

FREE SUPPLEMENT

PC TOPICS

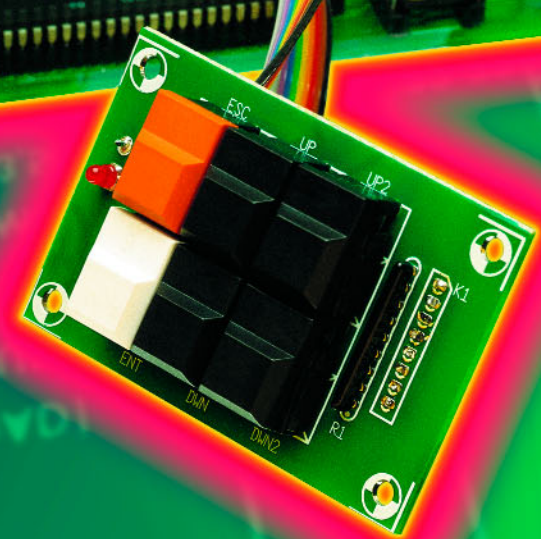
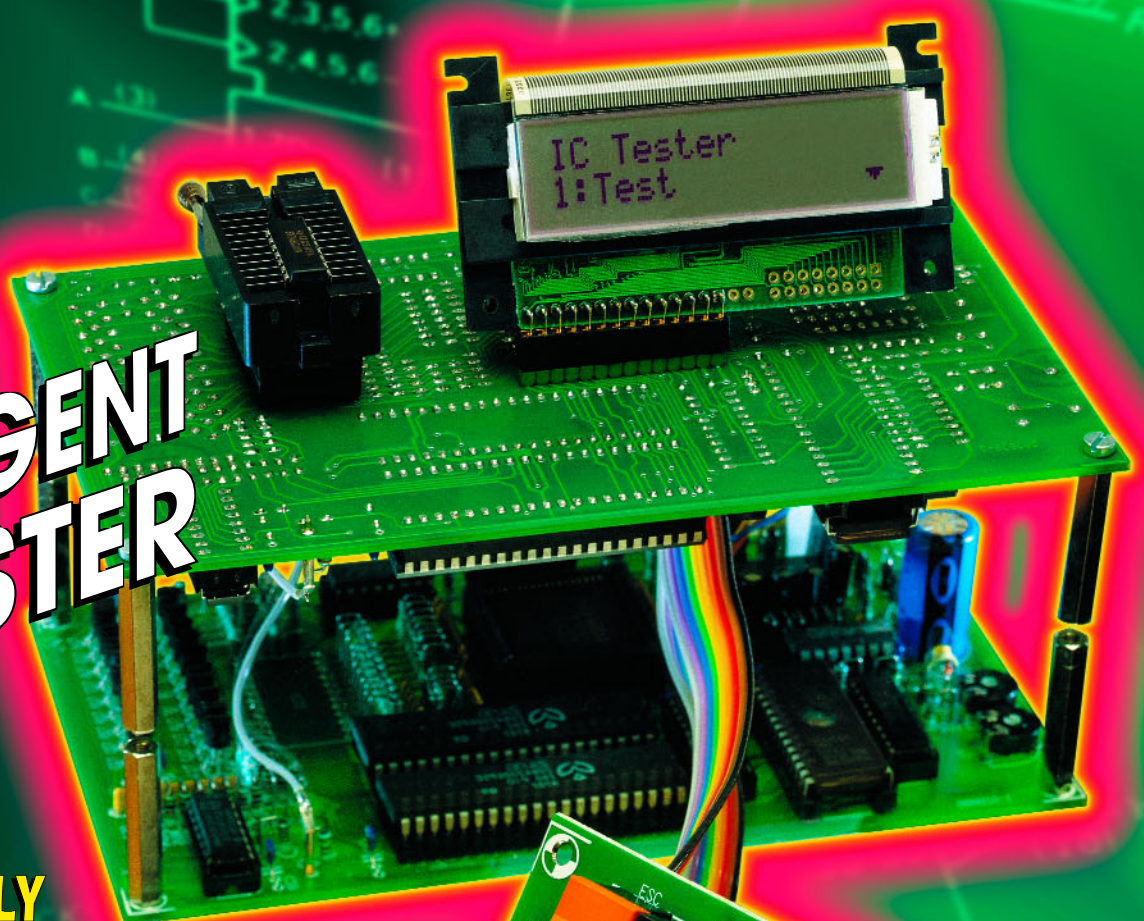
DIGITAL AUDIO
BROADCASTING (DAB)

ELEKTOR ELECTRONICS

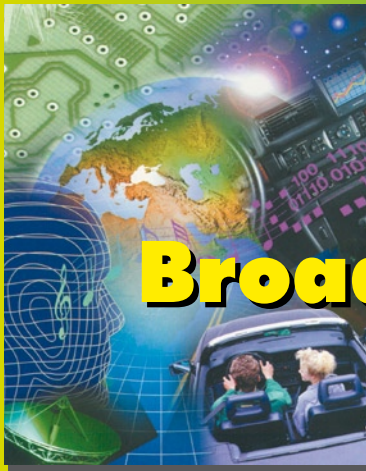
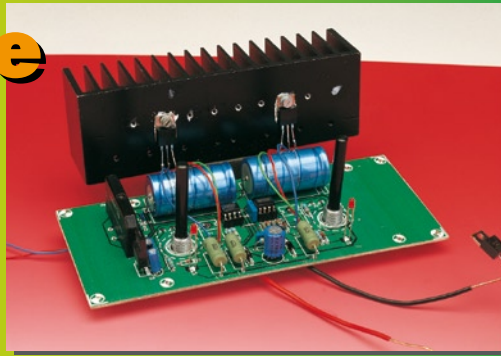
INTELLIGENT IC-TESTER

VARIABLE
POWER SUPPLY

BALANCED ↔ UNBALANCED
AF INPUT

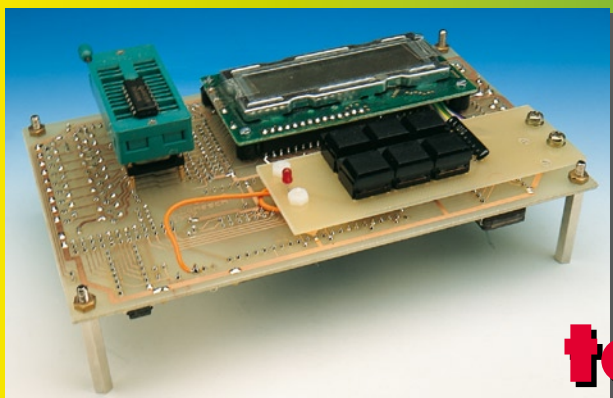
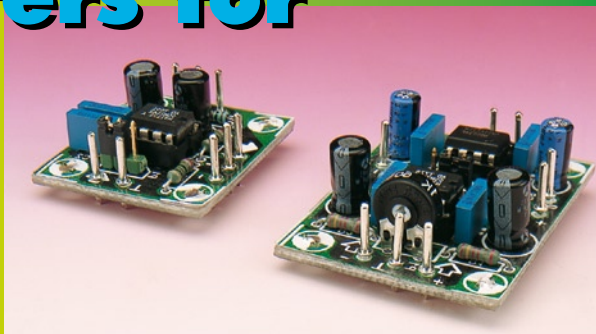


variable power supply 16



Digital Audio Broadcasting 34

balanced/unbalanced converters for audio signals 22



50 IC tester

March 1998 Volume 24
Number 264 ISSN 0268/4519

FREE 16-page SUPPLEMENT
PC Topics
Centrefold

AUDIO & HI-FI

- 22 PROJECT: Balanced/unbalanced converters for audio signals
☆☆ Design by J.F. Brangé

COMPUTERS & MICROPROCESSORS

- 40 PROJECT:
☆☆ 80C32 BASIC control computer (2)
Design by H.J. Böbling

FOCUS ON

- 34 Digital Audio Broadcasting (1)
By our Editorial Staff

GENERAL INTEREST

- 28 Introduction to Digital Signal Processing (3)
A six-part course
by Dr. Ing. M. Ohsmann
- 46 PROJECT: Ionization circuit
☆☆ Design by H. Bonekamp
- 64 PROJECT: Flashing brooch
☆☆ Design by K.A. Walraven

POWER SUPPLIES & BATTERY CHARGERS

- 16 PROJECT: Variable power supply
☆☆ Design by K.A. Walraven

TEST & MEASUREMENT

- 50 PROJECT: IC tester
☆☆ Design by L. Lamesch

MISCELLANEOUS INFORMATION

- 71 Data sheets: Line driver/receiver SSM2141/2142
- 11 Electronics now
- 62 Electronics on line: Semiconductor overviews
- 74 Index of advertisers
- 66 New books
- 74 Next month in Elektor Electronics
- 68 Readers' services-
- 63 Switchboard & Corrections

In a situation where we have two or more computers which exchange large amounts of data, share a printer and are separated by 10 metres or more, setting up a network is the best solution. If you have never worked with a network, this may appear to be a complicated task. Nonetheless it is a lot easier than you might expect; in addition the cost of a pair of network adapter cards is not all that high and a standard Ethernet network can achieve data transfer rates of 10 Mbit/s.

By P. Smit

How do I set up a network?

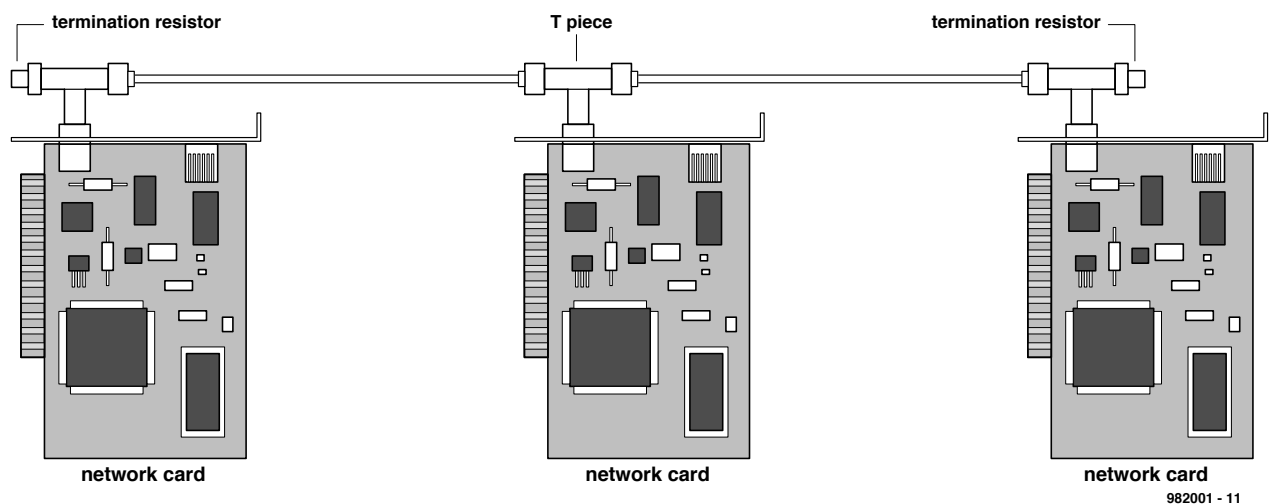


Figure 1. A simple network for three computers, based on three BNC network cards. The network cable must be terminated at each end by a suitable impedance.

In addition to simple data exchange, a network can be used to 'pep up' a less-powerful PC. For example, a 200-MHz Pentium computer with a 3-GB hard disk could 'loan' 1 GB of disk capacity to a 486DX4-100 machine with a 500-MB drive. The CD-ROM drive in the Pentium computer can also be read by the 486DX4-100 computer, so that in many cases a second CD-ROM drive for the 486 PC is no longer needed. Even a floppy-diskette drive and an internal 100-MB Iomega Zip drive can be shared via the network.

An Ethernet network

There is actually only one network topology which is suitable for smaller networks, namely the bus topology based on Ethernet. In this case there are two completely different physical

implementations. The so-called 10Base-2 network uses coaxial cables with BNC connectors. The more modern version is called 10Base-T and works with Unshielded Twisted Pair (UTP) cables.

A bus structure consists in principle of a long cable with a terminating resistor at either end. Network cards (sometimes called *transceivers*, from a contraction of *transmitter* and *receiver*) are connected to the bus cable via short branch cables. The protocol which governs how data is exchanged via the cable can for example be Ethernet.

The Ethernet protocol was originally developed by Xerox in 1976. (The 'think tank' of the Palo Alto Research Center, or PARC, where Ethernet was developed was also responsible for the development of the mouse and the first

operating system which worked with windows, called Smalltalk. This was the basis from which Apple later distilled its GEM and Microsoft its Windows.)

Ethernet is based on a mechanism called Carrier Sense Multiple Access/Collision Detection (CSMA/CD). A network station which wants to transmit data first checks whether the carrier tone is present on the cable (Carrier Sense). If it is not, then the station itself can send data. However, multiple stations can be attached to the network bus (Multiple Access). The network checks whether two or more network stations attempt to send data via the network at the same time. If this happens then there is a 'collision' between the data transmissions of the various senders, which results in corruption of the data. The senders are thus forced to resend their data. The

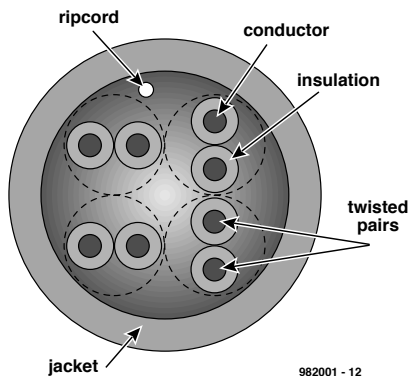


Figure 2. A UTP cable (Unshielded Twisted Pair) contains eight conductors arranged as four twisted pairs.

Ethernet protocol manages the network traffic. It determines which network card may communicate at a given time and performs collision detection for Ethernet data packets.

UTP or BNC?

If we want to set up an Ethernet network for two computers, we are faced with the fundamental choice between UTP and BNC. For somewhat larger networks UTP is preferred. In the case of only a few computers which are connected to each other, BNC is just as good a choice.

A BNC network

The simplest BNC network consists of two computers each equipped with a BNC network card. A BNC Tconnector is attached to the BNC connector of each network card. A terminator is attached to one arm of each of the T connectors, and a standard coaxial cable (patch cable) is connected between the other two arms. The purpose of the termination resistors is to avoid signal reflections in the cable.

A single network cable may be up to 185 metres long. A maximum of 30 stations (PCs) can be connected to the cable. The minimum separation between two connection points (T connectors) is 0.5 metre. Several BNC cable sections may be connected together via hubs, routers and repeaters, so that it is possible to create a Local Area Network (LAN) which is much larger in extent than the length of a single cable section.

For two computers we need two network cards with Tconnectors and two terminators. A third computer is added to the network bus by simply removing the terminator from the Tconnector of one of the network cards, connecting a coaxial patch cable from that Tconnector to a third Tconnector, and

A *router* serves to contain local traffic within a particular section of a network, so that it does not load the entire network. When routers are used, the network is configured as several interconnected local 'regions', and the only traffic which is passed out of a given region to the remainder of the network is that which is destined for a different region.

A *repeater* amplifies the network signals, so that a greater distance can be reached.

A *hub* in its simplest form is equivalent to an electrical 'multiple outlet' box.

More expensive hubs are suitable for higher data rates, support more connections and provide additional functions. An 'intelligent' hub can be remotely controlled.

A *patch cable* is a ready-made extension cable, available in various standard lengths (up to 20 m).

reconnecting the terminator to the other arm of the third Tconnector. A network card for the third computer can then be attached to the third T connector. As one can see, the terminators are always located at the extreme ends of the bus cable (see **Figure 1**).

The same bus structure is used for a larger network. However, with a larger network a special kind of connector box is used, to which a special sort of BNC extension cable is attached. Several Tconnectors can then be incorporated into this extension cable.

A disadvantage of a BNC network is that a single open cable or bad connection can bring down the entire net-

work. Every station which is included in the affected loop can no longer work when this happens. The use of BNC connector boxes helps to remedy this shortcoming, since such a box is constructed such that the network cable is automatically connected 'through' inside the box when the extension cable is disconnected from the box. It is thus possible to remove an extension cable without disturbing the operation of the network.

A UTP network

UTP is a more recent development. It is preferred in place of BNC for new installations. For a continuously expanding network, UTP offers clear

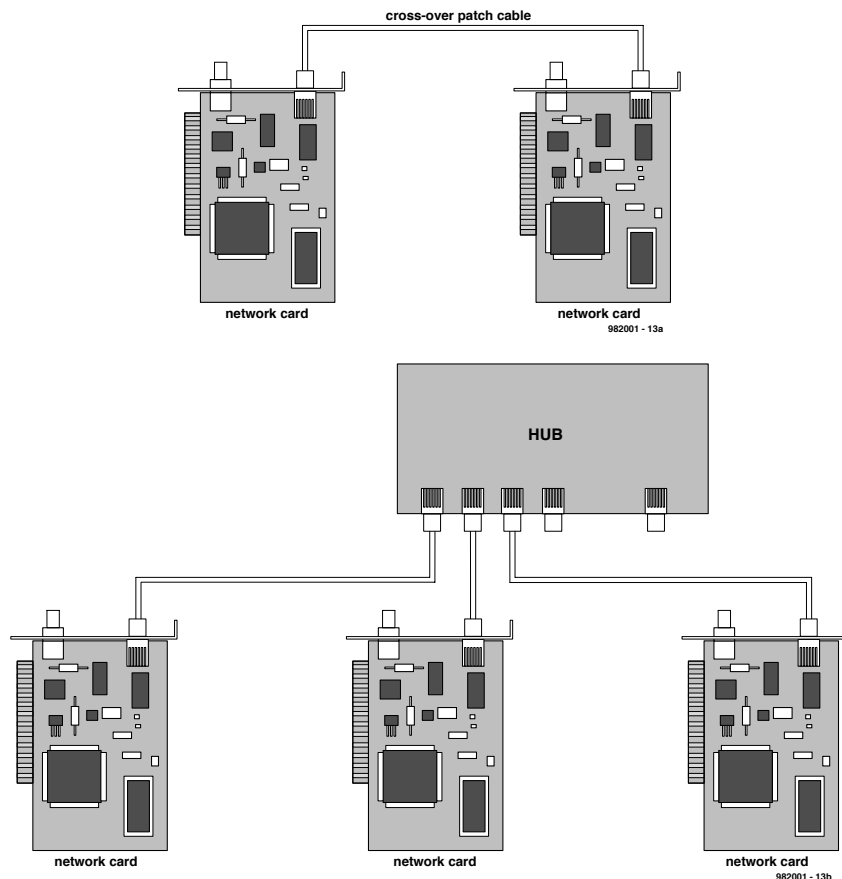


Figure 3. For a UTP network with two computers, a cross-over patch cable is sufficient (a). With three or more computers a hub is required (b).

advantages. The cable is less expensive, and the network is more reliable and easier to maintain. In addition, an ISDN-based telephone network and an Ethernet network can use the same cable, which makes for a simpler infrastructure in a large building. A standard BNC or UTP Ethernet runs at 10 MHz, but a UTP Cat 5 cable can be used at up to 100 MHz. This allows for the possibility of a migration to a faster 100Base-T or 100Base-T4 network at a later date. A UTP Cat 5 cable, as illustrated in **Figure 2**, contains eight leads arranged as four twisted pairs. When the same signal flows back and forth in the two wires of a twisted pair, the resulting magnetic fields cancel each other out. This allows for interference-free data transfers. For 10Base-T and 100Base-T two of the four pairs are used. All four pairs are used for 100Base-T4. In principle, all four pairs can be connected, since the system is upwards-compatible.

10Base-T and 100Base-T systems use the D1 and D2 pairs, while ISDN uses the D3 and D2 pairs. Thus, if we connect a UTP connector box as though we were using 100Base-T4 (all four pairs), it is then possible to use it for ISDN, 10Base-T, 100Base-T or 100Base-T4. To be sure, it is extremely important to take care that an ISDN primary lead does not become (accidentally) connected to the UTP network. A supply potential of up to 90 V can be present with an ISDN NT1 connection, and this can find its way into the UTP network via the D2 pair. If this ever happens, you had better hope that you have good insurance coverage...

In a 100Base-T4 network, all four pairs are used. For this reason such a network is sometimes called a 200-MHz network. In fact it is a 'doubled' 100-MHz network, which is adequately supported by a 100-MHz UTP Cat 5 cable. There are cables which allow even faster data transfers, such as Cat 5+ (up to 300 MHz) and Cat 6 (up to 600 MHz), but these are not of interest for everyday applications. They are naturally also more expensive.

To hub or not to hub...

When only two computers are to be connected together, then UTP and BNC cabling are equally suitable. However, as soon as a third computer is added there is a financial disadvantage associated with UTP. With UTP a central hub must be acquired to allow more than two computers to be connected to the network (see **Figure 3**), and this can easily cost £70. With BNC

cabling a hub is not required.

A hub works as a central connector box for UTP cables. The actual bus structure is based on the hub, and the hub manages the bus. For each computer connected to the network, there is one UTP port necessary in the hub. Multiple hubs can be connected to each other via patch cables and uplink ports. The smaller sorts of hubs have 4, 8 or 16 UTP ports.

Ethernet cards are available for prices ranging from £20 apiece to over £70. If we assume a price of £25 per card and a separation of 10 metres between the two computers, then we can set up a two-computer network for roughly £70. The cost difference between BNC and UTP for a two-computer network is negligible. With three computers the cost of the network using BNC rises to roughly £100, while with UTP the cost jumps to roughly £170 due to the addition of the hub.

The Ethernet card

Network cards are available for the standard ISA bus which is present in every PC, and also for the more recent PCI bus. A PCI network card is faster, but also more expensive. For home use an ISA card is adequate.

With older-model cards, one must configure the address and the interrupt channel on the card using jumpers. Modern cards are set up with the help of configuration software. With some operating systems the computer must be first started up using a MSDOS boot diskette in order to configure the card, since the operating system will otherwise not be able to do anything with the card.

The most obvious choices for the interrupt channel for a network card are IRQ5, 10 and 11. A sound card usually uses IRQ7 or IRQ5. The standard Soundblaster value is IRQ7, which is also shared with the printer port (LPT1). With the current generation of printer ports (ECP/EPP) this is no longer possible. In such cases, the sound card interrupt usually moves to IRQ5, and all interrupt channels below IRQ9 are thus already allocated. IRQ9 is not recommended. IRQ11 is sometimes used for a third IDE port (CD-ROM), and IRQ12 is used by a PS/2 mouse (if present). The most-commonly used interrupt for the network card is IRQ10, with a standard address of 300h.

In a Plug-and-Play system (PnP) the network card itself searches for a free address and interrupt channel. The selected values are passed to the operating system via the driver. With

Windows 95 this technique does not always work properly with some older-model PnP cards. The network card chooses an address and an interrupt vector while Windows 95 is still starting up, and then when Windows 95 is up and running it sees that this combination is not free and thus assigns a different address/interrupt set to the Windows 95 driver. Subsequently, the network card and the operating system cheerfully chatter away without achieving any communication, and Windows 95 insists that there is no network card installed. The only remedy in such a situation is to disable the PnP function of the network card via a MSDOS utility program. With more modern systems, 'Plug and Play' means that Windows 95 automatically recognizes the card during the startup and asks for software. This does not always mean that the user does not have to assist with the system configuration.

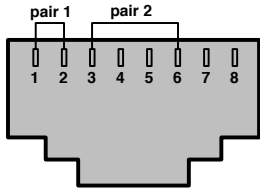
A PnP motherboard reports during startup which interrupts have been assigned in hardware by the PnP logic to the PCI VGA-card and a PCI network card. If the network card is an ISA card which has been software-configured for IRQ10 and there is a PCI card installed (for example, a VGA card) which is automatically assigned IRQ10 by the PnP logic, then you naturally have a problem. In such a case IRQ10 must be explicitly assigned to the ISA card. This can be done by invoking the Setup screen during the startup and configuring the computer to allow IRQ10 to be used for ISA cards only. The PnP BIOS will then skip this interrupt channel when assigning interrupts during subsequent startups.

If you decide to start with BNC, but you anticipate that your network will eventually grow significantly, then you should go for a combination card. Such a card supports both BNC and UTP. At a later date you can add a hub and replace the BNC cable with UTP. For a small firm which is just starting up it is in any case advisable to begin with combination cards or go directly to UTP.

There are several characteristics of network cards which together determine the overall speed of the network. The most important of these is the network type (10 MHz or 100 MHz), but features such as duplex mode, parallel tasking and bus mastering are also significant.

The duplex-mode capability of a network card can only be used if the central hub also supports this feature. In duplex mode the network card can simultaneously send and receive data

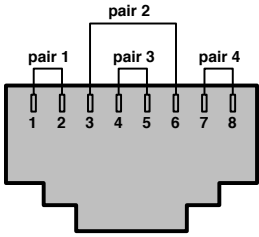
Ethernet 10/100Base-T



1	TX+	D1	Transceive Data+
2	TX-	D1	Transceive Data-
3	RX+	D2	Receive Data+
4	NC		
5	NC		
6	RX-	D2	Receive Data-
7	NC		
8	NC		

982001 - 14a

Ethernet 100Base-T4



1	TX+	D1	Transceive Data+	white/orange	10/100Base-T
2	TX-	D1	Transceive Data-	orange	10/100Base-T
3	RX+	D2	Receive Data+	white/green	10/100Base-T, ISDN B1
4	BI	D3	Bi-direct. Data+	blue	ISDN B2
5	BI	D3	Bi-direct. Data-	white/blue	ISDN B2
6	RX-	D2	Receive Data-	green	10/100Base-T, ISDN B1
7	BI	D4	Bi-direct. Data+	white/brown	
8	BI	D4	Bi-direct. Data-	brown	

982001 - 14b

Figure 4. UTP cable connections.

via the hub. This results in an effective doubling of the network speed. With parallel tasking, several different activities can be processed by the network card concurrently (and thus faster overall). This also reduces the load on the computer's processor chip. This feature is certainly advisable for a central server.

Bus mastering means that the network card can take over control of the PCI bus and thereby reduce the load on the processor chip. Not all motherboards support bus mastering. In some cases this can be remedied by a BIOS update.

If you are interested in picking up second-hand network cards at a jumble sale, you should make sure that you get 16-bit cards which allow the interrupt to be set higher than IRQ9, and that a suitable driver is available (NE2000 or 3Com-compatible). Every imitation-brand manufacturer takes care that his card is compatible with NE2000, for which generic drivers are always available. The disadvantage of generic drivers is that they do not always realize the full performance which a particular card can provide. The performance of a driver which is matched to the card is usually better. Support for 3Com Ethernet cards is generally adequate but not more than that. Even Linux (freeware Unix) first supported NE2000-compatible network cards and only later 3Com Etherlink cards.

Installing the network software

After the cables have all been pulled and the PhP adventure has been

brought to a successful conclusion, one is faced with a choice between a number of different network operating systems. Ethernet is only the low-level network protocol. What is communicated via Ethernet is a different subject entirely. One can compare Ethernet to the alphabet, and the network operating system to a particular language which uses the alphabet.

There are three important types of network operating systems for use with Ethernet:

1. NetBEUI Windows 4.11, Windows 95 and Windows NT
2. IPX/SPX Novell Netware
3. TCP/IP Internet

If we work with Windows 95 as our operating system, then the choice is easy: NetBEUI. Windows 95 has a nasty tendency to also routinely install IPX/SPX. This is a leftover from several years ago, when Novell Netware had a large market share. In the meantime that is ancient history, but Microsoft has not quite caught up to the current situation.

Under Windows, you can see what is installed via the selections Start/Settings/Control Panel/Network. A clear distinction is made between adapters (network cards) and protocols (network operating systems). If more than one network card is present, then the coupling between each adapter and its associated protocol is also shown. The second adapter is as a rule the dial-up adapter which is used for an Internet connection. This dial-up adapter makes the computer appear to the Internet as though it has a network card installed which works with the

TCP/IP protocol. In actual fact the network card is generated by the Internet service provider and the combination of the modem and telephone connection acts as a sort of extension of this network card. The TCP/IP protocol is required for the Internet connection. In the worst case you will have a network card plus a modem (for Internet), with the following standard installation:

- Client for Microsoft Networks
- Adapter: network card
- Adapter: dial-up adapter
- Protocol: NetBEUI → network card
- Protocol: NetBEUI → dial-up adapter
- Protocol: IPX/SPX → network card
- Protocol: IPX/SPX → dial-up adapter
- Protocol: TCP/IP → network card
- Protocol: TCP/IP → dial-up adapter
- File and printer sharing for Microsoft Networks

It's truly a technological wonder that such a babelesque situation actually works: here we have two adapters 'speaking' three different languages (protocols), all mixed together. In principle it is possible to have multiple network operating systems all working over the same cable, but this is not to be recommended. Performance will certainly suffer in such a situation.

There are only two reasons to use IPX/SPX. The first reason is that one will be working together with a Novell network. For home applications this will practically never be the case. The second reason is somewhat more important for the home situation: there are many multiplayer games which use IPX/SPX or TCP/IP to establish a connection between the various computers. Some of these games run faster with IPX/SPX than with TCP/IP. In such cases it makes sense to leave IPX/SPX coupled to the network card in those computers.

For the Internet only TCP/IP is necessary, so that all couplings of NetBEUI or IPX/SPX with the dialup card can be removed. Throw away everything which is not required! After a rigorous cleanup exercise our minimal network/Internet system configuration appears as follows:

- Client for Microsoft Networks
- Adapter: network card (eg NE2000)
- Adapter: dial-up adapter
- Protocol: NetBEUI → network card
- Protocol: TCP/IP → dial-up adapter
- File and printer sharing for Microsoft Networks

continued on page 11

For many applications, the use of an on-site computer to perform measurements or control processes is a good solution. A limitation of all of the data-acquisition systems which we have published up to now is that a direct electrical connection is required between the computer and the acquisition system. The system described here works via a modem, which allows data to be exchanged with the PC via the telephone line. This makes possible a considerable physical separation between the computer and the acquisition system. For example, one no longer needs to guess at the temperature in the weekend cottage: with a suitable sensor you can just ring up, log in and read it out.

Design by J. Joostens

Data acquisition by modem

remote measurement and control by telephone line

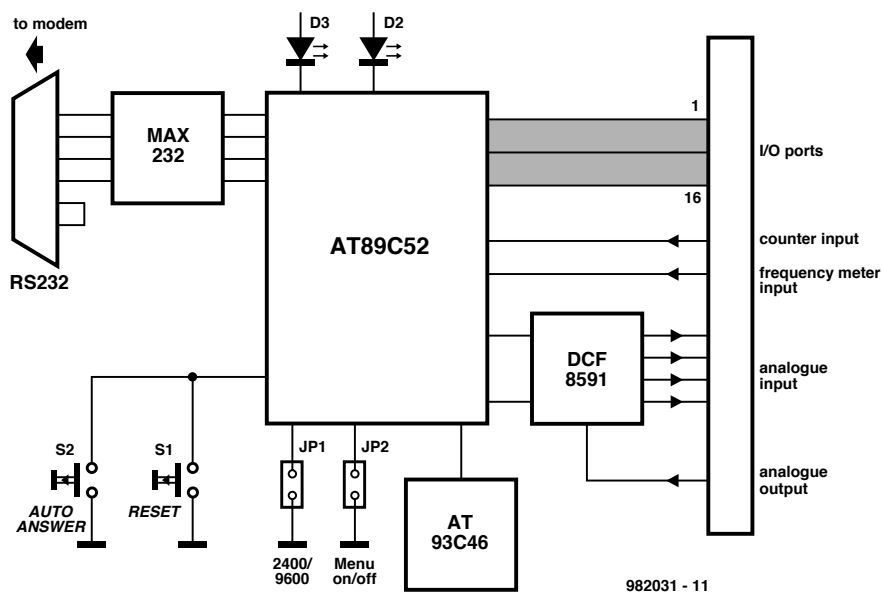


Figure 1. Block diagram of the complete circuit. A lot of capability is bundled into a few components.

Our demand for information seems to increase in step with the progress of technology. Now that a PC can be found in almost every household, users desire to expand their horizons. Adding a data acquisition system is an obvious possibility. Most such systems are connected to the PC via a parallel or serial port; a few of them are connected directly to the internal bus. Such sys-

tems are the natural choice when the computer is located at the site where the measurements are to be made. The data acquisition card which is described here allows measurements to be made, or functions to be switched on or off, at almost any desired location. The only condition is that there must be access to a telephone connection. The hardware and

software of the card are configured so that they can control a standard Hayes-compatible modem via a serial interface. This system supports a data rate of 2400 or 9600 baud. This means that even rather ancient modems can be given a new lease on life.

The design is based on an Atmel AT89C52 processor. In addition to a number of analogue and digital inputs, it has a serial port which can be connected to a standard modem. There is also a separate A/D-D/A converter and an EEPROM. In the present design there are 16 digital I/O lines available. These are supplemented by four 8-bit analogue inputs, one 8-bit analogue output, a 16-bit counter and an input for measuring the frequency of signals up to 65 kHz.

The available software includes a terminal emulator, which allows it to communicate with an ANSI or VT102 terminal program on the PC. Password protection is incorporated in the software, and the password can be stored in the EEPROM.

For the user, logging in to the data acquisition system is similar to connecting to a bulletin-board system. After starting the terminal program, one selects the proper telephone number, waits for the connection to be established and then logs in with the correct

Technical specifications

- ⇨ 16 digital I/O lines
- ⇨ 4 analogue inputs (8-bit resolution) with a range of 0–2.55 V
- ⇨ 1 analogue output (8-bit resolution) with a range of 0–2.55 V
- ⇨ 1 16-bit counter with reset and overflow indication
- ⇨ 1 frequency measurement input (range 0 to 65 kHz)
- ⇨ supports Hayes-compatible modems
- ⇨ compatible with ANSI and VT102 terminal programs
- ⇨ two data transmission rates: 2400 and 9600 baud
- ⇨ built-in password protection
- ⇨ user-configurable communications protocol

password. For those who have the ambition to do so, it is possible to write one's own communication program and disable the built-in terminal program.

A flexible approach

Figure 1 shows the system block diagram. The heart of the system is the Atmel AT89C52. This processor is compatible with the well-known MCS51 processor family, and has the advantage that it includes an 8-kB flash memory for storing program code. The processor has three 8-bit parallel ports and a single serial port. The P1 and P2 ports are made available for external connections; together they

form a 16-bit digital I/O port. The third port (P0) is used to control the operation of the PCF8591. This integrated circuit incorporates a four-channel A/D converter and a single D/A converter. An AT93C46 EEPROM with a capacity of 128×8 bits is also present. This chip has a guaranteed lifetime of 1 million write cycles — and will retain data for at least 100 years. It is used in this case to store configuration data. The conversion of signal levels between TTL and RS232 is handled by an old friend, the Maxim MAX232.

A Reset switch is provided to allow the board to be re-initialized. The Auto-answer switch allows the board to be temporarily placed in a mode in which it does not respond to the ring signal.

Two jumpers enable the selection of the communication data rate (2400 or 9600 baud) and select whether or not the built-in menu functions are used. Finally, there are two LED indicators which display the operating status of the board.

Note that the modem is not shown in the block diagram. In practice, the modem will be an external device which is connected to the serial port of the data acquisition card.

A compact circuit

Given its specifications, one might think that the data-acquisition card would be a large and complex construction. Nothing could be less true, and in fact we have here a project using very few components. Figure 2 shows the full schematic of the card. It incorporates only seven integrated circuits, including the voltage regulator and the reference source.

The central element is IC4, the AT89C52 processor, which runs at a clock rate of 12 MHz. The required clock oscillator is constructed using C1, C2, X1 and logic internal to the processor chip. I/O ports P1 and P2 are connected via 2.7-k Ω series resistors to the 'C'-row of the 64-way connector K1. A set of eight pullup resistors is provided for the third port

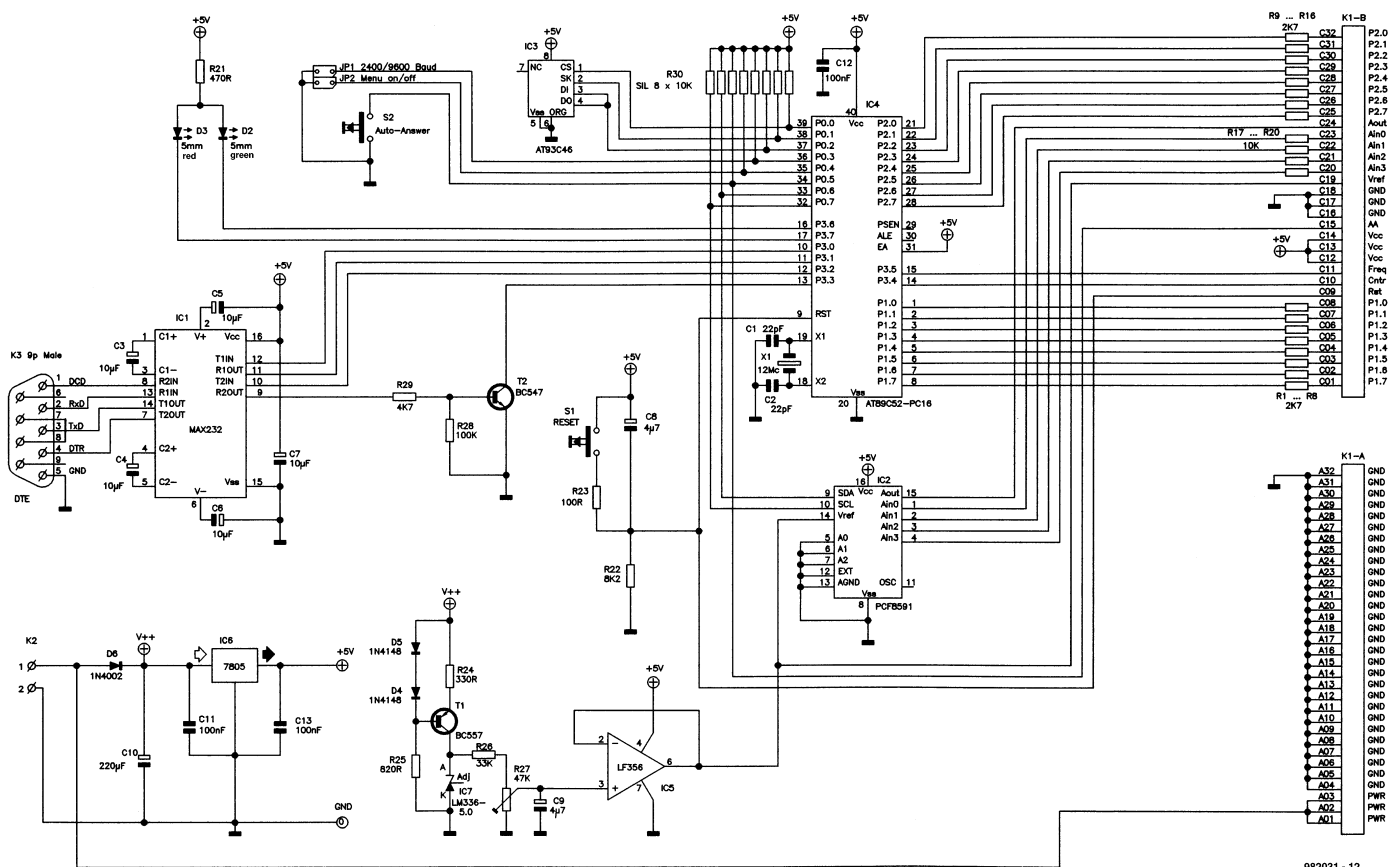


Figure 2. The complete schematic. Only seven ICs are needed to implement the design.

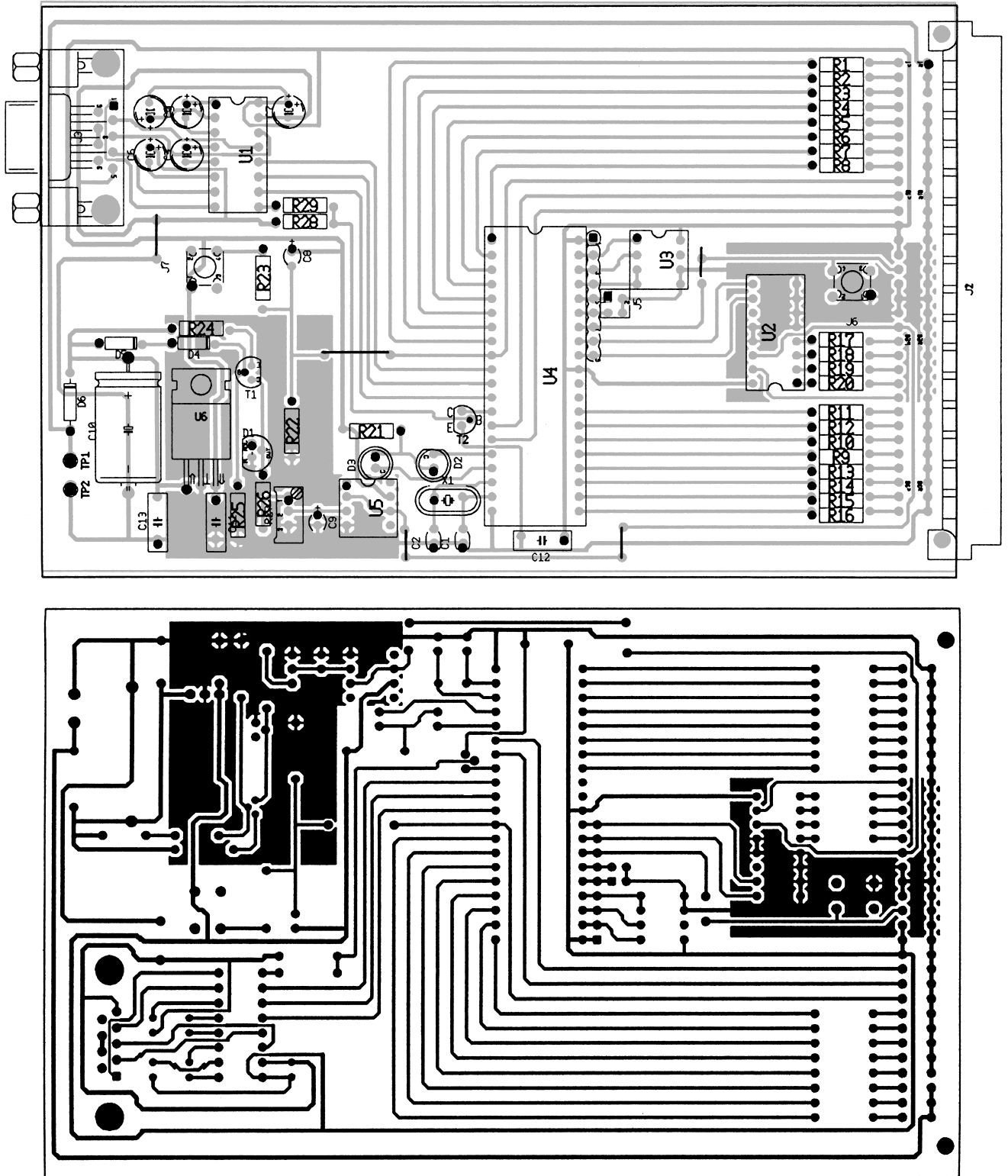


Figure 3. The copper track layout and the component overlay of the circuit board for this project (not available ready-made).

(P0), which is connected to the EEPROM IC3 (an AT93C46), jumpers JP1 and JP2, the auto-answer switch S2, the SDA and SCL lines for IC2 (A/D-D/A converter PCF8591) and finally to the AA input of K1. The fourth and final port (P3) is also used for a variety of tasks. P3.0–P3.3 are assigned to the serial communication port, P3.4 and P3.5 are used for the counter and frequency-measurement functions respectively, and P3.6 and

P3.7 drive the two LED indicators. The design of the serial port is straightforward, although it is wired as a DCE (data communication equipment) instead of DTE (data terminal equipment). The serial port has five leads: RxD and TxD, DCD (input) and DCR (output) and of course the earth (Ground) connection. In addition, the RTS and CTS lines are directly connected to each other at the connector.

The MAX232 chip (IC1) used here works with a supply potential of 5 V and converts signal voltages between the TTL levels used by the processor and the levels employed for the external RS232 connection. The DCD signal is inverted by a logic element consisting of R28, R29 and T1. A change in signal level on the P3.3 input indicates to the processor that a connection is being made and that a response is desired.

COMPONENTS LIST

Resistors:

R1-R16 = 2k Ω
R17-R20 = 10k Ω
R21 = 470 Ω
R22 = 8k Ω
R23 = 100 Ω
R24 = 330 Ω
R25 = 820 Ω
R26 = 33k Ω
R27 = 47k Ω preset, multiterm
R28 = 100k Ω
R29 = 4k Ω
R30 = 10k Ω SIL array

Capacitors:

C1, C2 = 22pF
C3-C7 = 10 μ F 16V, radial
C8, C9 = 4 μ F 10V, tantalum
C10 = 220 μ F 25V
C11, C13 = 100nF

Semiconductors:

T1 = BC557
T2 = BC547
D2 = LED 5 mm, green
D3 = LED 5 mm, red
D4, D5 = 1N4148
D6 = 1N4002
IC1 = MAX232
IC2 = PCF8591
IC3 = AT93C46
IC4 = AT89C52-PC16 (order code 986504-1)
IC5 = LF356
IC6 = 7805
IC7 = LM336-5.0

Miscellaneous:

X1 = 12-MHz-kristal
K1 = 64-pin DIN connector, AC row
K2 = 2-way PCB terminal block
K3 = 9-way sub-D connector
S1, S2 = single-pole push-button
JP1, JP2 = jumper
Disk (program source codes), order code 986504-1.

The A/D-D/A converter design is simple. It is based on the Philips PCF8591 chip. This device communicates via the I²C bus. The required control signals are generated by the processor via its P0.6 and P0.7 I/O port connections. In addition to an 8-bit analogue output, the PCF8591 has four 8-bit analogue inputs. The required 2.55-V reference potential is generated by a reference source built around a current source

(T1) and a voltage reference chip (IC7). The reference potential of IC7 is 5.0 V; this is reduced to the desired value of 2.55 V by a resistive divider consisting of R26 and R27. For expansion purposes, the reference potential is also bought out to K1. Resistors R17-R20 protect the inputs of the A/D converter against excessive input voltages.

Not much needs to be said about the interface to the EEPROM. This IC has a capacity of 128 \times 8 bits and is used by the software for storing configuration settings.

The last item is the power supply. This part of the circuit is based on a proven design and provides a stabilized potential of 5 V. The unregulated input voltage is connected directly to the reference-potential generator.

Construction: relatively simple

Although this is a reasonably advanced project, its construction should certainly not be difficult for an experienced hobbyist. Even making one's own circuit board should not be all that challenging, seeing that it is single-sided and the layout is relatively open. **Figure 3** shows the copper track layout and the component overlay. If you solder carefully and use IC sockets to avoid possible damage to the ICs, success is practically guaranteed. Mount the wire links and connectors K1, K2 and K3 before mounting other components.

Check the supply voltage after IC6 and IC7 have been installed, and then insert the remaining chips in their indicated positions. The system is now just about ready for use; it is only necessary to first adjust the reference potential. Use a digital multimeter to measure the voltage between pins 14 and 8 of IC2. Adjust R27 until this measures exactly 2.55 V.

It is not necessary to connect a modem at this point. Connect the power and wait for a little while. If everything is in order, the red LED should start to flash after about 1 second, which is a sign that the EEPROM checksum is incorrect. This is a normal occurrence with a new (and thus empty) EEPROM. The processor will now install the default configuration settings in the EEPROM. Press briefly on the Reset switch (S1) and then wait about 25 seconds. The red and green LEDs will light alternately for 5 seconds. Afterwards the green LED will start flashing, as a sign that the system could not initialize the modem. This cycle repeats itself every 25 seconds, which is evidence that the system is operating.

The software

The software can be installed without having a modem connected to the system. However, a special cable is necessary for this. Make up the cable using two female 9-pin sub-D connectors. Cross-connect pins 2 and 3 between the two connectors, and directly interconnect the remaining pins. The board can be directly connected to the PC as a peripheral device by means of this cable. Select the desired serial port settings (2400, N, 8, 1 or 9600, N, 8, 1) and start the terminal emulation program (ANS or VT102). The Xon/Xoff communications protocol is used. Now press both Reset (S1) and Auto-answer (S2) at the same time and hold the latter switch pressed until the setup menu appears on the screen. The menu selections provide access to a set of six functions which are self-explanatory. The password may contain numerals and letters. Note that the software distinguishes between uppercase and lowercase letters.

The modem initialization function is suitable for all commonly-available modem modems. In case a modem is not used, such as with a direct serial connection to the PC, the initialization string can be deleted. If desired, a user-specified initialization string can be installed. Note the following restrictions with regard to modem configuration:

- ⇒ a connection must be indicated via the DCD signal (&C1)
- ⇒ a falling edge on DTR invokes the command mode (&D1)
- ⇒ use Xon/Xoff (&K4)
- ⇒ the modem must be in auto-answer mode and respond after three ring tones (S0= 3)

The following menu options are used to enter the basic configuration settings for the I/O port and the D/A converter. These settings are used after a hard reset (cold start). If the Reset switch is pressed, the last-used configuration settings are retained. Note that port lines which are used as inputs will first be briefly set to a high level ('1') as a consequence of the internal design of the processor. If one selects the option 'Load default settings in ROM' then the controller selects the settings which have been stored in ROM by the designer. These are as follows:

- ⇒ system ID: none
- ⇒ password: a single space character
- ⇒ modem initialization string: AT&F&DLOV0&D1&K4&R1S0= 3S7= 90

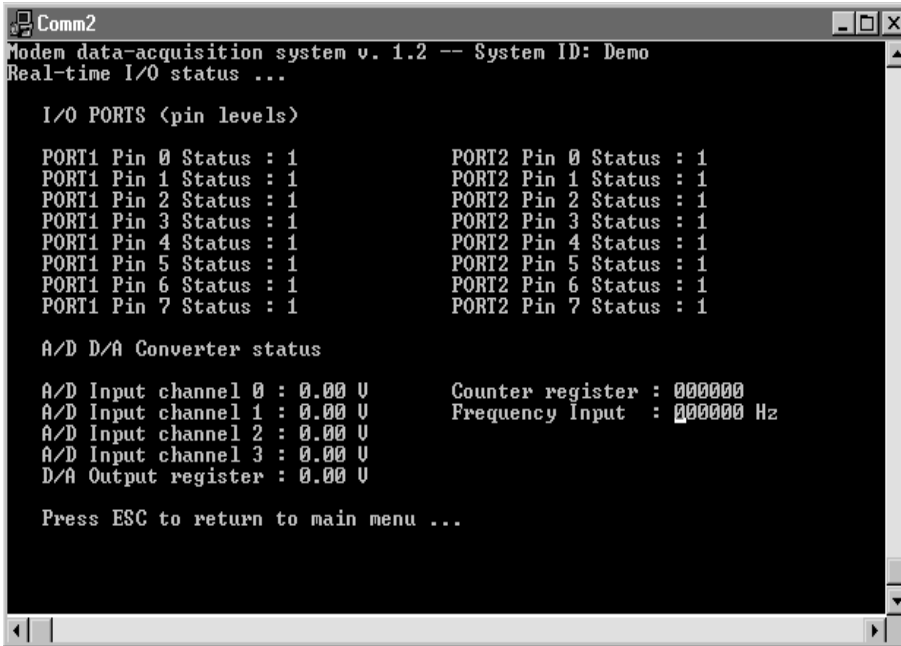


Figure 4. The assembled board can communicate with any ANSI or VT102-compatible terminal via a modem.

⇒ after a cold start, all 16 I/O lines are high and the output potential of the D/A converter is 0 V.

The system also stores these default settings in the EEPROM if an incorrect EEPROM checksum is detected.

The (new) configuration settings are stored in the EEPROM upon exiting the setup menu. In the case of certain older-style modems for which a delay of several seconds is desired between carrier detection and the start of data exchange, the Auto-answer switch must be activated and held (depressed)

while leaving the setup menu. By this means a supplementary 10-second delay is programmed. Whenever the setup menu is subsequently exited without holding the Auto-answer switch depressed, this extra delay is deleted.

Operation

Now it's time to put the card to use. Attach a modem to connector K3 via a normal serial cable. Select the desired baud rate with JP1 and leave JP2 open for the time being. (Note that the jumper positions are only read during



Figure 5. The status of all inputs and outputs appears on the screen at the press of a key.

the startup sequence, so that any changes made between startups will not affect the current selection.) The system is now ready for use. First switch on the modem, and then apply power to the data acquisition card. The red and green LED indicators will flash alternately. As soon as the modem initialization has been successfully completed, the green LED will light continuously. By the way, the configuration of the modem initialization string can be easily checked out by sending it from the PC in terminal mode to the modem. The response from the modem should be 'OK' or 'O'.

Disable the auto-answer mode by briefly pressing the Auto-answer switch. The green LED will flash at a slow rate, and the modem will now not respond to a ring tone on the telephone line. Press the Auto-answer switch again to re-enable the normal auto-answer mode.

Logging in and more...

Logging in to the system is similar to logging in to a BBS. Immediately after the connection is established, the user is requested to enter the password. If an incorrect password is entered, the request is repeated. Pressing 'ESC' or 'Ctrl-C' terminates the login process. If the correct password is entered, then the initial menu appears. The following functions are available in turn:

- ⇒ real-time I/O status
- ⇒ write to output register PORT1
- ⇒ write to output register PORT2
- ⇒ write to the D/A output
- ⇒ reset the counter register
- ⇒ ** disconnect **

The functions of the various options are self-explanatory. You will find that a few minutes' experimenting is enough to familiarize yourself with card's operation. As previously noted, the menu function can be disabled by means of a jumper setting. In this case a user-written procedure must be used to provide the communications functions. All commands are formed by a combination of the upper-case letters A-F and the numerals 0-9, followed as appropriate by a carriage return ('Return' character). After the connection has been established the system sends the text "ID:" followed by a system identification string and a carriage return. Following this the password must be entered. The correct password is confirmed via the 'ACK' character; the system responds to an incorrect password with the 'NACK' character. The

LED indicators

Red LED	Green LED	Status
off	on	standby/operation without modem
on	off	connection with another modem
flashing	off	EEPROM checksum error
off	slow flashing	auto-answer disabled
off	fast flashing	modem initialization error
alternately flashing		waiting for modem initialization

procedure can be terminated by sending the 'ESC' character.

Summary of the commands

C0 — Control command

This command is answered with 'OK'. This only works if no modem is being used; otherwise a 'NACK' character is sent in response.

C1 — Request I/O data

This command causes a string of characters to be sent after a delay of one second. This string has the following construction:

A B B C C D D E E F F G G H H I -
I J J J K K K K L L M M < C R >

in which the data is presented as follows:

AA = Port 1 register data
BB = Port 1 input levels
CC = Port 2 register data
DD = Port 2 input levels
EE-HH = A/D channels 1×4 values

II = D/A output register data
JJJJ = value of 16-bit counter
KKKK = frequency measurement result
LL = flag register data:
- bit 0 indicates an I²S communication error
- bit 1 indicates a counter overflow
- bit 3 indicates a frequency measurement overflow
- bits 4-7 are not used
MM = checksum value

C2 — Write to I/O

This command should be followed within one second by a character string containing the following data:

AA = new value for Port 1 register
BB = new value for Port 2 register
CC = new value for D/A output register
DD = checksum

If the received checksum is correct then the system responds by sending an 'ACK' character; if the checksum is incorrect then the system responds with a 'NACK' character.

C3 — Reset counter

This command resets the counter to zero and clears the counter overflow flag.

C4 — Break the connection

This command only works in combination with a modem. If it is used in the absence of a modem, a 'NACK' character is sent in response.

In general, the interval between a command and its associated data string may not exceed one second.

Perhaps this has been a bit much in one go, but we've now gotten through the complete design description. From now on, you should remember the rule that 'experience is the best teacher', and thus put the system to use in some practical applications. This means soldering and programming, and looking for suitable applications. Here we limit ourselves to the interface provided by the data acquisition system and leave the question of its application to you. However, numerous potential applications may be found in past issues of *Eektor Electronics*, so happy hunting! (tip: use the *Eektor Electronics* Item Tracer).

(982031)

continued from page 5

With this configuration there is no longer any extra ballast, but we have a functioning local network connection (via NetBEUI) and an Internet connection (via TCP/IP).

The options 'Client for Microsoft Networks' and 'File and printer sharing' must be present to allow our computer to share devices or files via the network. We can use 'File and printer sharing' to individually configure our computer for printer sharing alone or file sharing as well.

Let's share...

If we wish to share files, we must clearly indicate this via the MS Explorer. If we wish to make the contents of a subdirectory available on the network, then we identify the subdirectory and click once on the subdirectory with the rightmost mouse button. The option 'sharing' is displayed in the menu which then appears. After this option is clicked a configuration menu appears. In the

configuration menu we can make the subdirectory shareable, assign a name to it and determine whether it is shared read-only or read/write. We can also protect shared access with a password. Further down in Windows Explorer we find 'Network'. If we open this, we see a presentation of the various workgroups and computers. The shareable subdirectories are listed under the individual computers. If both file and printer sharing are disabled in a particular computer, then it is not visible to the NetBEUI network.

In a small network we work with a single workgroup, which has the default name of 'workgroup'. We can assign a name of our choice via 'Network/identification'. If a lot of data is exchanged with a particular computer via the network, then it is as a rule more convenient to assign the hard-disk drive of the other computer to our own computer in the form of a drive letter. To do so we first use the Explorer to display the network directories. A click on the desired subdirectory with the rightmost mouse button causes a menu to appear with

the option 'Map Network Drive'. Here we can enter a drive letter. The most important option appears at the bottom: 'Reconnect at logon'. If we wish to create a permanent coupling, then we enable this option.

A network printer may be assigned to one's own system by selecting Start/Settings/Printers/Add Printer. In the second window we can specify whether we want a local printer or a network printer. Select 'network printer'. A particular network printer can then be selected via the 'Browse' option. If we wish to print from a system running MSDOS, then we must reply 'yes' in response to the question 'Do you print from MS-DOS based programs?'. This option can also be enabled at a later stage via 'Capture Printer Port'.

With this information presented in this article it should not prove difficult to set up a small Windows 95/3.11 network. Such a network need not be all that expensive, and it offers a lot more possibilities than a collection of isolated computers.

(982001-2)

Many older PCs have accumulated lots of dust inside the case and can benefit from cleaning a number of areas and essential components. Although the build-up of dirt, dust, grime and debris inside the PC case will rarely be the cause of immediate hardware malfunctions, it does obstruct to some extent the absolutely vital airflow inside the computer case. This, in turn, lessens the cooling capacity of ventilators, in particular, the noisy one at the most dreaded and ugliest side of computer: the back! Spring-cleaning PC hardware is often forgotten as most PC users seem to associate the term maintenance with orphan-DLL clearing, hard-disk defragmenting and the like.

dust in the PC

spring-cleaning old dust eaters

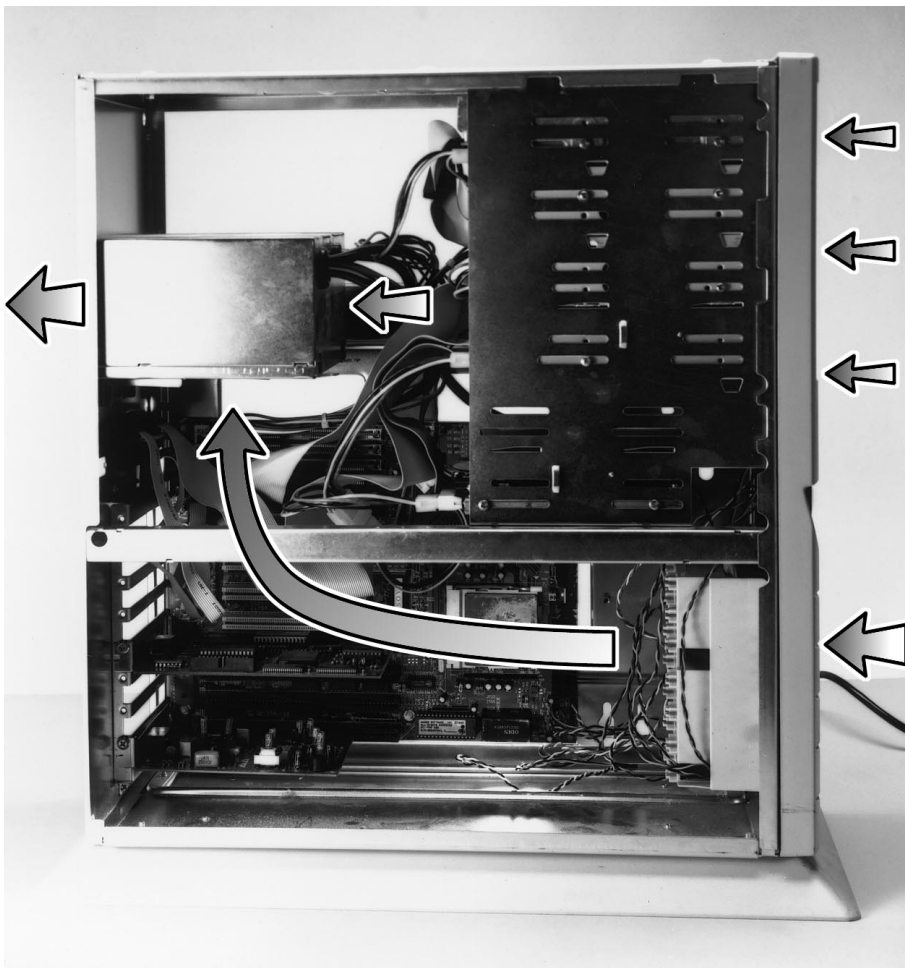


Figure 1. Illustrating the airflow in a typical medium-size tower case. Assuming that the cover is fitted on to the case, the ventilator at the rear of the power supply unit (PSU) causes air to be sucked into the case along various paths. Unfortunately, the main airflow causes dust particles from the floor to be carried into the case. For obvious reasons, the air intake of the PSU may not be obstructed by cables. Note that this PC was being overhauled when we made the photograph. Normally, it contains a number of extension cards, and all slot cover plates at the rear are fitted so there is no air intake in this area.

Browsing through the latest computer magazines and reading about new and ever faster machines (and some of the incredible problems they present), it's easy to forget that there are thousands of PCs around that have been in use for many years in homes and offices. In most cases, there's nothing amiss with these trusty 386 and 486 based machines, except, perhaps, that they are slow and their street value may be a disappointing few tenners or so. So, many of you will argue that such old beasts are best left to do whatever they are still able to do. And yet, cleaning the inside of these oldies is rewarding because it ensures that they continue to function; sometimes even better than before!

Airflow in a PC

If you put your hand near the ventilator at the rear of a running PC, you will notice that the fan produces an outward bound air stream. The temperature of the air stream will depend on the size of the PC and the amount of electronics inside. In our experience, desktop and tower PCs for home and office use never produce hot air. If your PC does, it's high time to review the situation inside the case!

The function of the PSU (power supply unit) ventilator is to establish a steady flow of (relatively) fresh air across and around electronic components that may be damaged if they become too hot. The PSU fan has been an essential component in PC design ever since the first PC-XTs and clones appeared on the market about

15_years ago. Okay, modern PCs have temperature-controlled ventilators which are much quieter than the early types, but that does not detract from the necessity of a cooling air stream in the case. The reason for mentioning the PSU fan in this article is that it has two unwelcome side-effects. The first is that it produces noise. Noise, although not the main subject of this article, may be reduced to a certain extent, as will be discussed further on. The second problem with the fan is that it collects dust which may ultimately cause it to run slower, and so endanger the life of the components that should be cooled, because the airflow is vastly reduced.

The build-up of dust in certain areas inside the PC may be explained on the basis of the air flow created by the PSU fan. Basically, (relatively) cool air is sucked into the case along various paths, passed through the PSU case, and blown out of the case. The air flow in a typical (medium-size) tower case is illustrated in **Figure 1**. It is, of course, assumed that the PC case is closed. Usually, 'fresh' air is sucked into the tower case via openings (slots, a perforated area or a grille-like structure) in the PC front side, near the base of the case. Air flows over the motherboard, along extension cards, and is eventually sucked into the PSU through ventilation holes in the PSU case. PC PSUs are typically switched-mode types which contain a number of components that run pretty hot, so cooling is really in order here. As you can see in **Figure 2**, the typical air flow in a desktop PC case is basically the same as in a tower case. You may not have realized that a small amount of air is also sucked in via the small openings in and around a floppy disk drive, hard disk drive, CD-ROM drive or tape drive mounted in the drive bay. Some cooling of these drives is essential, however, as some hard disk drives and tape drives run much hotter than one would imagine.

The PSU and CPU fans

There is a fairly simple way to make an educated guess about the amount of dust waiting to greet you when you open up an antediluvian PC. Without opening the PC case, look at the amount of dust which has settled in and around the PSU fan. In some cases, you may have to remove the protective grille. Typically, desktop PCs collect less dust than big-towers. This is logical in view of the air stream discussed above: tower cases 'inhale' more dust because the main air intake

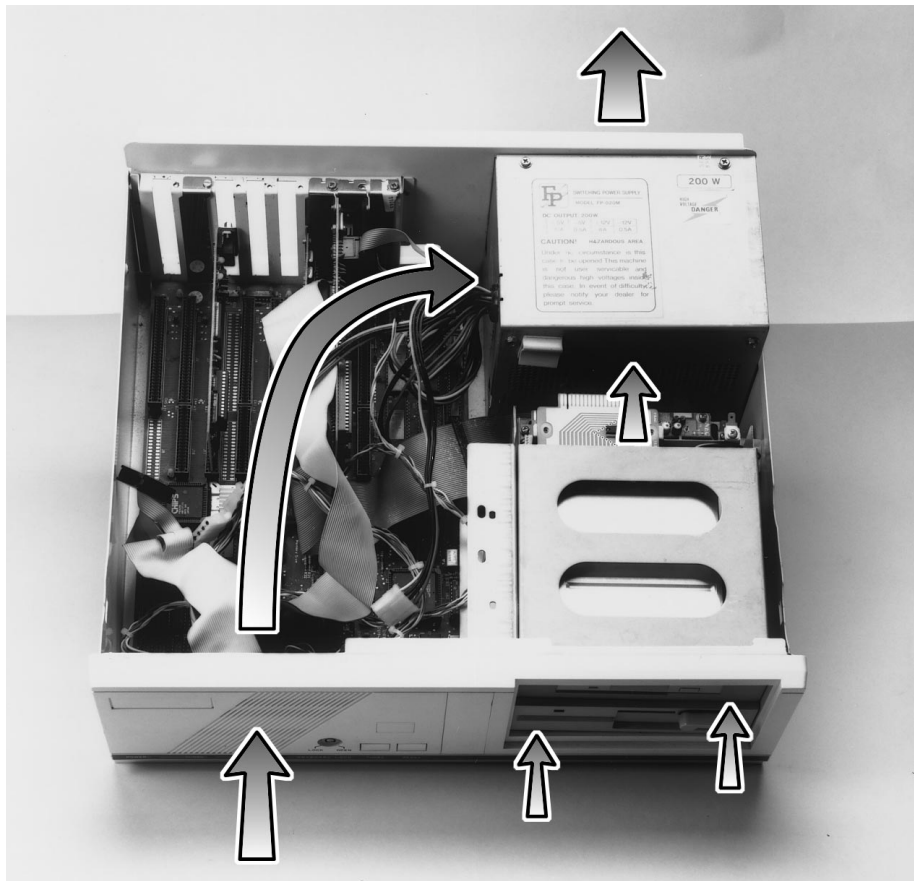


Figure 2. Illustrating the airflow in a typical desktop PC (this vintage one happened to be partly salvaged).

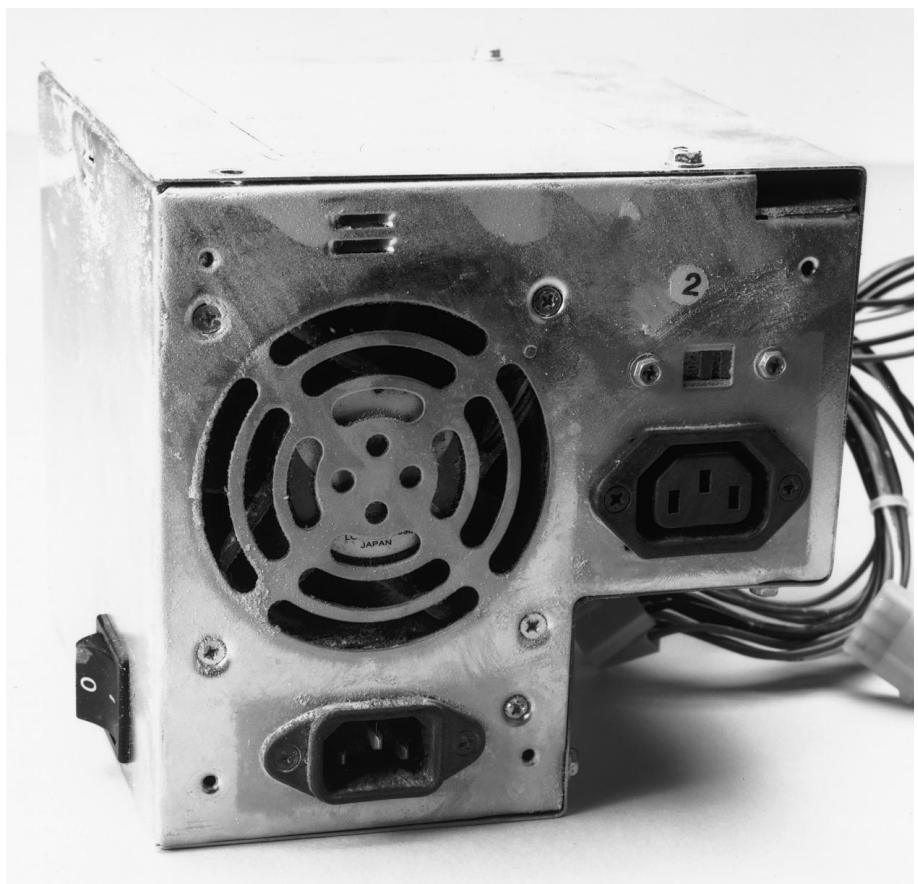


Figure 3. A dusty PSU fan like this one indicates that the inside of the PC is long overdue for cleaning.

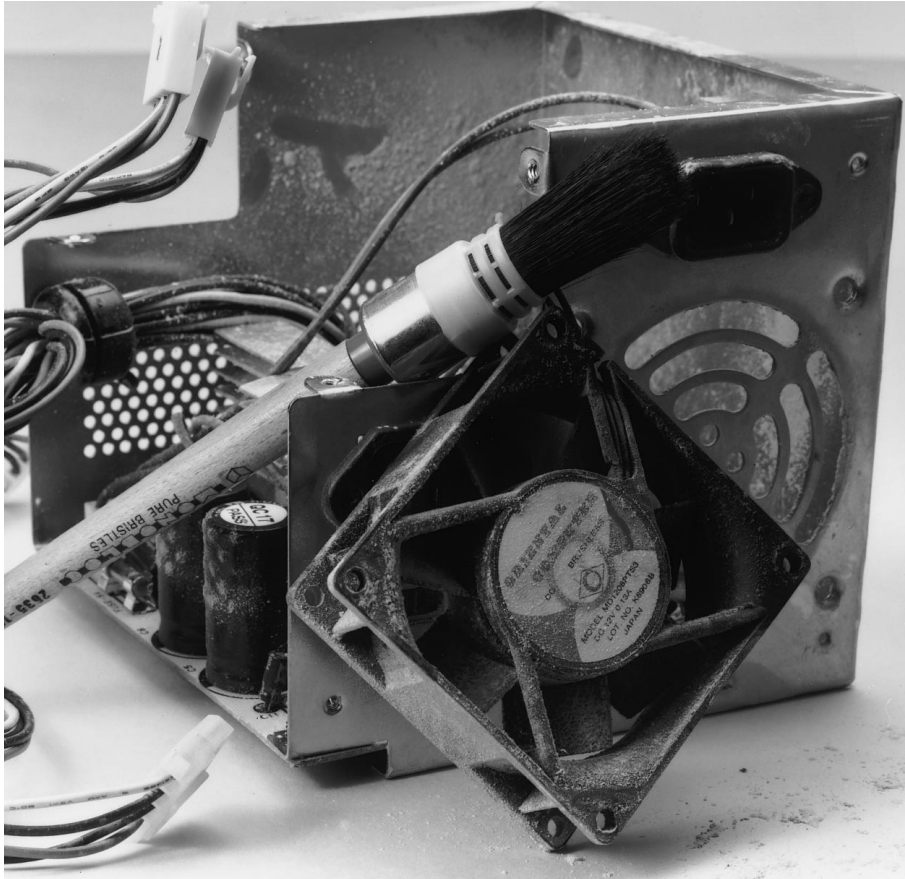


Figure 4. Dismantled PSU case with the fan removed separately. It is easily cleaned with a small brush and a vacuum cleaner fitted with a small nozzle. Check the fan for smooth operation, and if necessary replace it by a new, quieter, one.

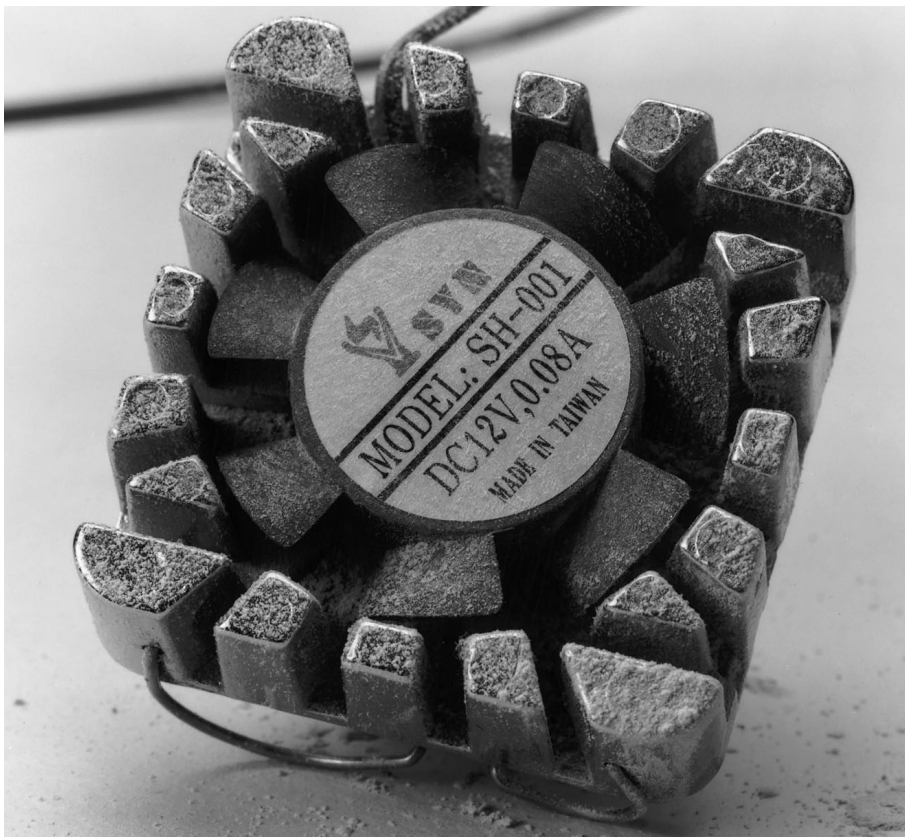


Figure 5. A dusty CPU fan like this ultra-low cost one we found in an ageing 486 PC can be the cause of a costly repair job if it is not cleaned and inspected for wear and tear. Like the PSU fan, the CPU fan is often best replaced by a more up to date type.

point is nearer the floor. **Figure 3** shows a likely candidate for cleaning. Dust is rife and clearly visible on this PSU fan boasting ten years of faithful operation.

Before we continue our story, an important point must be mentioned. **Removing dust from the inside of a PC involves opening the case and disassembling some of the internal components. This should not be attempted by beginners, or if the PC is still covered by a warranty. Also, all actions should be carried out with the mains cord and all peripherals disconnected. Observe all precautions relevant to electrical safety.**

Fortunately, cleaning the PSU fan is not required on a weekly or even monthly basis, the amount of dust having settled in and around the fan blades depending mainly on the number of hours the PC has been in use, and its location the office, study, cellar, broom cupboard, kitchen, attic or living room!

In some cases, it will be sufficient if the dust on and around the fan is removed using a small brush and a vacuum cleaner. However, for a thorough spring-cleaning job, you have to remove the PSU from the case. Usually, two or three Phillips screw drivers are all you need for this purpose. Be careful not to damage the screw heads as doing so may make it impossible to secure the screws properly again later. All power supply cables inside the case have to be disconnected from the motherboard, the drives (floppy disk, hard disk, tape drive, CD-ROM drive, etc.) and the CPU fan, if fitted. Sometimes the entire PSU has to be removed before you can get your hands on the motherboard supply connectors, insertion cards being in the way, and the connectors stashed away under the PSU block. Most PSUs have an attached cable for the mains switch connections, and this cable may only be disconnected at the power switch. It's just as well to disassemble the switch unit and give the lot a thorough cleaning, too, as it is an unexpected but serious dust collector.

The PSU is typically secured with four or six screws on the rear panel of the PC's internal frame. In many desktop cases, it is additionally secured to a bracket close to the bottom of the case. Fortunately, none of these constructions are complex or tricky to disassemble (we're not talking of the latest notebooks and other 'crammed' PC technology here).

The next step is to open the PSU proper. As there are countless varia-

tions on this theme, it is difficult to give hard and fast advice here. Take some time to study the structure of the PSU casing. The screws that need to be loosened at this point should be near the edges of the casing. Others further removed from the edges are best given a miss because they typically secure internal components like power semiconductors that require the metal side panels for cooling.

Take the PSU casing apart, and give the inside a thorough cleaning using the brush-and-vacuum-cleaner method already mentioned. Now's also a good opportunity to remove the fan, and clean it separately (**Figure 4**). Make sure you know how the thing is to be mounted again, however, as you run the risk of accidentally reversing the air flow on re-assembly. Sometimes these fans have an arrow printed on them to indicate the direction of the airflow at the correct polarity. You may not want to mount the same old fan again, however, because an attractive opportunity is available to replace it with a new and better one, i.e., temperature-controlled, quieter and/or with real (metal) ball bearings. Such an (inexpensive) upgrade is sure to eliminate much of the appalling noise produced by many ageing PC.

If you have access to an air compressor (the local garage may be able to help you) which you can use out of doors, then the PSU casing and the fan may be cleaned in one go. In general, however, it is not recommended to remove dust by any kind of blowing action as it presents a potential health hazard, and may cause the stuff you wanted of get rid of to end up a couple of inches further on, in places where it wreaks havoc.

The other, much smaller, fan which may need cleaning is the one fitted on top of those hot-headed 486 and Pentium CPUs (**Figure 5**). Dusting off and inspecting it will be relatively simple as there are no screws involved, and the same general guidelines apply as those for the PSU fan. This fan, too, is a good candidate for replacement as much quieter and longer lasting types are now readily available from many computer shops. Note, however, that 486-type coolers are becoming scarce, and that they are not interchangeable with Pentium coolers (which is not to say that the fan can't be removed and replaced separately). Here, too, go for a fan with ball bearings rather than friction bearing as found in most inferior, all-plastic, incredibly-cheap products. Remember, any dust permanently lodged on



Figure 6. Mice eating dust? The ones in our offices do.

the CPU fan will result in reduced cooling capacity, and, eventually, total breakdown with possibly catastrophic consequences for the CPU. And then, to add to the misery, a replacement for, say, a once stalwartly 486DX66 will be surprisingly hard to get, making the whole PC useless.

Heaps of dust may also be found at other spots in the PC, for example, in the rear corners of the metal frame, near the slot cover brackets, and at the outside of the air intake grille where the loudspeaker is secured.

Once the PSU is in place again, you may want to inspect its air intake area. In not a few cases, this is partly blocked by power supply cables and disk drive flatcables squeezed together in a chaotic manner. Organize these cables to clear the PSU air intake area, and remove any dust you may find lodged on the flatcables. These may be zigzag-folded where necessary, and held in place by a paperclip (watch out for short-circuits however). In some cases, it's even worthwhile to reshuffle the disk/CD-ROM/tape drives in the drive bay and, of course, extension cards in older PCs. Reshuffling also allows you to properly secure all cables.

Of mice and dust

Instructions on cleaning the mouse should be given in the manual that came with it. **Figure 6** shows a small dust ball collected by a mouse used in office surroundings over a period of about six months. In general, cleaning the mouse will only involve removing the internal ball and gently removing any dust build-up inside. In rare cases, the internal rollers or wheels that keep the ball in place may need cleaning also.

Keyboard shake-out

You'll be amazed at the amount of debris collected by an ordinary PC keyboard which is not protected by a plastic cover. Most PC users do not seem to bother about this, however, until one or more keys remains stuck, or does not produce a particular character any more. Such problems may be prevented by holding the keyboard upside down and shaking it vigorously, say, once a month. You may also rap one of the keyboard corners on the desktop (**Figure 7**). Don't be afraid to do this; all reasonably built keyboards will survive this gentle mal-



Figure 7. Illustrating the keyboard shake-out. You'll be amazed at the amount of debris lodging in a PC keyboard.



Figure 8. Internal cleaning of a PC monitor should not be attempted by beginners. The arrows in this photograph point at spots which are likely to be covered in dust.

treatment. For extra fun, put a large sheet of white paper on your desk. We found (among other bits best left unmentioned) hairs, bits of paper, bread crumbs, chocolate sprinkles, cigarette ash and tobacco.

Only if you are really serious about cleaning the keyboard, you may want to take it apart and remove *each and every foreign particle encountered therein*. This may be tricky however as some low-cost keyboards contain a single, very fragile circuit board.

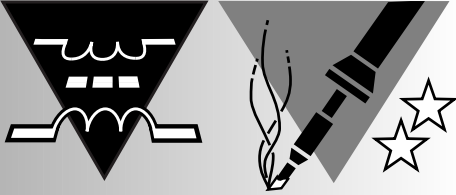
The monitor

When it comes to cleaning, the PC monitor is a separate story. There are a number of risks to be taken into account before opening *any* PC display. The main dangers are the high CRT (picture tube voltage, implosion of the CRT, and upsetting the (delicate) picture geometry adjustments. The undaunted among you may have a look at **Figure 8** which shows typical dust build-up spots: around the CRT high-voltage connector, the high-voltage cage, and the picture controls at the edge of the PCB (on modern monitors, these controls are usually digital and fitted at the front side). Cleaning the HV parts in particular will result in fewer crackling and other unnerving sounds from the monitor when it is switched on and off. It also allows you to get rid of the stuffy smell produced by some older monitors.

Sales ploys

Although the shelves of computer stores are loaded with special products for computer cleaning, most of the products on sale are overkill, and none are essential in our view. Computer sales people will first try to dissuade you from cleaning the computer internals yourself, and then try to talk you into buying 'professional' products. This is just sales talk, however. Plain pressurized air in a can (like Dust Blaster from HCS Global), for instance, is pretty expensive, yet only marginally useful for cleaning the debris found in keyboards. Other 'aerosol dusters' are not all they are cracked up to be, and should be used with extreme care because they make existing dust land in other places. By contrast, a clean brush and the vacuum cleaner borrowed from The Mrs do a much better job. What's more, these tools are safer and available in nearly every household.

(982033-1)



variable power supply

0–24 V, 1 A or 2 A

ideal for the small workshop



The variable power supply described in this article is the latest in a long line of power units published in this magazine over the past fifteen years or so. Because of its wide voltage range and presettable current limiting, it is ideally suited to general-purpose applications in a small electronics workshop.

A variable power supply, a soldering iron and a multimeter form the minimum basic equipment required in a small electronics workshop. Unfortunately for many, a commercial variable power unit is not exactly cheap, which is an excellent reason for building one from scratch. The power source described in this article is ideal for that purpose. It has a number of preset facilities, its design is straightforward, and it has the facility to be connected to a digital voltmeter – DVM – module to display the output voltage and current. Moreover, apart from some power field-effect transistors – FETs – it is constructed from readily available standard components. Finally, it may be constructed to provide an output current of 1 A or of 2 A.

Design by K.A. Walraven

DESIGN

The basic setup of a power source is fairly simple—see Figure 1. The alternating voltage available at the secondary of the mains transformer is converted into a direct voltage by full-wave rectifier bridge B₁. The level of the direct voltage is raised by two parallel-connected field-effect transistors, T₁ and T₂, located between the negative output terminal and ground.

The transistors are driven by two control circuits based on operational amplifiers – op amps – IC₁ and IC₂. These circuits continuously compare the output voltage and the output current with preset wanted values.

In contrast to usual power supply designs, the FETs are not arranged as source followers. This is a deliberate choice intended to save energy. This becomes clear when it is realized that the potential at the gate of the transistors needs to be about 6 V higher than that at the source. In the present design, this is effected by driving the gate with reference to the internal earth of the power unit and not with reference to the positive output rail as is usual.

An auxiliary voltage of +9 V for the control circuits is provided by regulator IC₃. This voltage also functions as reference potential: the wanted values for the voltage control and current control circuits are set with P₁ and P₂ respectively.

VOLTAGE REGULATION

The output voltage across capacitor C₂ floats, that is, the positive capacitor terminal is linked to the non-regulated supply voltage (+). The negative output rail is linked to the drains of transistors T₁ and T₂.

The reference voltage is measured with reference to the negative output rail, which is why the input of IC₁ is connected via R₃-R₄ and R₆-R₂. These resistor combinations ensure that the output voltage is compared with the wanted value set by P₁

This arrangement works fine as long as the ratios R₃:R₄ and R₆:R₂ are precise, which means that the resistors must have a tolerance ≤ 1%.

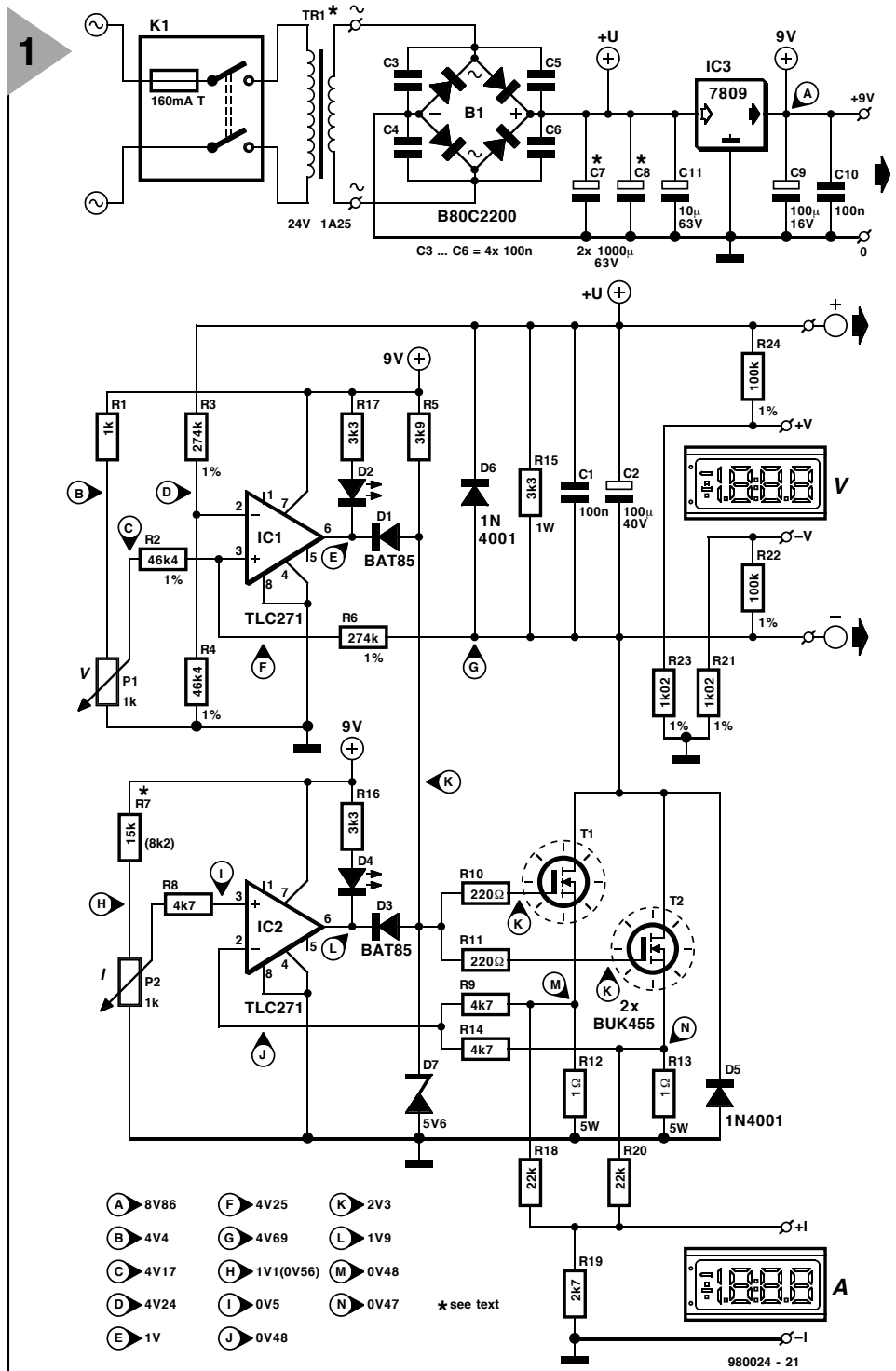
The differential voltage at the output of IC₁ is used to control the potential at the gates of the FETs via diode D₁. Normally, the transistors are driven into saturation via R₅ and cut off by the voltage circuit or the current control circuit. Diode D₇ is added to limit the maximum gate potential of the two transistors; this shortens the reaction time when the devices are in the saturation mode.

Resistors R₁₀ and R₁₁ prevent any high-frequency oscillations.

CURRENT REGULATION

The output current is monitored in the

Figure 1. Circuit diagram of the variable power supply. The output voltage is set with P₁ and the output current limit with P₂. Digital voltmeter and ammeter modules may be connected to +V and -V, and +I and -I, respectively.



traditional manner by measurement of the voltage drop across a shunt resistor. In the present circuit, this shunt resistor is formed by the source resistors, R₁₂ and R₁₃, of the FETs.

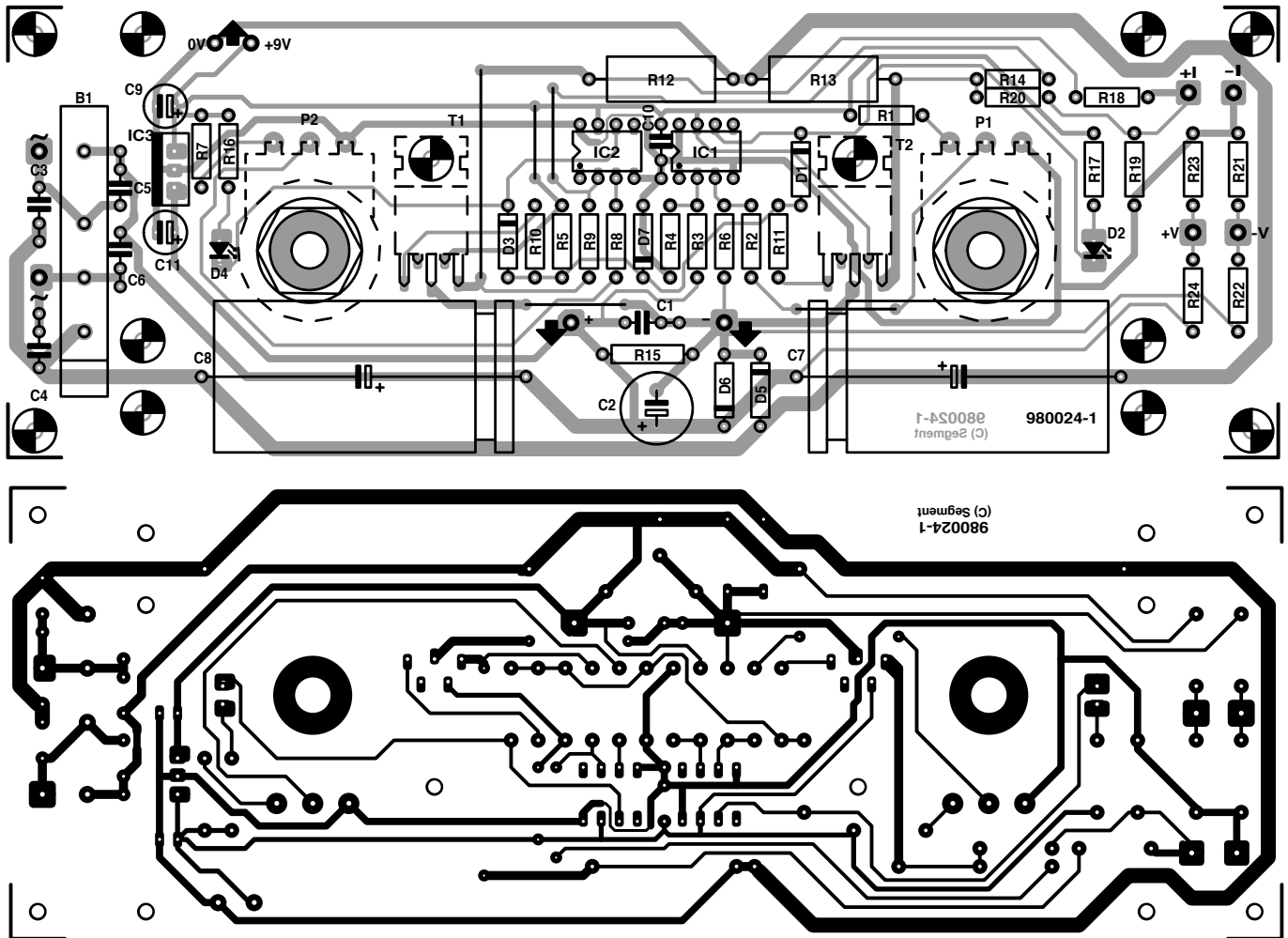
Since the differences between individual FETs may be significant, the transistors have been given a fairly large source resistor of 1 Ω. So, when the output current is, say, 2 A, that is, a current of 1 A flows through each transistor, the potential drop across

each resistor is 1 V.

The two voltages are averaged by resistors R₉ and R₁₄, so that, even if the split between the two transistors is far from ideal, the total current is measured at all times. The average voltage level is compared with the wanted value, set with P₂, in IC₂. If the current is unduly large, the output voltage of the op amp drops and the transistors are cut off via diode D₃. To ensure that they are firmly cut off, diodes D₁ and

2

Figure 2. The design of the printed-circuit board allows it to be mounted behind and in parallel with the front panel of the enclosure.



3



D_3 are Schottky types.

Light-emitting diodes D_2 and D_4 serve to indicate that the voltage regulation and current regulation respectively operate correctly. Note that these diodes cannot be connected in series with D_1 and D_3 , since then the transistors cannot be cut off completely.

It would be possible to give the op amps a negative supply line, but it is, of course, much simpler (and less expensive) to place the LEDs as shown. It is true that this raises the current by about 2 mA, but in a power unit this hardly matters.

ALSO ...

Diodes D_5 and D_6 protect the circuit against too high a voltage and against an incorrectly polarized voltage.

Resistor R_{15} drains away the tiny

Figure 3. Photograph of the completed prototype of the variable power supply. The mains transformer dictates the height of the enclosure.

Parts list

Resistors:

R₁ = 1 kΩ
 R₂, R₄ = 46.4 kΩ, 1%
 R₃, R₆ = 274 kΩ, 1%
 R₅ = 3.9 kΩ
 R₇ = 15 kΩ (1 A version); 8.2 kΩ (2 A version)
 R₈, R₉, R₁₄ = 4.7 kΩ
 R₁₀, R₁₁ = 220 Ω
 R₁₂, R₁₃ = 1 Ω, 5 W
 R₁₅ = 3.3 kΩ, 1 W
 R₁₆, R₁₇ = 3.3 kΩ
 R₁₈, R₂₀ = 22 kΩ
 R₁₉ = 2.7 kΩ
 R₂₁, R₂₃ = 1.02 kΩ, 1%
 R₂₂, R₂₄ = 100 kΩ, 1%
 P₁, P₂ = 1 kΩ linear potentiometer

Capacitors:

C₁, C₃–C₆, C₁₀ = 0.1 μF
 C₂ = 100 μF, 40 V, radial
 C₇, C₈ = 1000 μF, 63 V (1 A version); 2200 μF, 63 V (2 A version)
 C₉ = 100 μF, 16 V, radial
 C₁₁ = 10 μF, 63 V

Semiconductors:

B₁ = B80C3300/2200 rectifier
 D₁, D₃ = BAT85
 D₂, D₄ = LED, red, high efficiency
 D₅, D₆ = 1N4001
 D₇ = zener diode 5.6 V, 400 mW
 T₁, T₂ = BUK455-100A or BUK106-50S (Philips Semiconductors) – see text

Integrated circuits:

IC₁, IC₂ = TLC271CP

IC₃ = 7809

Miscellaneous:

K₁ = mains entry with integral on/off switch and 0.16 A slow-blow fuse
 Tr₁ = mains transformer, 24 V, 1.25 A (1 A version) or 24 V, 2.5 A (2 A version)
 heat sink (for T₁–T₂): 1.2 K W⁻¹
 2 off chassis socket, 3.5 mm enclosure 80–100×200×180 mm (1 A version) or 100–120×200×180 mm (2 A version)
 PCB order no. 980024 (see Readers Services towards the end of this issue)
 optional: instruments for measuring the output voltage and output current – see text

current through R₆ and any leakage of the FETs and so, in fact, determines the minimum output voltage.

Capacitors C₁ and C₂ improve the stability of the circuit and its performance at sudden variations in load.

VOLTMETERS AND AMMETERS

Several potential dividers (R₁₈–R₂₄) are provided on the printed-circuit board to enable digital measuring instruments to be connected.

Divider R₁₈–R₂₀ is intended for current measurement. It is in parallel with source resistors R₁₂ and R₁₃ (I₁ and I₂). The digital ammeter or DVM module is connected to +I and –I. Most digital modules have a sensitivity of 0.2 V. Since the potential drop across R₁₂ and R₁₃ is 1 V when the output current is 2 A, the attenuation of R₁₈–R₁₉ is ×5.

The attenuator for voltage measurement consists of resistors R₂₁–R₂₄ (remember that the output voltage floats). Assuming the same sensitivity of the module (0.2 V), the attenuation should be ×100 (20/0.2). The module is connected between +V and –V.

Since most standard 3½-digit modules can measure up to 1.999 only, the maximum voltage that can be displayed is 19.99 V. This difficulty may be overcome by the use of a module that can measure up to 3.999, or by increasing the attenuation to ×1000 (that is, giving R₂₁ and R₂₃ a value of 100 Ω). In the latter case, the 'hundredths' digit is no longer available.

MODULE SUPPLY LINES

Power for the modules may be drawn from the regulated +9 V rail (via 0 V and +9 V), but this is not always possible. Many standard inexpensive modules need a separate supply. In fact, the available +9 V line may be used only when the supply rails and the test voltage can be equal, that is, the common-mode range must lie within the power supply range. Mod-

ules with an IC from the 7106 family do not meet this requirement and these must, therefore, be given a separate supply.

There are, however, digital modules that can be used with the aid of a small integral voltage converter. The specification of these invariably states emphatically that they do not need an auxiliary voltage. In all other cases, it must be assumed that the module needs an auxiliary voltage.

CONSTRUCTION

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

Depending on the enclosure, potentiometers P₁ and P₂ may be mounted directly on the board, since this is to be mounted behind, and in parallel with, the front panel on a number of spacers. The heat sink for the power transistors is mounted at the back of the board. With luck, the fixing holes of the board coincide with the space between two adjacent fins of the heat sink. This would give a compact unit and ensure that the heat sink cannot be touched accidentally – it gets pretty hot!

The transistors are soldered to the underside of the board and screwed firmly to the heat sink. It is best to do this in reverse order: bend the terminals of the transistors to the required shape, mount the board on the heat sink, screw the transistors in place and then solder them carefully with the soldering iron between board and heat sink.

It is not necessary to isolate the transistors; in fact, from a thermal point of view, it is better not to. It is, however, essential to make sure that the heat sink does not touch other parts and is well isolated from its surroundings. The use of insulating washers, provided they are of good quality, is safer (use aluminium oxide types, not mica). Also, the use of heat conducting paste is a must.

Drill some additional ventilation

holes in the enclosure, both above and underneath the heat sink. Consideration should be given to the use of a small fan, because the inside of the small enclosure gets very hot. Standard 12 V PC fans run well on 9 V (and are then also quieter). It is, of course, possible to provide a 12 V line with the aid of an additional 7812 voltage regulator.

It is advisable to use a mains entry with integral fuse mounted at the back of the enclosure. This keeps the presence of mains voltage inside the unit to a minimum.

Note that DVM modules with integral lighting draw a current of 20–30 mA, and it is, therefore, advisable to mount the voltage regulator on a separate heat sink of about 20 K W⁻¹.

A photograph of the completed prototype is shown in **Figure 3**. Note that the operating controls on the front panel are limited to the two potentiometers, the indicator LEDs, and two chassis sockets for the output.

CHOICE OF OUTPUT CURRENT

If the power unit is intended to provide a current of up to 1 A only, a 2×12 V, 1.25 A mains transformer can be used. It may then be possible to fit the unit in an enclosure of 8–10 cm high. If an output current of up to 2 A is envisaged, the current rating of the transformer must be doubled, in which case the enclosure needs to be 10–12 cm high.

The values of the components in **Figure 1** are for the 1 A version. Some alterations in addition to the transformer are necessary for the 2 A version: the value of smoothing capacitors C₂ and C₇ must be increased to 2200 μF, and the value of R₇ must be halved to 8.2 kΩ to ensure that when P₂ is fully open, the output current is 2 A.

TEST AND INSPECTION

When the construction has been completed, switch on the mains and check

the voltage at the test points indicated in Figure 1 with a digital voltmeter. Note that the values in the voltage regulation section based on IC₁ refer to an input voltage of 28 V, an output voltage of 24 V and no load. Those in the current regulation section based on IC₂ and around the transistors refer to an input voltage of 28 V, an output voltage of 20 V, and a load of 1 A.

The circuit does not require setting up or calibration, but after verification of the test voltages, it should be ascer-

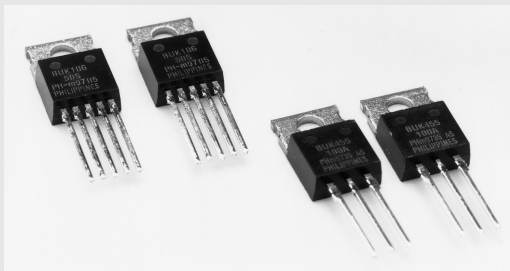
tained that the output voltage is 24 V and that an output current of 1 A or 2 A, depending on the version, can be attained.

Also, check that the output voltage can be reduced to nearly 0 V with P₁. A value of 0.2–0.3 V is acceptable, but if the output voltage cannot be reduced to below 1 V, the ratios R₃:R₄ and R₆:R₂ are not equal. This may be remedied by shunting R₂ or R₄ with a resistor of about 1 MΩ (the precise value needs to be ascertained by trial and error) until

the output voltage is a minimum.

In case of the voltage module connected to +V and –V, the meter may show a voltage that is not there. The only possible reason for this is an apparent inequality in the ratios R₂₂:R₂₂ and R₂₄:R₂₃, which may happen even if resistors with a 1% tolerance are used. The error may be eradicated by shunting R₂₁ or R₂₃ with a resistor of about 100 kΩ (the precise value needs to be ascertained by trial and error). [980024]

BUK series field-effect transistors



Many readers will be familiar with the BUZ and IRF types of field-effect transistor, but the BUK series used in the present power supply is not (yet) so well-known.

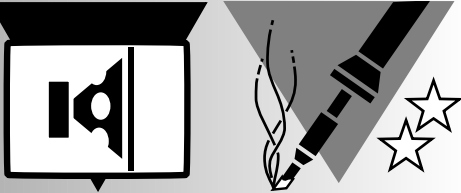
The BUK series comprises a number of versions permitting ever larger voltages and currents. The BUK455-100A used in the power unit, for instance, can handle voltages up to 100 V. A noteworthy property of this FET is its low thermal resistance of 1.2 K W⁻¹. This enables it to dissipate more power (125 W) in a TO220 case than the popular 2N3055 in an SO3 case (115 W). These are, of

course, theoretical values (cooling would have to be perfect), but in practice, with a heat sink of 1.2 K W⁻¹, the transistor would be able to dissipate 62.5 W at a ΔT of 150 °, which is a lot. Nevertheless, to play safe, the dissipation in the power supply is divided over two transistors.

The BUK106-50S, a so-called TOFET from the same series, may also be used. This device is more expensive but has some special properties. It has two additional pins: one for a protection supply input and the other for a flag output. When a supply voltage is applied to the protection supply input, the device will auto-protect itself against voltages higher than 50 V. When that happens, the transistor conducts slightly, which is not necessarily a good thing in a power unit. It will switch itself off when its temperature rises above 150 °C, which is a worthwhile facility in a power supply.

The flag output indicates when a protection circuit is enabled. This circuit is disabled by briefly switching off the supply voltage at the protection supply input.

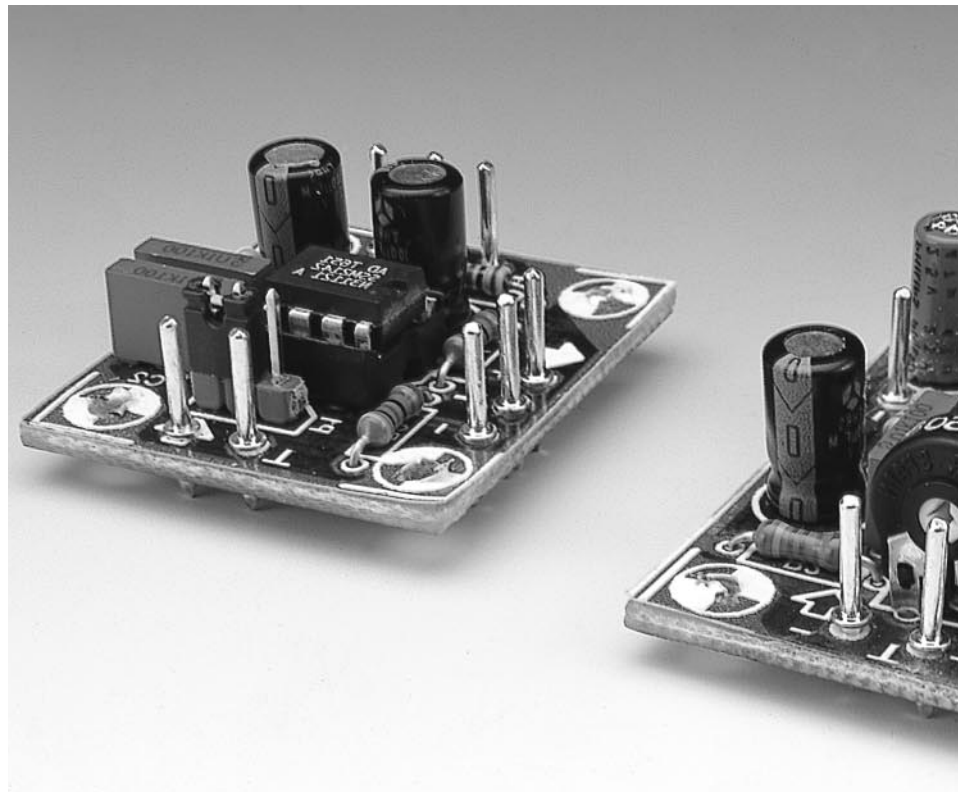
Both types of FET may be used on the printed-circuit board. The protection supply input pin of the BUK106-50S is then automatically linked to the +9 V rail provided by IC₃. The flag output is not used.



Balanced/unbalanced converters for audio signals

for high-end applications

In the Quest For Quality, a quasi-meta-physical activity zestfully practised by countless audiophiles, the use of 'balanced' (or symmetrical) signals is believed to contribute considerably to the end result. In this article we take pleasure in presenting balanced/unbalanced converters for audio signals. The designs, we are convinced, offer a solution to many problems you may stumble on when it comes to conveying small audio signals over large distances.



First things first. Let's recall that an unbalanced (asymmetrical) signal is defined as existing with respect to the ground line in a circuit. Consequently, conveying an unbalanced audio signal from one preamplifier stage to another by way of a cable may pose various problems including parasitics and radiation which degrade the quality of the audio signal. The use of shielded cable is an insufficient remedy, particularly when the signal source supplies low signal levels (say, a couple of millivolts).

The panacea in these cases is to make the signal balanced, that is, floating with respect to ground. Doing so allows a weak source signal to be conveyed over long distances (if necessary) without it being 'modified' underway. Sure, the problem of parasitics remains. However, the balanced signal being converted to unbalanced again at the input of the 'receiver',

noise is effectively cancelled out by the differential effect. The floating signal on the two wires arrives at the inputs of the differential circuit. Whereas the wanted audio signal arrives with opposite phases on the two wires, any noise picked up by the symmetrical cable will have the same phase on the two wires. Consequently, this noise is effectively eliminated by the subtracting operation of the differential circuit.

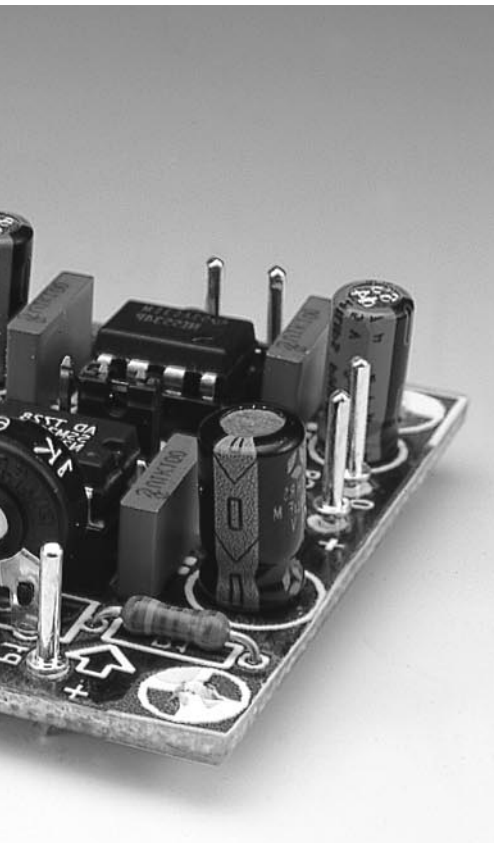
There are, without doubt, many circuits which enable an audio signal to be converted from balanced to unbalanced and the other way around. The operational amplifier (opamp) lends itself quite well to this kind of operation. Provided you use quality audio opamps, ample results will be obtained. However, a couple of precautions should be taken to prevent degrading the performance that may be achieved in theory. One of these conditions is the use of 'hand picked'

Design by J. F. Brangé

resistors with a tolerance of 0.1 per cent or better.

UNBALANCED-TO-BALANCED CONVERSION

There is a modern solution to this problem. Analog Devices has developed integrated circuits which are totally geared to this application. These ICs boast internal resistors which are laser-trimmed to a precision of 0.0001%! Not surprisingly, these ICs achieve 'professional-grade' performance as far as noise rejection, para-



itics suppression and distortion are concerned. These ICs now being relatively well distributed in Europe, we have few hesitations about presenting you practical circuits for a stereo application. Obviously, the two stereo channels being identical, it will be sufficient to describe only one of these.

The circuit diagram of the unbalanced-to-balanced converter is shown in **Figure 1**. The SSM2142 opamp from Analog Devices is a buffer/amplifier with an internal differential output driver. Its main function is to convert an unbalanced input signal into a high-level balanced signal. Based on an electronically balanced cross-coupled chip topology, the SSM2142 comes close to achieving the performance of balancing circuits that make use of a transformer for line driving. As a matter of course, the IC has the advantage of a much smaller footprint than that of a transformer, while offering compara-

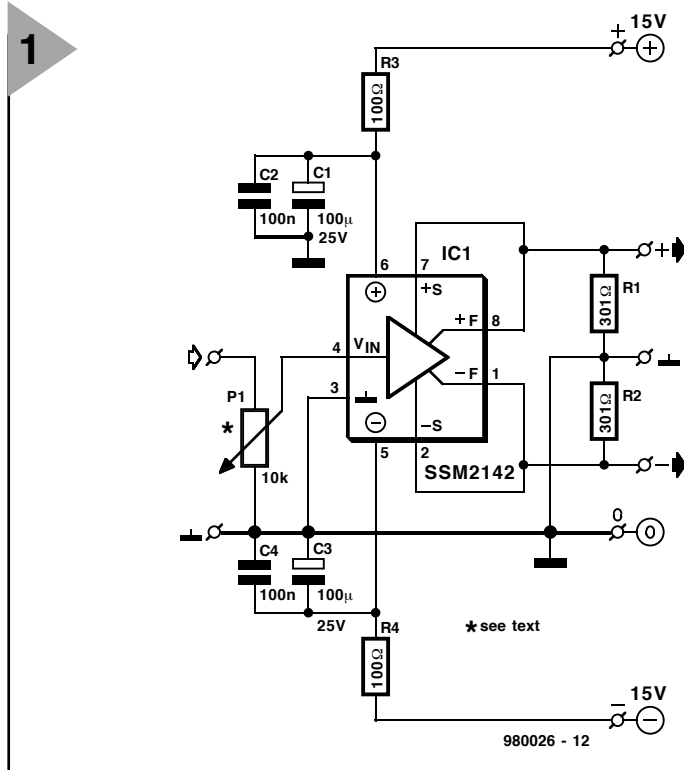
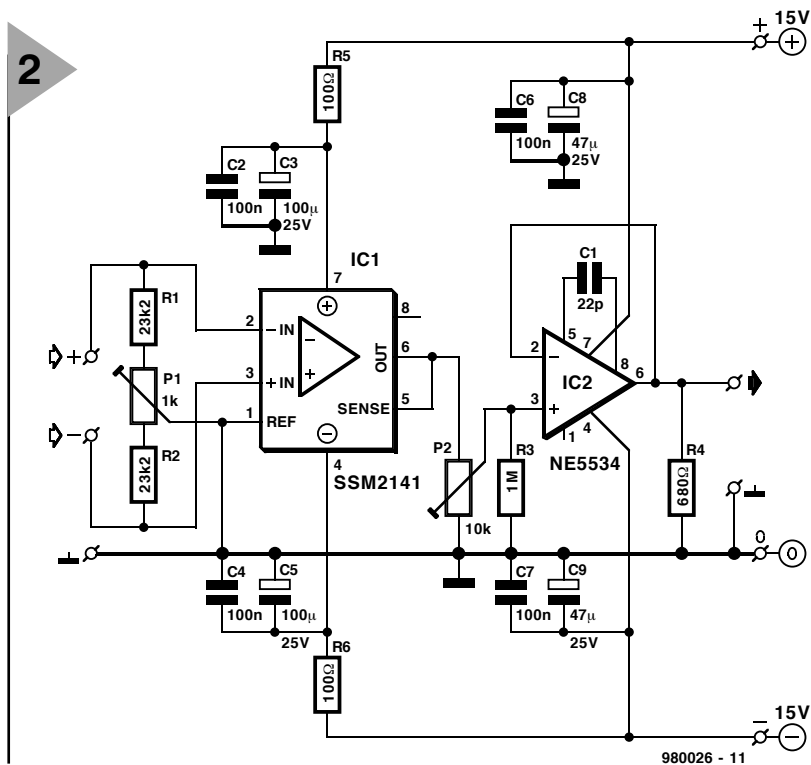


Figure 1. Circuit diagram of the unbalanced-to-balanced converter based on the SSM2142 from Analog Devices.

ble common-mode rejection. Those of you who are interested in the chief technical specs of the SSM2142 will no doubt find this month's *Datasheet* pages of particular interest.

The input signal is applied to the chip via a 10-kΩ preset, P1, whose function is to adjust the output signal level while also matching the IC input impedance recommended by the manufacturer. The preset may, of course, be replaced by either a potentiometer with the same value, or a 3-way pin-header on to which a jumper is

Figure 2. The balanced-to-unbalanced converter is designed around the SSM2142 and an NE5534 buffer opamp.



2

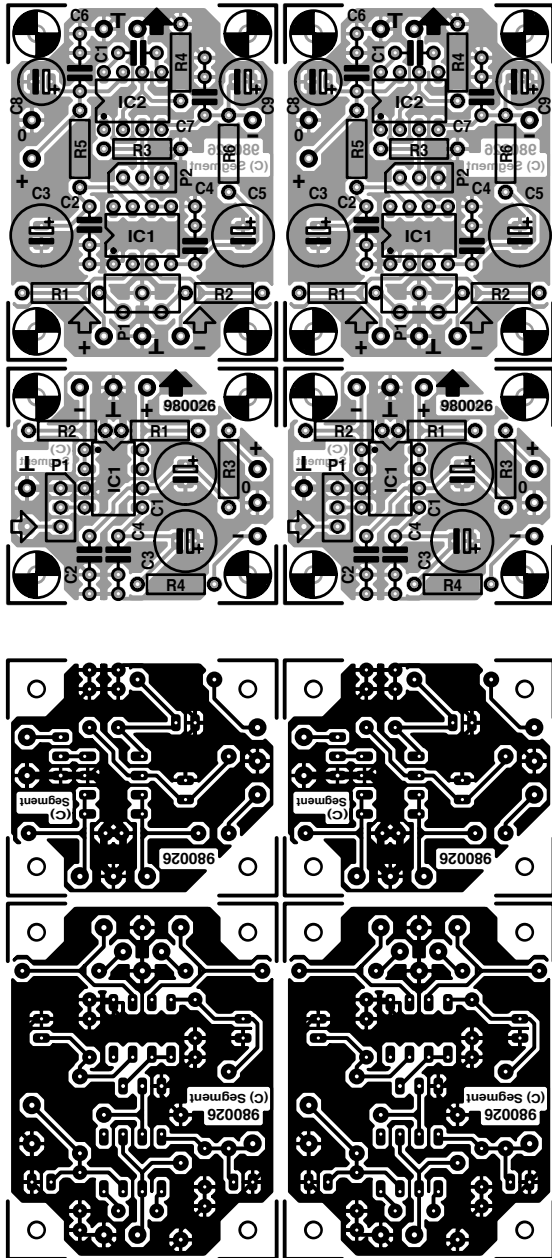


Figure 3. Copper track layout and component mounting plan of the printed circuit board designed for two balanced-to-unbalanced converters and two unbalanced-to-balanced converters (board available ready-made through the Readers Services).

installed which takes the signal from the 'input' pin to the centre pin. This is the solution we adopted. The output is also simple: pin 8 of the SSM2142 supplies in-phase (+) output signal, while pin 1 supplies

the inverted (-) signal. Since both outputs are loaded with a 301-Ω resistor to ground, an output impedance of about 600 Ω is created.

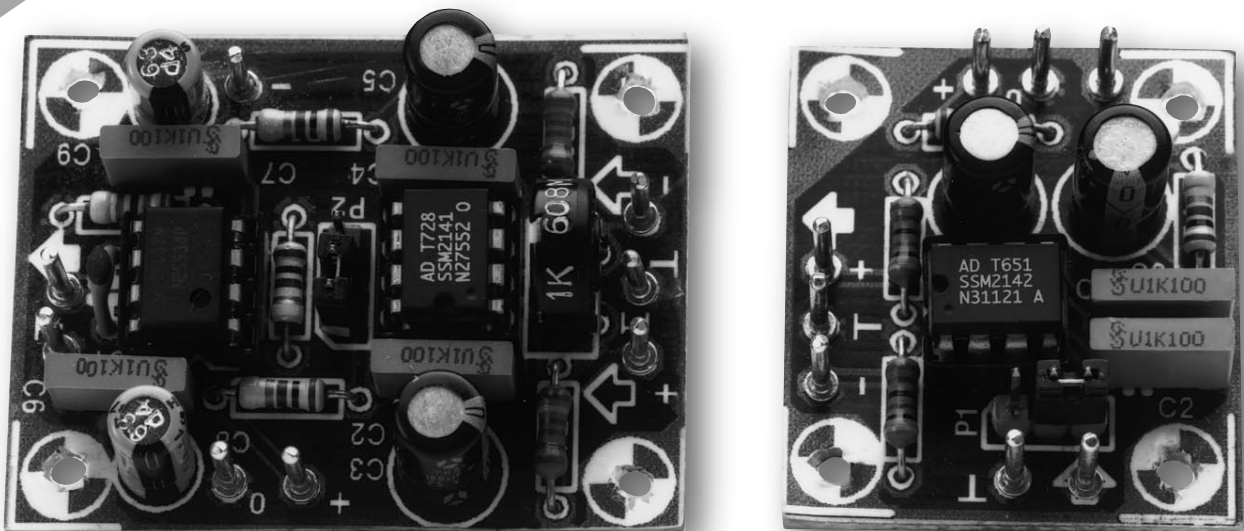
The SSM2142 is protected against parasitic signals arriving by way of the supply lines. This is achieved by connecting elementary RC filter networks comprising of R3-C1-C2 and R4-C3-C4 to the respective supply pins of the SSM2142. The output of the circuit supplies an audio signal which should be worthy of the very best home-brew audio projects.

A final word or two about the power supply: although a ±12 V symmetrical supply will be fine in many cases, we recommend using ±15 V as shown in the circuit diagram because that value results in an improved dynamic range. The absolute maximum supply voltage is ±18 V.

BALANCED - TO - UNBALANCED CONVERTER

For this purpose you need the SSM2141. This IC, a direct relative of the SSM2142, is an integrated differential-amplifier designed to receive balanced 'line' signal levels in audio

Figure 4. Finished prototype of each of the converters.



COMPONENTS LIST

Printed circuit board: order code 980026-1.

Balanced-to-unbalanced converter

Resistors:

R1,R2 = 23k Ω 22 1%
 R3 = 1M Ω
 R4 = 680 Ω
 R5,R6 = 100 Ω
 P1 = 1k Ω preset vertical
 P2 = 10k Ω logarithmic potentiometer (may be replaced by jumper)

Capacitors:

C1 = 22pF
 C2,C4,C6,C7 = 100nF
 C3,C5 = 100 μ F 25V radial
 C8,C9 = 47 μ F 25V radial

Semiconductors:

IC1 = SSM2141 (Analog Devices)
 IC2 = NE5534 (Philips Semiconductors)

Unbalanced-to-balanced converter

Resistors:

R1,R2 = 301 Ω 1%
 R3,R4 = 100 Ω
 P1 = 10k Ω logarithmic pot (or jumper)

Capacitors:

C1,C3 = 100 μ F 25V radial
 C2,C4 = 100nF

Semiconductor:

IC1 = SSM2142 (Analog Devices)

circuits requiring high noise immunity and common-mode noise rejection. This IC achieves a typical CMR (common-mode rejection) spec of 100 dB. By comparison, an opamp with four regular resistors around it will be hard pressed to achieve a CMR rating of anything over 40 dB or so, which is by no means enough for high-end audio designs. Let's cast a look at **Figure 2** which shows the schematic of this sub-circuit. The resistor networks between the SIG+ (pin 3) and SIG- (pin 2) inputs of the SSM2141 fix the input impedance at about 47 k Ω . Preset P1 (1 k Ω) allows the CMR value to be fine-tuned (see also further on). This component is optional, however, and may be omitted. As indicated by the component overlay of the balanced-to-unbalanced

converter, it may be replaced by wire links. This was also done on our prototype. Note, however, that the source impedance has to be perfectly controlled, as the slightest imbalance of the source resistance will reduce the achievable CMR value. For example, a difference of just 5 Ω is punished with a CMR increase of no less than 20 dB.

The output signal of the SSM2141 is applied to an NE5534 voltage follower by way of a 10-k Ω preset. The (low-impedance) output of the NE5534 should be able to drive almost any pre-amplifier input. The remarks on the supply filtering of the SSM2142 also apply to the SSM2141.

If used, the CMR fine-tuning preset has to be adjusted with the aid of a differential input signal. What better way to generate such a signal than use the SSM2142? Apply a 50-Hz, 100-mV signal to the input of the 2142. Connect its output signal to the 2141. Next, tweak P1 for the smallest possible signal at the output. This setting corresponds to the best possible CMR. Those of you who do not have an oscilloscope (or access to one) may replace the 1-k Ω preset by two wire links, as mentioned earlier. If you can get hold of two 23.2-k Ω resistors with a tolerance of 0.1%, no adjustment should be necessary.

As already mentioned, the circuits are powered by a ± 15 -V symmetrical supply. Current consumption being very modest indeed, you can make do with a mains adaptor with stabilized ± 15 V outputs.

CONSTRUCTION

As you can see from the artwork in **Figure 3**, a printed circuit board was designed for the two converters. The artwork comprises the copper track layout and the component mounting plan (overlay). The PCB design for each converter is duplicated so you need just this one board for a stereo application.

As a matter of course, it is best to start by separating the four small boards. The two smaller boards are used to build the unbalanced-to-balanced converters, while the boards with two IC sockets on them are intended for the balanced-to-unbalanced converters. Neither of these circuits should present undue difficulty when populating the boards. The only

points to be made here are to observe the polarity of the electrolytic capacitors and the orientation of the integrated circuits when they are inserted into their sockets. Also be sure not to mix up the two 8-pin integrated circuits on the balanced-to-unbalanced converter board.

The large unetched copper areas on the boards acts as ground planes which help to make the circuits immune to noise and other stray signals.

Having finished the construction of the converter boards you may mount them in small boxes, and wire them up to the external parts. The input and output connectors may be mini-DIN types of which only three pins are used. The unbalanced-to-balanced converter is best located close to the signal source. Its complement, the balanced-to-unbalanced converter, will typically be installed near the 'receiver'. Note the connections: the outputs of the unbalanced-to-balanced converter are the mirror-image of the inputs of the balanced-to-unbalanced converter.

The circuits should function spot-on. The photograph in **Figure 4** should allow you to compare your own efforts at building the circuits with those of our engineering laboratory. In particular, you should be able to detect missing components immediately in the (unlikely) case of a problem.

A final note aimed at those with a keen interest in figures: Below are the very encouraging results of exhaustive measurements on a pair of these converters built up in our design lab:

- unbalanced-to-balanced converter: THD (total harmonic distortion) between 0.0008% and 0.0015% from 20 Hz to 20 kHz.
- balanced-to-unbalanced converter: THD between 0.0008% and 0.0011% from 20 Hz to 20 kHz; CMR between -140 dB and -70 dB from 20 Hz to 20 kHz.

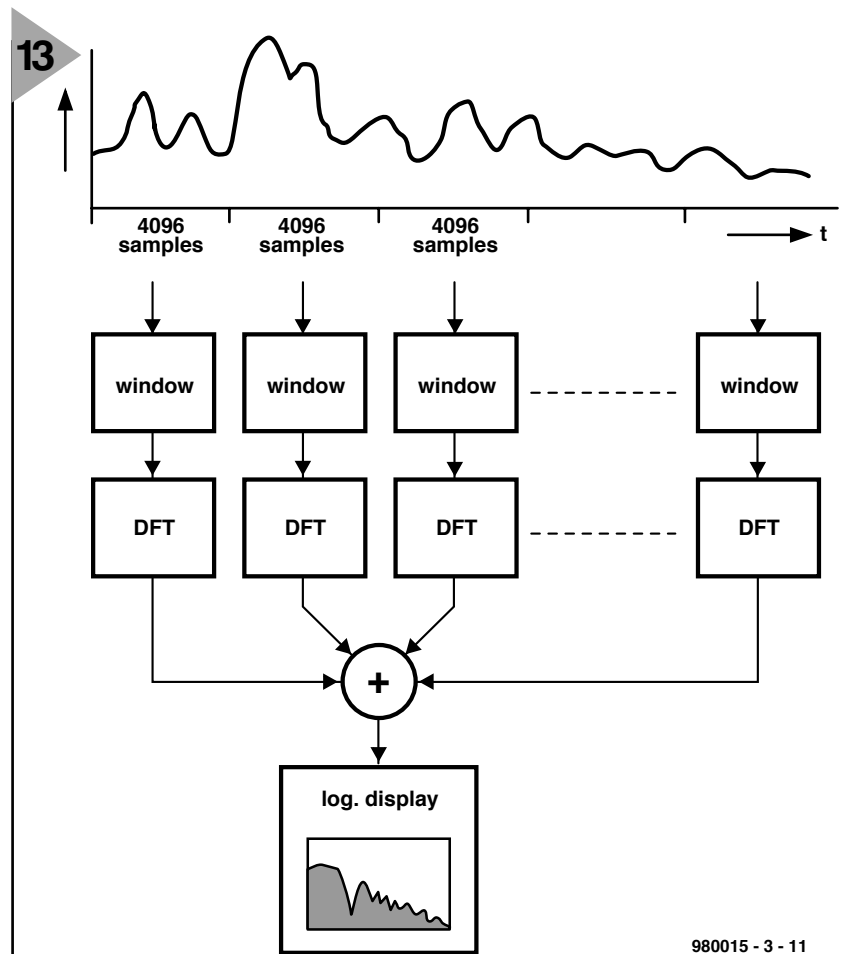
All measurements were made with an Audio Precision test system.

(980026-1)

introduction to digital signal processing

Part 3 – Digital bandpass filters

After last month's discourse on the computation of frequency spectra, that knowledge is used in this, the third, instalment to acquaint the reader with the ins and outs of digital bandpass filters.



980015 - 3 - 11

Figure 13. Schematic showing how longer signals are computed.

SPECTRA OF LONG SIGNALS

In the foregoing, the DFT (Discrete Fourier Transform) of a signal of fixed length (that is, $n = 4096$) was used to compute the spectrum. The computation of a much longer signal may be carried in a number of ways described in a number of books (see *References*). Our analyser makes it much simpler (see **Figure 13**). The input signal is divided into segments all 4096 bits long which are multiplied with the window function described in Part 2. The DFT of each segment is then com-

puted, the r.m.s. amplitudes are added together, so that the entire signal may be analysed, whereupon the resultant spectrum is displayed.

APPLICATION

We now wish to view the spectrum of a real signal and take for this purpose file `morse2.wav`. This contains two morse (telegraph) signals of different frequency. Experiment `XMORSE1.SPP` then computes the spectrum, which is shown in **Figure 14**. The spectrum clearly shows two peaks, whose frequency may be determined by measurement, even when the signals are weak and superimposed on many other signals. The reader is invited to try to analyse the 19 kHz stereo pilot carrier which is frequently still present

in the output signal of an FM receiver (available on the CD-ROM as a file).

NOISE ANALYSIS OF A LOW-PASS FILTER

Now for experiment XLP6.SPP, which simulates the setup shown in Figure 15. Signal generator NOISE1.EXE provides white noise, which is applied to a simple low-pass filter. The input signal and output signal are analysed with spectrum analyser SPEC1. The result is shown in Figure 16.

DFT AND FFT

The algorithm that computes the spectrum from the sampled values is called a Discrete Fourier Transform (DFT). The Fast Fourier Transform (FFT) is a method for carrying out the DFT computations rapidly and effectively. The number of multiplications carried out with both transforms is given below for three values of n , that is, the number of sampling points. In the table, c is the factor indicating how much faster a computation with an FFT is than one with a DFT.

n	DFT	FFT	c
16	256	64	4
128	16384	896	18
4096	16777216	49152	341

FROM SINE WAVE GENERATOR TO BANDPASS FILTER

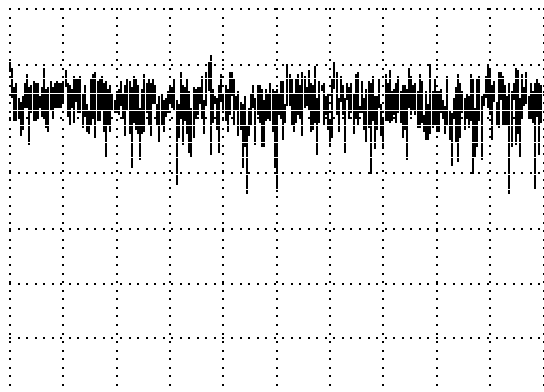
Readers who may have forgotten most of the trigonometry they learned at school are reminded that

$$\cos(\alpha+\beta) = \cos\alpha\cos\beta - \sin\alpha\sin\beta$$

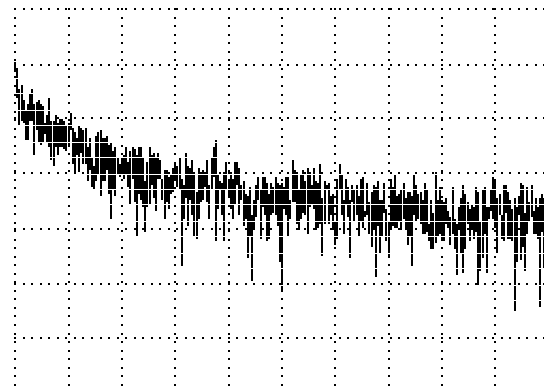
$$\sin(\alpha+\beta) = \sin\alpha\sin\beta + \cos\alpha\cos\beta$$

These simple equations enable a digi-

Figure 16. Spectrum of white noise before (left) and after being passed through a low-pass filter.



tmp1.wav (w) ya = 0.0 yb = 100.0
fa = 0.0 fb = 5000.0 cur = -1.0



tmp2.wav (w) ya = 0.0 yb = 100.0
fa = 0.0 fb = 5000.0 cur = -1.0

980015 - 3 - 14

14

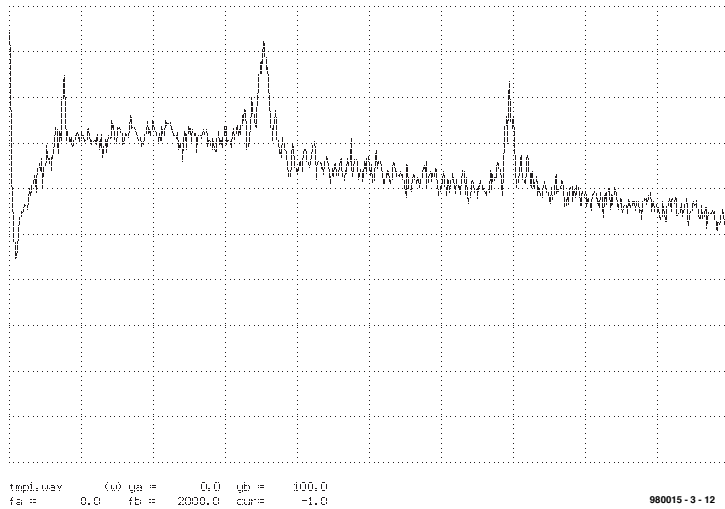


Figure 14. Two morse (telegraph) signals almost submerged in noise.

tal sine wave generator to be realized from which, with some modifications, a bandpass filter may be derived.

Enter these values into the upper line:

$$\begin{aligned} p &= \cos\varphi \\ q &= \sin\varphi \\ c_k &= \cos k\varphi \\ s_k &= \sin k\varphi \end{aligned}$$

If $\varphi = 2\pi f/f_s$, c_k and s_k are the sampled values of, respectively, a cosinusoidal and a sinusoidal signal of frequency f that is sampled at a rate f_s .

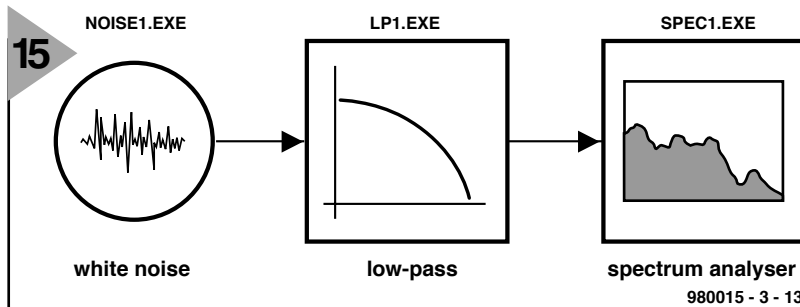
To digitally generate these signals, the values of c_k and s_k must be computed rapidly, starting, for instance, with $k = 0$. By substitution in the sine

and cosine equations, we obtain

$$\begin{aligned} c_{k+1} &= pc_k - qs_k \\ s_{k+1} &= qc_k + ps_k \end{aligned}$$

This means that once parameters p and q have been decided, the values of c_{k+1} and s_{k+1} can be computed by four multiplications, one addition and one subtraction from the values of c_k and

Figure 15. The removal of white noise with the aid of a low-pass filter.



980015 - 3 - 13

16

17

```

program sin0 ;
uses dos,graph,crt ;

{$I SIGLIB.PAS}

var
  k:int ;
f0,scale:float ;
p,q,ck,sk,ck_new,sk_new:float ;

begin
start('sin-wave-generator') ;
nsamples:=10000          ; set_par_long('\n=',nsamples) ;
fs:=22050                ; set_par_long('\fs=',fs) ;
f0:=100 ; set_par_real('\f0=',f0) ;
scale:=500               ; set_par_real('\scale=',scale) ;
out_fn:='sin1.wav'       ; set_par_string('\out=',out_fn) ;

open_out(out_fn) ;

p:=cos(2*pi*f0/fs) ;
q:=sin(2*pi*f0/fs) ;
ck:=1 ;
sk:=0 ;

for k:=1 to nsamples do
  begin
  output(scale*ck) ;
  ck_new:=p*ck-q*sk ;
  sk_new:=q*ck+p*sk ;
  ck:=ck_new ;
  sk:=sk_new ;
  end ;
stop ;
end.

```

Figure 17. Program for digitally generating a sinusoidal signal.

s_k . This can be done very rapidly and is readily programmed on a signal processor. For example, programming of a simple oscillator as in program SIN0.PAS (or .EXE) is child's play. The listing is given in **Figure 17**.

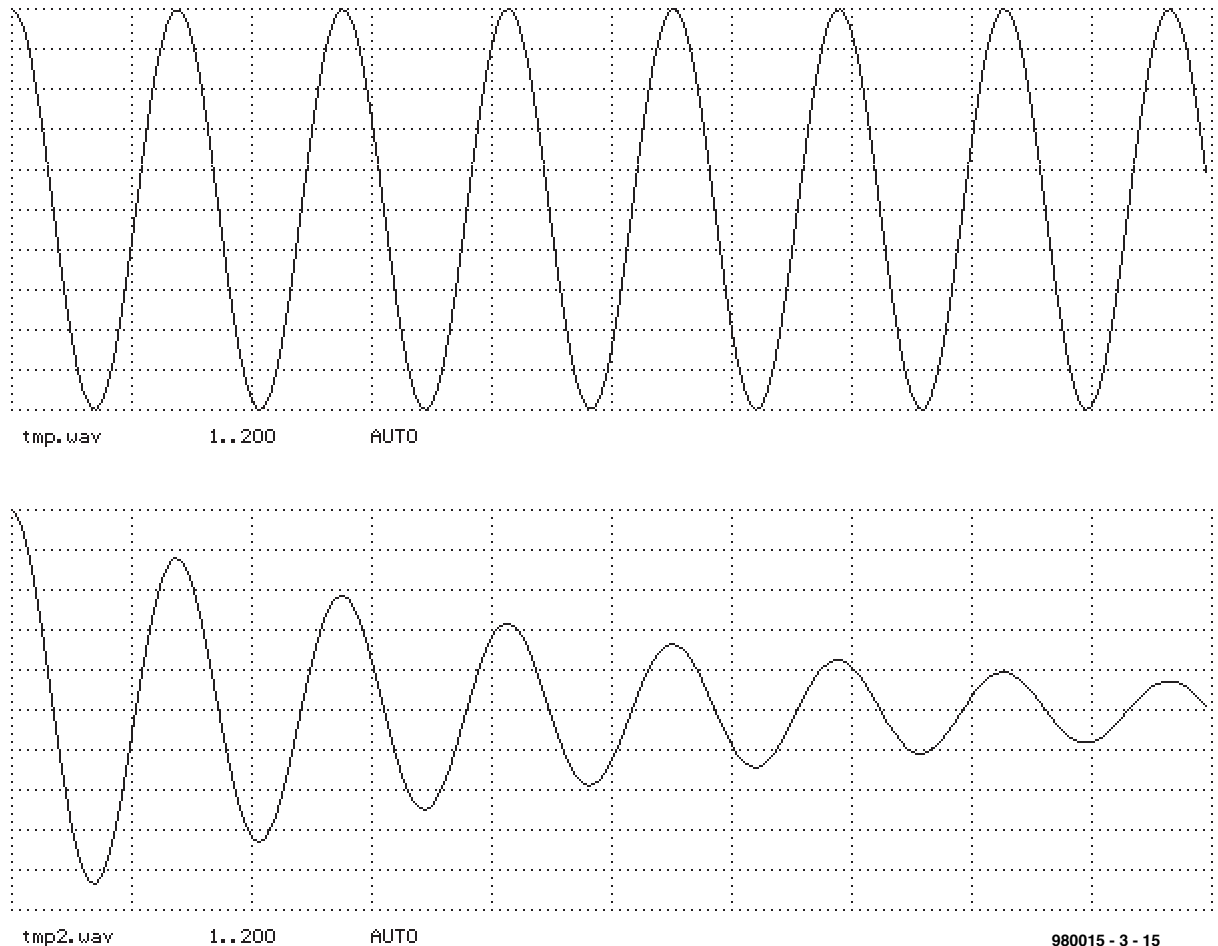
The program generates a sinusoidal signal (XSIN1.SPP), which is displayed in **Figure 18**. To start the oscillator, start values c_0 and s_0 must be entered as relevant, since these determine the phase and amplitude of the signal.

Although so far matters have not been very complicated, we have already simulated an undamped resonant circuit. In this, the value c_k represents, say, the value of the current through the inductor, and s_k the value of the potential across the capacitor.

We have come very close to a damped resonant circuit as shown in **Figure 19**. In the case of a damped oscillation, the values within successive sampling intervals reduce by a factor r , that is, the damping factor <1 . Consequently, the computation instruction must include a multiplication by $r < 1$. Moreover, to excite the resonant circuit, the instruction must also

Figure 18. A constant sinusoidal signal (upper curve) and a decaying one.

18



include an input signal u_k . The resulting equations are:

$$c_{k+1} = r(pc_k - qs_k) + u_k$$

$$s_{k+1} = r(qc_k + ps_k)$$

This represents a simple bandpass filter and also forms the basis of the associated program SINFIL.PAS (or .EXE). To test that this is really a bandpass function, a single pulse is used as input signal and the output of the filter observed. If all is well, this should be a damped oscillation, constituting XSIN1.SPP as shown by the lower curve in Figure 18. This is an exponentially damped waveform generated by the bandpass filter, that is, the resonant circuit.

Experiment XBANDP1.SPP enables a sweep signal to be passed through the filter. Again, various values of f_0 and r may be used; particularly interesting are the values $r = 0.5$; $r = 0.9$; $r = 0.99$; $r = 0.999$; and $r = 0.9999$.

An unusual aspect of the filter is that it computes not only the cosinusoidal, but also the sinusoidal, oscillation. This may be inverted to obtain

$$c_{k+2} = b_1c_{k+1} + b_2c_k + u_k$$

which yields with the aid of the so-called filter coefficient:

$$b_1 = -r^2$$

$$b_2 = 2r\cos(2\pi f_0/f_s)$$

The filter is realized in program BANDP1.PAS (or .EXE).

INFINITE IMPULSE RESPONSE FILTER

A comparison between the filter just derived and the earlier low-pass filter shows a general aspect. The output at one clock period affects the output during the next period. This will have some sort of exponential effect, so that each output has a smaller effect on the next output. These filters are called Infinite Impulse Response (IIR) filters, sometimes recursive filters.

The output value of the low-pass filter depends on only the preceding output value and the filter is, therefore, a first-order IIR filter.

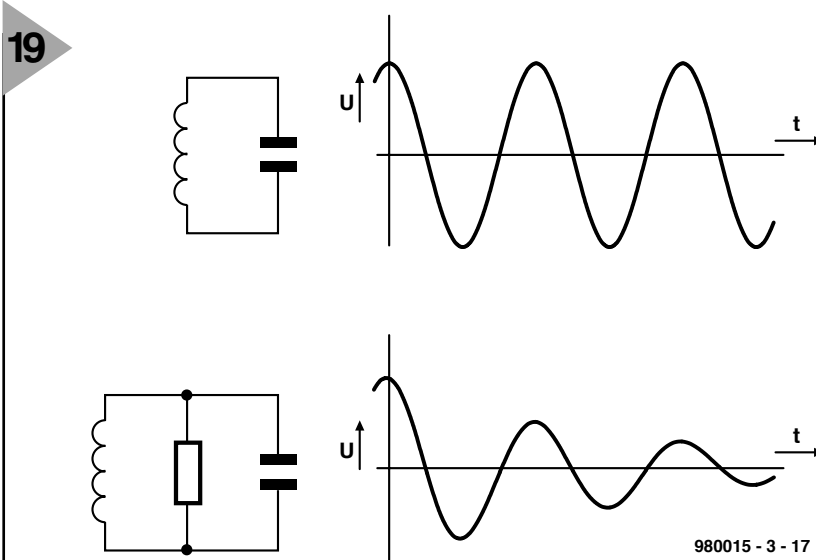
The output of the bandpass filter refers back two output values and is thus a second-order IIR filter.

There are, of course, higher order filters, but these normally consist of a number of cascaded second-order sections.

APPLICATIONS OF BANDPASS FILTERS

Bandpass filters are normally used to select a specific frequency or band of frequencies. File MORSE2.WAV contains the signal of an amateur radio set receiving two closely spaced morse

19



980015 - 3 - 17

Figure 19. A damped and an undamped oscillator circuit and associated oscillations.

signals. A bandpass filter enables one of these signals to be enhanced significantly. Detection of the signal may be effected automatically with experiment XMORSE3.SPP, which passes signal MORSE3.WAV through two bandpass filters with centre frequencies of 700 Hz and 1400 Hz respectively. The two separated signals are clearly recognizable in Figure 20.

Working with these associated files and experimenting with the filter parameters quickly clarifies the operation of a bandpass filter. Pass a music signal (MUS1.WAV) through a bandpass filter and listen to the result.

Next month's instalment will discuss an echo generator and show how this can be modified to make it suitable for digital filtering.

[980015-3]

References

Electronic Filter Design Handbook, ISBN 0 07 070434 1, by Arthur B. Williams and Fred J. Taylor; McGraw-Hill, 1988

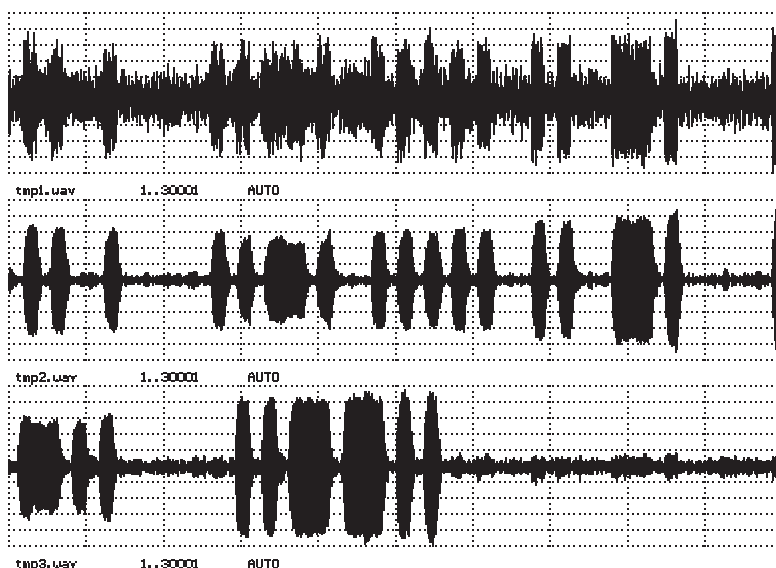
Digital Audio Signal Processing, ISBN 0 471 97226 6, by Udo Zölzer, John Wiley & Sons, 1997.

Digital Signal Processing, by Schafer & Oppenheim, Prentice-Hall, 1975

Digital Processing of Signals, C.M. Rader and B. Gold, McGraw-Hill.

Figure 20. Two morse signals at 700 Hz and 1400 Hz respectively before and after filtering. After filtering, the two separated signals are clearly recognizable.

20



980015 - 3 - 18



Digital Audio Broadcasting (DAB)

Radio programmes with CD quality



The European Union's Eureka* 147 DAB Project is the only digital audio broadcasting system to be fully specified and to meet the ITU's (International Telecommunications Union) requirements for a world standard. It provides radio broadcast data transmission at a bit rate of 1.2–1.5 Mbit/sec and is highly immune to noise and

interference, even in mobile use. Its main application is a radio system with CD quality for mobile and domestic use. It is intended to replace VHF/FM broadcasts within the next 10 years. Apart from providing additional data services for graphics and text, the new multimedia system can also transmit television programmes



The VHF broadcasting system introduced in 1949 has reached the end of the road. Owing to the overcrowding of the 88–108 MHz band and signal echoes, serious interference, especially in mobile use, is inevitable. Also, the transmission of additional digital data (RDS – radio data services) is possible in only a limited way. And finally, the VHF/FM service could never achieve the quality associated with compact disks (CD).

Against this background, the Digital Audio Broadcasting system (DAB) was introduced to provide CD-quality audio services, as well as a host of additional data services, to domestic and in-car receivers. It was originally developed under the Eureka* 147 (E147) programme within the European

* Eureka is an enabling organization set up by the Commission of the European Union in 1985 to promote and fund research, development and cooperation for the implementation of advanced technologies.

By our Editorial Staff

Union, but is now being accepted by many countries outside Europe. Unlike FM transmissions, DAB does not suffer from multi-path effects.

The manufacturers and research organizations that took part in the Eureka 147 development project associated themselves in 1995 into the EuroDAB Forum to promote DAB technology in Europe and to develop the formal standards for E147. But interest was shown also from outside Europe and so the EuroDAB Forum became the WorldDAB Forum early last year.

The two most important steps toward the realization of DAB were the development of MUSICAM (Masking Universal Subband Integrated Coding And Multiplexing) for signal encoding and an innovative modulation technique called COFDM (Coded Orthogonal Frequency Division Multiplexing).

In the past, the large bandwidth required to digitize audio signals prevented the use of digital broadcasting techniques, but the MUSICAM encoding method allows a significant reduction in bit rates without affecting the audio quality. It uses irrelevance and redundancy reduction by using certain psychoacoustic properties of human hearing. Consequently, high audio quality can be achieved with bit rates as low as 192 kbit/sec per stereo channel, compared with the 1411 kbit/sec required in the recording of CDs, in which a non-compressed technique is used.

The COFDM technique enables a high-quality, reliable and efficient transmission to be obtained. It is a multi-carrier, digital modulation system based on the principle of dividing the information over a large number of close-spaced, orthogonal (mutually perpendicular) carriers. There are 1536 orthogonal carriers in a 1.5 MHz DAB Band III block, and 384 or 768 orthogonal carriers in a 1.5 MHz DAB-L-band block.

The technique uses advanced error detection and correction methods to provide unimpaired reception even under difficult conditions. DAB can operate with a signal-to-noise level as low as 10 dB without any degradation as compared with 50 dB for a VHF/FM transmission. Furthermore, it avoids interference, and the resulting distortion, caused by multipath propagation. The resistance to multipath propagation prevents reflection from buildings or mountains to affect reception quality. In fact, these signals increase the reliability of the DAB service. The resistance makes it possible to provide a DAB service via a terrestrial single-frequency network.

In contrast to VHF/FM stations, DAB allows blocks of stations on one

1

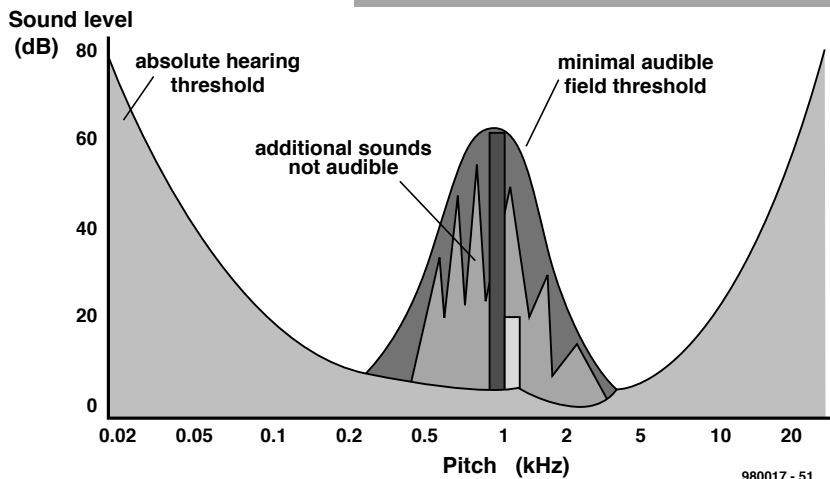


Figure 1. The MUSICAM technique uses psychoacoustic effects to reduce the data rate of DAB transmissions.

single DAB channel (1.5 MHz bandwidth) without resulting in interference. In conjunction with a single-frequency network, a block of at least six stations per country can be broadcast nationwide via the same DAB channel. By using one or more additional DAB channels, it is possible to provide further blocks of stations for regional and local programmes. In theory, DAB enables three times as many stations as before to be broadcast in the same frequency range.

Since a block of stations can be transmitted via DAB and the output power required to broadcast COFDM-modulated signals is reduced, the energy required for a DAB network is significantly smaller (up to 90 per cent) than that needed for a current FM network. This also means a much smaller E-field around the transmitter.

A DAB provides the associated digital receiver with indication of the transmitter name and the type of music programme. It also gives accompanying text

information about the radio programme.

In addition to, or instead of, radio programmes, the transparent and flexible transmission path opens the way for many new and innovative services: from text and picture information to the transmission of moving pictures or even television programmes, which may be received in a car or train.

Many electronics companies are building and developing a range of DAB-compatible units, ranging from car radios and multimedia mobile handsets to PC cards that will capture the data transmitted alongside the audio signal and display it on a PC.

AUDIO ENCODING

Recording a stereo audio signal on to a compact disk (CD) requires a data rate of 1411 kbit/sec. At a comparable

2

SAY, 6 PROGRAMMES

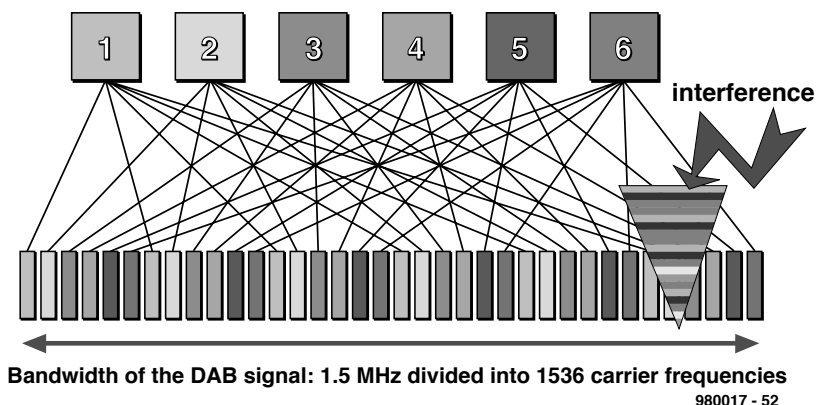


Figure 2. The continuous redistribution of the programmes over 1536 carriers, in conjunction with extensive error protection, prevents a partial loss of data through interference and reflections from affecting the received signal.

Table 1**Specification of DAB coding with MUSICAM**

Audio modes	mono stereo two-channel multi-channel (MUSICAM surround)
Sampling frequency	48 kHz
Lower sampling frequency* (LSF)	24 kHz
Transmitted AF range	0 Hz to 20.25 kHz With LSF* 0 Hz to 11.25 kHz
Resolution of PCM signal	up to 22 bit/sample
Audio bit rate	32 kbit/sec (mono) to 384 kbit/sec (stereo) in 14 steps With LSF* 8 kbit/sec (mono) to 160 kbit/sec (stereo) in 14 steps
Duration of audio frame	24 ms, equivalent to 1152 PCM samples With LSF* 48 ms

* Halving the sampling frequency during transmission enhances the audio quality at low bit rates of about 32–64 kbit/sec. This is of particular interest in spoken-word programmes, such as newscasts. Owing to the doubled duration of the audio frame, only half the bit rate is available for Programme Associated Data (PAD) services.

Other applications of MUSICAM comprise:

- Astra Digital Radio (ADR)
- Cable and satellite television (DVB, DirectTV in the USA)
- Dubbing between radio stations over telephone/ISDN lines
- Multimedia applications in PCs
- Electronic interfaces for sound processing in computers

Table 2**Technical parameters of DAB transmissions**

Radio-frequency characteristics	Mode I,	Mode II,	Mode III,	Mode IV
Bandwidth	1.536 MHz (all modes)			
Number of carriers	1536 (I);	384 (II);	192 (III);	768 (IV)
Symbol duration	1.246 ms (I);	312 μ s (II);	156 μ s (III);	623 μ s (IV)
Guard period	246 μ s (I);	62 μ s (II);	31 μ s (III);	123 μ s (IV)
Modulation	differential quadrature phase-shift keying (QPSK)			
Error protection	grade 1: 0.39			
(convolution code rate,	grade 2: 0.47			
average for sound,	grade 3: 0.55 (for mobile services)			
greater for control data)	grade 4: 0.64			
	grade 5: 0.80 (for instance, for cable services)			
Service characteristics				
Frequency range	mountainous terrain: < 375 MHz (individual transmitters) (Mode I)			
	flat terrain: < 1.5 GHz (Mode II)			
	flat terrain: < 3.0 GHz (Mode III)			
	flat terrain: < 1.5 GHz (Mode IV)			
	supra-national: satellite			
Transmitter spacing	up to about 80 km (< 375 MHz – Mode I)			
(terrestrial networks)	up to about 20 km (< 1.5 GHz – Mode II)			
	up to about 10 km (< 3 GHz – Mode III)			
	up to about 40 km (< 1.5 GHz – Mode IV)			
Multiplex characteristics				
Gross transmission bit rate	2.304 Mbit/sec			
Net transmission bit rate	about 1.2 Mbit/sec (grade 3)			
Configuration	up to 64 audio programmes and data services; typically 5–8 audio programmes and several data services			
Reconfiguration	dynamic during ongoing transmission			
Non-uniform configuration	typically six stereo programmes at a rate of 192 kbit/sec, incl. Programme Associate Data (PAD), and several data services at a rate of 24 kbit/sec			
Data services	Programme Associated Data (PAD) at 0.6–16 (later 64) kbit/sec, embedded in the audio signal			
	stream mode: capacity selectable in steps of 8 kbit/sec			
	packet mode: capacity selectable as necessary			

Table 3

Frequency ranges available for DAB

Band I	47–68 MHz; previously used for television broadcasts (2–4 channels) and mobile communications; can accommodate 12 DAB blocks (2A–4D)
Band III	174–230 MHz; previously used for television broadcasts (5–12 channels) and mobile communications; can accommodate 32 DAB blocks (5A–12D)
Band III	230–240 MHz; previously used for mobile and military communications*; can accommodate six blocks (13A–13F)
L-band	1452–1467.5 MHz; previously used for mobile and fixed communication services; can accommodate nine blocks (LA–LI)

The DAB blocks are identified by the number of the previous TV channel and a letter. For instance, since four DAB blocks can be accommodated in each former TV channel, the four blocks replacing TV Channel 12 are identified by 12A, 12B, 12C and 12D.

* These frequencies are apparently still used by the military in France, since it is feared there that the introduction of DAB could interfere with French defence communications.

rate, DAB, thanks to MUSICAM, can transmit up to 20 audio signals (without additional services) without loss of audio quality. MUSICAM was developed under the European Eureka Initiative by the Institute of Radio Technology (IRT) in Munich, Germany, Philips in the Netherlands, and CCETT, a French research centre.

MUSICAM is based on special algorithms, which are founded on two psychoacoustic effects in humans. The first one of these is that human hearing is not capable of discerning sounds that lie below the absolute hearing threshold. The second is that soft sounds which lie below the minimal audible field threshold cannot be perceived when they are masked by loud ones of about the same frequency.

MUSICAM makes use of these effects and conveys only those parts of the sound information that can really be perceived (see **Figure 1**).

Depending on the signal content and the quality requirements, different data rates may be used – the bandwidth of each mono(phonetic) channel stretches from 8 kbit/sec to 192 kbit/sec. Stereo signals are conveyed in the normal stereo mode as 2-channel signals (that is, double the mono rate).

Low bit rates result in the common stereo mode, in which the information common to both channels is conveyed only once.

During the audio encoding, bits are already reserved for (additional) Programme Associated Data (PAD).

The most important parameters for audio encoding are listed in **Table 1**.

TRANSMISSION CHARACTERISTICS

In a VHF/AM or FM transmission there is only one carrier frequency

modulated (amplitude, frequency or phase) with the audio information.

The DAB system uses coded orthogonal frequency division modulation (COFDM), whereby a group of programmes are multiplexed into a single broadcast channel. Although this requires a relatively wide bandwidth, the concept allows the use of a single frequency network (SFN) with a number of interleaved parallel programmes, thus making better use of the limited spectrum.

The system operates in various frequency bands (see **Table 3**). There are four modes of operating conditions that depend largely on the transmission frequency and the degree of acceptable Doppler shift.

The audio signals are first MUSICAM encoded to achieve bit rate reduction and then applied to the COFDM modulator using binary QPSK coding.

The time slot structure is also mode dependent; for instance, Mode III has a frame of 24 ms, a symbol* duration of 156 μ s (of which only the last 125 μ s is quality critical) and a guard period between time slots of 31 μ s. The system defeats multi-path effects because the first part of each symbol is discarded.

Continuous redistribution of the programmes over the carriers prevents sequential data of a given source to be affected simultaneously by reflections (see **Figure 2**). However, use of the reflections intercepted during the guard periods enhances the quality of the transmission.

After long and extensive research into the best ratio between bandwidth and received signal quality, it was decided to use frequency blocks 1.5 MHz wide. Each of these blocks

can contain between 192 and 1536 orthogonal carriers, depending on the mode of transmission and the frequency band.

A single television channel, 7 MHz wide, can contain four DAB blocks, which means that in practice a single television programme can be replaced by 24 stereo audio programmes and a number of digital services. The combined information (programmes and data) is transmitted in one of these blocks, termed an ensemble, at a gross bit rate of 2.304 kbit/sec, equivalent to an overall net bit rate of 1.2–1.5 Mbit/sec, depending on the degree of error-protection. The most important technical parameters of a DAB transmission are listed in **Table 2**.

The frequency bands allocated to the introductory DAB transmissions are listed in **Table 3**. For national coverage, Band III was deemed most propitious, and the L-band for regional and local stations. A simple rod suffices as the receive antenna.

Table 2 also shows that, depending on the frequency range, a different mode of transmission may be selected. Mode I provides the highest number of carriers and the longest guard periods, and is therefore particularly suitable for VHF co-channel networks in which the transmitters are well spaced. Mode II is for use in local co-channel networks. Mode III is best suited to use in cable and satellite systems, and also mobile systems operating at frequencies up to 3 GHz. It is particularly immune to phase noise. Mode IV is intended for use in L-band systems with well-spaced transmitters. It is susceptible to interference, particularly in the case of fast-moving mobile stations.

continued next month

* In modern data communications, the symbol replaces the baud as the unit of transmitted data. Like the baud, a symbol may (and frequently does) represent more than one data bit.

COMPONENTS LIST

Main computer board

Resistor:

R1 = 8k Ω 2

Capacitors:

C1,C2 = 22pF

C3-C6,C13,C14,C15 = 100nF

C7-C11 = 10 μ F 16V radial

Semiconductors:

IC1 = 80C32

IC2 = 74HC573

IC3 = 62256 RAM

IC4 = 27256 (BASIC EPROM,
986503-1)

IC5 = 27128

IC6 = 74HC00

IC7 = MAX232

Miscellaneous:

K1 = 20-way SIL pinheader with
long pins (Fischer SL5 156 20 G)

X1 = 11.0592MHz quartz crystal

JP1 = 3-way pinheader w. jumper

K2,K3 = 14-way SIL pinheader with
long pins (Fischer SL5 156 14 G)

K4 = 9-way sub-D socket (female),
PCB mount, angled pins.

Order codes for available products:

Main computer board: **980002-1**

Multifunction extension board:

980002-2

Diskette (example programs and Ter-
minal program): **986007-1**

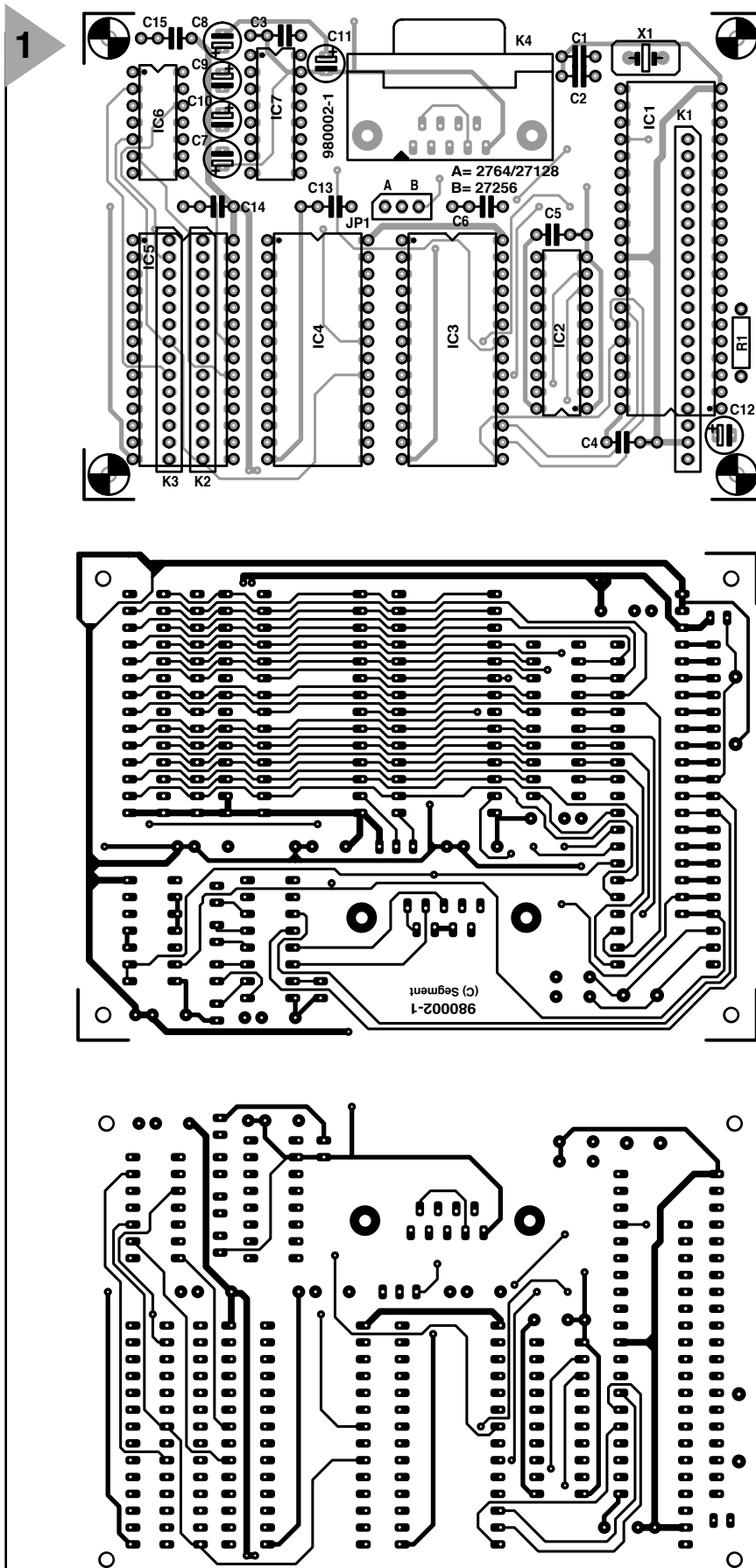
EPROM loaded with MCS51-BASIC:

986503-1

For prices and ordering information,
please refer to the Readers Services
pages elsewhere in this issue.

installed, and not connected to the main computer board. Carefully check the presence of the 5 V supply voltage on all IC sockets. Switch off, and insert IC4 on the extension board. Fit jumper JP1 and apply power. LED D5 should light at this stage, and go out for about 3 s when the reset switch, S1, is pressed. If JP1 is removed, then D5 flashes at an interval of 10 s. If this works so far, you may insert all other ICs (watch their orientation).

The main computer board is also tested step by step. Having checked the supply voltage, and switched off again, you may insert the CPU into its socket. Switch on again, and use an oscilloscope to verify that the CPU oscillator comes alive (CPU pins 18 and 19). Pin 11 of the socket for IC2 should supply a periodic signal. Switch off and insert IC2, IC3, IC7 and IC4 (the EPROM programmed with the MCS-51 BASIC interpreter). Next, hook up a PC to K4, using a null-



modem cable. Run a terminal emulation program like HyperTerminal, Telix or Procomm on the PC. Press the reset switch, S1, and then the spacebar on the PC keyboard. The welcome message

Figure 1. The main computer is accommodated on this board, which is fitted on top of the multifunction extension board.

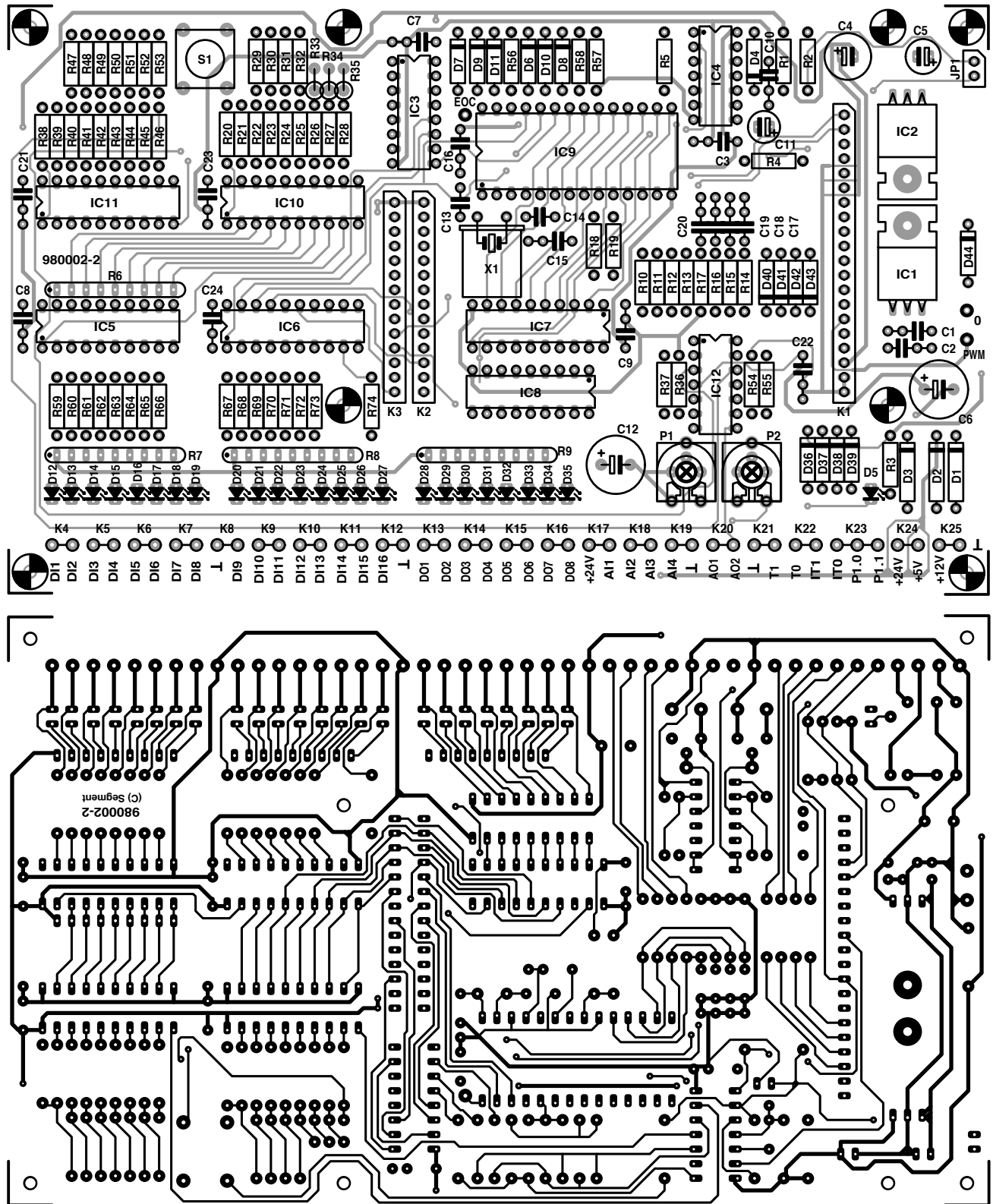


Figure 2. Multifunction extension board featuring digital and analogue I/O as well as some auxiliary functions.

COMPONENTS LIST

Multifunction extension board

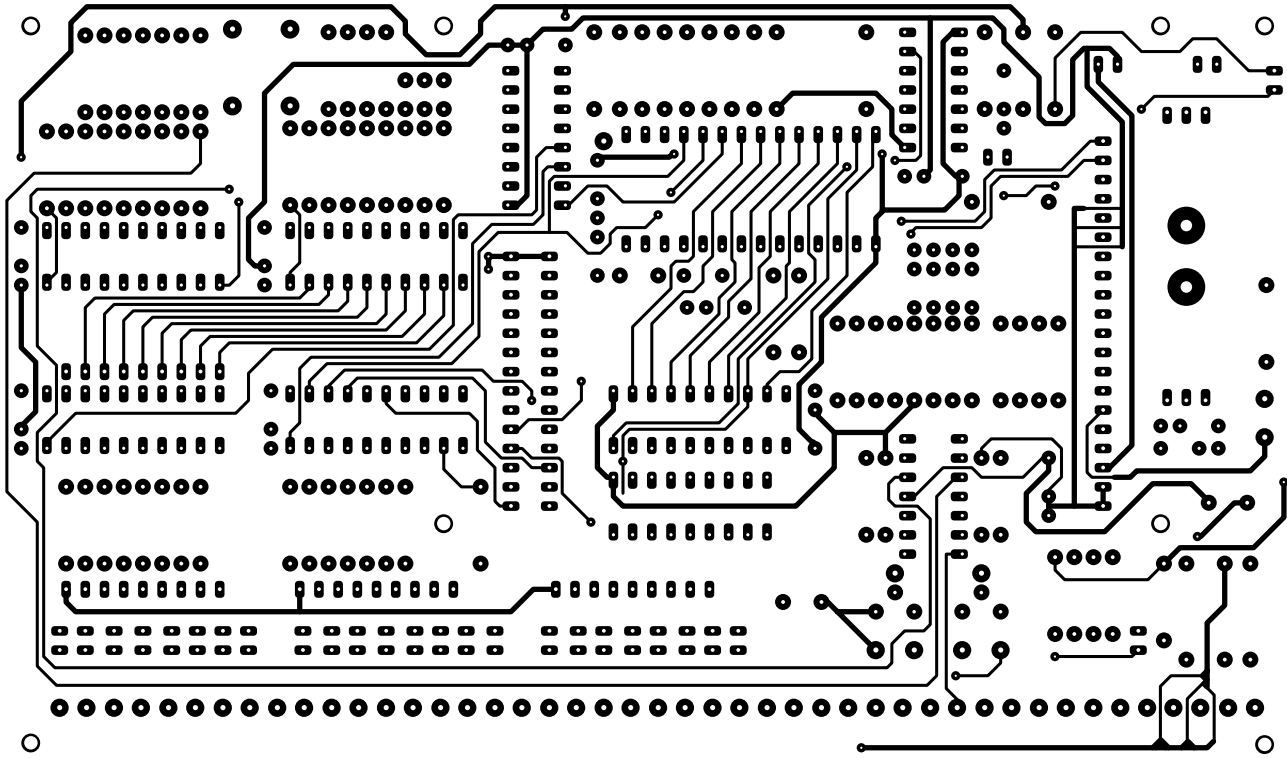
Resistors:

R1,R4,R10-R17 = 220k Ω
 R2,R36,R37,R54,R55,R59-R74 = 100k Ω
 R3 = 1k Ω
 R5 = 1k Ω

R6 = 8-way 4k Ω 7 SIL array
 R7,R8 = 8-way 820 Ω SIL array
 R9 = 8-way 1k Ω 5 SIL array
 R18,R19 = 10k Ω 1%
 R20-R28,R38-R46 = 200k Ω 1%
 R29-R35,R47-R53 = 100k Ω 1%
 R56,R57,R58 = 47k Ω
 P1,P2 = 100k Ω preset (optionally multiturn)

Capacitors:

C1,C2,C3,C7-C10,C16,C21-C24 = 100nF
 C4 = 100 μ F 16V radial
 C5 = 47 μ F 16V radial
 C6,C12 = 100 μ F 40V radial
 C11 = 33 μ F 10V radial
 C13,C14 = 22pF
 C15,C17-C20 = 15nF



***MCS-51(tm) BASIC V1.1**

READY > should appear on the display. On being powered up, the CPU checks the size of the available RAM (memory top), and indicates it if you type **>PRINT MTOP**. The BASIC interpreter is now ready to run your application programs. Its complete instruction set may be found on the datasheet pages in last month's issue.

TERMINAL SOFTWARE

The project diskette, order code **986007-1**, contains a number of test, auxiliary and example programs, which are briefly described in the inset. The disk also contains extensive descriptions of the programs. The programs may be burned into EPROM IC5, or downloaded to the 80C32 computer using one of the terminal programs mentioned above.

The author has supplied a terminal emulation program called Terminal-MCS-51, which aims to meet the specific requirements of the 80C32 BASIC computer and other MCS51-BASIC systems. This program enables simple downloading, storing and renumber-

ing (only in the full version) of MCS51-BASIC programs. It also comprises an MCS51-BASIC line editor and allows any ASCII word processor to be embedded. A shareware version of this program may be found on the project diskette supplied through the Readers Services or a kit dealer.

Alternatively, use the terminal program that comes with Windows to establish communication with the 80C32 BASIC computer. In general, all you have to do is select the communications port and the protocol. Then you press the reset button, followed by any key on the PC keyboard. The 80C32 computer will report back with the message *MCS51 ...* (depending on the BASIC version) and *READY>*. Next, you may type in a line of (syntactically correct and hopefully meaningful) BASIC, and send it to the 80C32 computer by pressing the Enter key. The BASIC interpreter on the 80C32 computer turns the received ASCII text into 'tokenized' BASIC, and returns the **>** prompt to the PC to signal that it is ready to accept a new line.

If you use **Terminal.exe** under **Windows 3.1**, go to Settings/Communication and set up this protocol: up to

19,200 bits/s (the highest speed depends on the serial cable), 8 data bits, no parity, 1 stop bit. Select: Flow control: none. Under *Settings, Text Transfer*, enable the options *Line at a time* and *Wait for prompt string*. Enter **^M>** for this prompt, where **^M** stands for 'carriage return' and **>** for the prompt returned by the MCS51 BASIC interpreter. This setting is extremely important because the MCS-51 BASIC interpreter needs some time to tokenize (evaluate) the received text.

HyperTerminal which comes with **Windows 95** is set up in a slightly different way. Run the program (Start/Programs/Accessories) and first think of a name and select an icon for the communication sessions with the BASIC computer (**Figure 3**). If no modem is installed on the PC, the *Modem Wizard* is automatically launched. Do not select a modem! Quit the Wizard by pressing 'cancel'. You are then allowed to create a new connection. Use 'direct to COMx' (x = 1-4) and select the right COM port. To make sure you use a free COM port, check the relevant information in the *System Control Panel (Start/Control Panels/System/Device Manager/Ports)*. Unfor-

Semiconductors:

- D1,D2,D3 = 1N4001
- D4,D6-D11,D36-D43 = 1N4148
- D5,D12-D35 = LED
- D44 = 5V6 zener diode
- IC1 = 7808
- IC2 = 7805
- IC3 = 74HCT139
- IC4 = 74HCT14

- IC5,IC6 = 74HCT541
- IC7,IC10,IC11 = 74HCT574
- IC8 = ULN2803
- IC9 = UPD7002C (NEC) (Farnell)
- IC12 = LM324

Miscellaneous:

- S1 = switch, single-pole make contact, CTL3
- JP1 = jumper

- K1 = 20-way SIL socket (Fischer BL5 20 S)
- BZ1 = buzzer 5V
- X1 = 2.4576MHz quartz crystal
- PC1 = PCB solder pin
- K2,K3 = 14-way SIL socket (Fischer BL5 14 S)
- K4-K25 = 45 PCB solder pins or 5 off 9-way PCB terminal blocks (pitch 3.5mm, Lumberg type KRMC9)

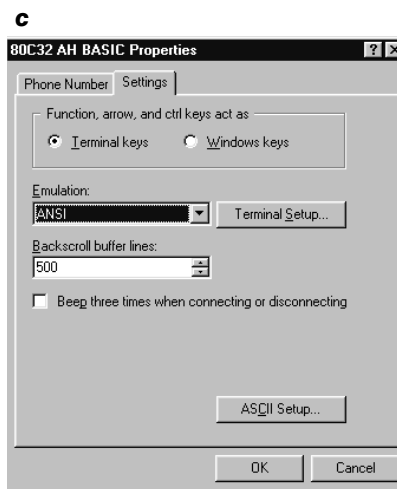
fortunately, this screen will not tell you to which COM port the mouse is connected, so some experimenting may be in order if you can't tell from the labels at the rear of the computer. If a modem is installed on your computer, the Wizard is not started. In that case, select *direct to COM* instead of '[modem type]'. The *Modems Control Panel* will then also reveal the mouse connection (use *Diagnostics*).

Once the COM port has been selected, a window appears showing the port settings. The required communication parameters are identical with those for Windows 3.1 (see above). The *Advanced* button in this window is not relevant to our application. Once the connection with the BASIC computer has been defined, all relevant settings are recalled simply via the *File/Open* menu.

Now, select *Properties* from the *File* menu, then the *Settings* tab. Check *ANSI Terminal Emulation*. Press the *ASCII Setup* button, and enter '500' for *Line Delay*. Although a value of 400 ms also worked during our lab tests, smaller values are bound to cause problems with the tokenizing of relatively long BASIC lines. Unfortunately HyperTerminal does not allow the data exchange to be synchronized by a specific character sequence (like the MCS-51 prompt). Consequently, communication with the 80C32 BASIC computer will be slower than with Terminal running under Windows 3.1.

(980002-2)

3



What's on the disk?

The program **CLOCK.LIS** (background clock) with watchdog timer shows how an Ontime interrupt may be used to generate a pulse for the watchdog timer. The clock may run in the background of your main program. To be able to use it, the clock program has to be stored in a boot EPROM (IC5) on the computer board, and jumper JP1 on the multifunction board has to be removed. An INPUT instruction is not allowed in your program, because the Ontime interrupt is then no longer serviced, causing the system to be reset. Input into the running program is then only possible by means of the GET instruction, which is also used to adjust the clock. The keys on the terminal (console) then have the following functions:

H	increase hours
h	decrease hours
M	increase minutes
S	increase seconds
s	decrease seconds
T	increase day
t	decrease day
W	increase day of the week
w	decrease day of the week
O	increase month
o	decrease month
J	increase year
j	decrease year

The program **DO-DI.LIS** (digital-out, digital-in test) performs a cyclic count from 0 to 255 on the digital output port. The output value may be read back via one of the two input ports. As

a matter of course, that requires fitting eight wire links between the relevant inputs and outputs.

The program **DA-AD.LIS** (digital-analogue / analogue-digital test) produces output voltages on the two D-A channels. These voltages may be read back via the A-D channels. This is achieved by first adjusting the two D-A outputs to +5 V using presets P1 and P2. The program writes the highest value, 255, to the relevant D-A outputs and then prompts you to do the adjustment. To perform this test, you obviously have to link the respective D-A (output) and A-D (input). Next, the output value of channel 1 is indicated, along with the current values of all four A-D channels.

The other programs on the disk are not specifically designed for the 80C32 BASIC computer described in this article. Rather, they are intended for MCS-51 BASIC boards in general. The program **ROMCOPY.LIS** (see also *Elektor Electronics* September 1990) extracts the 8-kByte large BASIC interpreter from the ROM of an 8052AH-BASIC chip, and copies it into an EPROM. Alternatively, you may find the interpreter on the Internet, Intel having released it in the freeware domain! The source code (*BASIC52.ZIP* or *BASIC-52.ZIP*) may be downloaded from the Intel ftp server at

<ftp://intel.com/pub/mcs51/tools>

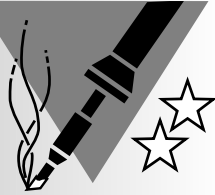
or

<ftp://funet.fi/pub/microprocs/MCS-51/signetics-bbs>

The latter server also supplies the file *BASIC31.ZIP*, which

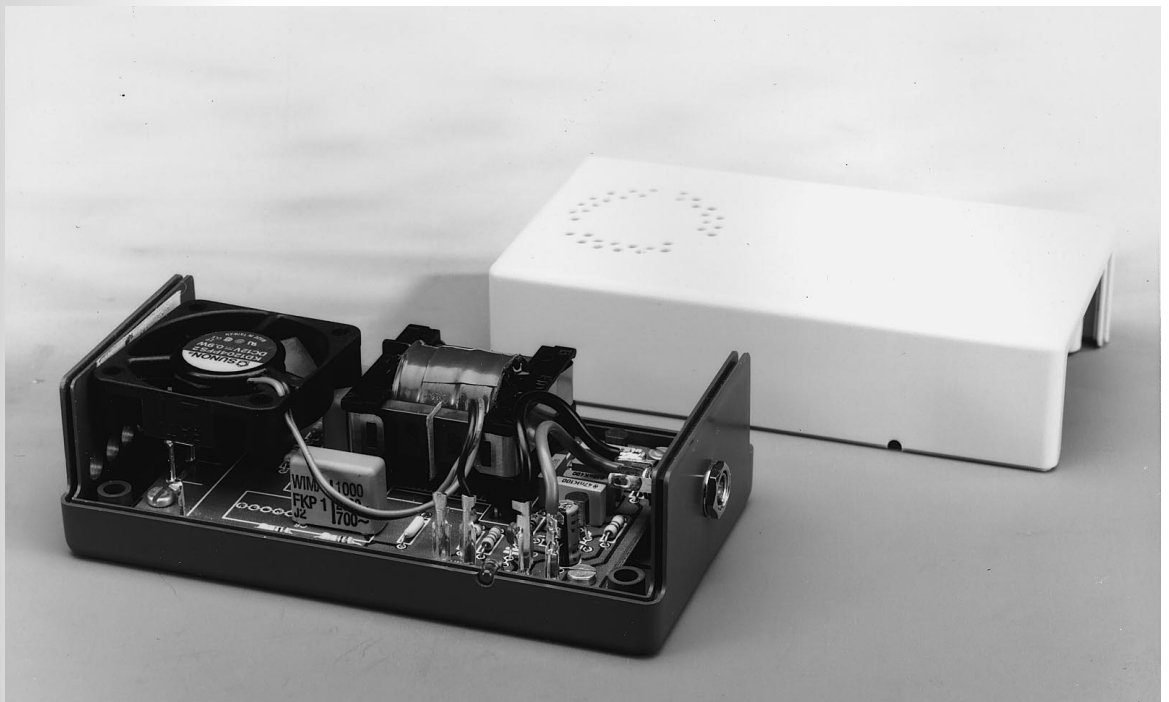
does basically the same as *ROMCOPY.LIS*.

Finally, the disk contains a file called *EPROM.LIS*, which turns the control computer into an EPROM programmer. For that function, however, certain hardware conditions have to be satisfied.



ionization circuit

***do negatively charged ions
improve the quality of life?***



Do you suffer from recurring headaches, chronic tiredness or a general feeling of being (slightly) unwell? It may well be that in your home or place of work there is an imbalance between positively charged ions and negatively charged ions. Although not medically proven, it appears that some people are adversely affected by a surplus of positively charged ions. The balance may be restored by the present circuit, which form a simple means of producing negatively charged ions. This addition to the range of alternative medicine may help sufferers, but readers with the symptoms described are well advised to seek the help of a qualified medical practitioner.

In this article, the definition of an ion (there are several) is 'an electrically charged atom or group of atoms. Positively charged ions have a deficiency of electrons, and negatively charged ions have a surplus of electrons'. Some people say that in gases the negatively charged ions are, in fact, free electrons, while the positively charged ions are the remaining parts of the atom where most of the mass resides.

In air, there is normally a balance between negatively charged ions and positively charged ions, but in some circumstances this balance is disturbed. Some people seem to be affected by this, as shown, for instance, by the fact that they feel (more) pleasant or more alive in the vicinity of waterfalls and in 'air spas'. Is this psychosomatic, coincidence, or what?

This phenomenon can also be observed after a thunderstorm, when some people have an overwhelming desire to go for a brisk walk in the 'fresh air' (this may also be due to the

Design by H.Bonekamp

Figure 1. The oscillatory voltage is raised by $\times 60$ by transformer Tr_1 . After the secondary voltage has been rectified and doubled, a direct voltage of about 3 kV is available.

fact that a thunderstorm drives all dust particles from the air, so the air is 'cleaner').

The reverse can also be seen in Mediterranean countries where some people feel nervous or depressed when the mistral (cold northerly or northwesterly wind) or the Föhn (warm dry wind on the ice side of mountains) blows. These weather conditions frequently (but not always) go hand in hand with high concentrations of positively charged ions. The people who appear to be sensitive to the imbalance of ions say that they feel the effect not only out of doors but also indoors. There are people who maintain that certain buildings exude a 'bad air'. Again, there is no impartial evidence for these sensations.

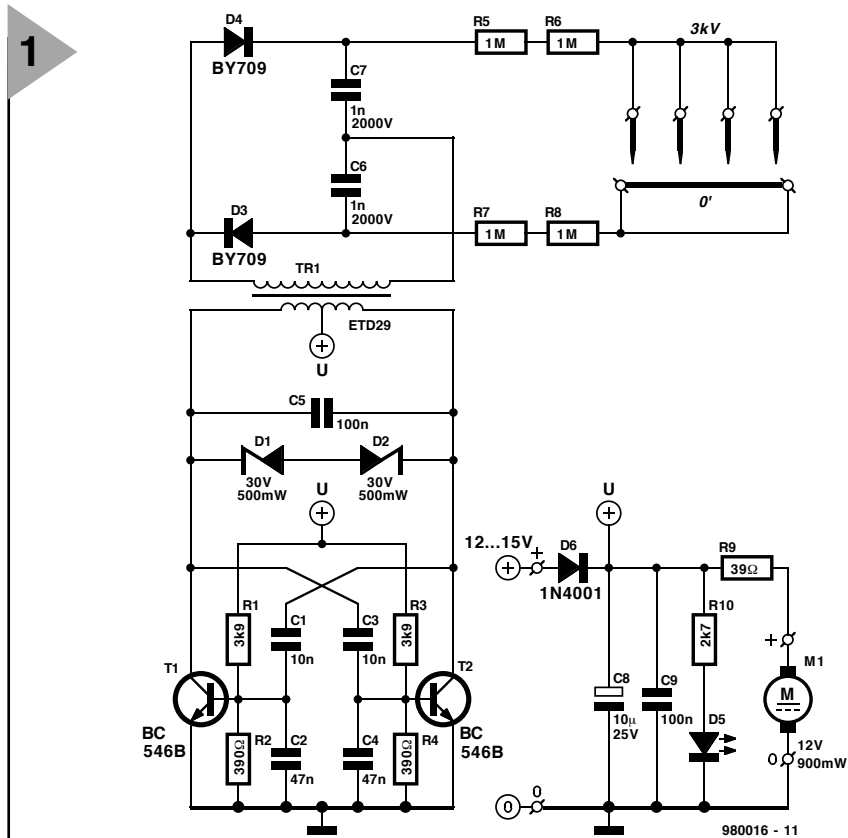
POSSIBLE REMEDIES

If you suffer at home or at work from feelings of discomfort or difficult-to-define ailments, it may not always be necessary to rush to the doctor. Maybe the culprit is the atmosphere (which may be dusty or humid) in the building. Often, this may be improved by added or improved ventilation. Fresh air not only provides more oxygen, but also tends to contain more negatively charged ions.

Unfortunately, it is not always possible to add or even improve the ventilation. In air-conditioned buildings, windows often cannot be opened (if the air-conditioning is sound, this should, of course, not be necessary) and cold or wet weather outside may also prevent the opening of windows. (It may be argued, of course, that good ventilation should not depend on open windows). In these circumstances, some people may like a source of negatively charged ions and this is provided by the present circuit.

VERY HIGH VOLTAGE

With the aid of a strong electric field,



it is possible to ionize the air and so produce negatively charged ions. In the present circuit, the field is produced with the aid of four electrodes that carry a direct voltage of about 3 kV. Owing to the small diameter of the electrodes, there is such a strong electric field around their pointed ends that the spray effect, typical of ionization, occurs. Because of the effect, dislodged electronics fly away in all directions. After they have travelled only a short distance, they collide with air molecules and ionize them. Since oxygen molecules also become ionized, ozone (triatomic oxygen, O_3) is formed. However, because the potential is not very high, the amount of ozone is not great. Nevertheless, use of the ionizer is not recommended in the vicinity of asthma sufferers. Also, do not place the ionizer too close to where humans sit, since even a small amount of reactive ozone may cause irritation of the respiratory system.

The ionizer has a secondary function: the dislodged electrons not only ionize air, but also give dust particles an electric charge. Such charged particles are deposited on the ionizer and its immediate vicinity. This removal of

particles in the air is applied in some industries to remove soot from smoke gases.

CIRCUIT DESCRIPTION

The high direct voltage is generated by a Meissner oscillator.—see **Figure 1**. In this, feedback is arranged via a transformer, which has an additional high-voltage winding that provides a potential of about 3 kV.

The circuit is based on transistors T_1 and T_2 , and transformer Tr_1 which is connected between their collectors. The requisite positive feedback for the oscillator so created is provided by capacitive potential dividers C_1 - C_2 and C_3 - C_4 . The d.c. operating point of the transistors is set with resistors R_1 - R_4 .

The tuned circuit of the oscillator is formed by the primary winding of Tr_1 and capacitor C_5 . The resonance frequency is about 50 kHz. With a supply line of 12 V, the oscillatory voltage across the primary is about 25 V per branch. Zener diodes D_1 and D_2 prevent this voltage from exceeding too high a level. Networks R_2 - C_2 and R_4 - C_4 provide the requisite time constants and determine the operation of the transistors, that is, the level of the

Parts list

Resistors:

$R_1, R_3 = 3.9 \text{ k}\Omega$
 $R_2, R_4 = 390 \Omega$
 $R_5\text{--}R_8 = 1 \text{ M}\Omega, 1.6 \text{ kV d.c.}$
 $R_9 = 39 \Omega$
 $R_{10} = 2.7 \text{ k}\Omega$

Capacitors:

$C_1, C_3 = 0.01 \mu\text{F}$, metallized polyester (MKT)
 $C_2, C_4 = 0.047 \mu\text{F}$, metallized polyester (MKT)
 $C_5 = 0.1 \mu\text{F}$, metallized polyester (MKT)
 $C_6, C_7 = 0.001 \mu\text{F}$, 2 kV d.c.
 $C_8 = 10 \mu\text{F}$, 25 V, radial
 $C_9 = 0.1 \mu\text{F}$, high-stability

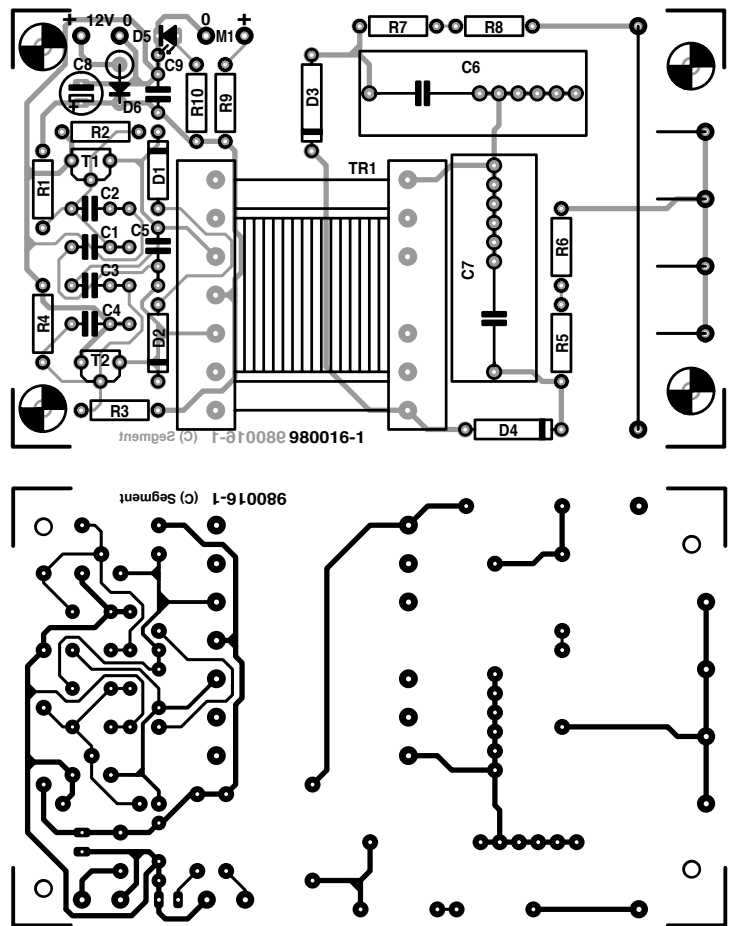
Semiconductors:

$D_1, D_2 =$ zener diode, 30 V, 500 mW
 $D_3, D_4 =$ high-voltage silicon diodes, e.g., Type BY709 (Philips Components)
 $D_5 =$ LED, red, high efficiency
 $D_6 = 1\text{N}4001$
 $T_1, T_2 = \text{BC}546\text{B}$

Miscellaneous:

$M_1 =$ miniature fan, 12 V, 900 mW, 40×40×10.5 mm
 ETD29 former with N27 cores
 Enamelled copper wire as described in the text.
 Plastic enclosure, e.g., Bopla E430

2



current pulses driving them.

The turns ratio of the transformer ensures that the potential across the secondary winding is about $\times 60$ that across the primary. This potential is rectified and doubled by high-voltage diodes D_3 – D_4 and capacitors C_6 – C_7 .

Ionization takes place around the 'electrodes' formed by four lengths of

wire placed at a distance of about 2 mm from the 'mother electrode'. Resistors R_5 – R_8 reduce the risk to life if the electrodes are accidentally touched.

Network R_{10} – D_5 forms an on/off indicator.

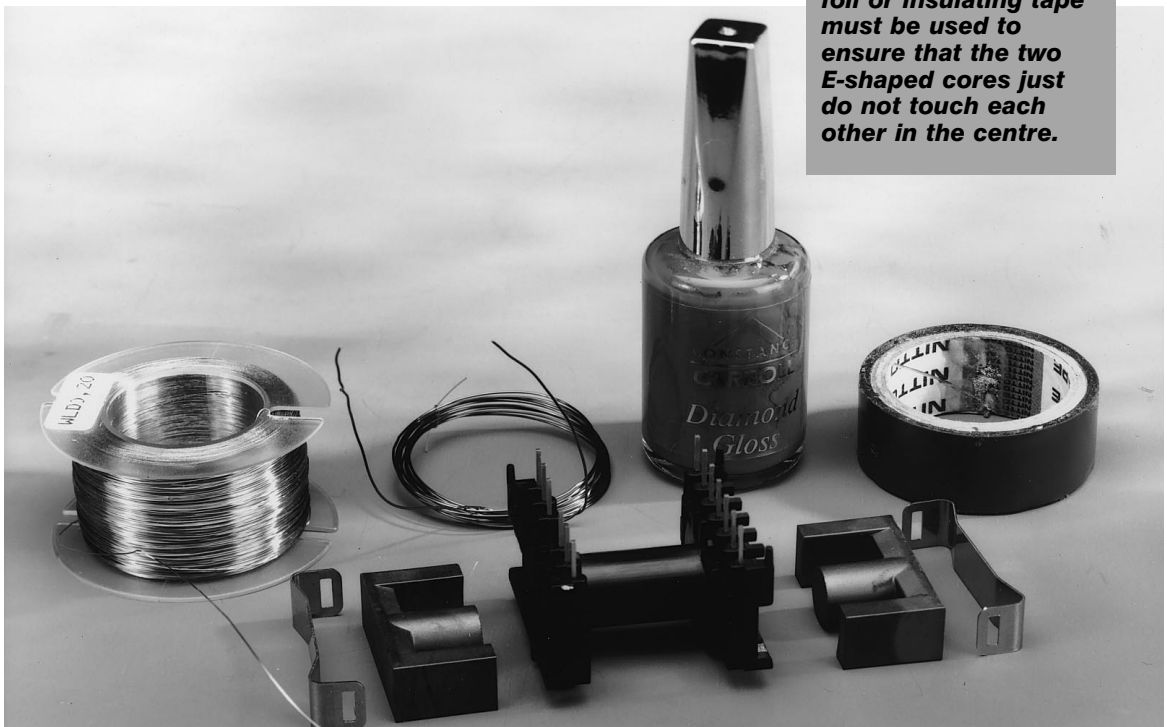
Capacitors C_8 and C_9 are decoupling elements.

Diode D_6 provides protection

Figure 2. The printed-circuit board for the ionizer, which is however, not available ready-made.

Figure 3. The requisite parts for making the transformer. Plastic foil or insulating tape must be used to ensure that the two E-shaped cores just do not touch each other in the centre.

3



4

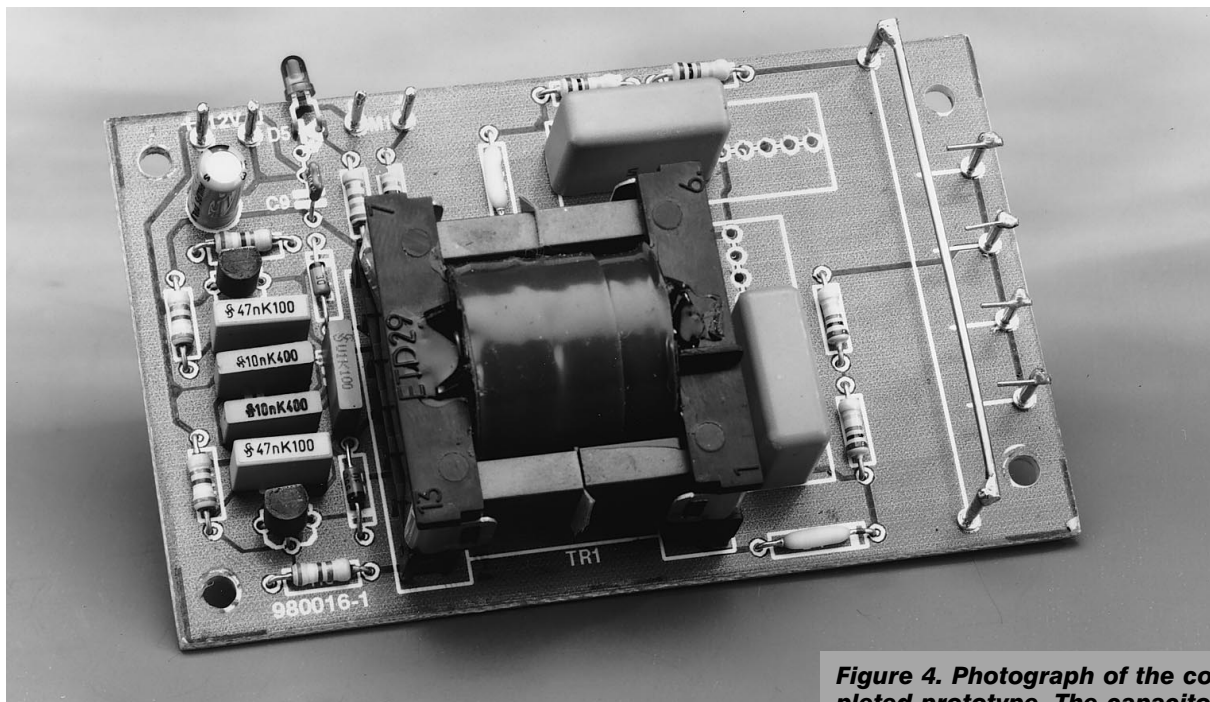


Figure 4. Photograph of the completed prototype. The capacitors used in the C₆ and C₇ positions are fairly small and occupy only half of the available space for them on the board.

against wrong polarity.

Fan M₁ provides better dispersion of the exigent electrons. Series resistor R₉ ensures that the fan does not make too much noise while still displacing sufficient air.

The circuit may be powered via a 12 V or 15 V standard mains adaptor, which need not be a heavy-duty type, since it draws a current of only about 150 mA.

CONSTRUCTION

The ionizer is best built on the printed-circuit board shown in **Figure 2**. Populating the board should prove straightforward. Plenty of space has been reserved for high-voltage capacitors C₆ and C₇, so that a variety of types may be used for these components. These capacitors should have a working voltage rating of not less than 2 kV d.c.

The reverse bias rating of diodes D₃ and D₄ as specified is 14 kV, but lower rated types, down to 4 kV, may be used as long as their recovery time does not exceed 0.2 μs.

The 'electrodes' are mounted on solder pins and may be made from 1–1.5 mm dia. circuit wire (mother electrode: 54 mm long) or 0.6 mm dia. (slave electrodes: 7 mm long). The slave electrodes may be filed to a sharp point, but this is not essential. The distance

between the electrodes must be 2 mm.

TRANSFORMER

Unfortunately, transformer Tr₁ cannot be purchased ready-made. It is wound on a Type ETD29 former which contains two E-shaped Type N27 cores—see **Figure 3**. Laying the windings is not difficult but time-consuming.

The secondary winding consists of 900 turns enamelled 0.2 mm dia. copper wire in 12 layers of 75 turns each. Place a short length of insulating sleeve over the start of the winding and solder this to the outer pin (1) of the former.

Each layer must be well insulated from the adjacent one(s) by two layers of appropriate tape. Note that more than two layers make the winding too fat and one provides insufficient insulation. Seal the edges of each layer as well as the sides of the completed winding with nail varnish or similar.

When the winding has been completed, place a short length of insulating sleeve over the the end of the wire and solder this to pin 6 of the former.

Cover the secondary winding with an additional layer of insulating tape and lay the primary winding on top of this. The primary consists of 14 centretapped turns of 0.4 mm dia. enamelled copper wire. Solder the start of the wire to pin 9 on the former, lay seven

turns and solder the wire, without cutting it, to the centre pin (10). Next, lay the remaining seven turns in the same direction as the first seven and solder the end to pin 11. Wind a double layer of insulating tape over the primary winding.

Finally, push the two E-shaped cores into the former after taping a double layer of insulating tape on the two outer edges of one of the cores. This ensures an air-gap between them of about 0.25 mm. Subsequently, clamp the assembly together with two spring clips and solder the transformer on to the board.

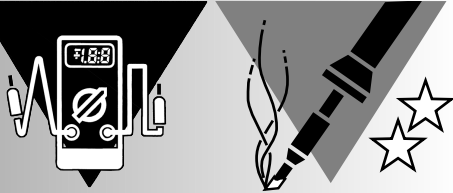
A photograph of the completed board is shown in **Figure 4**.

FINALLY

In view of the necessary safety measures, the ionizer must be housed in a strong, plastic enclosure. This must, of course, be provided with fixing holes for the on/off indicator and a number of holes for air inlet and ion outlet.

Fit the fan just above the electrodes with either plastic screws and nuts or strong double-sided sticky tape. Look at the introductory photograph.

[980016]



IC tester

Part 1: circuit description and construction



This article describes a stand-alone IC tester for logic ICs (with up to 24 pins) from the well-known 74xx (TTL) and 40xx (CMOS) series. The elementary building blocks that make up the design are an 80C535 microcontroller, a large EPROM, an LCD display, a small keyboard and an RS232 interface. In this first instalment, our main subjects will be hardware-related.

This design was awarded the International First prize in the Elektor Electronics 1997 Design Competition. A condensed description of the project appeared in the January 1998 Supplement on prize-winning contest entries.

In the January 1998 issue we promised a full-blown and tested version of the IC Tester, complete with PCB layouts and a ready-programmed GAL and EPROM. Many of you will have eagerly looked forward to the present article, which, we hope, lives up to expectation.

The IC tester is a fairly complex project, and an interesting combination of mixed-mode (analogue/digital) electronics on the one hand, and software (microprocessor as well as PC-hosted), on the other. The IC tester is capable of working in stand-alone mode, i.e., any connection to a PC is entirely optional. The standard version of the tester is capable of testing all ICs listed in **Table 1**. A number of software utilities are available which allow advanced users to add ICs to the library as listed in Table 1, and this subject will be covered in detail in part 2 of this article. We do, however, reckon that the 'default' library will be sufficient in the majority of cases — extending it with 'new' devices is specialist work!

This tester is a great tool for anyone who's ever had to do go/non-go testing on a vast amount of integrated circuits from the '74' TTL and '4000' CMOS series. These ICs are still extensively used by hobbyists because (1) they can often be salvaged from surplus equipment or bought 'ten a penny' or at least at knock-down prices, and (2) their datasheets are widely available, so you know how to use them in a design of your own. As a matter of course, the tester is also perfectly suitable for use in an electronics repair shop, where it will be necessary from time to time to check suspect devices. Lastly, the IC tester may also be used to identify unknown ICs, i.e., those with obscure print or a label someone painstakingly ground off...

HOW IT WORKS

The circuit diagram of the IC tester is shown in **Figure 1**. It may be divided into a digital control (microcontroller) section, a precision power supply, an RS232 interface, a zero-insertion-force (ZIF) socket (which receives the device under test, DUT), a keyboard section, an LCD and a power supply.

Design by L. Lamesch

Around the DUT

Let's start with a look at the electronics around the ZIF socket, position IC12. All input pins of the DUT inserted in the zero-insertion force socket may be pulled to the logic high (H) or logic low (L) level using current limiting resistors and appropriate control levels at the outputs of two Z80PIO I/O blocks, IC2 and IC4. The output states of the DUT may be interrogated via the same PIOs for subsequent evaluation by the CPU (IC3). The power supply pins of DUTs with 14, 16, 18, 20, 22 and 24 pins may be connected to ground or a current-limited supply voltage via BC639/BC640 switching transistors. These are controlled by outputs on counter cascade IC1-IC9. While the PIOs enable the exact logic states of the DUT outputs to be checked (i.e., 0 or 1), ports P1, P4 and P5 of the 80C535 are used to detect which DUT pins represent a high impedance (high-Z).

DUT power supply

The voltage source used to power the DUT is built around quad opamp IC6. It supplies an accurately regulated voltage of 5.2 V, and its output current is limited to about 0.2 A. The output current is converted into a proportional voltage for measurement by the

80C535 CPU via its AN0 (analogue) input. The current-sense resistors are R94 and R95. The output voltage is 5.2 V rather than 5.0 V (the typical supply voltage of all TTL ICs) in order to compensate the collector-emitter drop of the BC640 transistors when they are switched on.

Logic circuitry and firmware EPROM

The control program of the IC tester and the test vectors for the ICs that may be tested are contained in a single 27C512 EPROM, which may be obtained ready-programmed from the Publishers under order code **986507-1**. Larger (32-pin) EPROMs like the 27C020 or 27C021 may also be used in this design. For the 27C021 EPROM, jumper JP1 has to be set to the A17 position. More about this in next month's concluding instalment. The selection between the 64-kByte banks in the EPROM is accomplished by outputs B6 and B7 of IC2. These lines are applied to GAL IC5, which contains logic to control the A16 and A17 address lines of EPROM IC7. Basically, when a 28-pin EPROM is used, JP1 is set to the bevelled edge position ('A'). When a 32-pin EPROM is used, the A17 signal is required, so JP1 is set to the other position.

The 80C535 CPU runs at a clock speed of 12 MHz. The CPU does not contain firmware code, and fetches all

of its instructions and data from the system EPROM. None the less, it directly controls the LC display and a keyboard with 6 keys. The GAL, IC5, looks after the address decoding, and also generates the PHI signal for the Z80PIOs, as well as other essential control signals in the circuit. The GAL, like the EPROM, is supplied ready-programmed by the Publishers, the order code is **986506-1**.

The reason for using the Z80PIO to control and monitor the DUT inputs and outputs is that this chip is the only widely available 16-bit parallel port IC of which all port line directions are individually controllable, while the output drivers for all port lines consist of push-pull circuits.

User I/O

The system interacts with the user via a small keyboard (circuit diagram in Figure 2), an LED, D6, and an LCD (liquid crystal display). The LCD is a general-purpose type with 2↔16 characters, optionally with back-lighting. Its contrast is adjustable with preset P1. The LED lights to inform the user that the DUT is being powered and should not be removed from the ZIF socket.

An RS232 serial interface, traditionally designed around the MAX232, enables the IC tester to (optionally)

Table 1. Index of ICs that may be tested (default EPROM contents)

Library: 74xxx	74:38	74:139	74:239	74:386*	74:596*	74:758	74:7541*	4050**	40161	
74:00	74:39*	74:140*	74:240	74:390	74:620*	74:759*		4051	40162	
74:01*	74:40	74:147	74:241	74:393	74:621*	74:760*	Library: 40xxx	4052	40163	
74:02	74:42	74:145*	74:242*	74:412	74:622*	74:762*	4001	4053	40174	
74:03	74:45	74:148	74:243	74:425*	74:623*	74:763*	4002	4056	40175	
74:04	74:46*	74:150	74:244	74:426*	74:638*	74:810*	4009*	4060	40192	
74:05	74:47	74:151	74:245	74:445*	74:639*	74:811*	4010*	4066	40193	
74:06	74:48*	74:153*	74:247*	74:447*	74:640	74:1000*	4011	4067	40194	
Parent: 74:05	74:49*	74:154	74:248*	74:465*	74:641*	74:1002*	4012	4068 -RCA*	4502	
74:07	74:51 St,S*	74:155	74:249*	74:466*	74:642*	74:1003*	4013	4068 RCA*	4508	
74:08	74:51 LS,L	74:156*	74:250*	74:467*	74:643*	74:1004*	4014*	4069	4510	
74:09	74:54*	74:157	74:251	74:468*	74:644*	74:1008*	4015	4070	4511	
74:10	74:55*	74:158*	74:253	74:518*	74:645	74:1010*	4016	4071	4512	
74:11	74:73	74:159*	74:257	74:519*	74:646	74:1020*	4017	4072	4514	
74:12*	74:74	74:160	74:258*	74:520*	74:647*	74:1032*	4019	4073	4515*	
74:13	74:75	74:161	74:259	74:521	74:648*	74:1034*	4020	4075	4516*	
74:14	74:76	74:162	74:260*	74:522*	74:649*	74:1035*	4021	4076	4518	
74:15*	74:83	74:163	74:266	74:533*	74:668*	74:1036*	4022*	4077	4520	
74:16	74:86 -C,-L	74:164	74:273	74:534*	74:669*	74:1240*	4023	4078 -RCA*	4522	
74:17	74:86 C,L*	74:165	74:280	74:540*	74:670	74:1244*	4024	4078 RCA*	4526	
74:18*	74:90	74:166	74:283	74:541	74:682	74:1245*	4025	4081	4529	
74:19*	74:92	74:168*	74:290*	74:563*	74:683*	74:1640*	4027	4082*	4539	
74:20	74:93	74:169	74:293	74:564*	74:684	74:1645*	4028	4093	4543*	
74:21	74:95A,B	74:170	74:299	74:573	74:685*	74:2240*	4029	4094	4555	
74:22*	74:100	74:173	74:323	74:574	74:688	74:2241*	4030	4099*	4556*	
74:24*	74:107	74:174	74:347*	74:576*	74:689*	74:2244*	4040	40014*	4584	
74:25	74:109	74:175	74:348*	74:580*	74:699	74:2540*	4041*	40102	4724	
74:26	74:119	74:180*	74:352*	74:590	74:746**	74:2541*	4042	40103		
74:27	74:125	74:184*	74:353*	74:591*	74:747**	74:7245*	4043	40105		
74:28*	74:126*	74:185*	74:365	74:592	74:756*	74:7266*	4044*	40106		
74:30	74:128*	74:190	74:366*	74:595	74:757*	74:7540*	4049**	40160		
74:31*	74:131*	74:191	74:367							
74:32	74:132	74:192	74:368*	*	Test vector for this IC not yet verified with a correctly operating IC.					
74:33	74:133*	74:193	74:373	**	This IC has not been fully tested using the IC test vectors.					
74:34*	74:136*	74:194	74:374	:	Any TTL family identifier, except if the type number has a suffix.					
74:35*	74:137	74:237*	74:375	-X	Test vectors not valid for X family device of this IC (e.g. 74:86 -C means not for 74C86).					
74:37	74:138	74:238*	74:377*	X	Test vectors apply only to X family device of this IC (e.g. 74:86 C means for 74C86 only).					

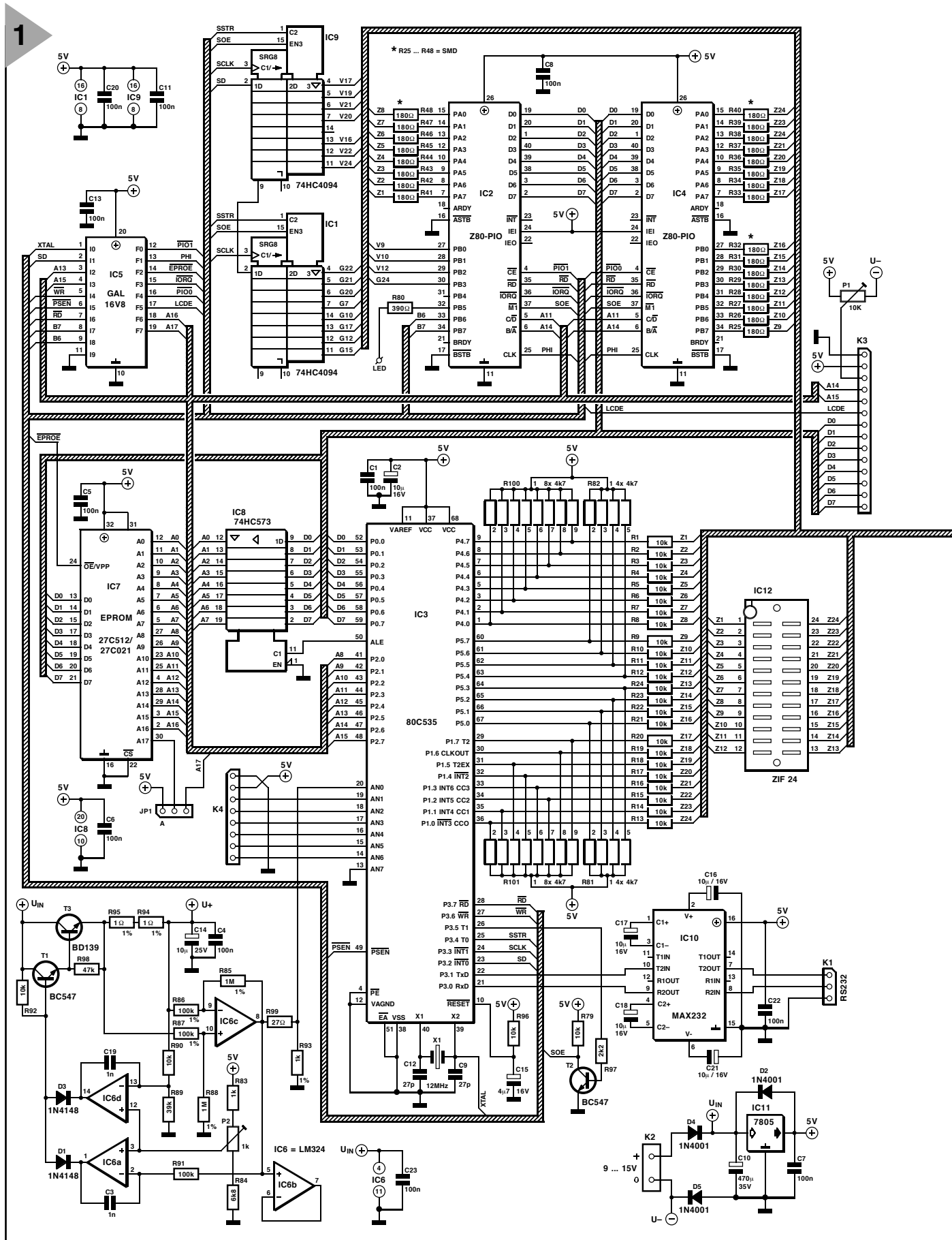
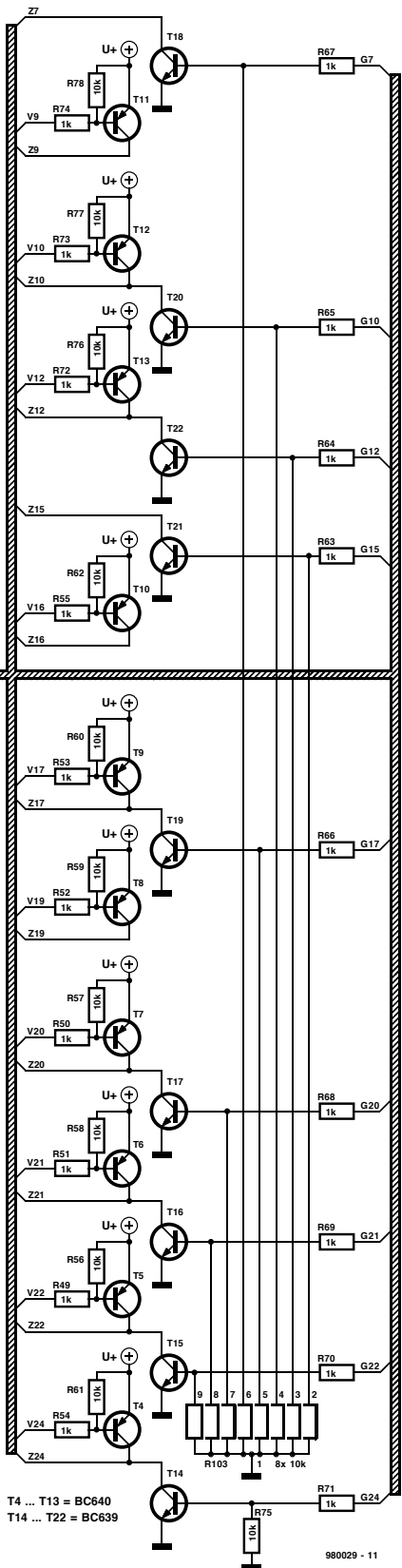


Figure 1. Circuit diagram of the IC tester, an interesting mixed-mode design based in the powerful 80C535 microcontroller from Siemens.

communicate with a PC running specially written programs. Details on these programs will be given in next month's final instalment. Briefly, the PC may be used to write your own IC

test vectors and debug them without removing the system EPROM. The link between the 9-way sub-D socket and the MAX232 on the board is accomplished via pinheader K1 as



T4 ... T13 = BC640
T14 ... T22 = BC639

980029 - 11

Power supply

The on-board 5-volt power supply for the IC tester is based on a single 7805 3-pin voltage regulator (IC11). A small negative voltage is created mainly for older LCDs by a stealer diode (D5) between the negative line of the unregulated input voltage and the circuit ground. This negative voltage provides a proper range for the LCD contrast setting, P1.

The circuit may be powered by an inexpensive mains adaptor with an output voltage between 9 VDC and 15 VDC. Battery powering is also possible. The unregulated voltage is also applied to the DUT supply discussed above. The current consumption of the circuit will be of the order of 150 mA.

CONSTRUCTION

As you can see from the photographs on this article and the artwork in **Figure 3**, the printed circuit board designed for the IC tester is densely populated. The board being double-sided and through-plated, production with hobbyists tools will be almost impossible, hence our recommendation to buy it ready-made through our Readers Services or one of the kit suppliers advertising in this magazine. Remember, successful construction almost entirely depends on *accuracy and soldering skills*.

Start by separating the keyboard from the main board. Put the keyboard section aside for later.

Populating the main board may take quite some time as there are relatively many components to sort and solder in place.

Resistors, diodes, capacitors, crystal

Start by fitting the SMD (surface-mount device) resistors, R25-R48. This should be done with a low-power (8-watt) soldering iron and lots of care and precision. Use an ohm-meter to check your work on each and every SMD resistor. All other resistors are mounted upright to save space on the board. Make sure you know the value of each and every resistor and capacitor before mounting it. If necessary, use your DMM and the component overlay printed on the board (and shown in **Figure 3**) to be absolutely sure. Also, the SIL resistor arrays on the board must be fitted the right way around, so make sure you know where the 'common' terminal goes. Likewise, observe the orientation of the electrolytic capacitors and diodes. Capacitors C1 (100 nF miniature ceramic) and C2 (10µF, 16V, also miniature) are mounted at the **solder side of the board**. The two presets are fitted and set to mid-travel.

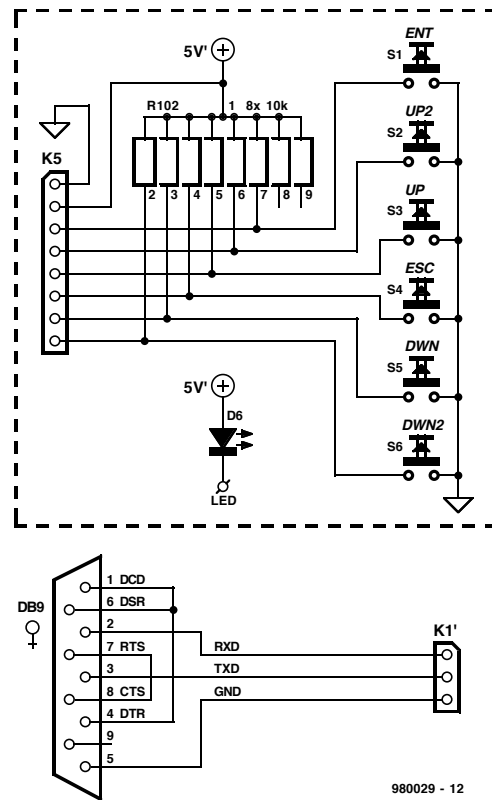
Semiconductors

Fitting the transistors and the voltage regulator should not present problems,

illustrated in **Figure 2**. Note that no active handshaking is used; the IC tester only uses RxD (received data), GND (ground) and TxD (transmitted data).

2

Figure 2. RS232 connection diagram and circuit diagram of the keyboard.



980029 - 12

although you have to be careful not to mix up the BC639s and the BC640s. All ICs are mounted in sockets. With the possibility of future extensions in mind, it is recommended to fit a 32-pin IC socket in position IC7. However, as 32-pin wide-DIL are few and far between, you may have to make one yourself by truncating a 40-pin socket. If you use the ready-programmed (28-pin) 27C512 EPROM supplied through the Readers Services, its pin 14 should go in socket pin 16. In other words, the EPROM is then inserted with its corner pins 14/15 close to the edge of the board.

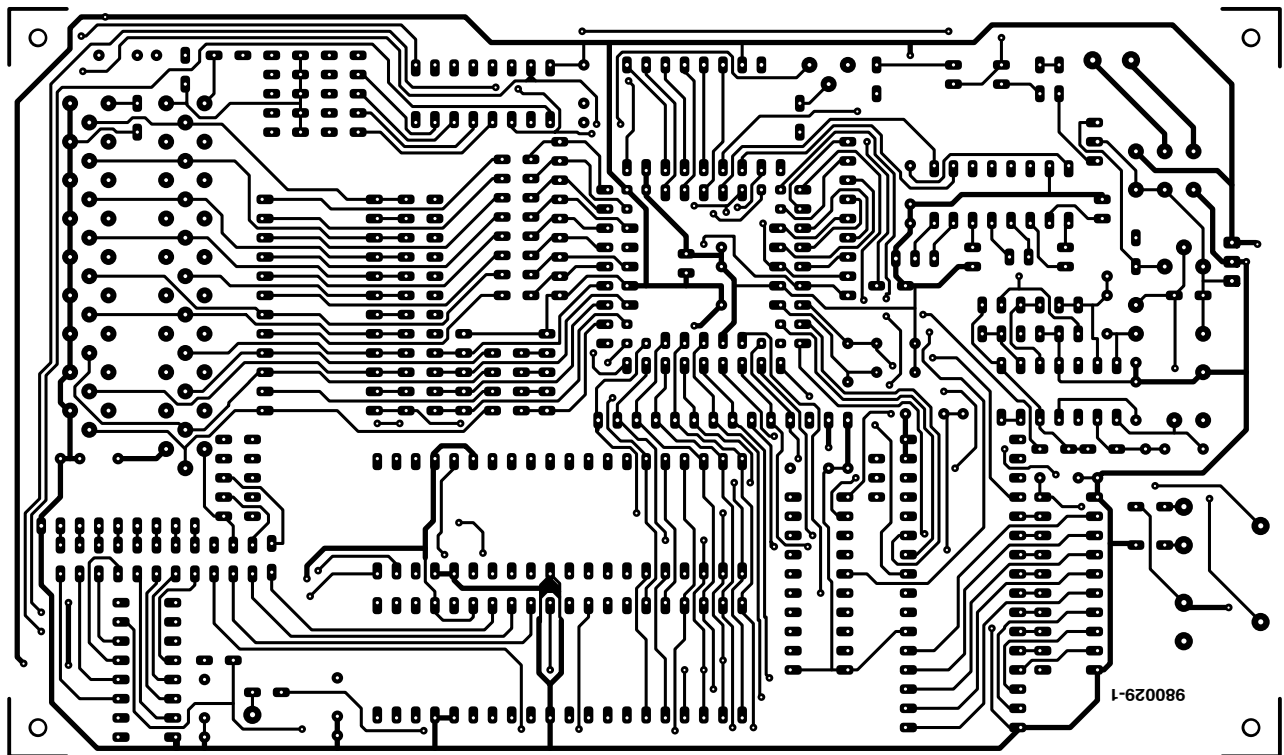
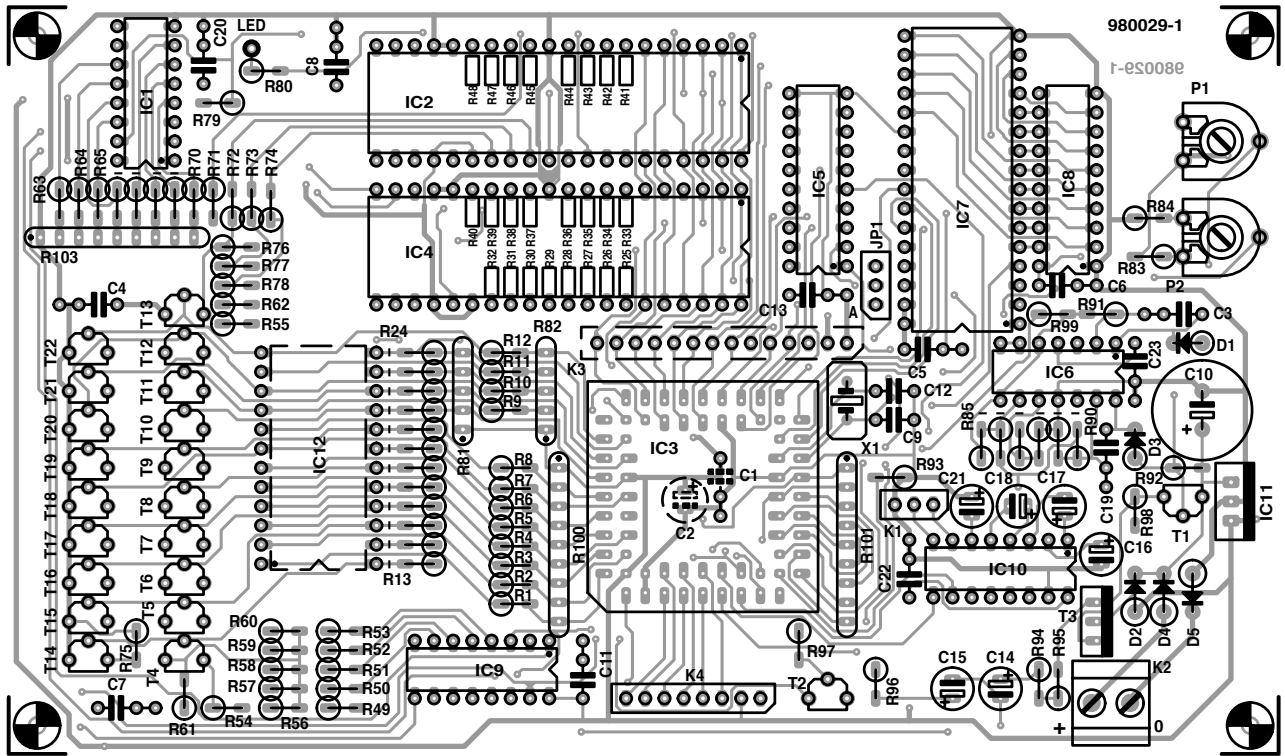
The CPU socket has a bevelled edge which is also indicated on the overlay to assist in positioning.

The socket in position IC12 is not intended for an integrated circuit and it is **fitted at the solder side of the board**. You can (carefully) solder the socket pins at the component side of the board.

Do not insert the ICs in their sockets yet.

Connectors and ZIF socket

Simple 3-way pinheaders are used in positions K1 and JP1. The former receives a mating socket, the second, a jumper. There are two longer pin-headers, K4 and K3. The latter is



COMPONENTS LIST

Resistors:

R1-R24, R56-R62, R75-
R79, R90, R92, R96 = 10k Ω
R25-R48 = 180 Ω SMD
R49-R55, R63-R74, R83 = 1k Ω
R80 = 390 Ω
R81, R82 = SIL resistor array 4 x
4k Ω 7
R84 = 6k Ω 8
R85, R88 = 1M Ω 1%
R86, R87 = 100k Ω 1%
R89 = 39k Ω
R91 = 100k Ω

R93 = 1k Ω 1%
R94, R95 = 1 Ω 1%
R97 = 2k Ω 2
R98 = 47k Ω
R99 = 27 Ω
R100, R101 = SIL resistor array 8 x
4k Ω 7
R102 = SIL resistor array 8 x 10k Ω
R103 = SIL resistor array 8 x 10k Ω
P1 = 10k Ω preset
P2 = 1k Ω preset

Capacitors:

C1, C4-C8, C11, C13, C20, C22, C23 =
100nF

C2, C16, C17, C18, C21 = 10 μ F 16V
radial
C3, C19 = 1nF
C9, C12 = 27pF
C10 = 470 μ F 35V radial
C14 = 10 μ F 25V radial
C15 = 4 μ F7 16V radial

Semiconductors:

D1, D3 = 1N4148
D2, D4, D5 = 1N4001
D6 = LED
T1, T2 = BC547
T3 = BD139
T4-T13 = BC640

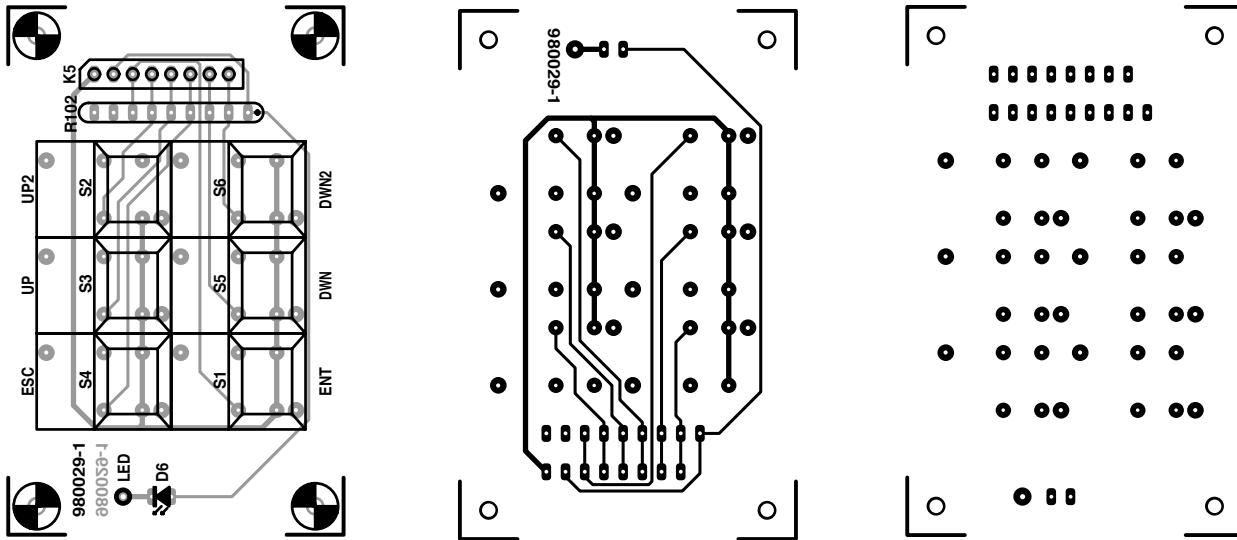
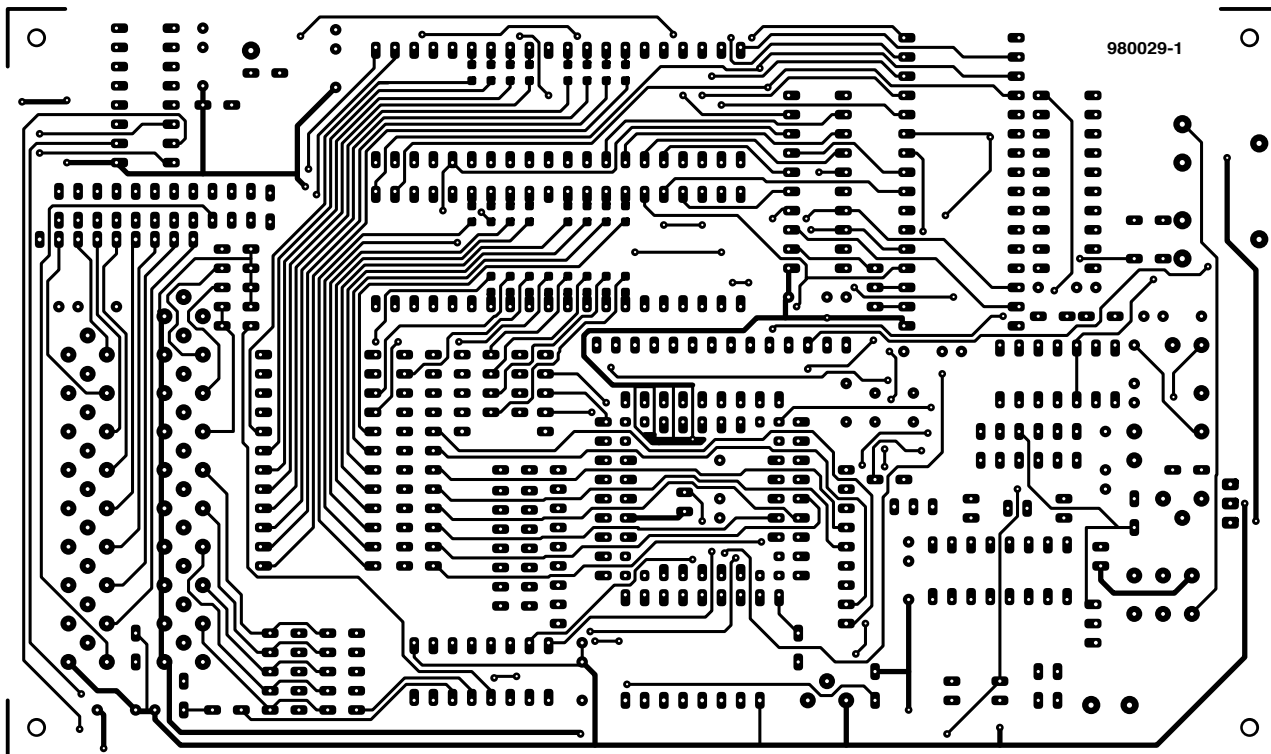


Figure 3. Copper track layouts and component overlays (actual size) of the double-sided, through-plated printed circuit board.

Items available from the Publishers:
 PCB, disk, GAL and EPROM; set, order code 980029-C.
 PCB only, order code 980029-1.
 GAL 16V8 only, order code 986506-1.
 EPROM 27C512 only, order code 986507-1.
 Disk only, order code 986014-1.



- T14-T22 = BC639
 - IC1, IC9 = 74HC4094
 - IC2, IC4 = Z80PIO
 - IC3 = SAB80C535-N
 - IC5 = GAL 16V8 (order code 986506-1)
 - IC6 = LM324
 - IC7 = EPROM 27C512 (order code 986507-1) (but use 32-pin socket!)
 - IC8 = 74HC573
 - IC10 = MAX232
 - IC11 = 7805
 - IC12 = 24-pin ZIF-socket (wide slots; Aries, Farnell)
- Miscellaneous:**
- X1 = 12MHz quartz crystal
 - K1 = 3-pin SIL header
 - K2 = 2-way PCB terminal block (pitch 5mm)
 - K3 = 14-pin SIL header
 - K4, K5 = 8-pin SIL header
 - S1-S6 = Digitast push button (ITT Schadow), 4 black caps, 1 white (Ent), 1 red (Esc)
 - JP1 = 3-pin SIL header + jumper
 - LCD module, 2x16 characters
 - 9-way sub-D socket (female)

mounted at the solder side of the board (and soldered at the component side). Its long pins receive a mating socket whose pins are soldered to the 14 copper spots on the LCD module. Doing so allows the LCD to be given a slant angle for optimum viewing.

Insert a second 24-pin socket into the one you soldered at the solder side in position IC12, and then insert the ZIF socket to make a nice stack.

K2 is a two-way PCB mount terminal block which receives the mains adaptor output voltage.

Keyboard

This is a simpler and smaller board which should not present any difficulty. Although a connector (K5) is indicated on the overlay, the 8-way flatcable between the keyboard PCB and the main board may be soldered directly to the spots at the solder side. One separate wire is used to control the LED, D6. It goes to a solder pin marked 'LED' on the main board.

That concludes the construction of the PCBs. Now's a good time to review your work so far. Any blatant errors?

TESTING

With the ICs still waiting to be inserted in the respective sockets, connect-up the input voltage and run a quick check on the presence of the 5-volt supply voltage at the relevant pins of all IC sockets. Switch off and insert the LM324 (IC6). Connect the DMM to ground and the top wire of R61, switch on again and adjust P2 for a reading of 5.2 V.

Switch off and carefully insert all ICs. Note their orientations on the board! Switch on again. The LCD should read

IC Tester

1:Test

Okay so far? Congratulations!

ADJUSTMENTS

The DUT supply output voltage, U_{+} , has to be set to $5.2\text{ V} \pm 0.05\text{ V}$ using preset P2. Next, P1 is adjusted for optimum contrast of the texts that appear on the LCD.

OPERATION

The tester is operated using six keys labelled Ent (enter), Esc (escape), dn (scroll down), up, dn2 (fast scroll down), and up2 (fast scroll up). The up and dn keys have an auto-repeat function which causes the repeat rate to be automatically increased as the key is held depressed. LED D6 lights to indicate that the IC under test is being powered, and should not be removed from the ZIF socket. **All ICs to be tested should be aligned towards pins 12/13 of the ZIF socket. Their 'top' notch is at the side of the ZIF socket lever.**

Pressing the Esc (escape) key takes you to the main menu. There, the following functions may be selected:

- 1. Test IC:** the user picks an IC from an IC library, and the DUT is checked for correct operation. The test may be repeated. If indicated by the test vectors, the current consumption of the IC under test is measured and displayed.
- 2. Identify:** this allows you to identify the type number of an unknown IC. If the GND and Vcc pins are unknown,

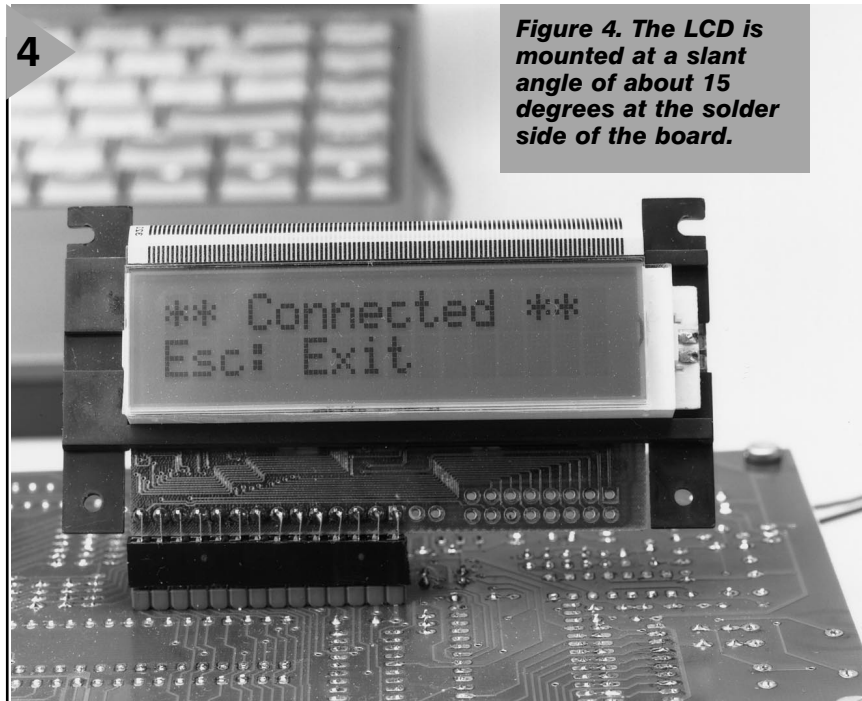


Figure 4. The LCD is mounted at a slant angle of about 15 degrees at the solder side of the board.

only those test vectors are used that have the GND and Vcc pins at the same positions. The GND/Vcc pin entry is optional. Next, you can select the libraries that have to be scanned.

3. Retest IC: once an IC has been tested or identified, it may be tested again without having to pick it from the libraries.

4. Trace: all test vectors and the response of the DUT to these vectors appear in succession on the LC display.

5. Options: here, you can define global options.

6. Info: information on version and copyright.

7. Self Check: the IC tester hardware may be checked using this function and a voltmeter.

8. Remote Mode: connect a PC to the RS232 interface and debug test vectors using the DOS program TVCHK.EXE.

The up/dn keys are used to scroll one item up or down. The up2/dn2 keys do the same, but then five items at a time. The Ent key is used to confirm a selection. Esc, finally, jumps to the main menu.

NEXT MONTH

Next month's second and final instalment will discuss the structure of the various menus which appear on the LCD, as well as the ins and outs of test vector creation, downloading, debugging and EPROM programming.

(980029-1)

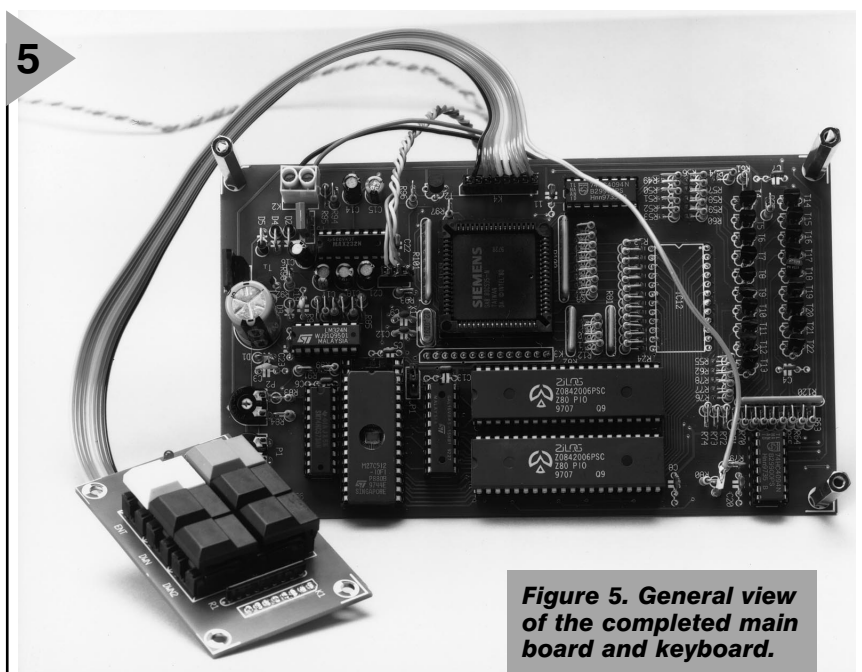


Figure 5. General view of the completed main board and keyboard.

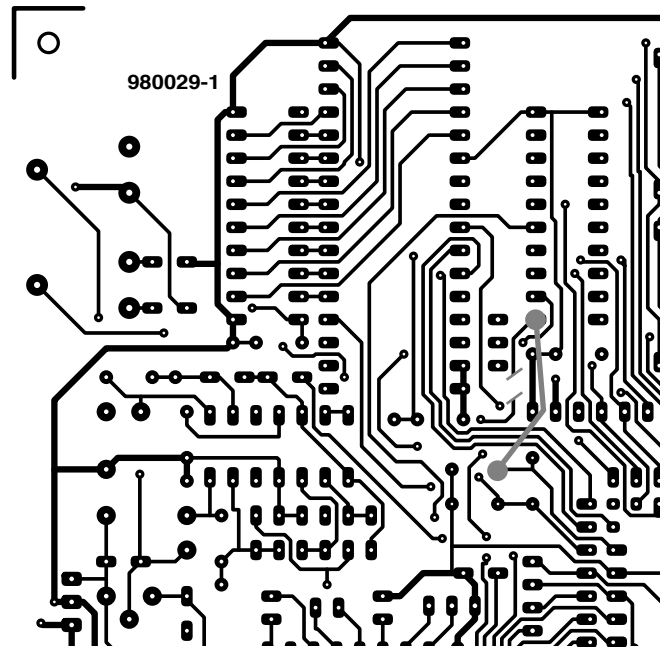
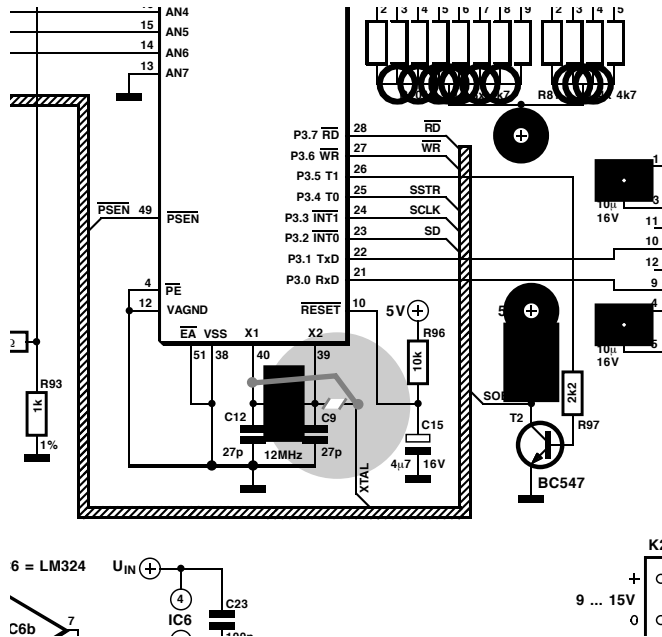
Intelligent IC Tester March 1998, 980029

Pin 39 of the processor (IC3) is connected to pin 1 of the firmware GAL (IC5). Due to specific signal

load conditions, this connection may cause problems with certain GAL brands.

The remedy is simple: instead of pin 39, use pin 40 of the processor as the oscillator output. The

two PCB drawings show how the modification is made. Using a sharp hobby knife, a track is cut. Next, the new connection is made using a short length of thin, insulated wire.



electronics on-line

semiconductor overviews



The Chip Directory is probably the largest independent IC overview on the Internet. It can be found at www.xs4all.nl/~ganswijk/chipdir/chipdir.htm.

This site, constructed and maintained by Jaap van Ganswijk from the Netherlands, contains information on many semiconductors, with special emphasis on IC used in computer technology.

The collection grows every day, as anyone is invited to contribute relevant data and/or links to interesting sites. The Chip Directory has many mirror sites, including sites in Africa, North America, Australia and Europe.

The Chip Directory allows users to search for semiconductor families, names, numbers and prefixes. Information on ICs from the former Soviet Union is also available. In addition to all this IC data the Chip Directory also offers a substantial list of other electronics-related web sites. Furthermore, there's information on important electronics venues, manufacturers, CD-ROMs with component data, and addresses of all important electronics magazines (yes, including Elektor).

Questlink at www.questlink.com is another search engine for integrated circuits. The site also offers quite some information on motherboards. It is, however, mainly a source for semiconductor company profiles and the latest industry news. Questlink is a free service for engineers by engineers, as they call it.

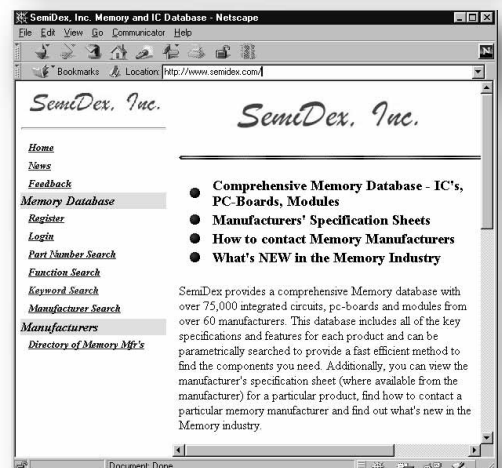
Yet another address you may want to use for finding component data is Semidex (www.semidx.com). The makers of this site claim that it offers data on about 75,000 integrated

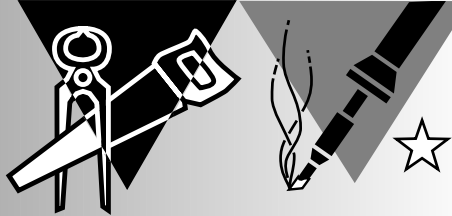
circuits, mainly memory chips. Semidex also supplies data on PC motherboards, as well as information on manufacturers and the latest news on memory technology. The search engine on this site provides you with a search system based on number, function, manufacturer and keyword. For the time being, the search service is offered free of charge. This will be changed to a paid-up service shortly. The IC overview may also be bought on CD-ROM.

If your chief interest is in processors, then the *Chiplist* (einstein.et.tudelft.nl/~offerman/chiplist.html) is certainly worth a visit. This site contains a hefty overview of CPUs and coprocessors.

Finally, if you are looking for data on distributors, representatives, services and semiconductor manufacturers in the electronics industry, the address to go to is www.electrobase.com which takes you to the site run by Electrobase. (985021-1)

Most major semiconductor manufacturers have their own web site which presents new products and allows datasheets to be downloaded. A problem arises, however, if you are stuck with an IC or a transistor of unknown make. Fortunately, there are a number of manufacturer-independent overviews and search engines on the Web.





flashing brooch

optoelectronics in pocket format

This is the third and last in a series of three miniature designs for beginners in electronics. Each of the designs is powered by a 3 V lithium manganese dioxide non-rechargeable battery and is provided with some sort of visual indication. The brooch presented in this article is an elementary flashing circuit which has no pretensions other than that of an optoelectronic toy.



With its, dare we say, intricate light effect, the flashing circuit may be seen, in all its simplicity, as a cute little trinket that will, no doubt, catch a few glances at a party or some similar get-together. And, indeed, like the die and trinket published in the past few months, the brooch is intended primarily as an eye-catching, optical ornament.

CIRCUIT DESCRIPTION

Designed to create an optically interesting miniature effect, the brooch has absolutely no practical use. However, the designer wanted the light effect to be quite different from the usual array of flashing and running lights, most of whose patterns quickly become drab, dreary, and predictable.

The aim was therefore to drive a number of LEDs in a way to produce a truly random light pattern and with an absolute minimum of electronic components. This resulted in a tiny circuit containing only two 14-bit counters and six LEDs—see **Figure 1**.

The use of two counters prevents the circuit exhibiting the same predictability of so many others. If only one were used, the effect would of

necessity be repetitive. So, the second counter serves to avoid monotony.

Should IC_1 work on its own, diodes D_2 – D_7 would light in perfect order and regularity, since they are linked to the successive outputs (Q_7 – Q_{13}) of the counter. However, with IC_2 also in circuit, when Q_7 of IC_1 is high, D_2 can light only if Q_{13} of IC_2 is low at the same time. In the same way, when Q_8 of IC_1 is high, D_3 can light only if Q_{12} of IC_2 is low at the same time. And so on ...

So, whether the diodes will actually light, although they are driven in perfect succession by IC_1 , depends on other factors as well. Not only are they linked to outputs Q_7 – Q_{13} of IC_2 in opposite order from their connections to IC_1 , but the integrated circuits count in different tempi. This is effected by making the value of C_3 almost five times greater than that of C_2 . Consequently, the clock oscillator in IC_1 runs at a frequency about five times higher than that in IC_2 . These factors combined result in the LEDs lighting in a truly random way.

Power for the circuit is derived from a 3 V lithium battery. Switch S_2 is the on/off switch.

Design by K.A. Walraven

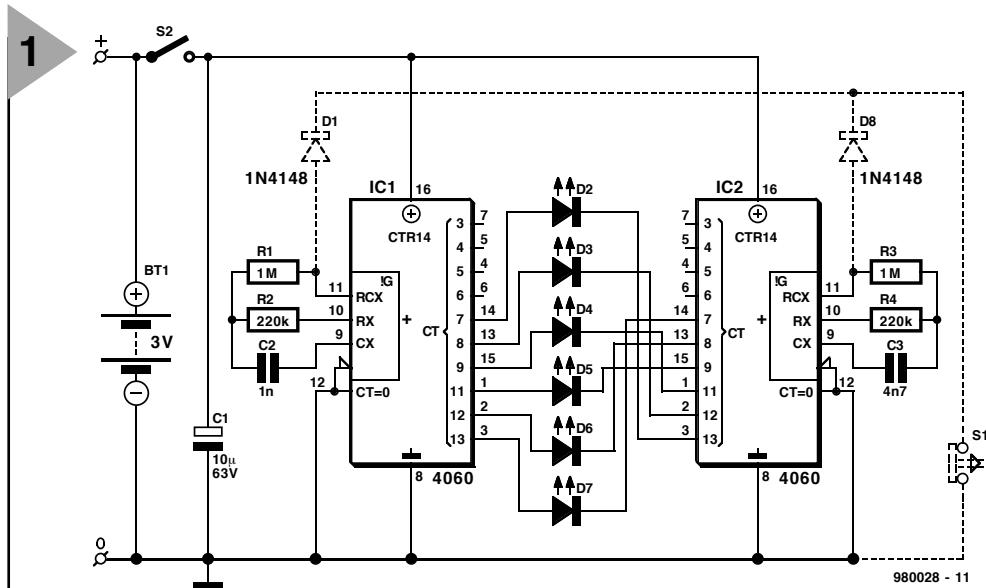
Figure 1. The use of two counters enables a completely random light pattern to be obtained.

Push-button switch S_1 serves to briefly enable the counters if the circuit is used as a die, but if this function is not envisaged, this switch, as well as D_1 and D_8 , may be omitted.

CONSTRUCTION

The brooch circuit is best built on the printed-circuit board shown in Figure 2, which is, however, not available ready made.

Completing the board cannot be simpler. Start with the passive components (resistors, capacitors), followed by the ICs and LEDs.



2

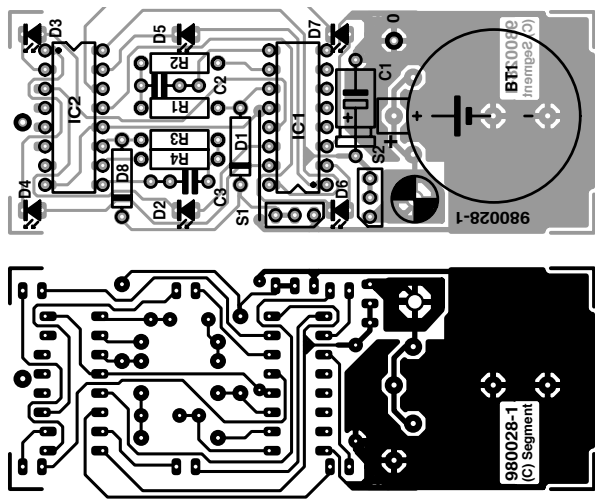


Figure 2. The tiny printed-circuit board for the flashing brooch is not available ready made.

sockets is left to personal choice: their use prevents any risk of damage to the ICs during soldering, while without them, the brooch is rather flatter. Mind the polarity of C_1 and D_1 – D_8 .

The circuit is powered by a 3 V lithium manganese dioxide non-rechargeable battery, Type CR2032 or the rather flatter CR2025. The diameter of both types is 20 mm. The battery is fitted on to the board with the aid of a specially available holder. Note that its +ve terminal must point upward. (Recently, types have become available for direct mounting on the PC board – see Parts list).

On/off switch S_2 may be

replaced by a three-pin PCB jumper system, where-upon on/off switching is effected by the

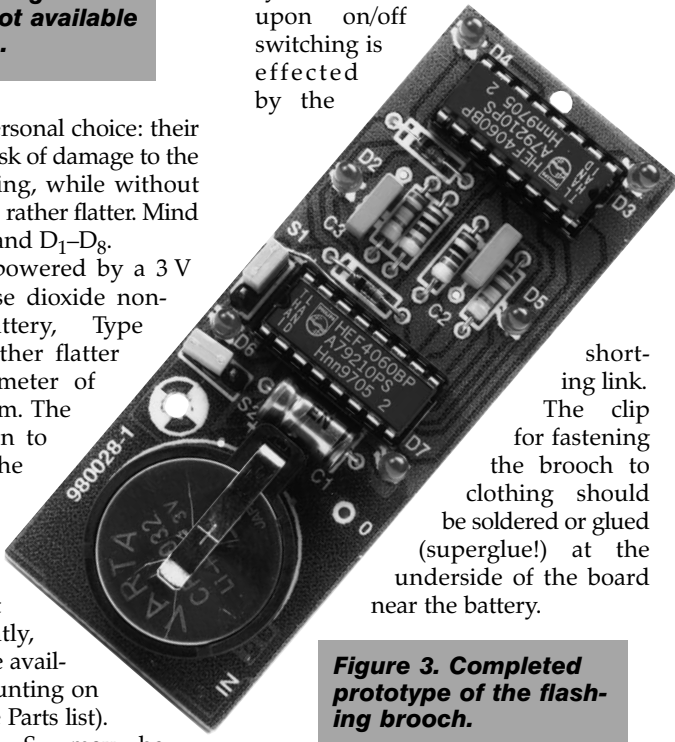


Figure 3. Completed prototype of the flashing brooch.

shorting link. The clip for fastening the brooch to clothing should be soldered or glued (superglue!) at the underside of the board near the battery.

Parts list

Resistors:
 $R_1, R_2 = 1\text{ M}\Omega$
 $R_2, R_4 = 220\text{ k}\Omega$

Capacitors:
 $C_1 = 10\ \mu\text{F}, 63\text{ V}$
 $C_2 = 0.001\ \mu\text{F}$
 $C_3 = 0.047\ \mu\text{F}$

Semiconductors:
 $D_1, D_8 = 1\text{N}4148$ (may be omitted – see text)
 D_2 – $D_7 = \text{LED}$, high efficiency

Integrated circuits:
 $\text{IC}_1, \text{IC}_2 = \text{CD}4060$

Miscellaneous:
 $S_1 = \text{push-button switch with single break contact}$ (may be omitted – see text)
 $S_2 = \text{SPST or three-pin PCB jump system (wire-wrap pin-strip header with shorting link – available from RS Components) – see text}$
 $\text{BT}_1 = 3\text{ V lithium manganese dioxide non-rechargeable battery Type CR2025 or CR2032 with holder for board mounting (there are types available for direct mounting on a PC board from RS Components)}$

Figure 3 shows the completed prototype brooch.

With components as specified in the Figure 1, the circuit draws a current of about 10 mA. At that rate, a CR2025 battery will have a life of 10–12 hours, and a CR2032 one of 14–17 hours.

EXPERIMENTATION

A simple circuit as described lends itself readily to experimentation. For instance, the light effect may be altered by changing the clock frequencies of the two counters. This only requires altering the value of C_2 and C_3 .

[980028]

SSM2142

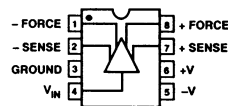
Integrated circuits
AudioSSM2142
Balanced Line Driver

Manufacturer

Analog Devices, One Technology Way,
P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617/329-4700 Fax: 617/326-8703.
Internet: www.analog.com.

General description

The SSM2142 is an integrated differential-output buffer amplifier that converts a single-ended input signal to a balanced output signal pair with high output drive. By utilizing low noise thermally matched thin film resistors and high slew rate amplifiers, the SSM2142 helps maintain the sonic quality of audio systems by eliminating power line hum, RF interference, voltage drops, and other externally generated noise commonly encountered with long audio cable runs. Excellent rejection of common-mode noise and offset errors is achieved by laser trimming of the onboard resistors, assuring high gain accuracy. The carefully designed output stage of the SSM2142 is capable of driving difficult loads, yielding low distortion performance despite extremely long cables or loads as low as 600 Ω , and is stable over a wide range of operating conditions. Based on a cross-coupled, electronically balanced topology, the SSM2142 mimics the performance of fully balanced transformer-based solutions for line driving. However, the SSM2142 maintains lower distortion and occupies much less board space than transformers while achieving comparable common-mode rejection performance with reduced parts count.



pin connections

8-Pin Plastic DIP (P Suffix)

16-pin Wide Body SOL (S suffix)

983001 - 17

ELEKTOR
ELECTRONICS

DATASHEET 3 / 9 8

The SSM2142 in tandem with the SSM2141 differential receiver establishes a complete, reliable solution for driving and receiving audio signals over long cables. The SSM2141 features an Input Common-Mode Rejection Ratio of 100 dB at 60 Hz. Specifications demonstrating the performance of this typical system are included in the full data sheet.

Features

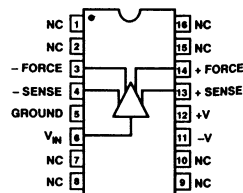
- Transformer-like balanced output
- Drives 10 V rms into a 600 Ω load
- Stable when driving large capacitive loads and long cables
- Low distortion: 0.006% typ, 20 Hz–20 kHz, 10 Vrms into 600 Ω
- High slew rate: 15 V/ μ s typ
- Low gain error (differential or single-Ended); 0.7% typ
- Outputs short-circuit protected
- Available in space-saving 8-Pin mini-DIP package
- Low cost

Applications

- Audio Mix Consoles
- Distribution Amplifiers
- Graphic and Parametric Equalizers
- Dynamic Range Processors
- Digital Effects Processors
- Telecommunications Systems
- Industrial Instrumentation
- Hi-Fi Equipment

Application Example

Balanced/Unbalanced Converters for Audio,
Elektor Electronics March 1998.



SSM2141

Integrated circuits
AudioSSM2141
High common-mode Rejection
Differential Line Receiver

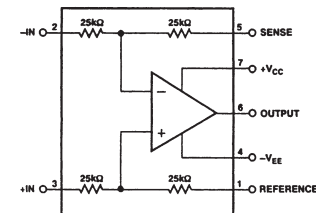
Manufacturer

Analog Devices, One Technology Way,
P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617/329-4700 Fax: 617/326-8703.
Internet: www.analog.com.

General description

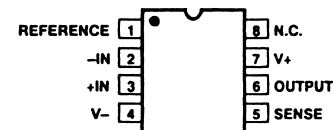
The SSM2141 is an integrated differential amplifier intended to receive balanced line inputs in audio applications requiring a high level of noise immunity and optimum common-mode rejection. The SSM2141 typically achieves 100 dB of common-mode rejection (CMR), whereas implementing an op amp with four off-the-shelf precision resistors will typically achieve only 40 dB of CMR — inadequate for high-performance audio.

The SSM2141 achieves low distortion performance by maintaining a large slew rate of 9.5 V/ μ s and high open-loop gain. Distortion is less than 0.002% over the full audio bandwidth. The SSM2141 complements the SSM2142 balanced line driver. Together, these devices comprise a fully integrated solution for equivalent transformer balancing of audio signals



983001 - 11

Functional diagram



983001 - 12

Pin connections 8-Pin Plastic Mini-DIP (P Suffix)

ELEKTOR
ELECTRONICS

DATASHEET 3 / 9 8

without the problems of distortion, EMI fields, and high cost.

Additional applications for the SSM2141 include summing signals, differential preamplifiers, and 600 Ω low distortion buffer amplifiers.

Features

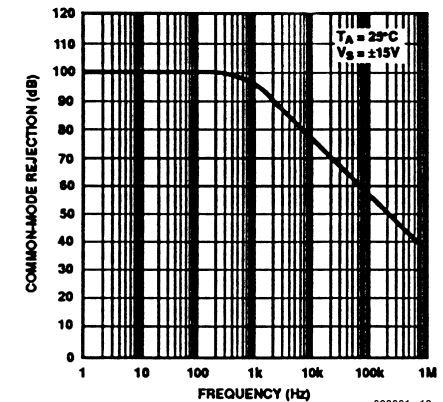
- High Common-Mode Rejection
 - DC: 100 dB typ
 - 60 Hz: 100 dB typ
 - 20 kHz: 70 dB typ
 - 40 kHz: 62 dB typ
- Low Distortion: 0.001% typ
- Fast Slew Rate: 9.5 V/ μ s typ
- Wide Bandwidth: 3 MHz typ
- Low Cost
- Complements SSM2142 Differential Line Driver

Applications

- Line Receivers
- Summing Amplifiers
- Buffer Amplifiers – drives 600 Ω load

Application Example

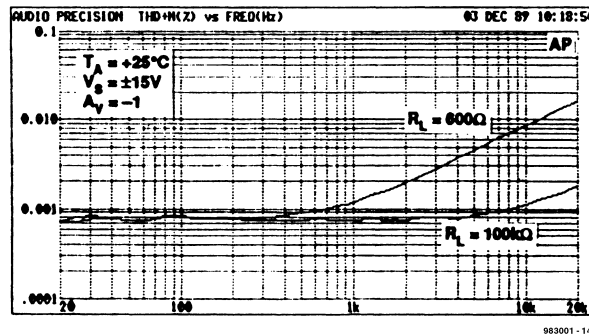
Balanced/Unbalanced Converters for Audio,
Elektor Electronics March 1998.



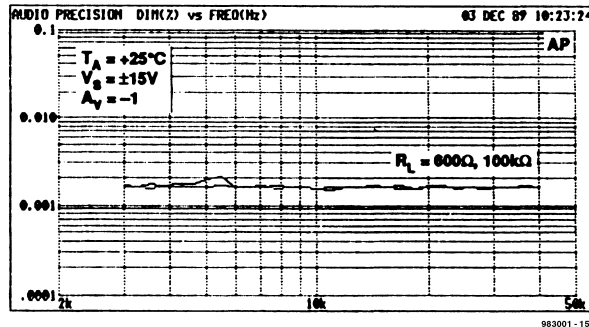
Common-mode rejection vs frequency

983001 - 13

Total harmonic distortion vs frequency



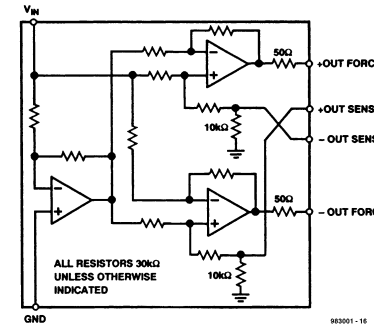
Dynamic intermodulation distortion vs frequency


Electrical characteristics

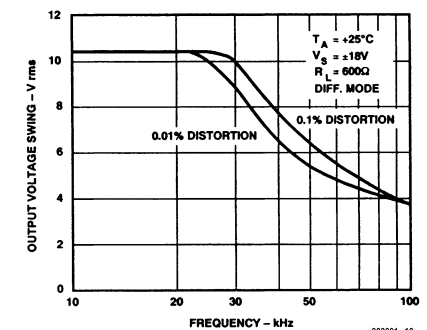
 (@ $V_S = \pm 18\text{ V}$, $T_A = +25^\circ\text{C}$, unless otherwise noted)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE	V_{OS}	$V_{CM} = 0\text{ V}$	-1000	25	1000	μV
GAIN ERROR		No Load, $V_{IN} = \pm 10\text{ V}$, $R_S = 0\ \Omega$		0.001	0.01	%
INPUT VOLTAGE RANGE	I_{VR}	(Note 1)	± 10			V
COMMON-MODE REJECTION	CMR	$V_{CM} = \pm 10\text{ V}$	80	100		dB
POWER SUPPLY REJECTION RATIO	PSRR	$V_S = \pm 6\text{ V to } \pm 18\text{ V}$		0.7	15	$\mu\text{V/V}$
OUTPUT SWING	V_O	$R_L = 2\text{ k}\Omega$	± 13	± 14.7		V
SHORT-CIRCUIT CURRENT LIMIT	I_{SC}	Output Shorted to Ground	+45/-15			mA
SMALL-SIGNAL BANDWIDTH (-3 dB)	BW	$R_L = 2\text{ k}\Omega$		3		MHz
SLEW RATE	SR	$R_L = 2\text{ k}\Omega$	6	9.5		$\text{V}/\mu\text{s}$
TOTAL HARMONIC DISTORTION	THD	$R_L = 100\text{ k}\Omega$ $R_L = 600\ \Omega$		0.001 0.01		%
CAPACITIVE LOAD DRIVE CAPABILITY	C_L	No Oscillation		300		pF
SUPPLY CURRENT	I_{SY}	No Load		2.5	3.5	mA

Note 1. Input Voltage Range Guaranteed by CMR test.



Functional block diagram



Maximum output swing vs. frequency

Electrical characteristics ($V_S = \pm 18\text{ V}$, $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$, operating in differential mode unless otherwise noted. Typical characteristics apply to operation at $T_A = +25^\circ\text{C}$.)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
INPUT IMPEDANCE	Z_{IN}			10		$\text{k}\Omega$
INPUT CURRENT	I_{IN}	$V_{IN} = \pm 7.071\text{ V}$		± 750	± 900	μA
GAIN, DIFFERENTIAL			5.8	5.98		dB
GAIN, SINGLE-ENDED		Single-Ended Mode	5.7	5.94		dB
GAIN ERROR, DIFFERENTIAL		$R_L = 600\ \Omega$		0.7	2	%
POWER SUPPLY REJECTION RATIO STATIC	PSRR	$V_S = \pm 13\text{ V to } \pm 18\text{ V}$	60	80		dB
OUTPUT COMMON-MODE REJECTION	OCMR	$f = 1\text{ kHz}$	-38	-45		dB
OUTPUT SIGNAL BALANCE RATIO	SBR	$f = 1\text{ kHz}$	-35	-40		dB
TOTAL HARMONIC DISTORTION PLUS NOISE	THD+N	20 Hz to 20 kHz, $V_O = 10\text{ V rms}$, $R_L = 600\ \Omega$		0.006		%
SIGNAL-TO-NOISE RATIO	SNR	$V_{IN} = 0\text{ V}$		-93.4		dBu
HEADROOM	HR	CLIP Level = 10.5 V rms		+93.4		dBu
SLEW RATE	SR			15		$\text{V}/\mu\text{s}$
OUTPUT COMMON-MODE VOLTAGE OFFSET ¹	V_{OOS}	$R_L = 600\ \Omega$	-250	25	250	mV
DIFFERENTIAL OUTPUT VOLTAGE OFFSET	V_{OOD}	$R_L = 600\ \Omega$	-50	15	50	mV
DIFFERENTIAL OUTPUT VOLTAGE SWING		$V_{IN} = \pm 7.071\text{ V}$	± 13.8	± 14.14		V
OUTPUT IMPEDANCE	Z_O		45	50	55	Ω
SUPPLY CURRENT	I_{SY}	Unloaded, $V_{IN} = 0\text{ V}$		5.5	7.0	mA
OUTPUT CURRENT, SHORT CIRCUIT	I_{SC}		60	70		mA

Notes 1 Output common-mode offset voltage can be removed by inserting dc blocking capacitors in the sense lines. See Applications Information.