 10 (be careful with the mains voltage on the board!), and the high level at pin 4 of IC1.

Once the test has been completed successfully, you may start installing the detector wiring throughout the premises, the door switch and the on/off push-button(s). (970022)
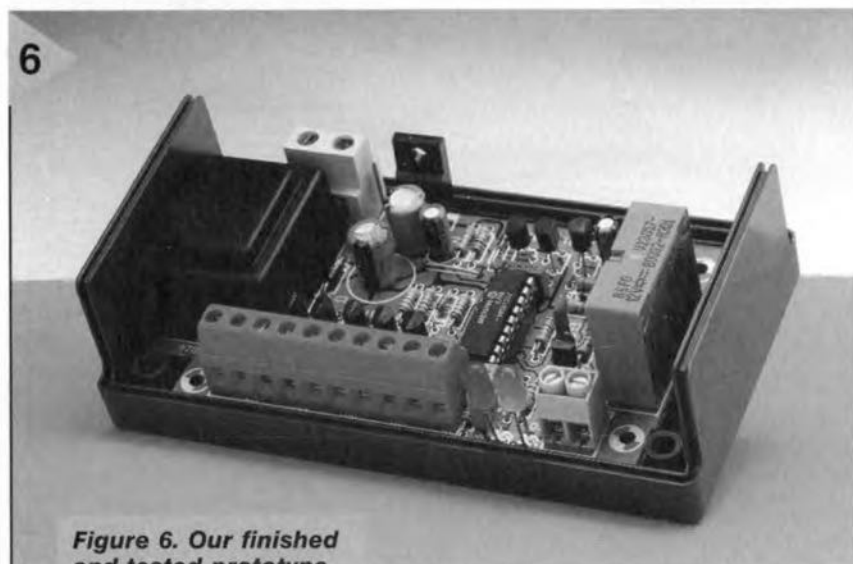

Figure 6. Our finished and tested prototype of the control unit. The large terminal blocks at the edge of the board allows sensors to be easily connected to the circuit.

itors, diodes and LEDs the right way around on the board, and don't forget the single wire link. Next, carefully mount all transistors and IC1, and the circuit is ready for use.

other situations, the LEDs in the alarm circuits will flash, indicating that the stand-by mode has been selected.

CONSTRUCTION

There is not much to say about building the circuit. The copper track layout and component mounting plan of the printed circuit board designed for the alarm controller are given in **Figure 5**. The board is available ready-made from the Publishers, see the Readers Services page elsewhere in this issue. If you work accurately, and the components are fitted in the right places,

Figure 7. The alarm controller is completed by a number of suitable sensors and actuators like the ones shown here.
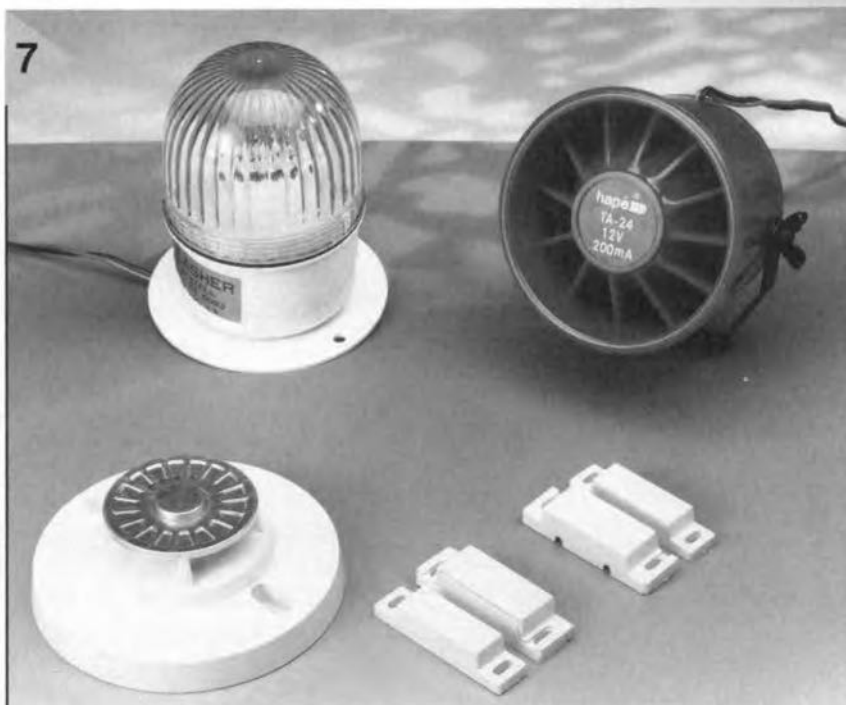
CORRECTIONS & UPDATES

Motor Controller for R/C models
(February 1997 - 960095)

The components list printed on page 18 should be amended to read
C3,C5 = 100nF, SMD
C4 = 10nF, SMD
C6 = 47µF 10V SMD
IC2 = L4940V5

PIC Controlled Home Alarm System
(April 1997 - 970022)

All PICs in the first batch we supplied to individual readers and kit dealers contain an incorrect oscillator code word which totally disables the device. These PICs are marked by the total absence of oscillator activity. Readers experiencing problems are requested to return the faulty PIC (order code 976501-1) to us for a free replacement. Please enclose a short note stating your name and return address, and ensure proper packaging.

Magnetic-Field Meter
(960100 - January 1997)

In the circuit diagram on page 28, R12 is incorrectly shown as a 10 kΩ resistor. The correct value is 22 kΩ 1%, as stated in the components list.

4-Channel Logic Analyser
(970042 - May 1997)

The program shown in Figure 3 has been tested under QBASIC 1.1 and QuickBASIC 4.5, not GW-BASIC as mentioned in the article. Because QuickBASIC is a compiler, it will produce a faster executable program than QBASIC. The highest signal speed the program can handle is mainly determined by the speed of the PC. Using a 486DX33 the maximum input signal frequency will be about 75 Hz under QBASIC 1.1, or about 20 Hz in 4-channel mode. The respective values for a Pentium 150 PC are about 250 Hz and 75 Hz. The use of QuickBASIC 4.5 will result in values which are about 6 times higher. The program will only work in a true DOS environment, i.e., not in a DOS box produced by Windows 95.
Finally, to obtain a calibrated timebase, simply apply a clock signal with a known frequency to one of the channels.

CORRECTIONS & UPDATES

4-way serial port switch
October 1997 - 970057
The correct value for capacitors C4 and C5 is 10µF, 25V, not 4.7µF, 25V as stated in the Components List on page 31.

PIC-controlled home alarm system
April 1997 - 970022
In some cases, D7 starts to flash rapidly although the alarm should go off. Normally, rapid flashing of D7 indicates an alternating-voltage fault. The problem may be solved by increasing the value of C2 to 33µF.

Function Generator
June 1995 - 950068
If the decimal point and the colon (:) are not displayed correctly, IC2 (in the frequency meter section) has to be replaced by a type 74HC7266.

ADC for Centronics port
July/August 1997 - 974088
Lines 130 and 140 in the program printed with this design generate a clock pulse too early. Once CS has dropped low, D7 is available on D-out (IC2). Lines 130 and 140 however cause D7 to be overwritten by D6, thus killing the MSB. This happens again in line 150 as a result of the assignment i=1.
The recommended remedy is to (1) delete lines 130 and 140 from the program, and (2) change line 150 to read: FOR i = 0 to 7.

advanced LCR meter

based on a digital signal processor—DSP

Part 1

All electronic circuits contain resistance, capacitance or inductance or a combination of two or three of these quantities. Yet, there are amateur constructors and even service engineers whose workshop does not include a single instrument for measuring these quantities—an *LCR* meter. The instrument described in this article provides the accuracy of a reasonably good commercial *LCR* meter but does not cost the earth.

Design by H. Bonekamp

Brief specification

Measuring range

Resistance	$100\ \mu\Omega - 100\ M\Omega$
Self-inductance	$100\ nH - 10\ kH$
Capacitance	$0.5\ pF - 10\ mF$
Q factor	$1 - 1000$
D factor $(=R/X = 1/Q)$	$1 - 1000$

Accuracy	0.25%
Test voltage	$100\ mV - 1\ V$
Test frequency	1 kHz
Test time	1.5 second
Offset voltage	programmable
Test	2-wire or 4-wire

An instrument that can determine accurately the parameters of passive components is a boon in any workshop, yet, it is not found in some of these. Many constructors think that a modern multimeter that can measure resistance, capacitance, and self-inductance is quite sufficient. It is true that such an instrument is capable of determining the value of a resistor to within 1%, and that of a capacitance and inductance to within, say, 5%. What it does not show, however, is that a resistor also has some (parasitic) self-inductance and capacitance, or that an inductor also has some (parasitic) resistance and capacitance. In low-frequency circuits, these parasitic constituents are generally not of any

importance. In high-frequency circuits, however, they can and do play a role. If their presence is not taken into account by the constructor, inexplicable errors may occur in his design. The *LCR* meter enables the constructor to assess the actual properties of resistors, capacitors, and inductors.

The electrical properties are determined with the aid of sinusoidal and cosinusoidal signals within a fixed time frame. The method used aims to determine a co-relation between the (two) electrical signals that ensue when the component on test is inserted into a measurement bridge, and sinusoidal and cosinusoidal reference signals generated by a digital signal processor (DSP). Traditional *LCR* meters use analogue signals, which has the drawback that relative complex circuitry and an extensive calibration procedure are needed. Modern *LCR* meters use a DSP, which results in a compact instrument that is smaller an less expensive and does not require elaborate calibration procedures.

DESIGN

The block schematic of the *LCR* meter shown in **Figure 1** is centred on a digital signal processor from Analog Devices. The DSP generates the digital data for a sinusoidal signal with a frequency of 1 kHz. This test signal may have a fixed level of 100 mV or a level of 0.1–1 V as required and set automatically by the instrument.

The digital data are converted into a sinusoidal test signal by a digital-to-analogue converter (DAC).

The measurement bridge is arranged so that an analogue-to-digital converter (ADC) in the test circuit can process the output signal of the measurement bridge optimally. Note that the DAC and ADC are contained in single IC.

The setting of the measuring bridge automatically matches the measurand (electrical value of the component being tested). This ensures that the full range of the ADC is used at all times.

The DSP analyses the measurands
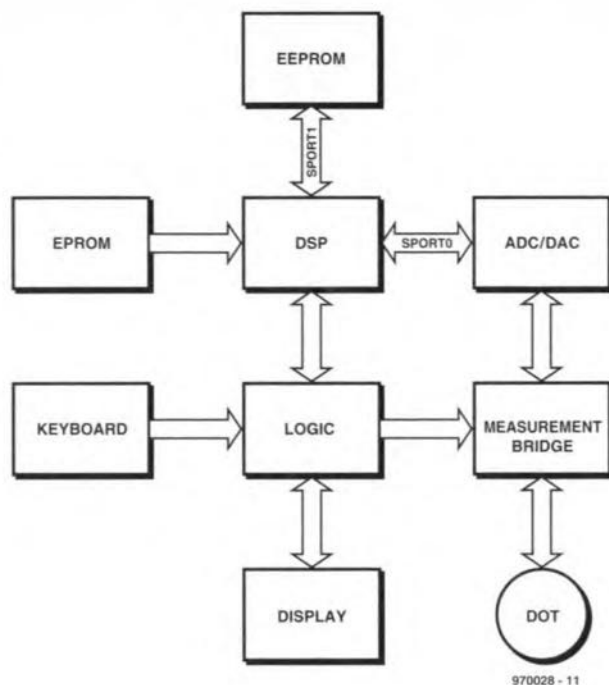
Figure 1. The block diagram of the LCR meter. A DSP enables all tests to be carried out in real time.

in real time into orthogonal (right-angled) components that form the basis for computing the properties of the component on test.

After the measurement has taken place, the DSP processes the measurand and the results are shown on the display. When a key on the operating pad is pressed, the process is stopped and the DSP continues executing the menu. After the menu has been run
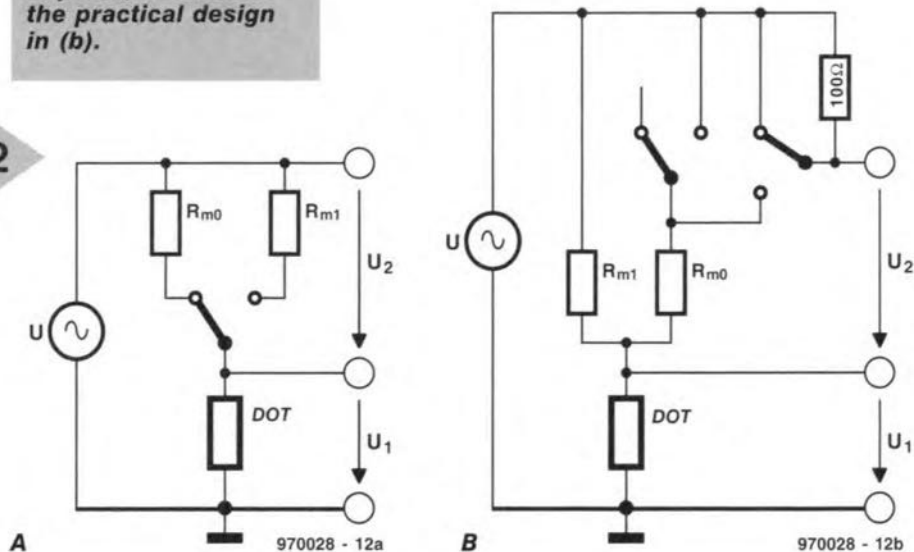
Figure 2. The basic design of the measuring bridge is shown in (a); when some modifications are put in place, it becomes the practical design in (b).
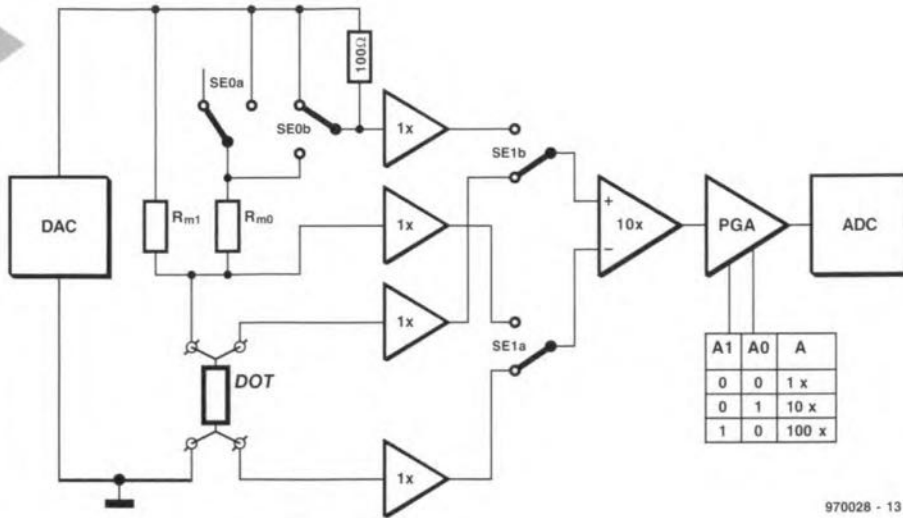
through, measurements are restarted on the basis of the new settings. Calibration details may be stored in an EEPROM (electrically erasable programmable read-only memory).

MEASURING BRIDGE

A measuring bridge is used that consists of a current measuring resistor, R_m, and the component to be tested—see **Figure 2a**. The current is determined by the voltage drop, pd, across a reference resistor, which ensures good stability. Making the current measuring resistor consist of two or three resistors that are switched by a relay (an electronic switch proved to possess too large parasitic effects) lessens the requirements on the instrument amplifiers that follow. It also reduces the noise floor.

The actual design is shown in **Figure 2b**. In the quiescent state, R_{m1}

Figure 3. The instrument uses traditional four-wire tests in which one pair of leads carries the test signal and the other pair the measurand.

970028 - 13

forms part of the measuring bridge. This arrangement has the advantage that in the most sensitive position of the bridge the relay coil is not energized, so that it cannot generate any interference signals. Note that, except for the test terminals on the front

panel, there are no other contacts in the signal path. If for whatever reason the relay contact is poor, the link between the bridge and the test circuit is assumed by the 100 Ω resistance.

When the relay is energized, R_{m0} is connected in parallel with R_{m1}, resulting in a total resistance of $10^2/10^5 = 99.9001$ Ω. The measurand, Z_{out}, is then

$$Z_{out} = U_1/U_2 \times R_m. \quad [\Omega]$$

The effect of test leads and transfer resistances is minimized by a tradi-

tional four-wire test as represented in **Figure 3**. In this kind of test, two separate wires are used for the test signal and two (high-impedance) for tapping the measurand. Test voltages U_1 and U_2 are buffered and applied to a programmable-gain amplifier, PGA, via a differential amplifier.

Alternate testing yields a small reduction in cost of the differential amplifier, the PGA and the ADC.

Since testing is carried out alternately and because the impedance is directly proportional to the quotient U_1/U_2, the ADC needs only have good a.c. properties, particularly good linear operation. Any d.c. errors are automatically eliminated in the computations.

CIRCUIT DESCRIPTION
Considering the good accuracy of the auto-ranging instrument, its circuit – **Figure 4** – is relatively straightforward.

Beginning with the measuring bridge, note that resistor R_{10}, and diodes D_2, D_3 suppress any voltage

Measurement method

The measurement method used in the LCR meter is that of assessing the co-relation between two signals. More particularly, it investigates the effect the component on test has on the current flowing through it and the potential drop, pd, across it. In case of a pure resistance, the current through it and the pd across it will be in phase. When a sinusoidal current is passed through a pure inductance, the current through it and the pd across it will be 90° out of phase (the current lags behind the voltage). The voltage wave form is cosinusoidal. In case of a combination of resistance and reactance, the resulting signal is composed of a sinusoidal and a cosinusoidal component.

In the present instrument, the assessment is carried out by a digital signal processor with the aid of a digital reference signal.

The test setup is shown below. In this, voltage source U_{DAC} causes a sinusoidal current through the series circuit R_m and the practical (as opposed to ideal) inductance. The

vector diagram shows that voltages U_1 and U_2 are complex (that is, they consist of a real component – represented on the X-axis – and an imaginary component – represented on the Y-axis). The peak values of the voltages are computed as follows.

$$U_{1x} = U_1\cos\varphi_1 \qquad U_{1y} = U_1\sin\varphi_1$$
$$U_{2x} = U_2\cos\varphi_2 \qquad U_{2y} = U_2\sin\varphi_2$$
$$|Z| = R_m \frac{U_{1x} + jU_{1y}}{U_{2x} + jU_{2y}} \quad [\Omega]$$

$$U_1\cos\varphi = \frac{2}{N}\sum_{i=0}^{N-1}\left[U_1\sin\left(\frac{2ni}{N} + \varphi_1\right)\right]\left[\sin\left(\frac{2ni}{N}\right)\right]$$
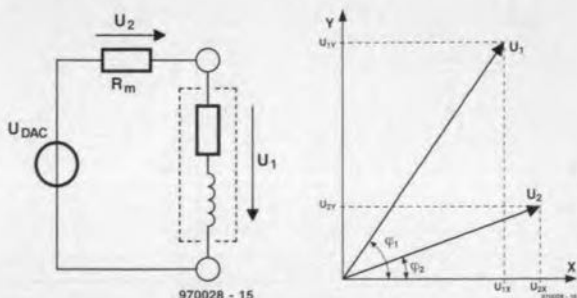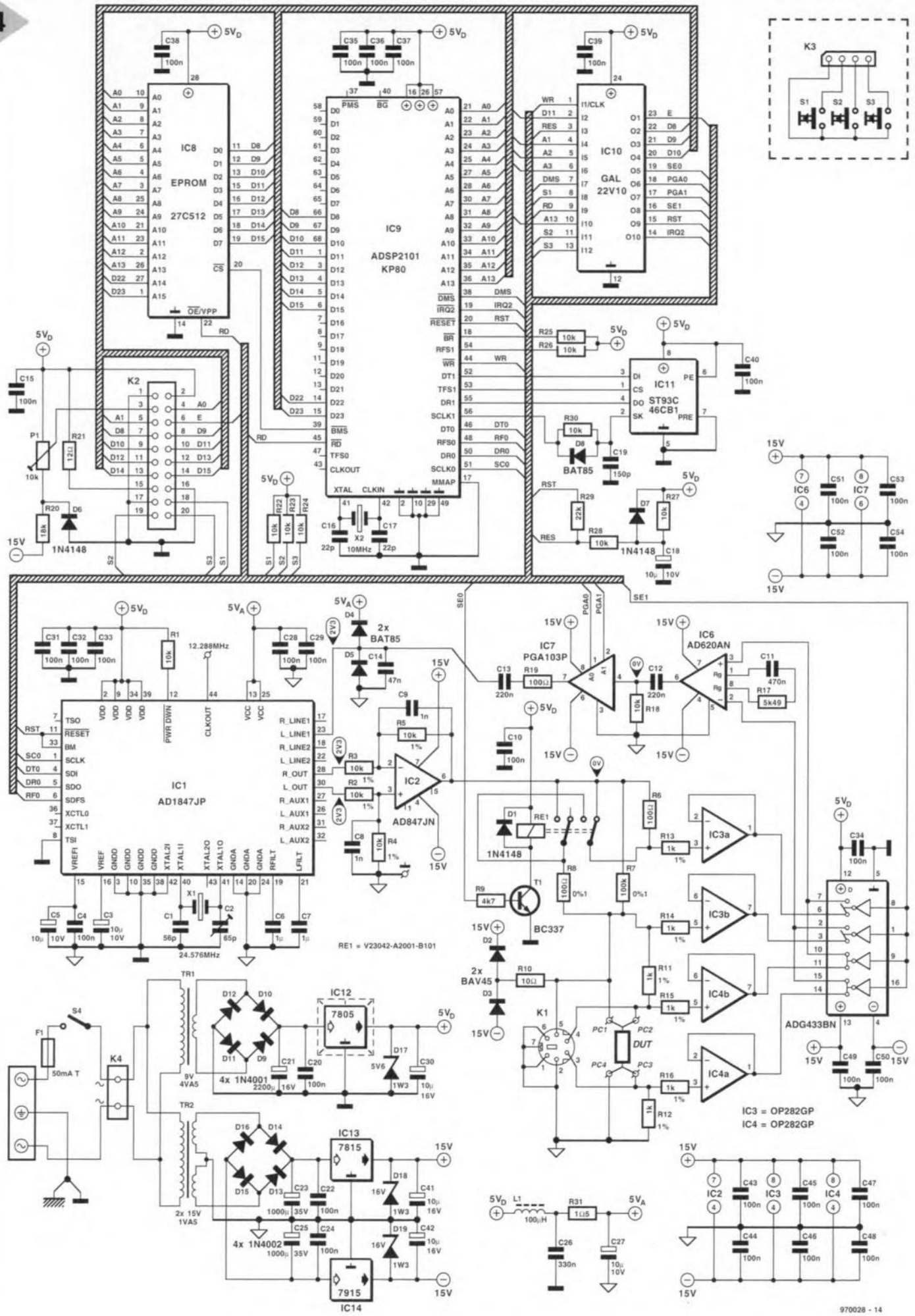
The last term is the reference within the DSP

$$U_1\sin\varphi = \frac{2}{N}\sum_{i=0}^{N-1}\left[U_1\sin\left(\frac{2ni}{N} + \varphi_1\right)\right]\left[\cos\left(\frac{2ni}{N}\right)\right]$$

The last term is the reference within the DSP

$$U_{DAC} = U\sin\left(\frac{2ni}{N} + \alpha\right)$$

where α is the phase shift in IC_1.

970028 - 15

970028 - 14

peaks arising when inductive components are connected to the instrument and the test voltage is switched off. The diodes have a low leakage current and small parasitic capacitance. Together with resistors R_{13}–R_{16} they form some protection against electrostatic discharges.

Resistors R_{11}, R_{12} form the link between the component on test and the instrument in case of a two-wire test.

Signal S_{e0} controls relay Re_1, while signal S_{e1} controls the electronic switches in IC_5.

Op amps IC_3 and IC_4 are arranged as voltage followers to buffer the signal from the measuring bridge.

Circuit IC_6 is an instrument amplifier with unity d.c. amplification and ×10 a.c. amplification.

The programmable gain amplifier is based on IC_7.

Resistor R_{19} and capacitor C_{14} form an anti-aliasing filter. The use of such a simple filter is made possible by the sigma-delta ADC with ×64 oversampling. The output of the filter is applied to the ADC in IC_1.

The differential amplifier, based on IC_2, subtracts the signals at the L-OUT and R-OUT outputs of the DAC from one another. The L-OUT output carries the sinusoidal test voltage and R-OUT an optional d.c. offset. The latter is used particularly when electrolytic capacitors are being tested. Otherwise, there are no direct voltages in the signal path to avoid problems with offset compensating. If such direct voltages would not be compensated, the PGA which, depending on the settings, has an amplification of ×1, ×10, or ×100, would be driven into saturation.

Resistors R_{17}, R_{18}, and capacitors C_{11}–C_{13} form a high-pass filter with cut-off point at 72 Hz.

Capacitors C_{13}, C_{14} form a ×0.82 capacitive attenuator, which ensures that the ADC reaches its limits of operation less rapidly.

The components to be tested are connected to test terminals PC_1–PC_4. The adaptor also connected to these test terminals will be discussed in Part 2. Measurements well away from the instruments may be carried out via mini DIN socket K_1.

DIGITAL SIGNAL PROCESSOR CIRCUIT

The 16-bit digital signal processor contains all facilities needed for this application. To some constructors, its only limitation may be the absence of a floating-point unit. However, even a modest software designer can overcome this difficulty readily.

The processor is associated with an EPROM, IC_8, in which the necessary software is stored, and an EEPROM, IC_{11}, in which the 49 variables for setting and compensating are stored semi-permanently.

Circuit IC_{10} is a GAL which is central to the circuit in that it intercouples all digital stages efficiently.

The liquid-crystal display (LCD) and key pad are connected to K_2.

The power supply uses two small mains transformers, Tr_1 and Tr_2. The first provides the +5 V supply line and the second the symmetrical ±5 V lines. The +5 V line is decoupled by L_1, R_{31} and C_{26}–C_{28}. This line powers the analogue stages and some of the digital ones. Zener diodes D_{17}–D_{19} across the supply lines effectively suppress any spikes that may be induced on to these lines.

The construction of the instrument will be discussed in Part 2 in next month's issue.   [970028-1]

CORRECTIONS & UPDATES

Dark-room timer
(October 1996 - 960086)

The proposed stop scale for the timer (Figure 5) should be turned around because the delay time increases when the control is turned clockwise. Also, the value of C_1 is incorrectly given as 1 μF in the parts list, whereas the correct value is 1.8 μF as shown in the circuit diagram.

Matchbox BASIC computer as data logger
(September 1996 - 960065)

Owing to a text conversion error, all underscores in the names of variables have dropped out of the program listing shown in Figure 4. The correct variable names are LOG_MAX, START_LOG, COM_CHR, LOG_RAM, LOG_DATA, READ_MAXIM and DUMP_PTR.
Also, The compiler is unable to process the line
WHILE DUMP_PTRG MAX DO
which is best replaced by
WHILE DUMP_PTR GMAX DO

Motor controller for R/C models
(February 1997 - 960095)

The text incorrectly states that D_1 and D_2 are not required for unidirectional mode. This should be D_1 and T_1. The penultimate paragraph on page 17 and the first complete paragraph in the right-hand column on page 18 should be amended accordingly.

68HC11 Emulator
(February 1997 - 970008)

The correct name of the Talker for use with a 5 MHz crystal is TKAXTS_B00 (inset *Talkers for use with the emulator*, page 25).
Contrary to what is stated under the *Applications examples, FAQs* heading, the Hi-Tech compiler is not in the M11DISK\UTILI\ directory. Users having access to version 7 of this compiler may, however, use SYMWICE.EXE to build a small high-level debugger. Likewise, the SYMWICE.C file may help users of other compilers or earlier versions of the Hi-Tech

compiler. SYMWICE.EXE also works for the WICE emulator.
The text *In the latter case, ports B and C ...* (page 23, third line from bottom) should be corrected to read: *In both cases, ports B and C ....*
The TL7705 will switch at a low-supply voltage of 4.5 V, not 3.6 V as stated at the top of the right-hand column on page 24. The reference voltage is calculated from:
$V_{ref} (R_2+R_1)/R_1 =$
$2.53 \times 17.8/10 = 4.5$ V.

Simple inductance meter
(February 1997 - 970009)

In the circuit diagram on page 32, diodes D_2 through D_9 should be connected to K_1 pins 2 through 9, not pins 1 through 8. The layout of the printed circuit board is not affected.

Copybit inverter
(January 1996 - 950104)

The input stage around gate IC_{1a} may start to oscillate when the optimum sensitivity is reached by adjusting preset P_1. This spurious

oscillation may upset the normal operation of the circuit. The problem is remedied by fitting a 47μF/25V electrolytic capacitor in parallel with C_2 at the track side of the board. The relevant connections should be kept as short as possible.
The settings of the three presets on the board are determined to a large extent by the quality of the applied S/PDIF signal. The settings are, therefore, dependent on the digital signal source.

lcr meter - part 1
(April 1997 - 970028/1)

Some unfortunate errors have crept into some text and the box on p. 32.
In the 8th line, centre column, $10^2/10^5$ should read $10^2//10^5$.
Z_{out} in the 9th and 12th lines should read Z_{dot} (where dot is the device on test).
In the formulas in the box, $2ni$ should read $2\pi i$ in all five cases.
The first formula should start: $U_1\cos\varphi_1 =$, and the second formula: $U_1\sin\varphi_1$.

CORRECTIONS & UPDATES

68HC11 Emulator
February 1997 - 970008

If the reset does not work properly it is recommended to fit a 100-nF capacitor near C5, between pins 1 (REF) and 4 (ground).

In case there is insufficient room for C10 (located inside the socket), then this part (preferably SMA) may be fitted at the under-side of the board.

Earth Leakage Meter
June 1997 - 970046

The article states incorrect type numbers for the inductor cores. Although this does not affect the operation of the circuit, problems may arise when the circuit is built into the specified case. The correct core type is:

TN26/15/10-3C11, $A_l = 5\mu H$ (Philips Components)

Advanced LCR Meter
April, May, June 1997 - 970028

Crystal X1 has to be suitable for oscillation at its fundamental frequency (24.576 MHz). A number of kit and parts dealers apparently supply third-overtone crystals, which produce oscillation at 8.192 MHz in this circuit. The frequency measured at the adjustment point on the PCB is then 4.096 MHz. The problem may be solved by changing C1 to 68 pF, and shunting it with an L-C series network consisting of a 1-nF capacitor and a 4.7-μH inductor. These parts are fitted at the underside of the board.

Focus on: measuring with a PC multimeter

More options for digital multimeters with an RS232 interface

Since a couple of years, multimeters with an RS232 interface are available at prices which are affordable to the hobbyist. Thanks to their flexibility and wide application range, these multimeters are now starting to become popular. Few users of these instruments, however, exploit the added value and capacity of the connection with a PC. This article aims at showing what can be done with the PC link, and how users can write their own programs.

By S. Wojahn

Digital multimeters (DMMs) with a serial interface are marked by their ability to connect the instrument to an IBM compatible PC via a simple interface cable. The measurement results (values) are then sent to the PC for further processing. This approach creates a number of advantages and even new application ranges.

THE ADVANTAGES

A useful application of the PC connection could be a large display for measurement values using the PC monitor, with the obvious aim of improving the legibility of test results, or for presentations. Alternatively, series of measurement values could be visualised in diagrams, or stored in files for processing according to a certain protocol. Having two or more of these DMMs at hand allows you to create a mathematical junction for measurement values supplied by the individual instruments, one acting as a voltmeter and the other, an ammeter. This arrangement already creates new measurement ranges.

A bit more extensive is the application of sensors for just about any physical quantity, including temperature, light intensity, pressure, humidity, and others. In that case, the output of the sensor, or the sensor interface, supplies a voltage or resistance which can be measured, while unit-conversion is required to the correct value or dimension, using a look-up table or an established calibration function. This system allows users to simply read the correct value from the PC screen, without the constant need to do conversion sums. This 'calibration feature' also enables nearly all measurement equipment without a PC interface, for example, a Geiger-Muller counter or a decibel meter, to be hooked up to a PC, simply by using the DMM as a kind of analogue-to-digital converter (ADC).

THE MULTIMETER

If you do not yet count yourself among the owners of a digital multimeter with a serial interface, you will no doubt welcome some advice as regards

Figure 1. Readout options of DigiScope for Windows: tracer oscilloscope, measurement value list, bar-graph and giant display.
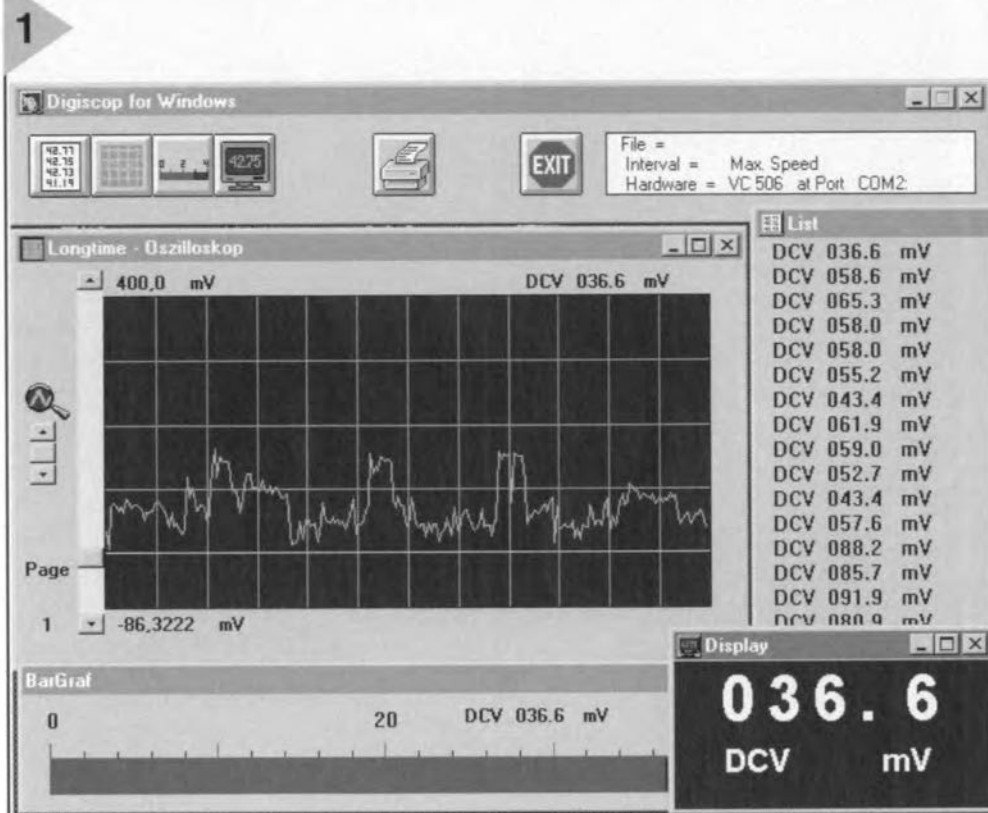
choosing such an instrument. The general advice in selecting a suitable (and affordable) instrument is to look for one that has the desired measurement ranges. The standard ranges such as voltage, current, resistance and frequency are, of course, offered by virtually all of today's more advanced DMMs. If you want additional ranges such as capacitance, inductance, transistor/diode testing, logic testing, temperature (internal or using a separate probe), dB sound pressure level (Protek 506 or Voltcraft/Hung Chang VC 506), or power (M-3860M), then you should choose a matching instrument.

External measurement range extensions are, however, also possible, as will be seen further on in this article. Regarding the connection to the PC, it should be noted that the software you

Figure 2. Structure of a simple control system: the resistance value of a temperature sensor (e.g. GTF150 from Greisinger) is calibrated in software. As long as the temperature remains below the nominal level (here, 80°C), the PC switches on the heater via the relay card. System control and measurement results indication are arranged by the program Windows Laboratory Software in combination with the DMM type HC506 from Hung Chang or VC506 (Voltcraft) and an 8-channel Centronics relay card.
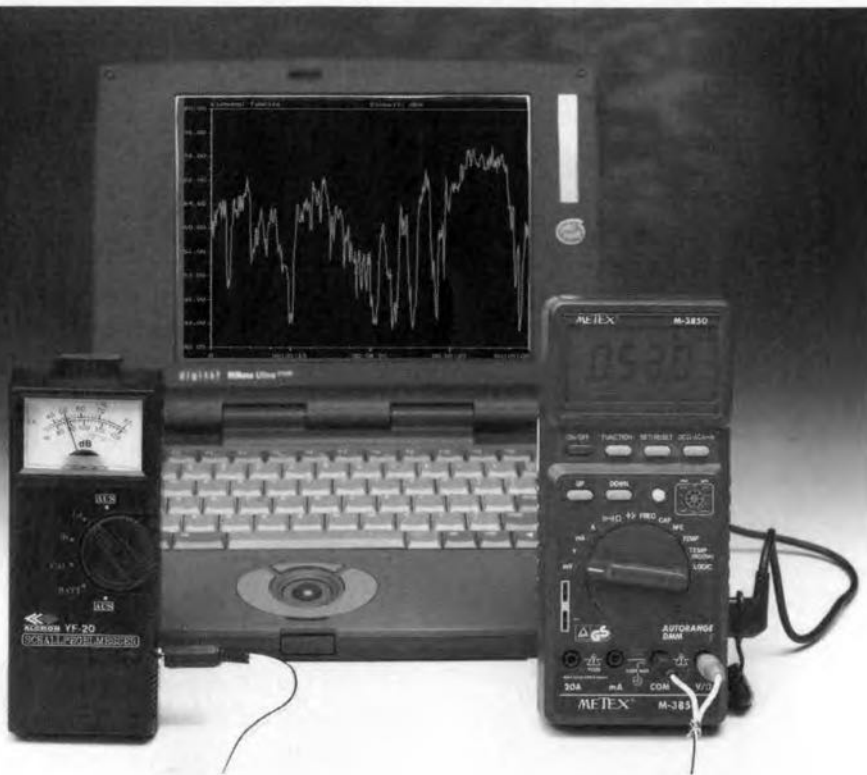
THE SOFTWARE

If you are unable or unwilling to write your own, special, program for the processing of measurement values, there is no option but to rely on available software. Commercially available software may be divided in two classes. Some programs are restricted to simple displaying of data (with the monitor acting as a large readout or a long-period oscilloscope), or the ability to store measured values in the form of strings. Other programs in addition offer the possibility of logic combinitation or conversion of measurement values, thereby adding to the useful range extensions already mentioned.

As a representative of the simpler class we should mention the program **DigiScope**, which is available in DOS or Windows versions. DigiScope for DOS offers large readouts, a long-period oscilloscope ($y(t)$ diagram), bargraph, measurement value listing and data storage in text format, which enables programmers to load measurement data into a table calculation program or a data bank, not forgetting the option of manual editing of all measured data. A negative aspect of this software is that diagrams can not be printed. The operation, unfortunately, requires some getting used to, and will certainly fail to appeal those of you who are used to the 'Windows look and feel'. A definite advantage is, however, that DigiScope runs without problems on an old XT or AT computer, under DOS, provided, of course, an EGA or VGA graphics card is installed. All this allows an old, available, PC to be given a useful application as part of, say, an measurement

Figure 3. Here, a dB meter with voltage output is applied as an A-D converter in conjunction with an RS232-DMM as part of a PC-controlled measurement system. The DMM is an M-3850 set to the mV range, the program, MeasurePC.

have available does not necessarily support all instruments, because some DMMs use a slightly modified data format (for example, the Protek 506 or VC 506, and the M-3860M).

An additional selection aspect should be the measurement accuracy. If you are after relatively high accuracy, you should value low tolerances, and have your test instrument duly calibrated. A special position in this respect is held by the digital multimeter type M-4650-CR. While all other DMMs use a 3½ or 3¾ digit display, the M-4650-CR boasts a 4½-digit LCD readout, which is also fully copied to the PC. Although the accuracy is so high in some measurement ranges that the last digit has no meaning, this problem does not occur with other measurement ranges (for example, resistance, where the tolerance is 0.15% or 3 digits). Furthermore, calibration is helpful with this meter.

Other buying criteria are features such as automatic maximum/minimum hold, measurement value storage, dual displays, auto-ranging (which should, incidentally, be switched off with computer use), and others.

THE PC CONNECTION

To be able to use the DMM with a computer, you will need a suitable interface cable and, of course, a PC. In many cases, the cable is included in the DMM package. If not, you have to buy it separately at about £10. Be sure to come home with the cable that's right for your DMM, however, because three are three different types around.

As regards the PC, there are hardly restrictions: all you will need in most cases is an IBM compatible PC which has at least one free serial port (also called RS232 or COM). This requirement may still cause problems, however, if a mouse and a modem already occupy COM1 and COM2, and a serial communication extension card has to be installed. Unfortunately, that may not be possible in some cases – worse, it may not work at all because of interrupt conflicts.

Basically, it is immaterial whether you use an old 8088 XT or a Pentium PC sporting RS232 FIFO. The main point is that the software to be used

Figure 4. Data format of the measurement data string. The Hung Chang/Voltcraft 506 and the M-3860M use slightly different formats.

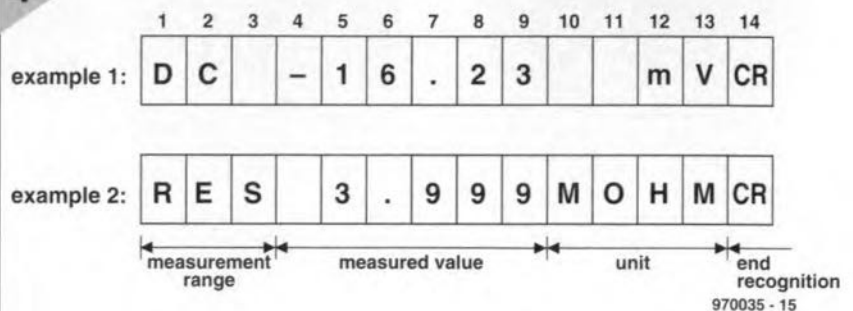|	1	2	3	4	5	6	7	8	9	10	11	12	13	14
example 1:	D	C		–	1	6	.	2	3			m	V	CR
example 2:	R	E	S		3	.	9	9	9	M	O	H	M	CR

measurement range | measured value | unit | end recognition

970035 - 15

```
PRINT "Press space to quit"
' initialise interface :
OPEN "COM2:1200,N,7,2,RS,CS,DS,CD" FOR RANDOM AS #1
DO
    PRINT #1, "D"; ' request meas. data
    DO
     IN$ = INPUT$(1, #1)
     PRINT IN$;
    LOOP UNTIL IN$ = CHR$(13)
    FOR Z = 1 TO 3000   ' short delay loop
    NEXT Z
LOOP UNTIL INKEY$ = CHR$(32)
CLOSE #1
END
```

station, while the new Pentium computer remains available for other applications. This dividing of tasks between the new and the old computer has obvious advantages for long-period measurements.

Under Windows, DigiScope brings you an appealing, Windows-compliant user interface. The internal operation of the program is, however, not much different from the DOS version (see **Figure 1**). The only advantage is the available printing option for measurement diagrams. Unfortunately, this function is poorly implemented, and fails to deliver satisfactory hard copy. An additional shortcoming is that only one measurement instrument may be connected, although that problem can be eliminated simply by starting the program several times over.

The Protek 506 multimeter (or the Voltcraft 506) is already supplied with Windows software. As regards performance, this is at the same level as DigiScope for Windows.

In the better league are programs such as MeasurePC (original German name: MessPC) and Windows Laboratory Software (WLS). Both enable measurement values to be converted, so that the data processing and the readout have the right unit of measure when a certain sensor type is connected.

MeasurePC offers two possibilities for measurement value conversion: if the functional relation between the measured quantity and the desired unit is known, then a function may be entered for the value calculation. This conversion function should either be known, say, from the sensor datasheets, or be established by regression of measurement value pairs using mathematics software. As an alternative, the program offers direct entry of value pairs, which, by interpolation (linear or with splines), are used to compute the conversion function. The value pairs required to do this are either taken from the sensor's datasheet, or from reference measurements obtained from a calibrated instrument specifically designed for the relevant quantity. The software offers readouts on the PC monitor as well as a long-period (tracer) oscilloscope with data storage. Regrettably, a bar-graph readout and measurement value listings are not provided.

Furthermore, MeasurePC offers useful functions such as smoothing of the measurement curve, and post-conversion of measurement strings

(post-calibration). The program runs under DOS and works with any graphics card on any PC. This ability makes it very well suited to use on an old PC. The graphics display of a string of measured values is adequate, while printer output as well as diagram exporting (using the bitmap format) are possible. A zoom function for better detailed displaying of certain screen areas is, however, not provided. Unfortunately, this program, too, allows only one multimeter to be connected.

Not so with **Windows Laboratory Software (WLS)**: totally in line with Windows thinking, four DMMs may be connected simultaneously, while this program spoils you with a well-designed, message-controlled user interface ('shell'). WLS requires only one equation to allow mathematical combination of measurement values captured by different digital multimeters. If necessary, integration or differentiation may be included in your equation. On the down side, calibration or value conversion by means of a look-up table is not provided.

The measurement value indicators (which may be freely placed anywhere on the screen) include a digital readout, an analogue (moving-coil) scale, a bar-graph, a $y(t)$ recorder (long-period oscilloscope) a measurement value list, a max./min. readout, and triggering on these, in any combination. An excellent point is the control of the various instruments by means of the messages exchanged between them. A message is a number between 1 and 9999 sent whenever an instrument registers a status change. If, for instance, the trigger level is reached on a certain trigger instrument, this is automatically prompted to transmit a message which initiates, say, the writing of a $y(t)$ graph.

The message instruments include a switching clock, a stopwatch, a clock source, a message counter, a sound signal, or the possibility to drive an 8-channel relay card. The relay card (price approx. £35) is connected to a parallel printer port (LPT), allowing the relays to be actuated by individual messages. By clever coupling of the

instruments via the various messages, it becomes possible to create extremely useful switching systems, or accomplish synchronised measuring and automation tasks (**Figure 2**). Despite some minor flaws, the well-designed concept and matching user interface, all at a price of less than £25, give Windows Laboratory Software (WLS) the edge over the other programs mentioned in this article.

THE USE OF SENSORS

The use of sensors results in a tremendous increase in the possibilities of a digital multimeter. Cost-effective sensors are available these days for many physical quantities including temperature, pressure, light intensity , magnetic field strength and relative humidity. Such sensors usually supply a voltage or a resistance value. Next, these output values have to be converted (calibrated) before they appear with the proper value and unit. Such a function is already provided by software products such as Windows Laboratory Software (WLS) and MeasurePC. If the required conversion is not clear from the sensor's datasheets, you can't avoid acquiring them the hard way, i.e., by means of a reference measurement on a calibrated instrument. Although that may hardly be a problem with a temperature sensor, things may become considerably more complex if you want to measure, say, ozone levels. That is, if you do not have the datasheet.

Quite simple, by contrast, is the connection of an analogue meter, for example, a decibel (dB) meter (**Figure 3**). All you need to do is tap the voltage at the meter indicator, and measure it using a DMM switched to the millivolt (mV) range. A technically clean method of doing so is to fit the dB meter with a small jack socket and making a suitable cable for connecting the output voltage to the multimeter inputs.

The conversion from measured voltage to the required unit is easily accomplished with the aid of a couple of measurement pairs which may be read from the analogue instrument or the DMM. In this way, the sensor (the

analogue measuring device) itself is employed for the calibration.

Provided you know what you are doing, the same may be achieved with a digital instrument by 'tapping' a voltage at a suitable point just before the A-to-D converter.

YOUR OWN PROGRAMS

If you are not satisfied with the options and features offered by the available software, you may want to consider writing your own programs using whatever programming skills you have. Alas, programming an oscilloscope is out of the question because the DMMs discussed here supply measurement data at a rate of two per second only.

The software may be written in a higher programming language such as BASIC, C, Pascal, Visual BASIC, or Delphi. First, the serial interface has to be initialised to 1,200 baud (9,600 baud for the M-3860), no parity, 7 data bits in ASCII format, 2 stop bits and software handshaking. That's all there is to preparing for the transfer of measurement data – all the computer (or the program) has to do is request a measurement value. This is achieved by transmitting the ASCII character 'D' (#68) to the DMM, which responds by returning a string containing the current measurement value, the unit and the measurement range. The received string has a length of 14 bytes (**Figure 4**). An exception is formed by the Protek 506 (or VC 506) and the M-3860M. On being told to do so, the M-3860M uses a baudrate of 9,600 bits/s, and transmits the measurement values of the main display and its three subdisplays in a single data packet with a length of 56 bytes each. The Protek 506 transmits at 1,200 baud and uses a variable data packet length of between 6 and 15 bytes.

A simple demonstration program is shown by the listing in **Figure 5**. The results of a conversion to Delphi-Pascal running under Windows are seen in **Figure 6**. Both programs have been kept as simple and spartan as possible to emphasise their crucial function of continuously requesting a measurement value string and displaying it without any kind of filtering. It should be noted that these example programs are not geared to the Protek 506 and M-3860M, although it should not be too difficult to adapt the relevant routines. Obviously, if the measurement values are to be subjected to further

```
unit Main; {  Protocol unit for indication of measurement
                data from a DMM with interface; not suitable
                    for Protek 506, VC 506 or M-3860M  }
interface

uses
   SysUtils, WinTypes, WinProcs, Messages, Classes, Graphics,
   Controls, Forms, Dialogs, StdCtrls, ExtCtrls;

type
TFormMain = class(TForm)
   LabelDMM: TLabel; { should be placed on FormMain }
   Timer: TTimer;      { Timer also placed on FormMain }
   procedure FormCreate(Sender: TObject);
   procedure FormDestroy(Sender: TObject);
   procedure TimerTimer(Sender: TObject);
   private
      ComPort : integer;
end;


var FormMain: TFormMain;


implementation

{$R *.DFM}

procedure TFormMain.FormCreate(Sender: TObject);
Var DCB : TDCB ;
begin
   ComPort:=OpenCOMM('COM2',100,100); { initialise Port }
   GetCOMMState(ComPort, DCB); { load standard settings }
   with DCB do begin { implement own settings }
      Baudrate:=1200;
      ByteSize:=7;
      Parity:=0;
      Stopbits:=2;
      Flags:=2;
   end;
   SetCOMMState(DCB); { set parameter }
   Timer.Enabled:=true; { activate timer }
end;

procedure TFormMain.FormDestroy(Sender: TObject);
begin
   Timer.Enabled:=false; { deactivate Timer }
   CloseCOMM(ComPort); { close Port }
end;

{ TimerTimer is OnTimer refresh (interval 1000) }
procedure TFormMain.TimerTimer(Sender: TObject);
var Buf       : array[0..100] of char; { receive buffer }
    ComStat : TComStat;
begin
   WriteCOMM(ComPort,'D',1); { request meas. data }
   Repeat
      GetCommError(ComPort, ComStat);
      Application.ProcessMessages; { don't block application ... }
   until ComStat.cbInQue=14; { wait for daten }
   ReadCOMM(ComPort, Buf, 20); { read out meas. data }
   FlushComm(ComPort,1); { clear receiver queue }
   LabelDMM.Caption:=Copy(StrPas(Buf),1,13); { display meas. data }
end;

end.
```

processing, the measurement string will have to be disassembled into its components as shown in Figure 4. Fortunately, even less experienced programmers should not find it too difficult to adapt and extend the example listings to their personal requirements, or convert them into another programming language.   (970035)

P.O. Box 1414

Simple Frequency Meter

(July/August 1996)
964023

A ▶ INT.OSC.
B ▶ LATCH
C ▶ RESET

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

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

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

IC5 and **IC6** to ground instead of to +5 V. Else, the numbers will appear inverted on the readout.

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

Magnetic-Field Meter
960100

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

New Item Tracer

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

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

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

Accelerometer Type ADXL05

Low cost sensor for vibration, shock and tilt measurement

The Type ADXL05 integrated accelerometer converts a rate of change of velocity into a proportional electrical potential. It will measure accelerations with full-scale ranges of ±5 g to ±1 g or less. Acceleration is normally measured in metres or feet per second squared, but that due to gravity is expressed in g. The value of this quantity varies according to the distance from the earth's centre, but the internationally adopted standard value is 9.80665 m s–2. The correct value for anywhere on earth is given by Helmert's formula*.
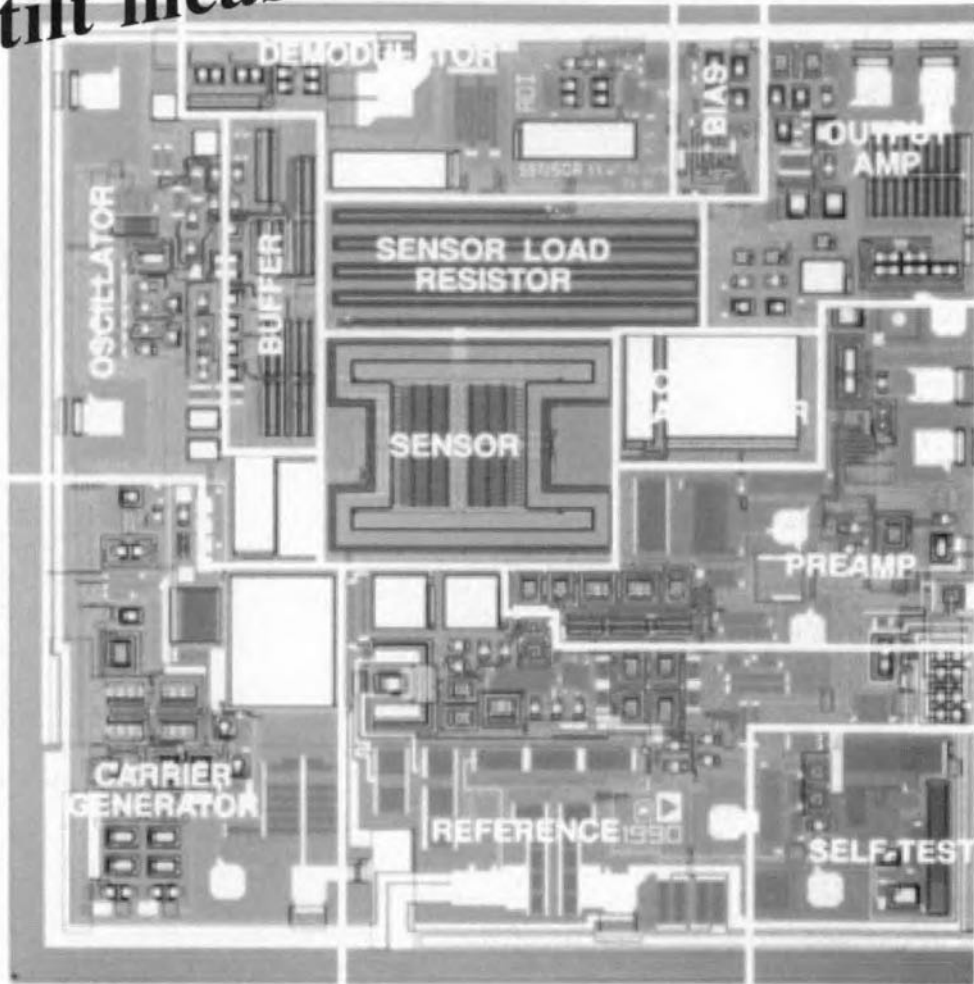
The accelerometer is contained in a 10-pin TO100 metal case, and consists of a sensor, an oscillator, a demodulator, preamplifier, voltage reference, and a buffer amplifier (**Figure 1**).

The device will measure accelerations with full-scale ranges of ±5 g to ±1 g or less. Typical noise floor is 500 $\mu g/\sqrt{Hz}$, allowing signals below 5 mg to be resolved. It can measure uniform accelerations, such as that due to gravity, as well as variable accelerations, such as vibrations.

Since acceleration is a vector quantity, the device has three axes: a sensitive axis (X) which is defined by a line drawn between pin 5 and the package tab in the plane of the pin circle; a transverse Y axis, which is perpendic-

ular to the axis of sensitivity in the plane of the package pin circle; and a transverse Z axis which is perpendicular to both the axis of sensitivity and the plan of the package pin circle. The transverse sensitivity is virtually nil.

Three external capacitors and a simple +5 V power supply are all that is required to measure accelerations up to ±5 mg. Three resistors are used to configure the buffer amplifier to set scale factors from 200 mV g^{-1} to 1 V g^{-1}.

The ADXL05 has a reference voltage (3.4 V) output, and a TTL-compatible self-test function that can electrostatically deflect the sensor beam at any time to verify that the sensor and its electronics are functioning correctly.

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* $g = 9.80616 - 0.025928\cos 2\lambda + 0.000069\cos^2 2\lambda - 0.000003086H$,

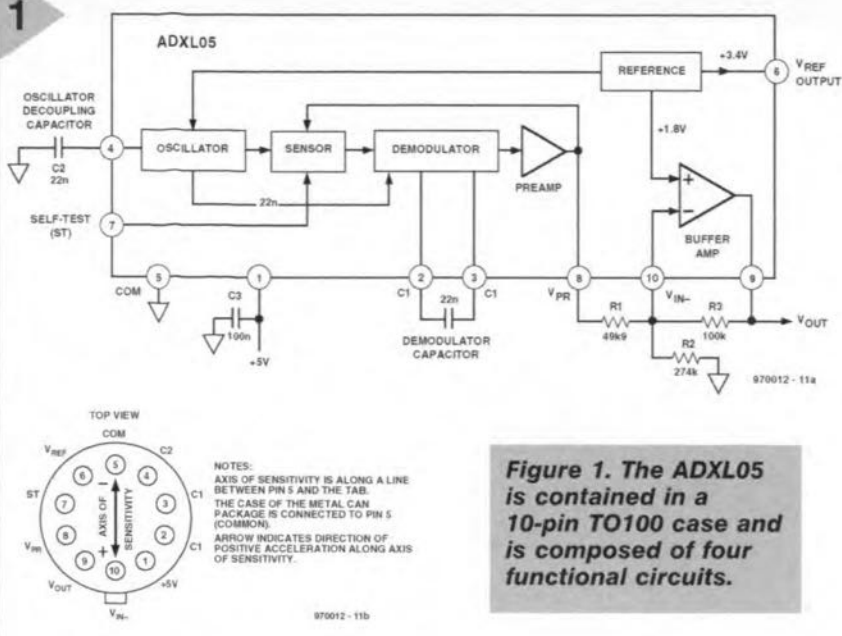where λ is the latitude, H is the height in metres above sea level and g is in m s^{-2}.

Figure 1. The ADXL05 is contained in a 10-pin TO100 case and is composed of four functional circuits.

NOTES:
AXIS OF SENSITIVITY IS ALONG A LINE BETWEEN PIN 5 AND THE TAB.
THE CASE OF THE METAL CAN PACKAGE IS CONNECTED TO PIN 5 (COMMON).
ARROW INDICATES DIRECTION OF POSITIVE ACCELERATION ALONG AXIS OF SENSITIVITY.

THEORY OF OPERATION

The ADXL05 is a complete acceleration measurement system on a single monolithic IC. It contains a polysilicon surface-micro-machined sensor and signal conditioning circuits that implement a force-balance control loop. The device is capable of measuring both positive and negative acceleration up to a level of $\pm 5\,g$.

Figure 2A is a simplified view of the ADXL05's acceleration sensor at rest. The actual structure of the sensor consists of 46 unit cells and a common beam. The differential capacitor sensor consists of independent fixed plates and central plates attached to the main beam that moves in response to an applied acceleration. The two capacitors are series-connected, forming a capacitive divider with a common movable central plate. The sensor's fixed capacitor plates are driven differentially by a 1 MHz square wave: the two square-wave amplitudes are equal but are 180° out of phase from one another. When at rest, the values of the two capacitors are the same, and the voltage output at their electrical centre (i.e, at the centre plate) is, therefore, zero.

Figure 2B shows the sensor responding to an applied acceleration. When this occurs, the common central plate or 'beam' moves closer to one of the fixed plates while moving further from the other. This creates a mismatch in the two capacitances, resulting in an output signal at the central plate. The output amplitude of the signal varies in direct proportion to the amount of acceleration experienced by the sensor.

Figure 3 shows a functional block diagram of the ADXL05. The voltage output from the central plate of the sensor is buffered and then applied to the synchronous demodulator which is clocked, in phase, by the same oscillator that drives the fixed plates of the sensor. If the applied voltage is in sync and in phase with the clock, a positive output will ensue. If the applied voltage is in sync but 180° out of phase with the clock, the demodulator's output will be negative. All other signals will be rejected. An external capacitor, C_1, sets the bandwidth of the demodulator.

The output of the synchronous demodulator drives the preamp – an instrumentation amplifier buffer which is referenced to +1.8 V. The output of the preamplifier, V_{PR}, is fed back to the outer plate of the sensor via a 3 MΩ isolation resistor. The V_{PR} voltage electrostatically resets the sensor to its $0\,g$ position and is a direct measure of the applied acceleration.

The output of the preamplifier is $1.8\,V \pm 200\,mV\,g^{-1}$ with an output range of $\pm 1\,V$ for a $\pm 5\,g$ input. An uncommitted buffer amplifier provides the capability of adjusting the scale factor and $0\,g$ offset level over a wide range. An internal reference supplies

Figure 2. (A) Simplified diagram of the ADXL05 in the quiescent state (0 g level). (B) The ADXL05 sensor momentarily responding to an externally applied acceleration. (C) This close-up of the chip clearly shows the interleaved unit cells and common central beam that form capacitances.

the necessary regulated voltages for powering the chip and +3.4 V for external use.

The self-test is initiated by applying a TTL high logic level (>2.0 V d.c.) to the device's self-test pin, which causes the chip to apply a deflection voltage to the beam which moves it an amount equal to $-5\,g$ (the negative full-scale output of the device). Note that the $\pm 15\%$ tolerance of the self-test circuit is not proportional to the sensitivity error.

MISCELLANEOUS ASPECTS

The values of the components shown in Figure 1 are those needed to measure accelerations in the $\pm 5\,g$ range with an output scale factor of $400\,mV\,g^{-1}$, a 2.5 V $0\,g$ level, a $\pm 2.0\,V$ full-scale swing around $0\,g$, and a 3 dB bandwidth of about 1.6 kHz. The
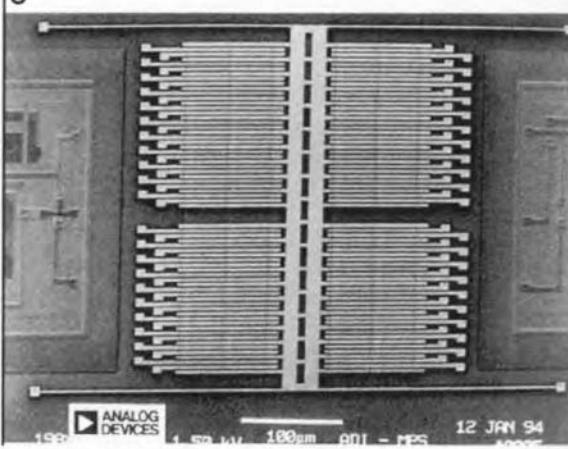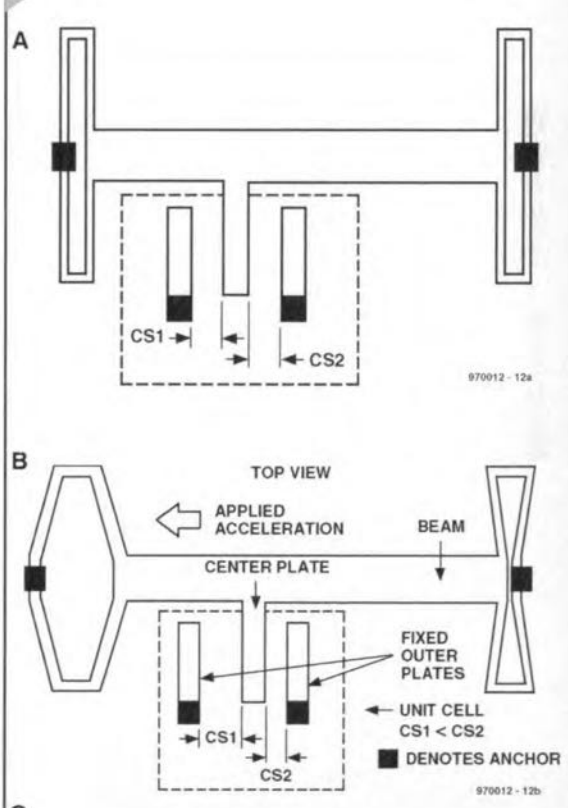
ADXL05J/A: Specifications

(T_A = 25 °C, V_S = 5 V, a = 0 g, unless otherwise stated)

Parameter	Conditions	Min.	Typ.	Max.	Units
SENSOR INPUT					
Measurement range	Guaranteed full scale	−5		+5	**g**
Non-linearity	Best fit straight line, 5 **g** FS		0.2		% of FS
Alignment error	Angle between true and indicated axis of sensitivity		±1		degrees
Transverse sensitivity			±2		%
SENSITIVITY					
Initital sensitivity at V_{PR}	+25 °C	175	200	225	mV/**g**
Initital sensitivity at V_{OUT}	+25 °C, R_3/R_1 = 5	0.875	1.000	1.125	V/**g**
Temperature drift			±0.5		% of read-
ZERO g BIAS LEVEL at V_{PR}					
Initial offset		1.50	1.80	2.10	V
vs. Temperature	From 25°C to T_{MIN}/T_{MAX}		±25/40		mV
vs. Supply voltage	V_S = 4.75 to.5.25 V		10	32	mV/V
NOISE PERFORMANCE at V_{PR}					
Voltage noise density	BW = 4 Hz to 1 kHz		500	1000	μV/√Hz
Noise in 100 Hz bandwidth			5		m**g** rms
Noise in 10 Hz bandwidth			1.6		m**g** rms
FREQUENCY RESPONSE					
3 dB bandwidth	C_1 = 22 nF	1000	1600		Hz
3 dB bandwidth	C_1 = 10 nF		4		kHz
Sensor resonant frequency			12		kHz
SEL F TEST INPUT					
Output change at V_{PR}	ST pin from logic 0 to 1	−0.85	−1.00	−1.15	V
Logic 1 voltage		2.0			V
Logic 0 voltage				0.8	V
Input impedance	To common	50			kΩ
+3.4 V REFERENCE					
Output voltage		3.350	3.400	3.450	V
Output temperature drift	From +25° C to T_{MIN}/T_{MAX}		±5		mV
Power supply rejection	DC, V_S = 4.75 V to .5.25 V		1	10	mV/V
Output current	Sourcing	500			μA
PREAMPLIFIER OUTPUT V_{PR}					
Voltage swing		0.25		V_S−1.4	V
Current output	Source or sink	30	80		μA
Capacitive load drive			100		pF
BUFFER AMPLIFIER					
Input offset voltage	Delta from nominal 1.8 V		±10	±25	mV
Input bias current			5	20	nA
Open-loop gain	DC		80		dB
Unity-gain bandwidth			200		kHz
Output voltage swing	I_{OUT} = ± 100 μA	0.25		V_S−0.25	V
Capacitive load drive		1000			pF
Power supply rejection	DC, V_S = 4.75 V to 5.25 V		1	10	mV/V
POWER SUPPLY					
Operating voltage range		4.75		5.25	V
Quiescent supply current			8.0	10.0	mA

transfer characteristic is

$$V_{OUT} = \left(\frac{R_3}{R_1}\left(1.8V - V_{PR}\right)\right) + \left(\frac{R_3}{R_2} \cdot 1.8V\right) + 1.8V$$

where V_{out} and V_{PR} are in volts.

Scale factor

The output scale factor (SF) of an accelerometer indicates how many volts output are provided per g of applied acceleration. This should not be confused with its resolution. The resolution of the device is the lowest g level the accelerometer is capable of measuring. Resolution is principally determined by the device noise and the measurement bandwidth.

The 0 g bias level is simply the d.c. output level of the accelerometer when it is not in motion or being acted upon by the Earth's gravity.

The scale factor, the quiescent level at 0 g, and the frequency response, are determined by the independent buffer amplifier and the values of the external components. Since the scale factor at output V_{PR} is fixed at 200 mV g^{-1}, all that needs to be done to obtain the scale factor at the V_{out} pin is to multiply it with the amplification factor of the buffer, that is:

$$SF = R_3/R_1 \times 200 \text{ mV } g^{-1}.$$

As far as the scale factor is concerned, R_2 is of no consequence. This means

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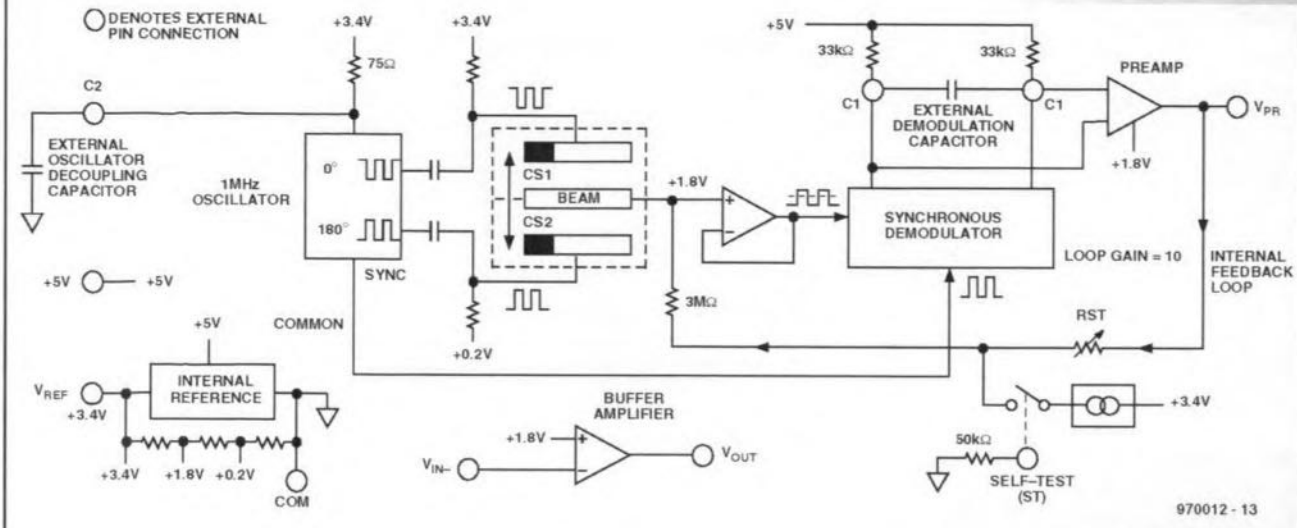
that if a base level of 1.8 V for 0 g^{-1} is to be the permanent norm, R_2 may be omitted. The scale factor can be set finely by making up R_1 from a fixed resistor and a preset.

Quiescent level

The quiescent, or inert, level (0 g level) is fixed at 1.8 V by the internal linking of the reference source to the non-inverting (+ve) input of the buffer amplifier. Other levels may be selected by giving R_2 a value of

$$R_2 = R_3 \left(\frac{1.8V}{V_{OUT} - 1.8V} \right)$$

where R_2 is in ohms and V_{out} in volts.

If a.c. coupling is used, the self-test feature must be monitored at V_{PR} rather than at the buffer output (since the self-test output is a direct voltage).

Measurement range

A maximum symmetrical measurement range is obtained by fixing the 0 g bias level at 2.5 V. This may be done, for instance, by linking R_2 not to earth but to the wiper of a 50-kΩ potentiometer which connects the reference voltage output to earth. The value of R_1 may be as high as feasible.

Filtering

Although the ADXL05 can be used to measure uniform as well as variable acceleration, the uniform component may be eliminated in a straightforward manner. All that is needed is a capacitor, C_4, in series with R_1; the resulting network is a high-pass filter with a cut-off frequency of

$$f_c = 1/2\pi R_1 C_4,$$

where R_1 is in ohms and C_4 in farads. The capacitor must be non-polarized with a low leakage current.

CALIBRATION

If a calibrated shaker is not available, both the 0 g level and scale factor of the ADXL05 may be set to a fair accuracy by using a self-calibration technique based on the 1 g (average) acceleration of the Earth's gravity. Note that the output polarity is that which appears at V_{PR}; the output at V_{out} will have the opposite sign.

With its axis of sensitivity in the vertical plane, the ADXL05 should register a 1 g acceleration, either positive or negative, depending on orientation. With the axis of sensitivity in the horizontal plane, no acceleration (the 0 g bias level) should be indicated

APPLICATIONS

Popular applications for low g accelerometers tend to fall into three categories: measurement of tilt and orientation; inertial measurement of acceleration, velocity and distance; and vibration or shock measurement.

The ADXL05 is a 'dc' accelerometer, meaning that it is capable of measuring uniform accelerations such as the Earth's gravity. The ADXL05 differs from other acceleration measurement technologies, such as piezoelectric and piezo film sensor, which can respond only to 'ac' signals greater than roughly 1 Hz. This dc capability is required for tilt and inertial measurement. For ac shock or vibration, the ADXL05 can measure frequencies of up to 4 kHz and has the added benefit of measuring all the way down to dc. [970012]
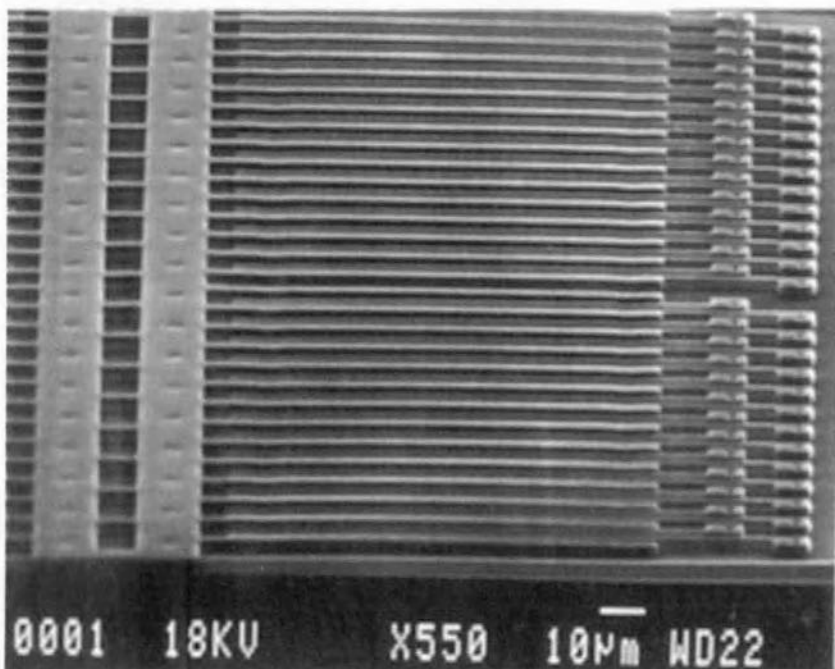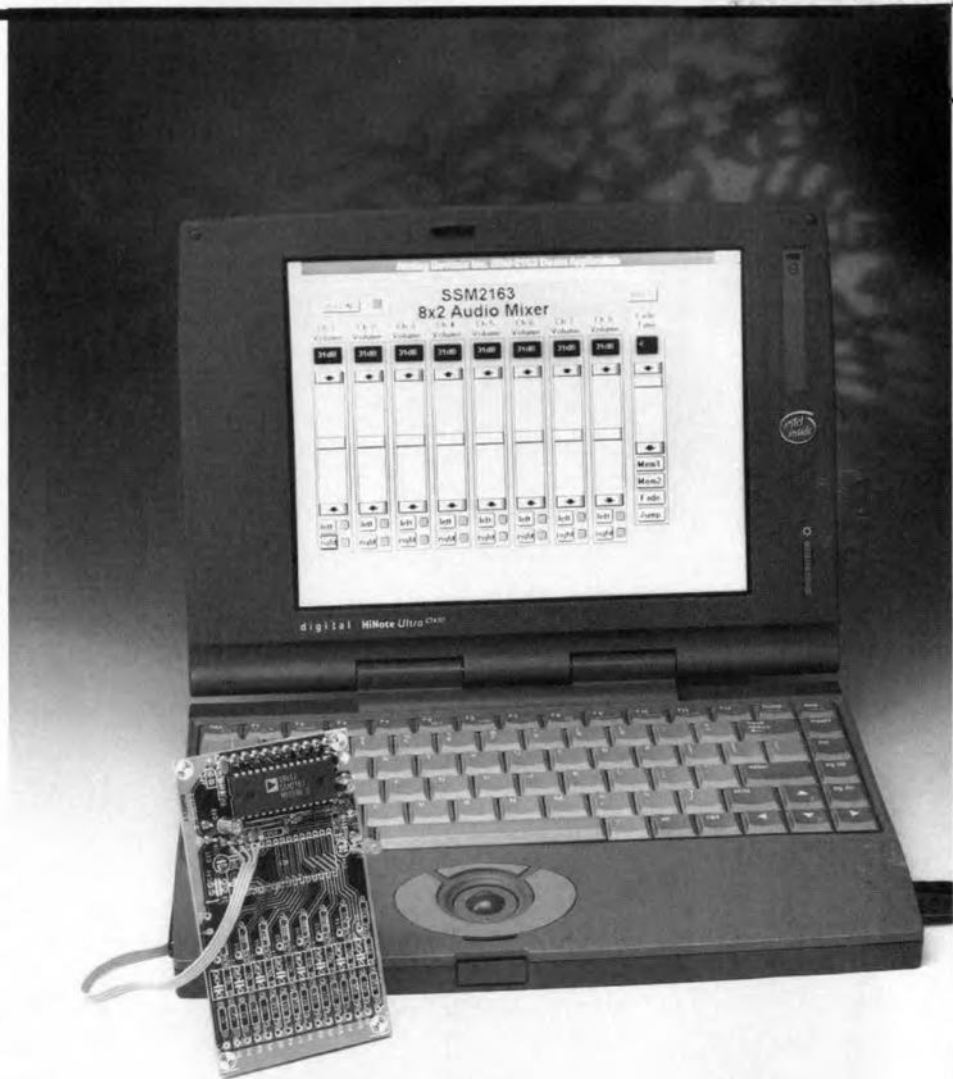
µP-controlled mixer board

Part 2 - Construction and computer control

This second and final part of the audio mixer board deals with the construction and the control of the board via a PC. To do this, all that needs to be done is to connect the board to the computer via a simple three-wire link and exchange some of the hardware by some intelligent, free software. This arranges for the mixer board to appear on the monitor, whereupon it can be controlled by the computer mouse. This part starts, however, with the construction of the board.

Design by T. Giesberts

Last month, the operation of digitally controlled audio mixer SSM2163, on which the 8-channel mixer board is based, the control circuits, and the complete circuit diagram, were discussed in detail. This second and final part starts with the construction and installation.

CONSTRUCTION

The mixer board is conveniently built on the compact printed-circuit board in **Figure 7**. In view of the small number of components, construction should not present anyone with undue difficulties. Sockets must be used for both ICs. The connections for the potentiometers and odd-numbered switches for the left-hand channel are at the left-hand side of the board; the even-numbered ones for the the right-hand channel are at the centre of the board; and the signal inputs and terminals for the mute switch are all at the right-hand side of the board. The supply line terminals and the two LEDs are located at the long sides of the board. **Figure 8** shows the completed prototype board.

INSTALLATION

While the construction of the board is simple, its fitting into a suitable case is rather more tedious: not difficult, but tedious since a great many short lengths of wire have to be soldered into place.

The audio (input) sockets and output sockets are linked to the relevant parts of the circuit with short lengths of screened audio cable. Flexible, stranded circuit wire may be used for all other connections. The +ve and –ve terminals of the potentiometers, as well as the +ve terminals of all left-hand channel switches, may be interlinked at the front panel. When all this is done, there will be quite a cable loom between the front panel and the printed-circuit board.

An illustration of the completed prototype is shown in **Figure 9**. The enclosure is specifically designed to house mixer boards. The one used in the prototype is a Retex Type ABOX RA.2, but similar cases (some without holes and cut-outs) are available from a number of manufacturers.

POWER SUPPLY

The mixer board requires a symmetrical ±5 V power supply. The current drawn from the positive line is about 20 mA, and that from the negative line, 8 mA. The supply in the prototype consists of a 2×9 V, 350 mVA transformer followed by a rectifier, a 7805 and a 7905 voltage regulator and the necessary smoothing capacitors. The design described in 'General-purpose power supply' elsewhere in this issue is very suitable.

POTENTIOMETERS

Slide potentiometers are available in a variety of models, sizes and prices. The ultimate choice is up to you and will depend on the demands you are likely to make on the mixer board. Whatever type is chosen, it cannot cause noise on the output, but at the same time its slide action must be smooth, and this is not always the case with the cheap-

est on the market.

If certain pairs of channels are used frequently, you may find it handy to couple the knobs of the relevant (adjacent!) potentiometers with a special clamp.

Note that it is possible in stereo use to do with one mono potentiometer for the two channels. If, for example, you arrange channels 1 and 2 permanently as the left- and right-hand channels of one stereo signal, channel 1 may be switched to 'left' with switch S_1, and channel 2 to 'right' with S_4 – the pins for P_1 and P_2 must be interlinked, of course.

ADDITIONAL CHANNELS

Although the board and software described in this article are not suitable for expansion, two or more SSM2163s can be paralleled to provide additional channels. This is done simply by interlinking inputs CLK, WRITE, LD and SYSMUTE. The DATA OUT pin of the first SSM2163 is linked to the DATA IN pin of the second. If outputs V_{OUTL} and V_{OUTR} of the two SSM2163s are summed by suitable buffers – a dual audio op amp such as the SSM2135 will do nicely – a 16-input, 2-output mixer is obtained. An advantage of the

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> **Figure 7. The printed-circuit board for the 8-channel mixer console is surprisingly compact.**

Parts list

Resistors:
R_1, R_5, R_9, R_{13}, R_{17}, R_{21}, R_{25}, R_{29}, R_{33}, R_{36} = 10 kΩ
R_2, R_4, R_6, R_8, R_{10}, R_{12}, R_{14}, R_{16}, R_{18}, R_{20}, R_{22}, R_{24}, R_{26}, R_{28}, R_{30}, R_{32} = 47 kΩ
R_3, R_7, R_{11}, R_{15}, R_{19}, R_{23}, R_{27}, R_{31} = 82 kΩ
R_{34} = 680 Ω
R_{35} = 820 Ω

Capacitors:
C_1–C_8 = 330 nF
C_9, C_{10} = 22 pF
C_{11} = 22 µF, 40 V, radial
C_{12}, C_{13}, C_{17} = 10 µF, 63 V, radial
C_{14}, C_{15}, C_{16} = 100 nF ceramic

Semiconductors:
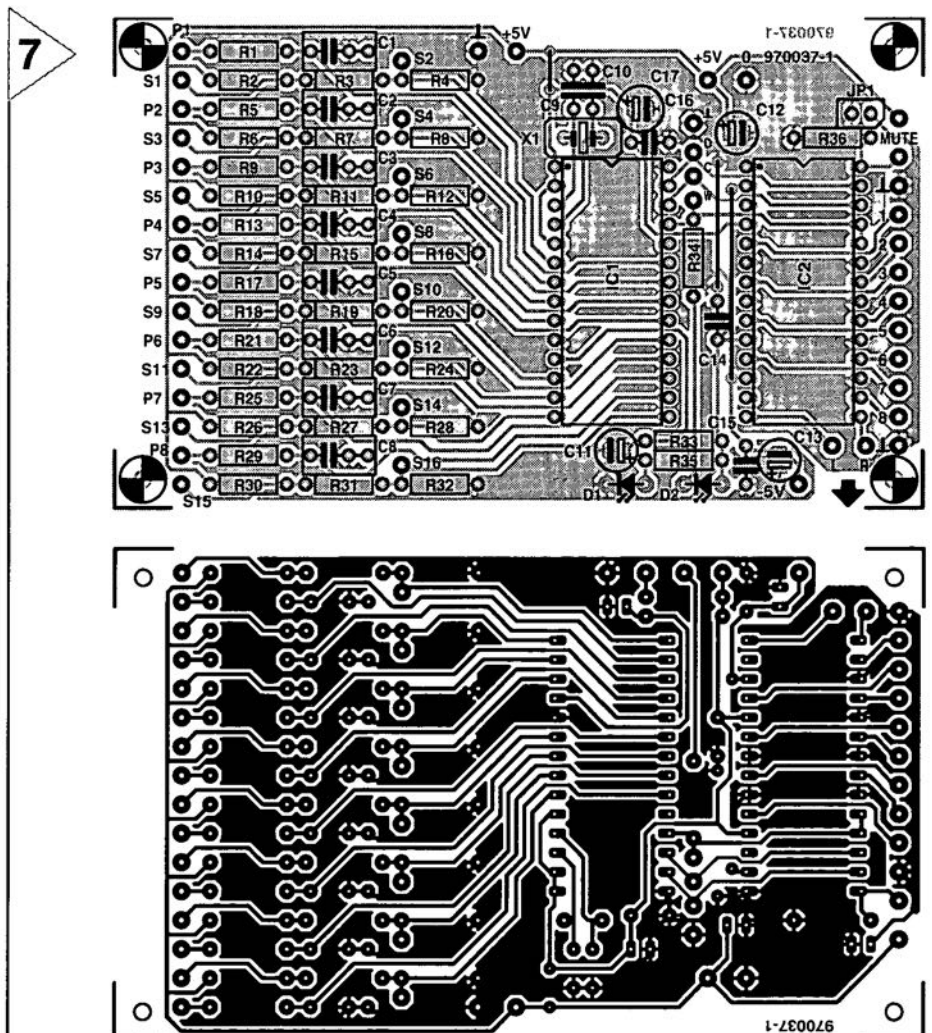D_1 = LED, low-current, green
D_2 = LED, low-current, red

Integrated circuits:
IC_1 = ST62T25B* – available programmed against Order no. 976502-1 (see Readers Services towards the end of this issue)
IC_2 = SSM2163 (Analog Devices)

Miscellaneous:
S_1–S_{17} = SPST switch
P_1–P_8 = slide potentiometer, 25 kΩ
JP_1 = jumper (wire bridge)
X_1 = crystal, 8 MHz
Enclosure = Retex ABOX RA.2 or similar
PCB Order no. 970037-1-AV*
* These are available as a combination against Order no. 970037-C – see Readers Services towards the end of this issue.

Figure 8. Completed prototype printed-circuit board. Note that sockets have been used for IC₁ and IC₂.

Figure 9. The most tedious job in completing the mixer board is the wiring up.

daisy-chaining is that it allows a 3-wire serial interface as used in the 8-input mixer to control two or more SSM2163s.

The serial data format for the daisy-chain circuit is similar to the 8-channel application, except that the SSM2163s are loaded in tandem. After setting WRITE and LOAD low, two bytes are clocked into the first SSM2163. When WRITE and LOAD return high, data will be latched into both SSM2163s simultaneously.

COMPUTER CONTROL

As mentioned earlier, the connections for the serial interface – DATA IN, CLK, and WRITE/LD – are accessible via PCB terminals. This enables control of the mixer board by a computer, for which Analog Devices, the manufacturer of the SSM2163, have special software available. Once you have this, the electronics can be reduced appreciably, and the operation of

the slide potentiometers and the switches carried out via the monitor screen of the PC.

To achieve this, the D(ata in), C(lock), W(rite/LD) and ⊥ terminals on the PCB are linked to pins 2, 3, and 4 of the parallel (printer) port of the PC via a screened 3-wire cable. The screen is connected to the ⊥ terminal on the PCB and to pins 22, 23, and 24 of the parallel port. The manufacturers advise to include a 100 Ω resistor in series with each of the three links as protection against external potentials. Furthermore, IC₁, the potential dividers linked to the controller, the channel switches and the slide potentiometers on the mixer board are then superfluous and may be removed (but only if you are absolutely certain that you will always control the mixer board via the PC). What is left of the circuit in Figure 6 is shown in **Figure 10**, which also shows how the mixer board is connected to the PC.

SOFTWARE

Minimum requirements of the PC are 386/4 MB RAM/Windows 3.1. Since the software offered free by Analog Devices can be obtained only via the Internet, connection to this network (either your own or a friend's) is indispensable.

The software is installed as follows:
- Access Internet address www.analog.com/adibin/locate?SSM2163.
- Select 'SSM2163 Evaluation Board Software'.
- A file named 'SSM2163.ZIP' is then loaded. This can be unzipped with program 'PKUNZIP' or 'WINZIP'.
- Once the file is unzipped, a number of other files, among which 'Setup.exe' are shown. When this program is started, the software is installed automatically.
- After installation, a number of files have been added to Windows. Program 'SSM2163.exe' is found in a separate directory.
- When 'SSM2163.exe' is started, the software version of the mixer board appears on the monitor screen. Provided that the inputs and outputs of the SSM2163 are connected and that the mixer board is linked correctly to the PC, the program is then fully operational.

CONTROL ON THE SCREEN

The screendump on the monitor screen is illustrated in **Figure 11**. It is a neatly worked out version of the operating panel – the inscription 'SSM2163 8×2 Audio Mixer' leaves nothing to the imagination.
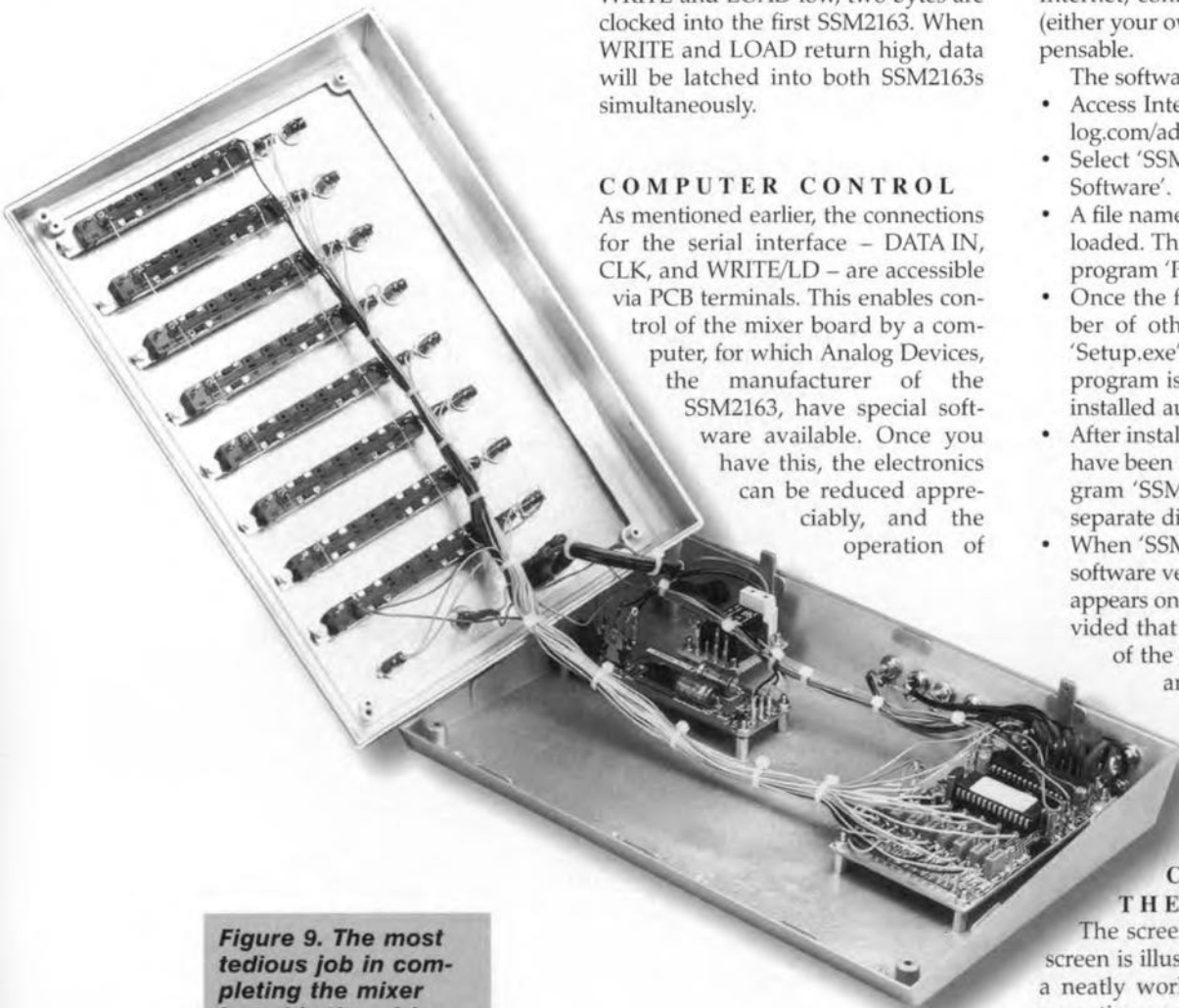
Just as on the actual board, there is a slide potentiometer for the volume control in each channel, as well as two switches with which the output channel is determined. Clicking on the knob of a slide potentiometer enables it to be moved to and fro with the mouse. If you are not used to working with a mouse, this operation may be slightly unusual, but you will soon get the hang of it, so that smooth in and out fading is achieved.

Note that there is a useful additional facility: in the window above each slide potentiometer, the exact attenuation in dB is shown.

Beside the channel switches marked left and right is an indication by means of a coloured square whether the switch is actuated or not: green is 'on' and red is 'off'. Clicking on the switch suffices to change the colour.

The switch at the top lefthand side, 'All ON' offers a kind of mute function, since it enables all channels to be switched on or off simultaneously. Here also: green is 'on' and red is 'off'.

The rectangular field at the righthand side, 'fade time', 'Mem 1', 'Mem 2', 'fade' and 'jump' offers some features that are not available on the original mixer board. These switches enable automatic fading between two previously selected positions of each of the eight slide potentiometers. If, with the mouse, you have set the controls to a certain position, these positions are stored in memory by a click on 'Mem 1'. If then the controls are set to different positions, a click on 'Mem 2' stores these positions in memory. If then 'fade' is clicked, the controls automatically move from one stored posi-

tion to the other. The speed at which this occurs may be set between 1 and 10 seconds with the 'fade time' control – the set time can be read in the window underneath this control. A click on the 'jump' key moves the controls instantly from stored position 1 to stored position 2.

The 'HALT' key is for use if, for one reason or another, it is desired to interrupt the automatic fading process.

Reading this may make operation appear slightly tedious, but once you have the control panel on the monitor, you will see how smoothly it all works and how simple it is to operate.

[970037-2]

Figure 10. The mixer board may be controlled by a PC with the aid of this circuit. Pins D, C and W are linked via 100 Ω resistors to pins 2, 3 and 4 of the parallel port of the PC.
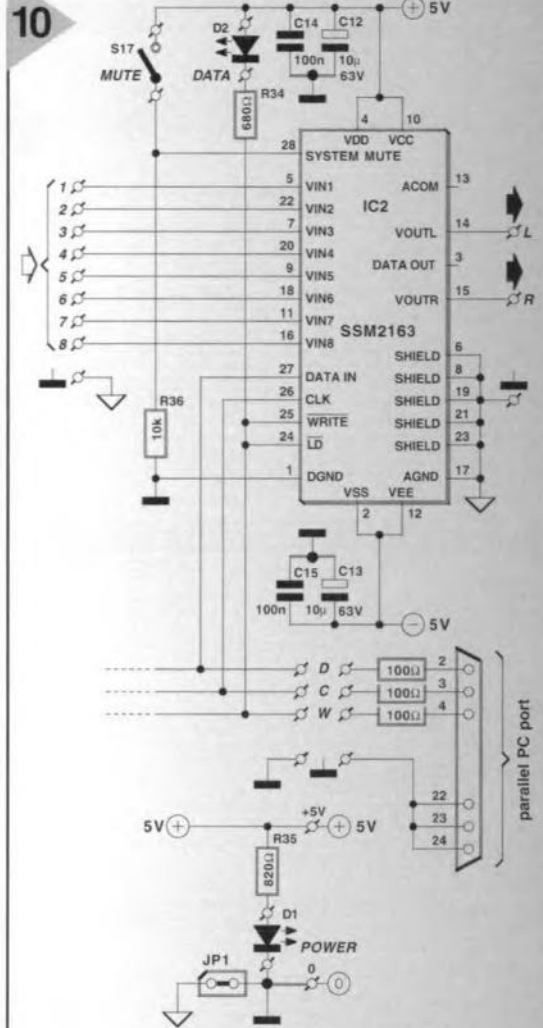
Figure 11. Screen dump of the software developed by Analog Devices. Additional features are the indications of the attenuation in dB and the possibility of automatic fading between two previously stored settings of the controls.

general-purpose power supply

five versions on one board

Electronic circuits have at least one thing in common: they need power to operate. The power supply described in this article has been designed for use with most circuits published in this magazine. It may use a variety of different transformers, and provide various output currents and output voltages.

Design by P. Verhoosel
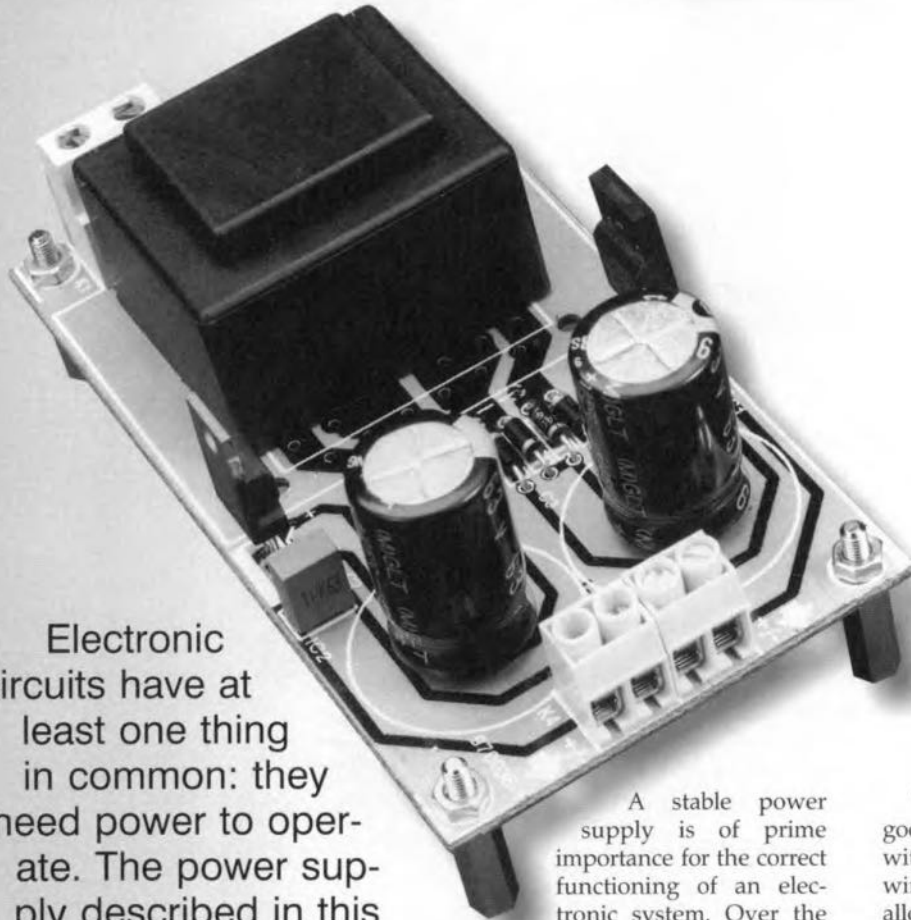
A stable power supply is of prime importance for the correct functioning of an electronic system. Over the past ten years or so, the design of such a supply has become much easier thanks to the availability of reliable integrated regulator circuits, which are specially intended for use on power lines. Most of these circuits not only provide voltage regulation, but also current limiting and thermal protection. Normally housed in a three-pin case, they can now be bought for around a pound. Most of them form part of the 78xx or 79xx families, which are now so extensive that there is a regulator for almost any voltage encountered in a modern electronic circuit. These properties have been taken into account in the design of the general-purpose board on which this article is based. The board can house a supply that, to individual requirements, can supply (a) a positive output voltage; (b) a negative output voltage; or (c) a combination of (a) and (b).

The maximum output current is a good one ampere. Mains transformers with a single or a dual secondary winding may be used. The board allows transformers of different manufacturers to be employed.

The output voltage is determined by the regulator IC used, which, in practice, means one of the following positive levels: 5, 6, 9, 10, 12, 15, 18, 20, or 24 V, or these negative levels: 5, 6, 8, 12, 15, 18, 20 or 24 V. If both a positive and a negative output are required, either a common ground version or two isolated pairs of power lines can be accommodated.

VARIOUS DESIGNS

Figure 1 shows five supply circuits that are different as regards output voltage and mains transformer used, yet can all be constructed on the same board. This is made possible by the use of a variety of wire bridges.

Designs A and B use a transformer whose terminal pins are fairly close together (narrow pitch), whereas designs C and D use a transformer

with wide-pitched terminals. Design E is intended for use with a transformer with dual secondary winding (which enables either output voltage to be used independently). Note that designs A, D and E use a bridge rectifier, whereas designs D and E use a single diode rectifier. The ripple on the (rectified) output of a bridge rectifier is smaller than in the case of a single diode.

When a bridge rectifier is used, the value of the buffer capacitor should be about 2200 µF, whereas in a single-diode design, it should be at least twice that value.

Note in the circuit diagrams that the order of the terminals of the positive-line regulators (78xx) and those of the negative-line regulators (79xx) are different. In both types of regulator the output pin is the same, but those for input and ground are dissimilar. This is why on the board provision is made for a wire bridge near the regulator connections which is used or not depending on the desired output.

The transformer is preceded by a fuse – as long as this is of the correct rating, nothing much can go wrong.

CONSTRUCTION

Whether you have bought a PCB via our Readers Services, or made it yourself on the basis of **Figure 2**, it is vital to start with the placing of the wire bridge(s) needed for the chosen design. Construction is simplified by placing board layout for each design adjacent to the diagram. Some important points to watch in each case are as follows.

Design A.
Transformer with single secondary winding; terminals narrow pitch.
Output positive or negative (former is shown).
For a positive output line, $IC_1 = 78xx$; wire bridge to +.
For negative output line, $IC_1 = 79xx$; wire bridge to –.

Design B.
Transformer with single secondary winding; terminals narrow pitch.
Output symmetrical.
For a positive output line, $IC_1 = 78xx$; wire bridge to +.
For negative output line, $IC_2 = 79xx$; wire bridge to –.

Design C.
Transformer with single secondary winding; terminals wide pitch.
Output symmetrical.
For a positive output line, $IC_1 = 78xx$; wire bridge to +.
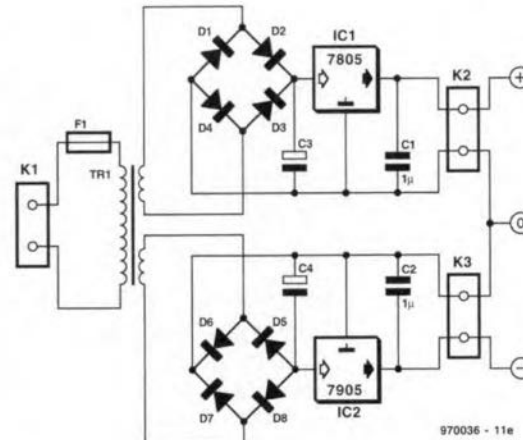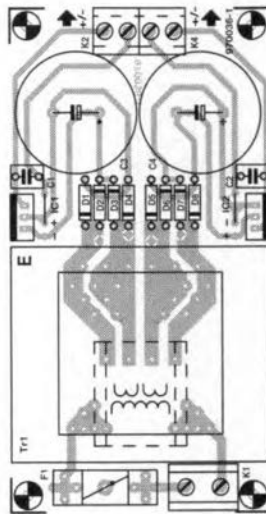For negative output line, $IC_2 = 79xx$; wire bridge to –.

Figure 1. Circuit diagrams of the five possible designs. Particulars are shown at the right of the diagrams. Read the text about the various design possibilities.
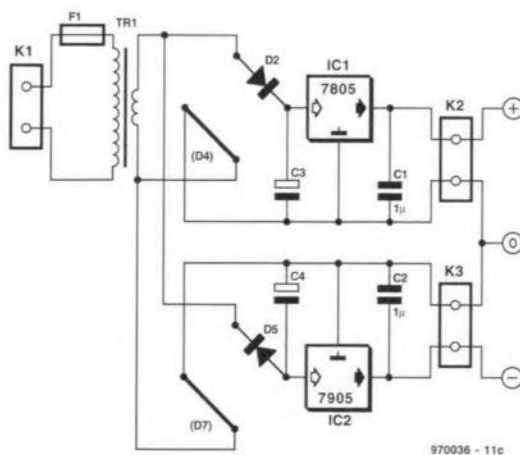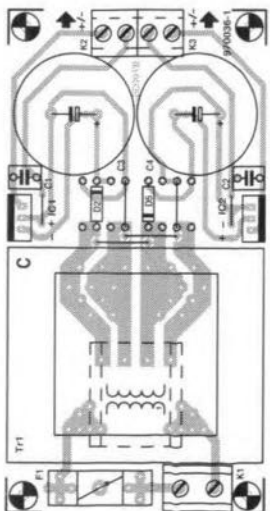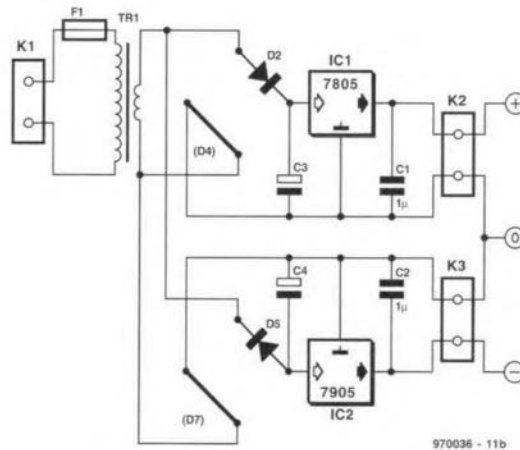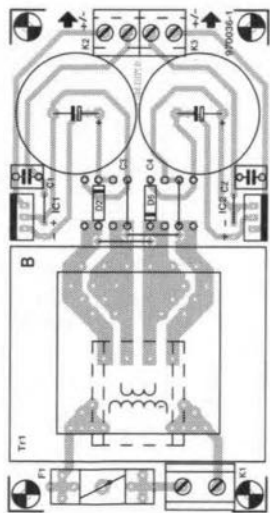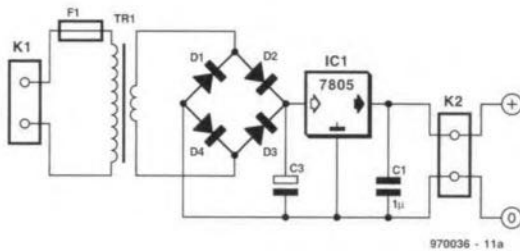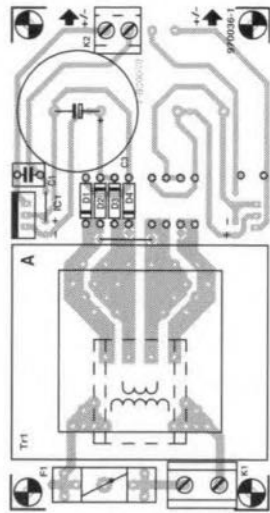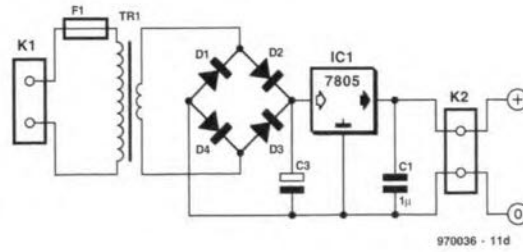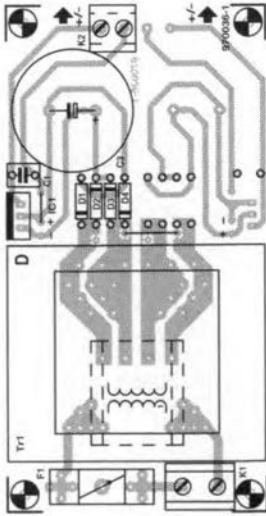
Design D.
Transformer with single secondary winding; terminals wide pitch.
Output positive or negative (former is shown).
For a positive output line, $IC_1 = 78xx$; wire bridge to +.
For negative output line, $IC_1 = 79xx$; wire bridge to –.

970036 - 11d

Design E.
Transformer with dual secondary winding.
Output two positive lines or two negative lines or symmetrical (latter shown).
For a symmetrical output lines, $IC_1 = 78xx$; wire bridge to +, $IC_2 = 79xx$; wire bridge to –.
For two positive lines, IC_1 and IC_2 are both 78xx, wire bridge to +.
For two negative lines, both IC_1 and IC_2 are 79xx, wire bridge to –.

970036 - 11e

Construction of the remainder of the circuits, including what wire bridge(s) and choice of rectifier, is conveniently seen on the component layout in Figure 2. How to determine what mains transformer to use (from a technical rather than cost aspect) is shown in the first of the two boxes. The remaining components needed for a particular design are shown in the parts list and on the circuit diagram. Note that additional components cannot be accommodated and may give rise to short-circuits.

What transformer?

In theory, the output voltage of the rectifier, U_{dc}, is related to the secondary potential, U_{sec}, of the mains transformer by

$$U_{dc} = \sqrt{2} U_{sec},$$

in which both U_{dc} and U_{sec} are in volts.

In practice, however, there is a voltage drop across the rectifier of about 2 V, the voltage across the buffer capacitor has a ripple of 1.5–2 V, and the drop across the regulator IC is also about 2 V. This means that the input to the rectifier, U_{sec}, must be about 6 V higher than that of the output voltage, U_{out}. So, for example, if the required $U_{out} = 5$ V, U_{sec} must be $(5+6)/\sqrt{2} \approx 8$ V.

The output current should also be considered well. Most manufacturers state the rating of the transformer in VA. Since, after rectification, the voltage is increased by a factor $\sqrt{2}$, the current is reduced. The transformer should be able to provide a current of not less than $\sqrt{2} I_{out}$.

Calculating the rating and consequent dimensions of a heat sink is not too difficult. Measure the voltage drop (in volts) across the regulator and multiply that by the current (in amperes), which yields the power dissipation, P, of the device. Assuming a maximum ambient temperature of 30 °C and a maximum temperature of the IC case of 60 °C, the maximum temperature rise of 30 °C is permitted. This means that a heat sink of thermal resistance 30/P must be used. As an example, say the voltage drop across a regulator is 6 V and the current through it is 1 A. The device's power dissipation is then 6 W, so that the thermal resistance of the required heat sink is $30/6 = 5$ K W^{-1}.

Suitable transformers

Monacor: VTR11xx; VTR12xx; VTR31xx; VTR32xx; VTR41xx; VTR42xx; VTR81xx; VTR82xx; VTR121xx; VTR122xx
Hahn: BV EI 303; BV EI 304; BV EI 305; BV EI 306
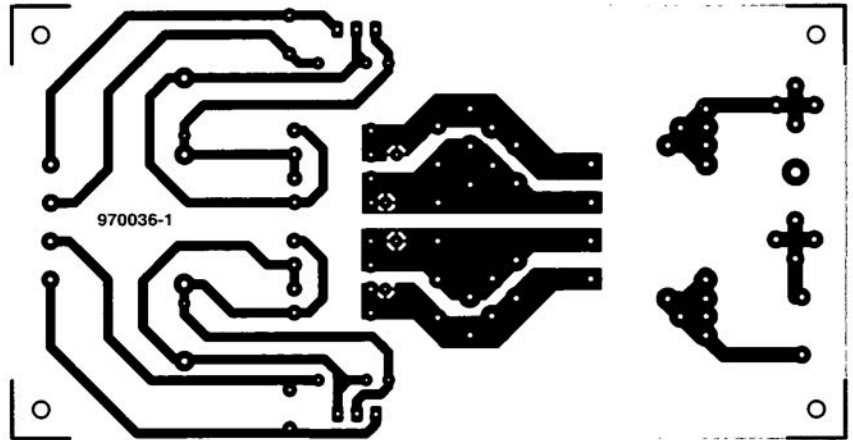**Velleman:** E130/x; E138/x; E142/x; E148/x; E154/x

2

970036-1

Figure 2. The component and track layout of the printed-circuit board that is suitable for all five designs described.

Make sure that the regulator ICs are fitted in the correct position. The flat side to which a heat sink may be mounted should always point outwards.

Since the full mains voltage exists at the fuse terminals, it is advisable to use a holder with insulating hood.

Some of the tracks of the board carry the mains voltage. Therefore, do not connected the mains to the board until this has been mounted in a suitable case on 10 mm long spacers. See also the Safety page regularly included in this magazine.

When the mains is switched on, the requisite output voltage(s) should appear at the relevant output(s). If not, check the correct operation of the rectifier(s) by measuring the potential across C_3 and C_4 respectively. If the expected voltage exists across the capacitor(s), but there is no output, the relevant regulator is not connected properly or it is defect.   [970036]

Figure 3. Photograph of the completed prototype which may be used with a great variety of electronic circuits.

79xx regulators

Regulators for use in negative supply lines (79xx series) possess a troublesome property: they give the requisite output voltage only if the load current is at least a few milliamperes. Under no-load conditions, the output voltage differs from the nominal one by a few volts. It is therefore advisable to include a light-emitting diode (LED) in series with a resistor in the negative output line. The value of the resistor, R, should be such that, in the absence of another load, the output current is 2–5 mA. It is calculated from

$$R = (U_{out}-2)/2 \times 10^{-3} \ (\Omega),$$

where U_{out} is in volts.

3
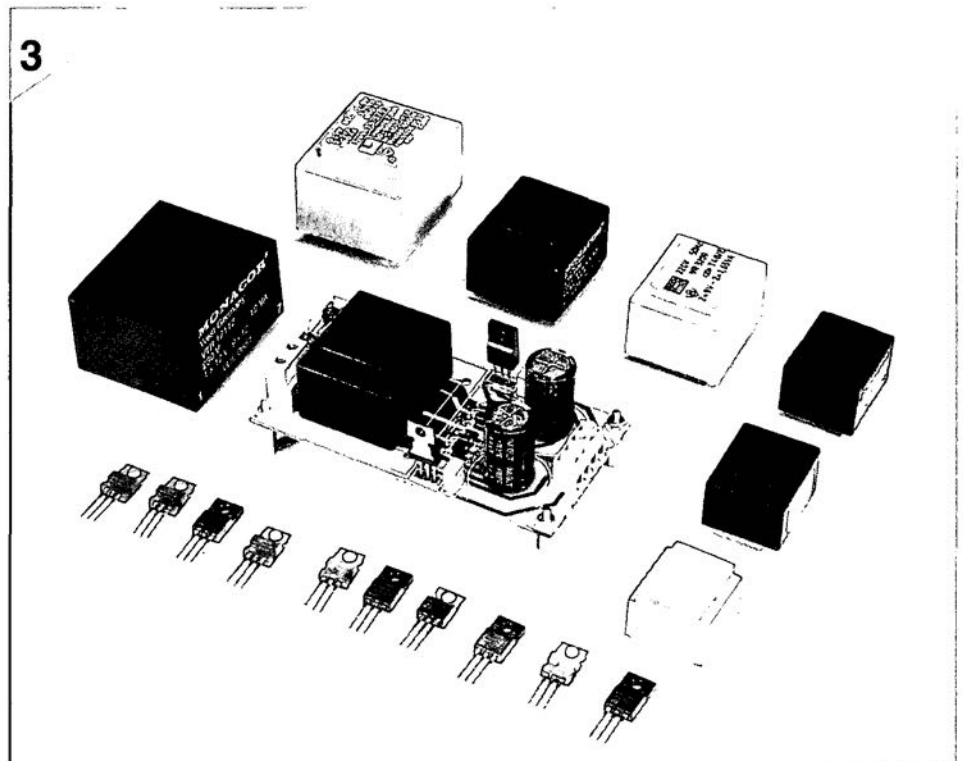
NEW PRODUCTS

Vann Draper doubles the power

Vann Draper Electronics have just announced the introduction of a dual output power supply with comprehensive features and full protection.

The ADPS305 is a dual output 0 to 30V, 0 to 5 amps regulated DC linear bench power supply capable of operating in constant voltage and constant current modes with front panel switching for isolated, serial or parallel operation. This has the advantage of allowing the user to easily select 0 to 60V at 0 to 5 amps or 0 to 30V at

0 to 10 amps or dual 0 to 30V 0 to 5 amps. In serial or parallel modes the unit operates as a master slave.

The output voltages are set by both coarse and fine controls with output voltage and current monitored by four 3.5 digit liquid crystal displays which provide clear and concise readings.

Load regulation is better than 0.2% and ripple less than 5mV. Full overload and short circuit protection is provided by means of a current foldback circuit which minimises the risk of damage to the power supply or target should an overload occur.

The ADPS305 has a light steel case finished in a hard wear-

ing matt black coating.

The unit measures 350x320x150 mm and is priced at £289.00, representing one of the best value and lowest cost units available.

(977052)

Vann Draper Electronics Ltd., Unit 5, Premier Works, Canal Street, South Wigston, Leicester LE18 2PL. Tel. (0116) 2771400, fax (0116) 2773945.

New programmer from Smart Communications

The new ALL-07A from SMART supports over 3,000 devices. This includes programming for devices with as few as 8 to over 200 pins including EPROM, E2PROM, FLASH, Bipolar, Serial PROM, IC Memory Cards, PCMCIA cards, PAL, GAL, PEEL, EPLD, FPL, FPGA, CPLD and microcontrollers with testing for TTL 74/54, CMOS 40/45 and DRAM and SRAM parts.

The ALL-07A runs either under DOS or Windows (3.1 or 95) using the new WINADP-96. The simple batch file setup procedure enables you to run the mundane repetitive operations on the production line with a single key stroke. This both simplifies operation of the programmer and significantly reduces the risk of operator error.

The system is based on a range of interchangeable PACKS which reduces considerably the number of adapter changes for each different device. The ALL-07A connects directly to your parallel printer port or optionally via the serial port or optionally via the serial port or through a PCMCIA adapter.

For even greater flexibility the

ALL-07A has a series of gang PACKs for gang E/EPROM/FLASH memory, gang microcontroller, gang PLD/CPLD and finally gang PCMCIA card programming.

For specifiers, the system is CE and TÜV approved and both the algorithms and hardware are approved by a range of IC manufacturers including AMD, Atmel and Texas Instruments. (977054)

SMART Communications, 2 Field End, Arkley, Barnet, Herts EN5 3EZ. Tel. (0181) 4413890, fax (0181) 4411843. Email: sales@smartcom.co.uk.
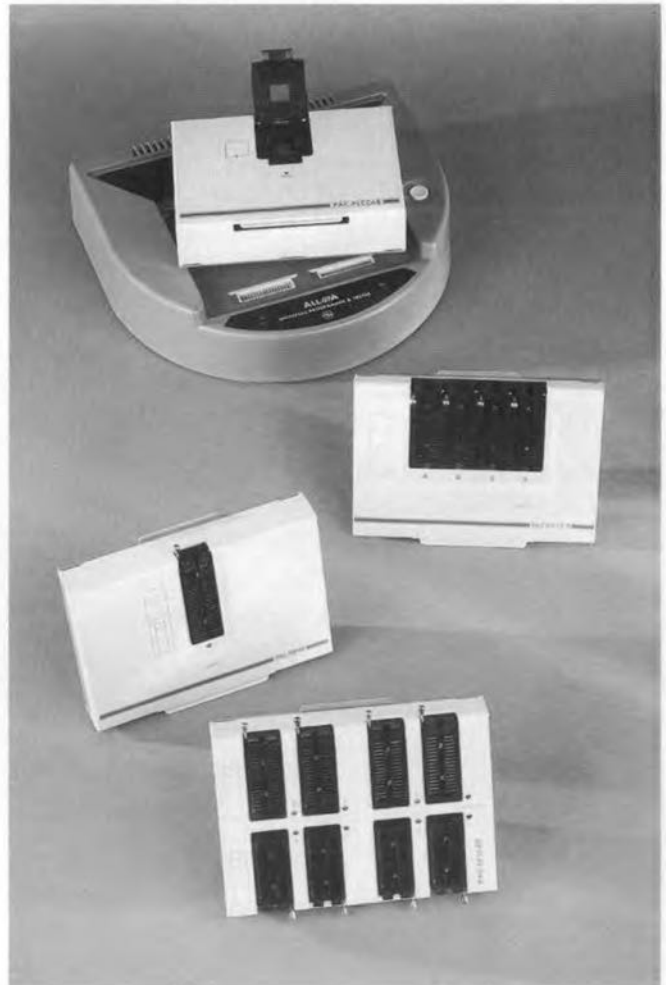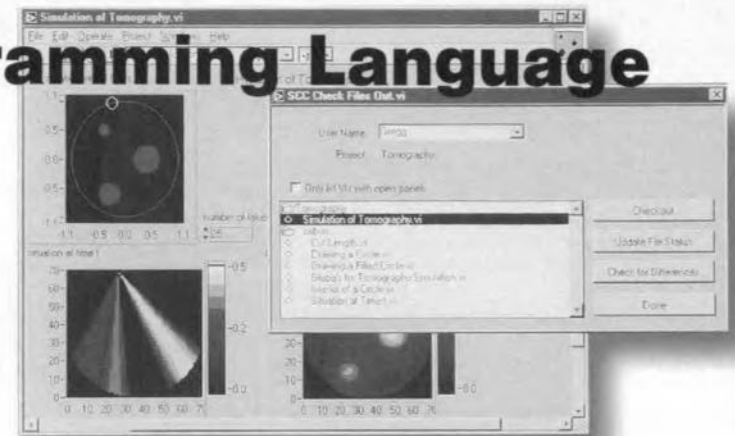
LabVIEW
'G' Graphical Programming Language

National Instruments has announced the LabVIEW Professional Developers Suite (PDS), designed to help LabVIEW users develop high-end, large-scale applications.

Similar to tools available only for text-based languages like C, this product provides graphical programmers with the tools needed for managing and tracking code in large development projects. These tools are ideal for large teams of developers, for individual users developing large suites of virtual instruments (VIs), and for G programmers needing to adhere to stringent quality standards such as those required by ISO 9000 or FDA. The LabVIEW Professional Developers Suite includes the LabVIEW Full Development System, the Application Builder, and the new Professional G Developers Toolkit. For existing LabVIEW and BridgeVIEW users, the Professional G Developers Toolkit is available separately. The Toolkit includes code management tools for source code control, code complexity metrics, and documentation utilities, as well as G programming standards useful for designing well structured applications. These new products will be available for Windows NT/95, Mac OS 68K/PPC, Sun Solaris 1 and 2, HP-UX, and PowerMAX OS.

(977055)

National Instruments, 21 Kingfisher Court, Hambridge Road, Newbury, Berkshire, RG145SJ. Tel. (01635) 523545, fax: (01635) 523154.
Email: info.uk@natinst.com.
Internet:
http:///www.natinst.com/uk/.

Portable Power from a Matchbox

Merlin Equipment's new NOTEpower 75i inverter allows computer users to run and re-charge notebook computers in their car.

By simply and silently converting the car's 12 volt battery power to 230VAC mains electricity, business people have enough power to run all day without the need for expensive spare battery packs! Even today's high-tech notebook computers will last for just a few hours when running from their internal battery. By using the new match box size NOTEPower 75i, they never need to worry about short battery life again.

The NOTEPower is safe to use with all machines available on the market. The NOTEpower 75i simply plugs into the car cigar lighter socket for easy connection. Output is then fed to the computer's own power supply 'brick' using he standard cable provided.

The NOTEPower 75i is CE approved, conforming to EU directives for electrical interference and safety, allowing units to be confidently used in many applications involving sensitive electronics. Retail price for the unit is around £80 excluding VAT and carriage.

(977056)

Merlin Equipment, Unit 1, Hithercroft Court, Lupton Road, Hithercroft Industrial Estate, Wallingford, Oxfordshire OX10 9BT. Tel. (01491) 824333, fax (01491) 824466. Email: 101756.3500@compuserve.com.

Differential Phase Change Thermal Interface

ORCUS Inc. announces the immediate availability of THERMAPHASE, a new type of thermal interface material for thermal management of power semiconductors, microprocessors, and other power electronics.

This new Phase-Change material is a dry-to-touch solid at room temperature. At a temperature slightly above normal semiconductor operating temperatures the material changes to the liquid state. It flows into the microscopic voids of both semiconductor and heatsink to provide 100% thermal contact. The resulting decrease in thermal resistance cools the semiconductor to a temperature below the phase change temperature of the compound, so that it re-enters the solid state. The material is available in two versions: electrically insulating and electrically conductive. The thermal resistance of the electrically insulating version can be as low as 0.170 C/W.
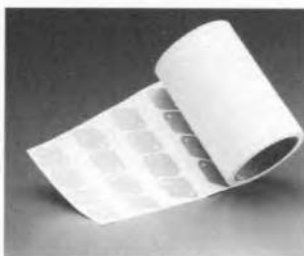
The electrically conductive type has a thermal resistance of only 0.025 C/W.
The new material has several unique advantages over older thermal interface materials:
- Very low mounting forces

- Uses only Food Grade materials
- Improved chemical resistance
- Operates in the solid phase
- Eliminates Cold-Flow of Elastomeric materials
- Eliminates mess of thermal grease
- Available on adhesive backing paper

(977053)

ORCUS Inc., Box 307, Stilwell, Kansas 66085, U.S.A. Tel. (913) 768 1875, fax (913) 768 0494. Email orcusnet@tyrell.net.
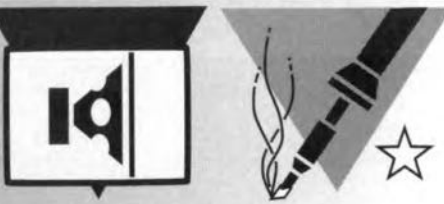
opto-to-coaxial audio converter

converts digital outputs

Most audio equipment produced in the past five to ten years has digital inputs and outputs. It is a pity, though, that there are two standards: optical and coaxial, and not all equipment has both. Fortunately, the connection difficulties that may ensue are easily resolved by the use of the adaptor described in this article. This enables any optical output to be converted into a coaxial one or vice versa.

Design by T. Giesberts
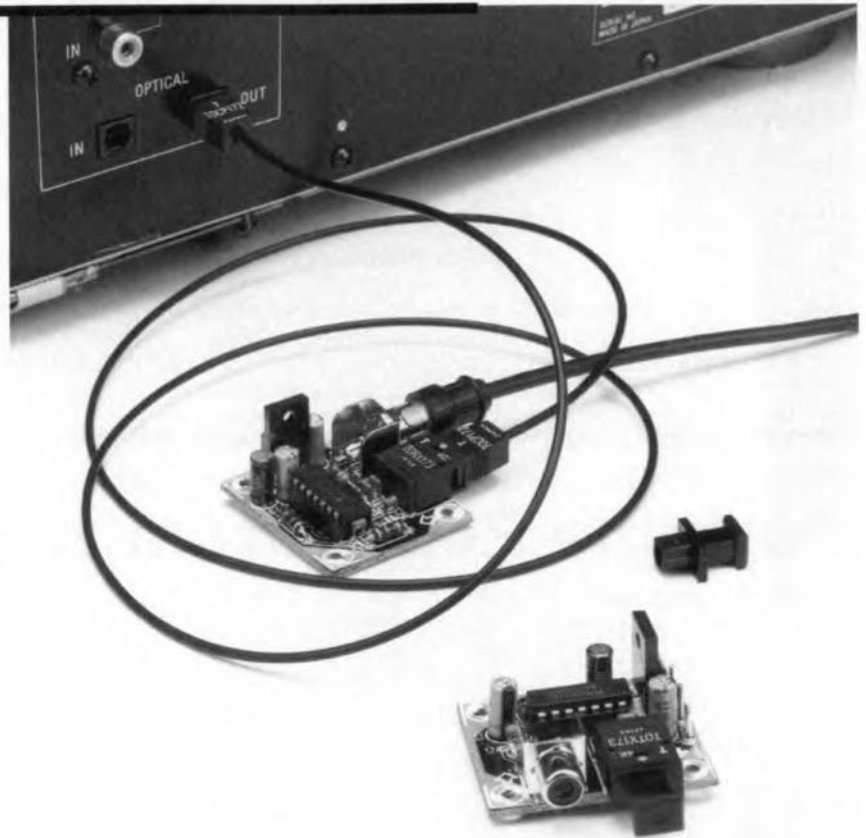
THE PROBLEM

Connection difficulties are frequent phenomena in the audio world. In the beginning there was the DIN (Deutsche Industrie Normen = German Industrial Standards) standard. Within a very short time, there were a number of variants on this: a five-pole plug does not fit into a three-way socket; 180° plugs and 240° sockets are not compatible either. And let's not even talk about the seven-way plugs and four-way square DIN connectors. The result of this was a thriving market in adaptors.

After the DIN era, there came the phono socket era. Once this had established itself, there was a period of relatively calm – until the advent of 'per-sonal audio'. On this small equipment there was no space to fit standard phono sockets for the line outputs and so the 3 mm mini jack was born. And again, an adaptor was required if such a Walkman™ or Discman™ had to be connected to another piece of audio equipment.

It seems that history will repeat itself in respect of the connectors on modern audio equipment. From day one it was the case that where exchange of digital signals took place, there were two standards: one working with electrical pulses and the other with light pulses. In itself, that is, of course, no problem as long as both types of connector are fitted on all audio equipment. And that is mani-

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* S/PDIF = Sony/Philips Digital Interface Format – the consumer version of the AES/EBU standard. This standard was devised by the American Audio Engineering Society and the European Broadcasting Union to define the signal format, electrical characteristics and connectors to be used for digital interfaces between professional audio products.

festly not happening. It is true that there is equipment on the market that has both, but the majority has not.

THE SOLUTION

Two converters are described that remedy the connection problem. They are easy to build and put paid to any interface problem between digital inputs and outputs.

One of the designs converts electrical signals into optical ones and the other does exactly the opposite. Both designs are based on the well-known Toslink™ modules. These compact converters may be built into the relevant audio equipment or they may be constructed as stand-alone units.

If the converter is built into the audio equipment, its power may be derived from that equipment. If used as stand-alone unit, the unit derives power from a mains adaptor.

FROM COAX TO OPTO

The circuit of the electrical-to-optical converter (EOC) is shown in the diagram of **Figure 1**. It is a straightforward design.

The S/PDIF* signal input to K_1 has a peak-to-peak value of about 0.5 V and is applied across 75 Ω terminating resistor R_1. This signal is amplified first by IC_{1a} and then by IC_{1b}, whereupon it has a peak-to-peak value of 5 V (HC level). The design of the amplifiers prevents any clipping taking place.

The supply to IC_{1a} is ½V_{cc} because of resistor R_2. Any input offset is blocked by C_1. This capacitor also prevents the operating point of IC_{1a} being affected by R_1.
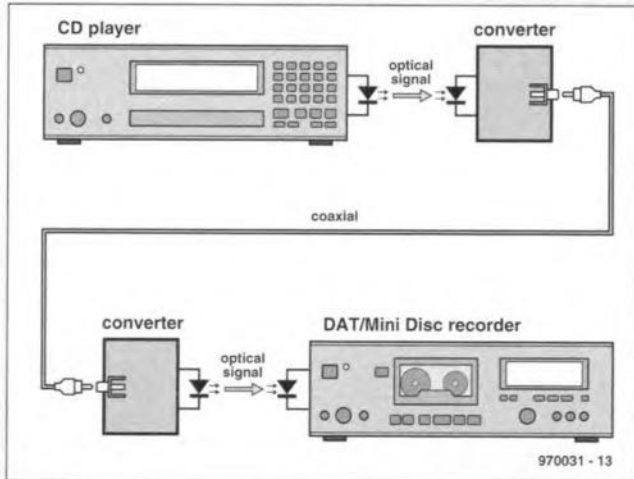
The output of IC_{2b} is applied to IC_2, a Toslink™ sender, in which the actual conversion from electrical to optical signal takes place.

The circuit is powered by a supply line that is regulated by IC_3. Choke L_1, resistor R_4 and capacitors C_2–C_4 ensure adequate decoupling of the supply line. More about the supply later.
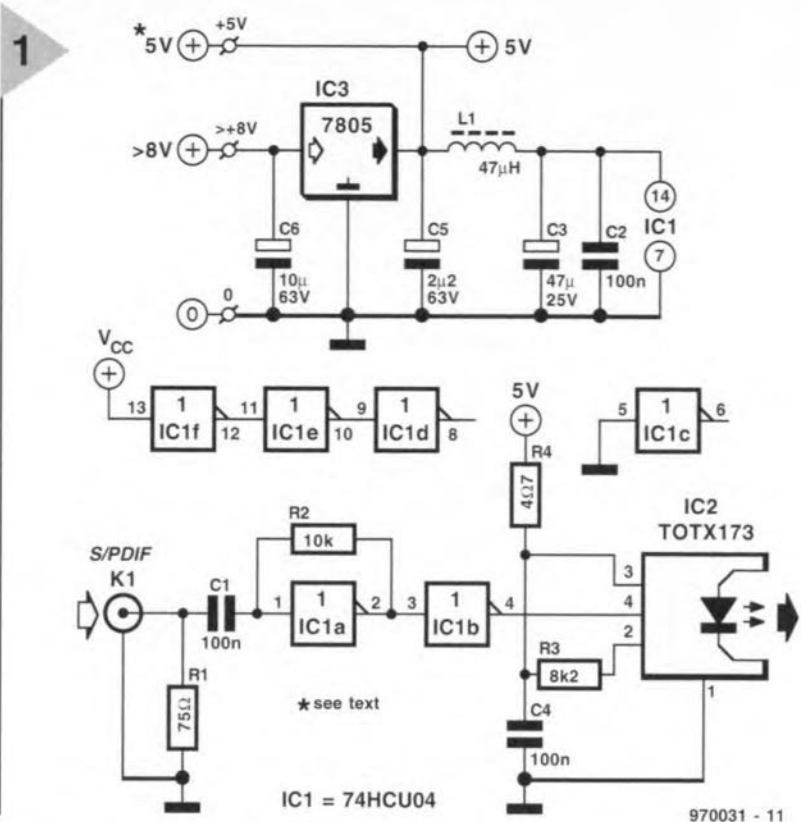
Long(ish) optical link

The converters described in this article may also be used for another purpose that has nothing to do with connection problems. It is a known fact that optical links suffer from a slight drawback: in practical use their length is very limited. This means that when it is desired to link two units that have only optical connectors over a distance of a few metres (10 feet or so) there is a little problem. However, the use of two converters makes the link possible. To do this, connect a converter to each of the two audio units via a short optical cable and link the converters via a standard, screened coaxial cable (see illustration). It may seem rather a long way around the problem, but it works well.

Figure 2. *An optical-to-coaxial converter needs a Toslink™ receiver and not much more. A potential divider ensures the correct level of the output signal and the value of the output impedance.*

Parts list

COAX-TO-OPTO CONVERTER

Resistors:
R_1 = 75 Ω
R_2 = 10 kΩ
R_3 = 8.2 kΩ
R_4 = 4.7 Ω

Capacitors:
C_1, C_2, C_4 = 100 nF ceramic, pitch 5 mm
C_3 = 47 μF, 25 V, radial
C_5 = 2.2 μF, 63 V, radial
C_6 = 10 μF, 63 V, radial

Integrated circuits:
IC_1 = 74HCU04
IC_2 = TOTX173 (Toshiba)
IC_3 = 7805

Miscellaneous:
L_1 = 47 μH (standard available)
K_1 = audio connector for board mounting
PCB Order no. 970031 (see Readers' services towards end of this issue)

OPTO-TO-COAX CONVERTER

Resistors:
R_1 = 374 Ω, 1%
R_2 = 93.1 Ω, 1%

Capacitors:
C_1–C_3 = 47 nF, ceramic, pitch 5 mm
C_4, C_5 = 100 nF, ceramic, pitch 5 mm
C_6 = 47 μF, 25 V, radial
C_7 = 2.2 μF, 63 V, radial
C_8 = 10 μF, 63 V, radial

Integrated circuits:
IC_1 = TORX173 (Toshiba)
IC_2 = 74HCT04
IC_3 = 7805

Miscellaneous:
L_1, L_2 = 47 μH (standard available)
K_1 = audio connector for board mounting
PCB Order no. 970031 (see Readers' services towards end of this issue

FROM OPTO TO COAX

The circuit of the optical-to-electrical converter (OEC) is shown in the diagram of **Figure 2**. Like its sister circuit, it is a straightforward design.

The input signal is applied to IC_1, a Toslink™ receiver. Provided that the level of the optical signal is sufficient, the output of IC_1 is at TTL level (low = 0.5 V high = 3 V). This means that amplification is not necessary in this circuit, so that IC_1 is followed by buffer IC_{2a}. The five remaining inverters in IC_2 are paralleled to function as the output stage. The output signal is applied to K_1 via coupling capacitors C_1–C_3 and potential divider R_1-R_2.

The potential divider has two meet two criteria. The first is that, provided the output is correctly terminated into 75 Ω, the output voltage level does not exceed 0.5 V. The second is that the output impedance must be 75 Ω to prevent any mismatch. Consequently, the values of the two resistors are fairly low and this means that the output stage has to provide a relatively large current. This, in turn, is the reason that the five inverters in IC_2 are connected in parallel.

Asymmetric loading of the output stage is prevented by a.c. coupling.
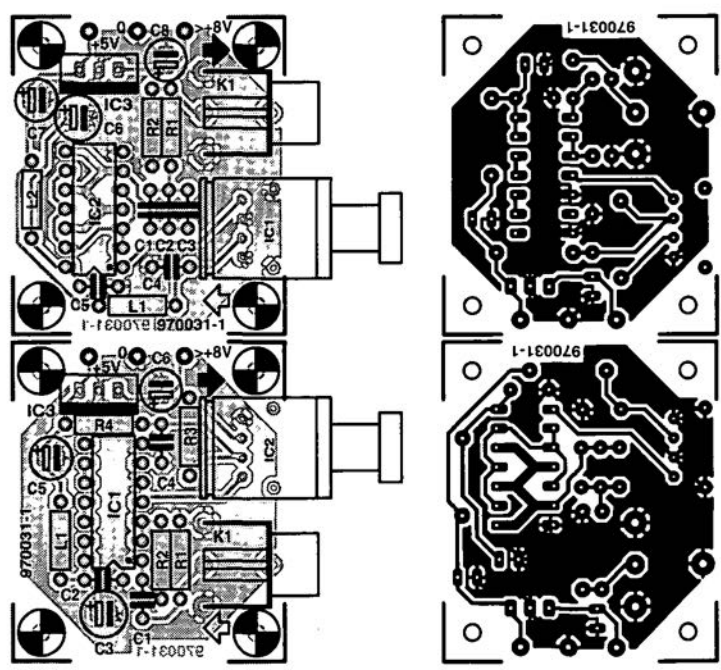
Figure 3. *The printed-circuit boards for the two converters are manufactured as one.*

This is effected by three capacitors connected in parallel so as to reduce the series resistance.

The power line is decoupled by chokes L_1 and L_2 and capacitors C_4–C_6.

POWER SUPPLY

As mentioned earlier, power may be derived from the relevant audio equipment into which the converters may be built, but it may also be provided by a discrete unit.

It is, of course, better to use a discrete power supply, since it being derived from the audio unit may give rise to hum and earth loops. In that case, it may even be necessary to use an output transformer to keep the various earths separated.

A discrete power supply is simply obtained from a mains adaptor whose output may be 8–35 V. Since the converters already have a regulator on board, and they draw a current of only

Figure 4. Completed prototype boards.

a few milliamperes, the demands on the adaptor are small.

If the two converters are fitted in one and the same case, just one mains adaptor will do, otherwise each will need its own, of course. If only one mains adaptor is used, the regulator may be omitted from one of the boards and the +5 V and 0 terminals on the two boards interlinked. Again, take care that earth loops do not arise.

CONSTRUCTION

The converters are best built on the printed-circuit board shown in **Figure 3**. Note that this needs to be cut into two before any work is done.

Completing the boards is straightforward provided the usual sequence is followed: start with the resistors and capacitors, followed by the chokes and integrated circuits. Do not use sockets for the ICs. The Toslink™ modules and audio connectors may be soldered directly to the board.

When the board has been completed give it a good going-over to check that all connections are good, that the polarity of capacitors has been observed and that the ICs are fitted correctly. Note that the heat-conducting side of IC_3 is indicated by a small white square. **Figure 4** shows the completed prototype.

The enclosure(s) used depend on the application of the converters. If they are used permanently for one purpose only, the quality of the enclosure is not very important. If they are used for many purposes, a rather more robust case is necessary.
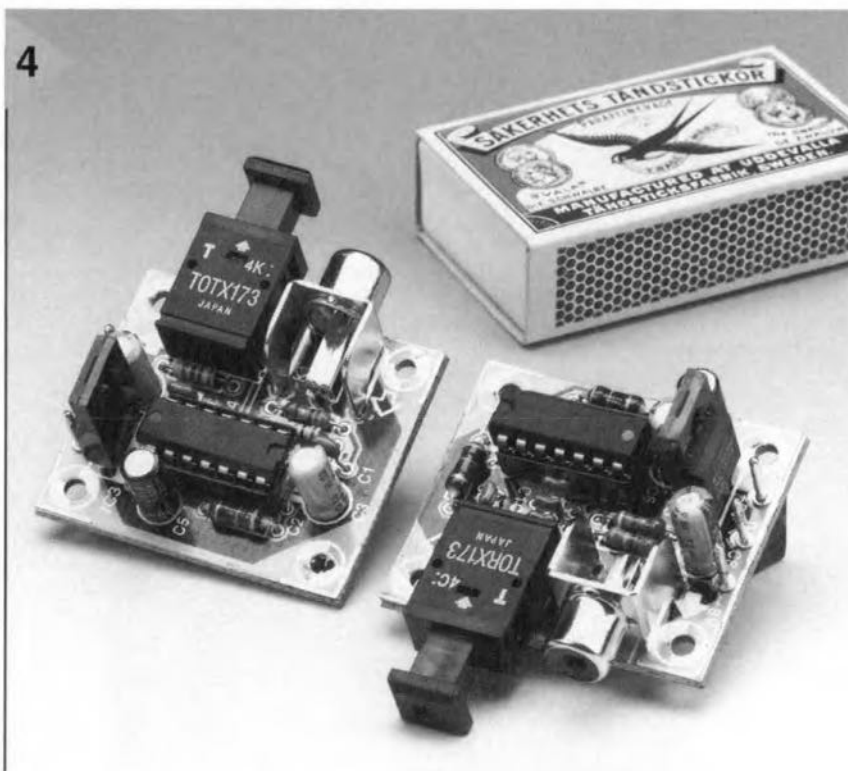
[970031]

AT89C2051

Integrated Circuits
Microcontrollers

8-bit Microcontroller with 2 Kbytes Flash

Manufacturer
Atmel Corporation,
2125 O'Nel Drive,
San Jose, CA
95131. Tel. (408)
441-0311, fax (408)
436-4200.
Atmel UK, Ltd., Coli-
seum Business Centre, Riverside Way, Camberley, Sur-
rey GU15 3YL. Tel. (01276) 686677, fax (01276)
686697.
Internet: http://www.atmel.com

Description
The AT89C2051 is a low-voltage, high-performance
CMOS 8-bit microcomputer with 2 Kbytes of Flash pro-
grammable and erasable read-only memory (PEROM).
The device is manufactured using Atmel's high-density
non-volatile memory technology, and is compatible with
the industry standard MCS-51™ instruction set and
pinout. By combining a versatile 8-bit CPU with Flash on
a monolithic chip, the Atmel 89C2051 is a powerful
microcomputer which provides a highly flexible and
cost-effective solution to many embedded control appli-
cations.
The 89C2051 provides the following standard features:
2 Kbytes of Flash, 128 bytes of RAM, 15 I/O lines, two
16-bit timer/counters, a five source two-level interrupt
architecture, a full-duplex serial port, a precision ana-
logue comparator, on-chip oscillator and clock circuitry.
In addition, the AT89C2051 is designed with static logic
for operation down to zero frequency and supports two
software selectable power saving modes. The Idle
Mode stops the CPU while allowing the RAM,
timer/counters, serial port and interrupt system to con-
tinue functioning. The Power Down Mode saves the
RAM contents but freezes the oscillator, disabling all
other chip functions until the next hardware reset.
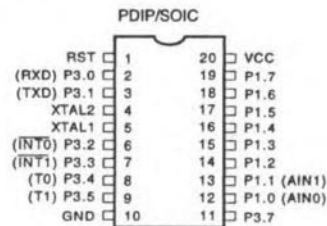
Features
- Compatible with MCS-51™ Products
- 2 Kbytes of Reprogrammable Flash Memory
    - Endurance: 1,000 Write/Erase Cycles
    - Data Retention: 10 Years

- 2.7 V to 6 V Operating Range
- Fully Static Operation: 0 Hz to 24 MHz
- Two-level Program memory Lock
- 128 x 8-Bit Internal RAM
- 15 Programmable I/O Lines
- Two 16-Bit Timer/Counters
- Five Interrupt Sources
- Programmable Serial UART Channel
- Direct LED Drive Outputs
- On-Chip Analogue Comparator
- Low Power Idle and Power Down Modes

Application example
Flash EPROM programmer/emulator, *Elektor Electronics*
June 1996.

Pin configuration

```
        PDIP/SOIC

        RST  [ 1      20 ]  VCC
(RXD) P3.0  [ 2      19 ]  P1.7
(TXD) P3.1  [ 3      18 ]  P1.6
      XTAL2 [ 4      17 ]  P1.5
      XTAL1 [ 5      16 ]  P1.4
(INT0) P3.2 [ 6      15 ]  P1.3
(INT1) P3.3 [ 7      14 ]  P1.2
  (T0) P3.4 [ 8      13 ]  P1.1 (AIN1)
  (T1) P3.5 [ 9      12 ]  P1.0 (AIN0)
        GND [ 10     11 ]  P3.7
```

Pin Description
Vcc Supply voltage.
GND Ground.
Port 1 Port 1 is an 8-bit bidirectional I/O port. Port pins
P1.2 to P1.7 provide internal pullups. P1.0 and P1.1
require external pullups. P1.0 and P1.1 also serve as
the positive input (AIN0) and the negative input (AIN1),
respectively, of the on-chip precision analogue com-
parator. The Port 1 output buffers can sink 20 mA and
can drive LED displays directly. When 1s are written to
Port 1 pins, they can be used as inputs. When
pins P1.2 to P1.7 are used as inputs and are externally
pulled low, they will source current (I_{IL}) because of the
internal pullups.
Port 1 also receives code data during Flash program-
ming and program verification.
Port 3 Port 3 pins P3.0 to P3.5, P3.7 are seven bidi-
rectional I/O pins with internal pullups. P3.6 is hard-

AT89C2051

Integrated Circuits
Microcontrollers

Special Function Registers
An overview of the on-chip memory area called the
Special Function Register (SFR) space is shown in the
table below. Note that not all of the addresses are occu-
pied, and unoccupied addresses may not be implement-
ed on the chip. Read accesses to these addresses will
in general return random data, and write accesses will
have an indeterminate effect. User software should not
write 1s to these locations, since they may be used in
future products to invoke new features. In that case, the
reset or inactive values of the new bits will always be 0.

Programming the Flash
The 89C2051 is shipped with the 2 Kbytes of on-chip
PEROM code memory array in the erased state (i.e.,
contents = FFH) and ready to be programmed. The
code memory array is programmed one byte at a time.
*Once the array is programmed, to re-program any non-
blank byte, the entire memory array needs to be erased*

AT89C2051 SFR map and reset values		
Range: 0A0H through 0FFH		
0A8H	IE	00000000
0B0H	P3	11111111
0B8H	IP	X0000000
0D0H	PSW	00000000
0E0H	ACC	00000000
0F0H	B	00000000
Range: 80H through 9FH		
81H	SP	00000111
82H	DPL	00000000
83H	DPH	00000000
87H	PCON	00000000
88H	TCON	00000000
89H	TMOD	00000000
8AH	TL0	00000000
8BH	TL1	00000000
8CH	TH0	00000000
8DH	TH1	00000000
90H	P1	11111111
98H	SCON	00000000
99H	SBUF	XXXXXXXX

electrically.
Internal Address Counter: The AT89C2051 contains an
internal PEROM address counter which is always reset
to 000H on the rising edge of RST and is advanced by
applying a positive going pulse to pin XTAL1.

Programming Algorithm: To program the AT89C2051,
the following sequence is recommended:
1. Power-up sequence: Apply power between Vcc and
   GND pins → Set RST and XTAL1 to GND → With all
   other pins floating, wait for >10ms.
2. Set pin RST to 'H' → Set pin 3.2 to 'H'.
3. Apply the appropriate combinations of 'H' or 'L' logic
   levels to pins P3.3, P3.4, P3.5, P3.7 to select one of
   the programming operations shown in the PEROM
   Programming Modes table.
To program and verify the array:
4. Apply data for Code byte at location 000H to P1.0 to
   P1.7.
5. Raise RST to 12V to enable programming.
6. Pulse P3.2 once to program a byte in the PEROM
   array or the lock bits. The byte-write cycle is self-
   timed and typically takes 1.2ms.
7. To verify the programmed data, lower RST from 12V
   to logic 'H' level and set pins P3.3 to P3.7 to the
   appropriate levels. Output data can be read at the
   port P1 pins.
8. To program a byte at the next address location,
   pulse XTAL1 pin once to advance the internal
   address counter. Apply new data to the port P1 pins.
9. Repeat steps 5 through 8, changing data and
   advancing the address counter for the entire 2
   Kbytes array or until the end of the object file is
   reached.
10. Power-off sequence: Set Xtal1 to 'L' → set RST to 'L'
    → Float all other I/O pins → Turn Vcc power off.
Data Polling: The 89C2051 features Data Polling to
indicate the end of a write cycle. During a write cycle,
an attempted read of the last byte written to will result in
the complement of the written data on P1.7. Once the
write cycle has been completed, true data is valid on all
outputs, and the next cycle may begin. Data Polling may
begin any time after a write cycle has been initiated.
Read/Busy: The progress of byte programming can
also be monitored by the RDY/BSY output signal. Pin
3.1 is pulled low after P3.2 goes high during program-

ming to indicate BUSY. P3.1 is pulled high again when the programming is done to indicate READY.

Program Verify: If lock bits LB1 and LB2 have not been programmed, code data can be read back via the data lines for verification:

1. Reset the internal address counter to 000H by bringing RST from 'L' to 'H'.
2. Apply the appropriate control signals for Read Code data and read the output data at the port P1 pins.
3. Pulse pin XTAL1 once to advance the internal address counter.
4. Read the next code data byte at the port P1 pins.
5. Repeat steps 3 and 4 until the entire array is read. The lock bits can not be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

Chip Erase: The entire PEROM array (2 Kbytes) and the two Lock bits are erased electrically by using the proper combination of control signals, and by holding P3.2 low for 10ms. The code array is written with all 1s in the Chip Erase operation, and must be executed before any non-blank memory byte can be re-programmed.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 000H, 001H, and 002H, except that P3.5 and P3.7 must be pulled to a logic low. The values returned are as follows:

(000H) = 1EH indicates manufactured by Atmel
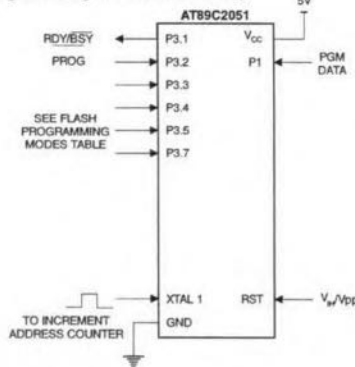(001H) = 21H indicates 89C2051
(002H) = FFH indicates 12 V programming

Programming the Flash memory

Verifying the Flash memory

Flash Programming Modes

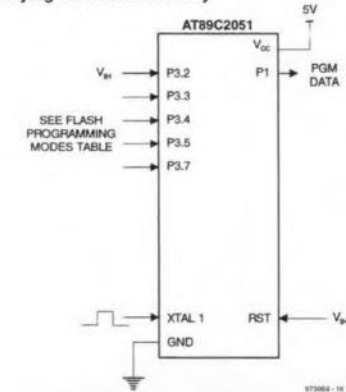| Mode	RST	P3.2/PROG	P3.3	P3.4	P3.5	P3.7
Write Code Data(1,3)	12V		L	H	H	H
Read Code Data(1)	H	H	L	L	H	H
Write Lock Bit - 1	12V		H	H	H	H
Write Lock Bit - 2	12V		H	H	L	L
Chip Erase	12V	(2)	H	L	L	L
Read Signature Byte	H	H	L	L	L	L

Notes:
1. The internal PEROM address counter is reset to 000H on the rising edge of RST, and is advanced by a positive pulse at XTAL1 pin.
2. Chip Erase requires one 10ms PROG pulse.
3. P3.1 is pulled low during programming to indicate RDY/BSY.

wired as an input to the output of the on-chip comparator and is not accessible as a general-purpose I/O pin. The Port 3 output buffers can sink 20 mA. When 1s are written to Port 3 pins, they are pulled high by the internal pullups, and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (I_{IL}) because of the pullups.

Port 3 also serves the functions of various special features of the 89C2051 as listed below:

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	INT0 (external interrupt 0)
P3.3	INT1 (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)

Port 3 also receives some control signals for Flash programming and programming verification.

RST Reset input. All I/O pins are reset to 1s as soon as RST goes high. Holding the RST pin high for two machine cycles while the oscillator is running resets the device.

XTAL1 Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2 Output from the inverting oscillator amplifier.

Oscillator Characteristics

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown below. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in the second drawing. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.
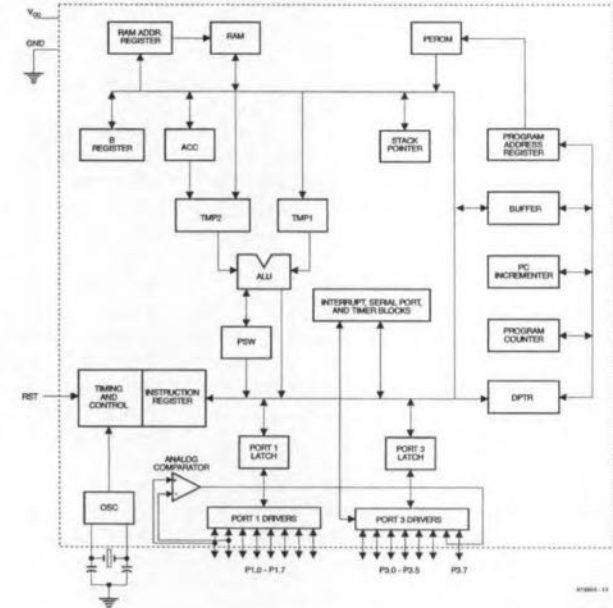
Oscillator connections
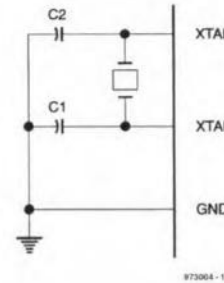
External clock drive configuration
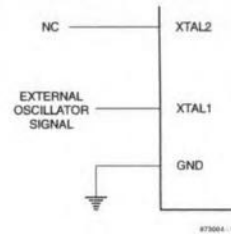
Block diagram

software for electronics

ST6-Realizer® V2.0
the CASE solution

The Realizer®, originally developed by ACTUM Solutions, is now available as a CASE (Computer Aided Software Engineering) software bundle geared to ST6 microcontrollers from SGS-Thomson.

The evaluation copy we received from SGS-Thomson was supplied in a small cardboard box containing four disks in an envelope, together with the 240-page ST6-Realizer® user manual and a much thinner booklet of 30-odd pages covering, according to the title, the ST62 family, although the booklet really ly discusses the ST622x kit (i.e., hardware). The ST6-Realizer® package normally comes with a fat (700-page) databook which provides ample information on all ST62xx family members and the different development kits available for these microcontrollers.

These days, it is essential for microprocessor code to be rapidly created, easily transferable, fully tested and easy to update. ST6-Realizer® allows functions to be designed in the form of block schematic diagrams, before proceeding with a logic analysis of the project, and then using simulation to test its functionality with the aid of simulation objects. In the end, ST6xxx object code is generated which is error-free.

Installing the software from backup copies of the original diskettes is a matter of minutes. The installation

procedure creates a window containing six icons.

Although you may launch any of the four programs by double-clicking on the respective icon, do bear in mind that there has to be something to analyse or simulate, or that diagram data is available for conversion from a previous version.

Let's launch the ST6-Realizer program.

Because ST6-Realizer® runs under Windows, and even under Windows 95, it offers all advantages of this user interface as far as ease of use is concerned.

Having defined a new project, you may start by loading its diagram. At this level you have various tools available which are necessary to fill in the different functions. Once the diagram has been drawn, you have to choose a target component if you want to be able to proceed with an analysis or a simulation-run. The software enables the following members of the SGS-Thomson ST6 family to be simulated: ST6200, 201, 203, 208, 209, 210, 215, 220, 225, 230, 232, 235, 240, 242, 245, 253, 260, 263 and 265.

The analysis software examines the diagram in respect of its logic functionality. Having launched the analyser, the

netlist is created, as well as a cross-reference. Next, the actual analysis is run, whereupon the final object code for the target system is generated. The process is accompanied by a full report of what's going on and what has been produced by the system. Unfortunately, the length of the report is such that it can not be printed. Not to worry, though, because it is easiyl transferred to Notepad (W95). Provided the analysis has finished properly, the system has created a .ANA file, and you may proceed with the simulation phase.

This level allows you to test the behaviour of the application created with the Realizer®. In practice, an object is subjected to a number of variable logic conditions (stimuli) to see if it behaves the way you want it to.

Finally, a symbol editing level is available which offers various possibilities.

A number of example projects are
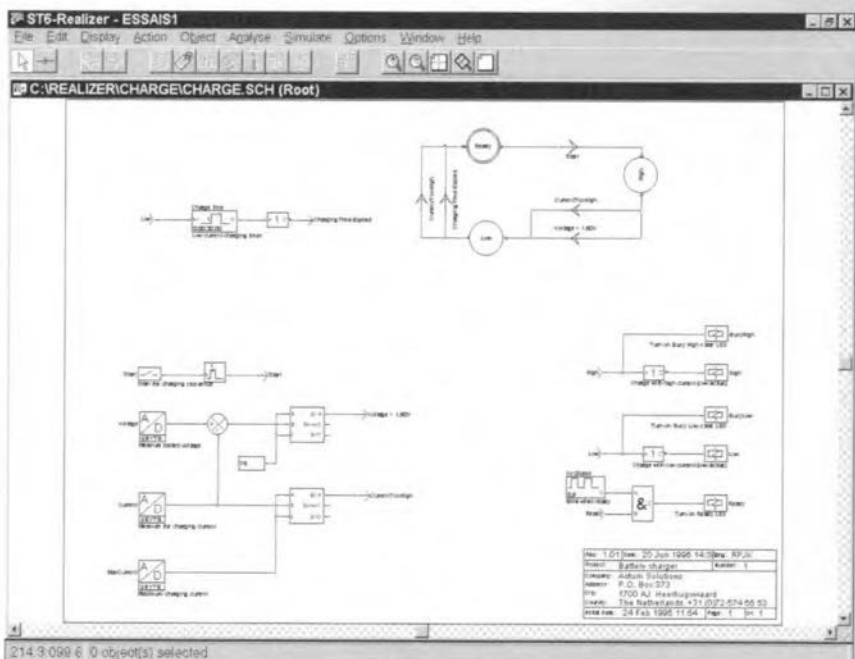
available to help you grasp the operating principles of the software.

The documentation with the Realizer software is extensive and leaves nothing to be desired. The user manual in particular is worth mentioning in this respect because it contains a number of very useful examples.

Two minor criticisms, to close off: although we came across many references to *Tutorial Movies*, none of these could actually be located. Perhaps SGS-Thomson intends to publish these on a future CD-ROM. Secondly, although the package we received for reviewing was clearly identified as V2.0, we were surprised to see that it contained a form for a free upgrade to... version 2! **(975029-1)**
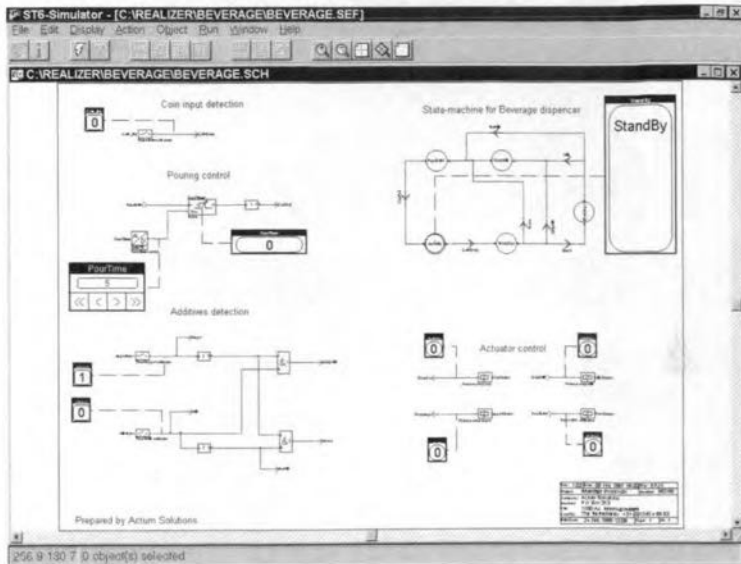
electronics on line
Internet Sites
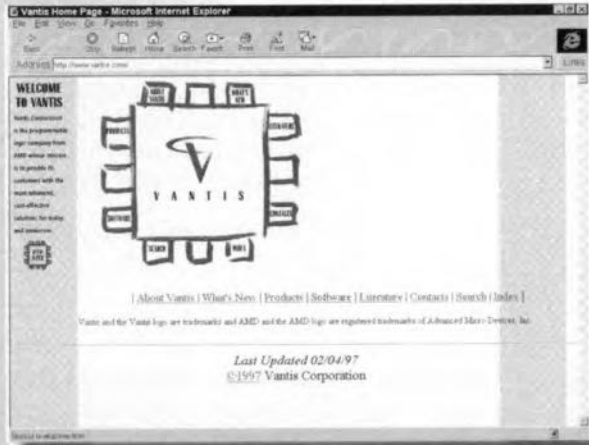
All programmers using AMD chips and/or software are well advised to visit the Vantis Corp. web site. Vantis say that *their mission is to provide its customers with the most advanced cost-effective solutions for today and tomorrow.* Well, The site has a lot of software in store for you to download, as well as pointers to obtaining literature. The web address is:
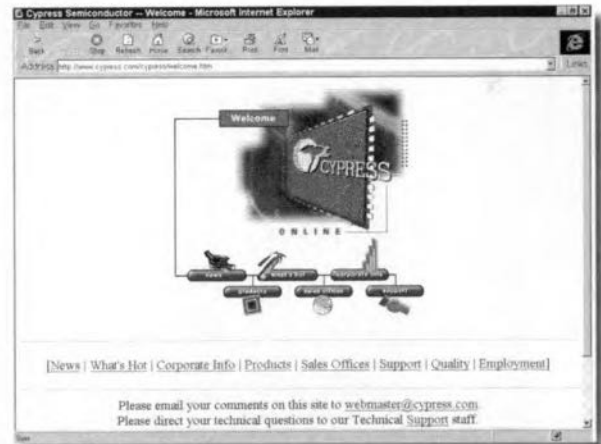**http://www.vantis.com**.

Another interesting site is that of Cypress, one of the main players in the field of programmable components. The web pages contain all sorts of information on components and software from Cypress. The web address is:
http://www.cypress.com.

Another novelty, for us, at least, is the site published by Zilog, one of the first companies actively involved in mass production of microprocessors (you may remember their famous Z80 CPU which was very popular between 1975 and 1985). Zilog now produces many highly interesting components which go into the implementation of stand-alone or turn-key systems. Have a look at
www.zilog.com.

The last site to be mentioned in this month's quick tour is that of fuzzyTECH®, one of the specialists on fuzzy logic. All fuzzy enthusiasts should surf to
http://www.fuzzytech.com.

(975029-2)