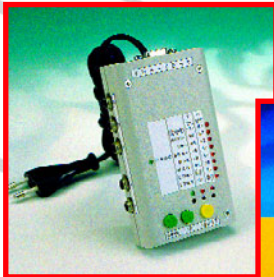# ELEKTOR
ELECTRONICS

PC TOPICS:
electronics
freeware
free software on the Internet
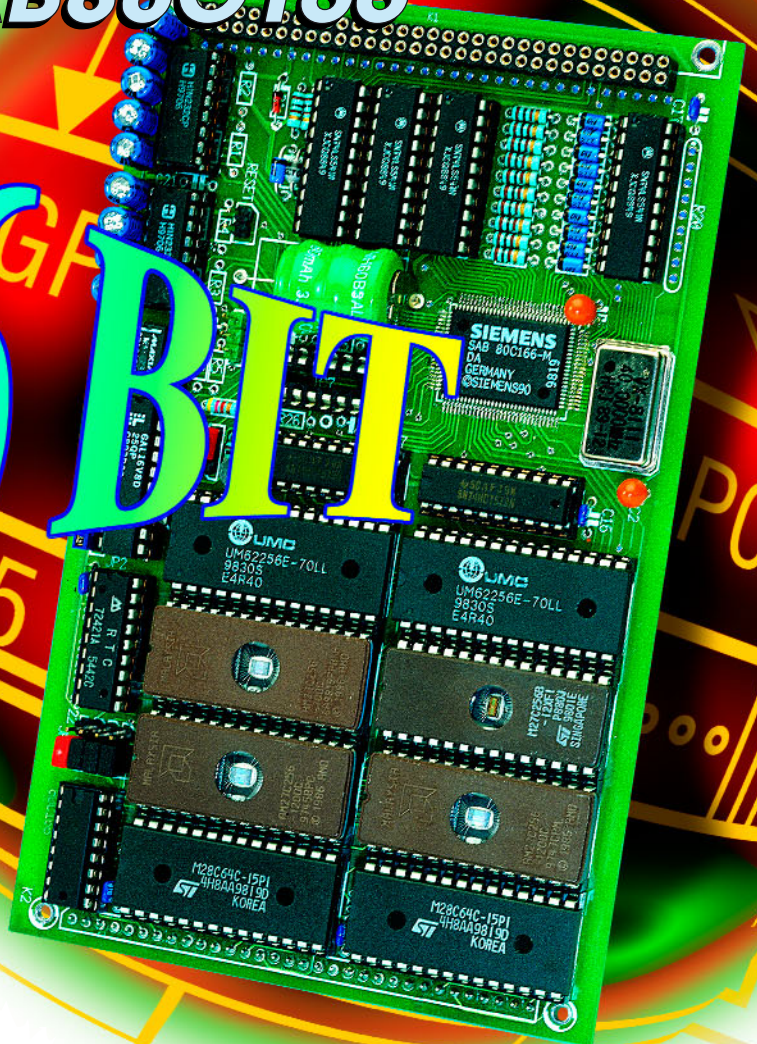
VGA display tester

AF noise source

16-bit processor board
using SAB80C166

circuit testing with a sawtooth

16 BIT

CONTENTS

■ INFORMATIVE ARTICLES

■ CONSTRUCTION PROJECTS

■ MISCELLANEOUS

■ THIS MONTH IN PC TOPICS:

Computers are an expensive hobby. Not only is the hardware expensive, but you often have to reach deep into your pocket to pay for the software. Nevertheless, there are also firms and individual programmers who make their products available free of charge. Many such freeware programs can be found for electronics applications as well. We have ferreted out a few for you, which we present here with brief descriptions and their Internet download addresses.

By our Editorial Staff

electronics freeware

free programs for a variety of applications

Distributing a freeware version of a simulation program among students, for example, has the advantage for the manufacturer that the students will later encourage their bosses to buy the commercial version.

In the remainder of this article, we describe a large number of freeware programs that we have found on the Internet. We classify as freeware only programs that are available free of charge, have no operating time limits (that is, they do not stop working after 30 days or so) and also have a usable set of functions. A demo version of a simulation program in which the print and save functions are disabled, for example, would thus not qualify as freeware.

The list is classified under a number of topics. A short description is provided for each program, including its size (if known) and the Internet address where it can be found. We have put the list together with as much care as possible, but it is possible that a certain Internet link no longer works or that the set of functions of a particular program is not exactly as described here. There is unfortunately not much that we can do about that, but you should keep in mind the happy fact that these programs cost you nothing except for telephone charges, so it's certainly worth the effort to try them out!

Audio

Interactive Speaker Designer
The Finn Juha Hartikainen maintains a number of Internet pages on the sub-

Unfortunately, many people only consider the price of the hardware when they buy a computer, giving little thought to the software. However, software is in fact one of the major cost factors in a computer system. Especially for electronics applications, such as circuit simulation or designing circuit board layouts, the software packages are often expensive and can easily cost several hundred pounds. Still, software does not always have to be so expensive. In addition to shareware (programs that you can try out for a while before having to pay for them), there is freeware, which is entirely free of charge. Why would a manufacturer or programmer give away software? There are various reasons. Sometimes it's purely a case of idealism, but there are usually more practical considerations. Some freeware programs are offered to whet the user's appetite for a more comprehensive version, which is of course not free. In other cases, manufacturers offer freeware versions of their programs to promote product awareness.

ject of building loudspeaker systems. A special feature is the program ISD (Interactive Speaker Designer), which visitors to his site can use free of charge to calculate the size of the enclosure for a given driver. The program works only via the Internet and cannot be downloaded.
http://orion.pspt.fi/~jhartika/isd/index.html

Spec for Windows
This spectrum analyzer program runs under Windows 95/NT and 3.1 (with the Win32S extension). It includes a fairly complete FFT spectrum analyzer for processing signals applied to the inputs of the sound card. A freeware version with certain functions disabled is available, as well as a demo version and the professional version.
http://ourworld.compuserve.com/homepages/jussi/sMain.htm
Size: 800 kB

Spectrogram Ver 4.2.7
This is a two-channel audio spectrum analyzer for Windows 95/98/NT. You can display the time/frequency spectrum or the spectral composition in real time on the monitor.
http://www.monumental.com/rshorne/gram.html

Programmable logic

MPLAB V 4.0
This is a complete, integrated development package for designing, debugging and optimizing circuits using controllers from the popular Microchip PIC family.
http://www.microchip.com/10/Tools/mTools/MPLAB/index.htm
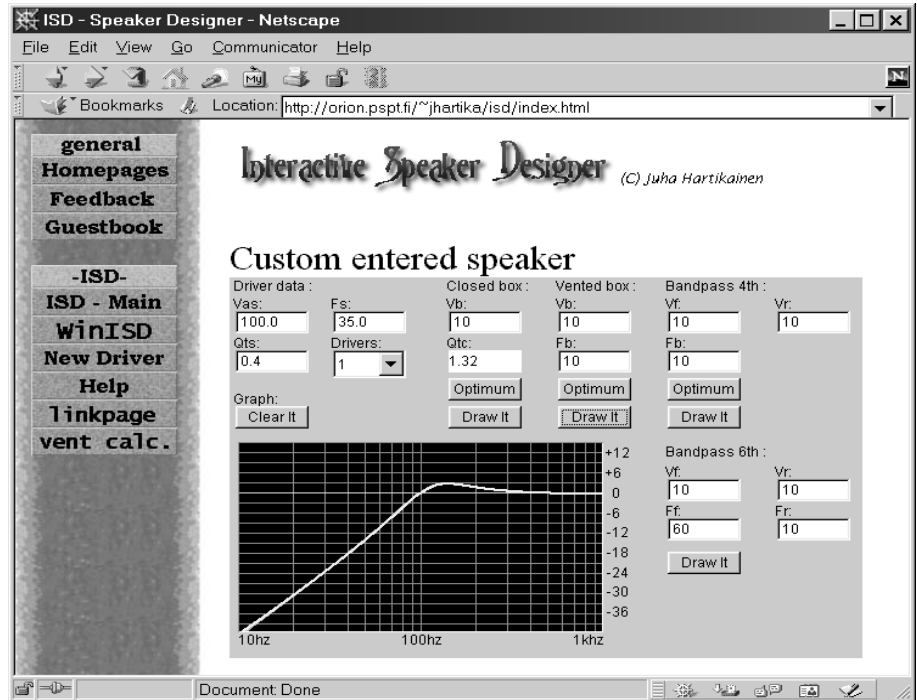Size: 6.5 MB

CUPL
This is a complete logic design environment, whose most important element is a C-like compiler. The CUPL output format can be used to program PLD or FPLA devices via a logic programmer. The package includes other functions for synthesis, compilation, partitioning and design rule checking. The CUPL starter kit is free.
http://www.logicaldevices.com/cupl/

ISP Synario Starter
This is a collection of Windows 95/NT software tools for generating designs based on Lattice ispLSI 1000, 1000E, 2000 and 2000V devices and the Lattice GAL family. This package includes (among others) a compiler, a simulator, a schematic drawing pro-

gram and a timing analyzer.
http://www.latticesemi.com/ftp/synario.html

Palasm V1.5
Palasm is a PLD compiler for programming PAL, MACH1 and MACH2 ICs. Equations can be entered using a text editor, and they can be compared and simulated.
http://www.vantis.com/software/software.html

Circuit board layout

Circad
There are two free versions of this drawing and layout program available, one for DOS and the other for Windows 95/NT. The limitations of the programs are not specified.
http://www.holophase.com/dleval.htm

Eagle 3.5 Light Edition
This is a complete schematic drawing and circuit board layout program from the German firm Cadsoft. The limitations of the freeware version are: maximum board size 100 x 80 mm, maximum two layers. However, you can do quite a lot with that!
http://www.Cadsoft.de/freeware.htm
Size: 3.2 MB (DOS version); 3.9 MB (Windows 95/NT version)

Easyedit
The Australian firm RCS provides freeware versions of the DOS programs Easyedit and Easyplot via the Internet, under the name IMBEZCAD.zip. Library

updates are also regularly available at this site under the name RCSEZLIB.
http://www.cia.com/au/rcsradio/index2.htm
Size: 1.1 MB

Express PCB
This is a circuit board layout program for Windows 95 that is suitable for double-sided boards with plated-through holes. There are no limitations. The idea behind the program is that you let the firm that provides the program manufacture the circuit boards that you design, but handy hobbyists can use the layout functions for their own designs.
http://www.expresspcb.com/ExpressPCBHtm/Download.htm
Size: 4 MB

Quickroute 4.0
This is a completely functional demo version of this commercial simulation and circuit board layout program. The demo version is limited to a maximum of 40 pins.
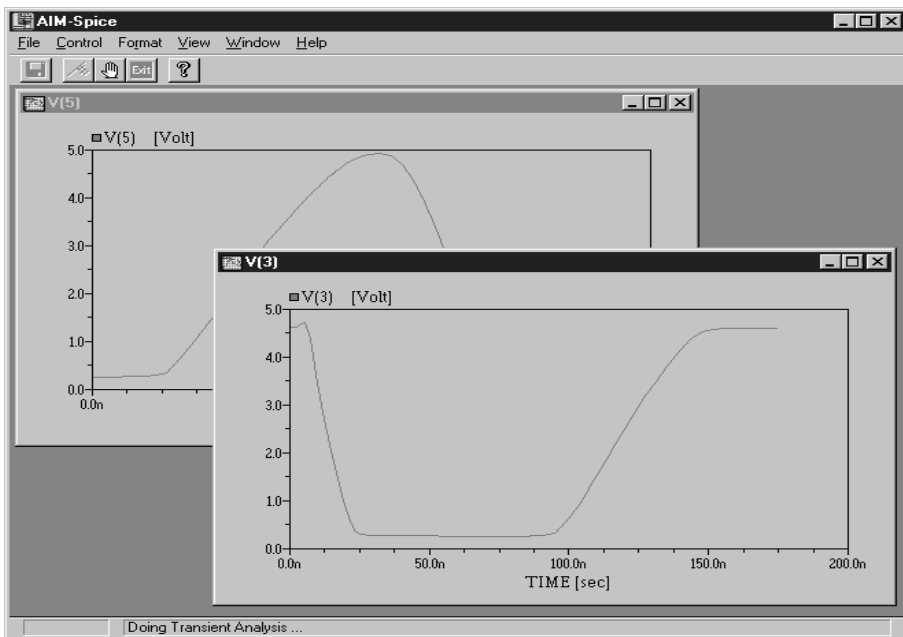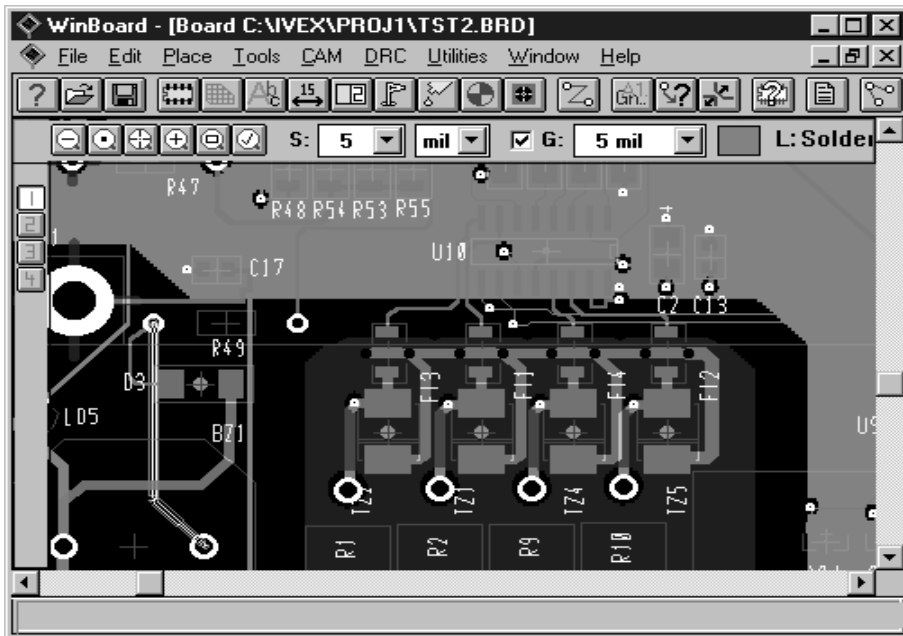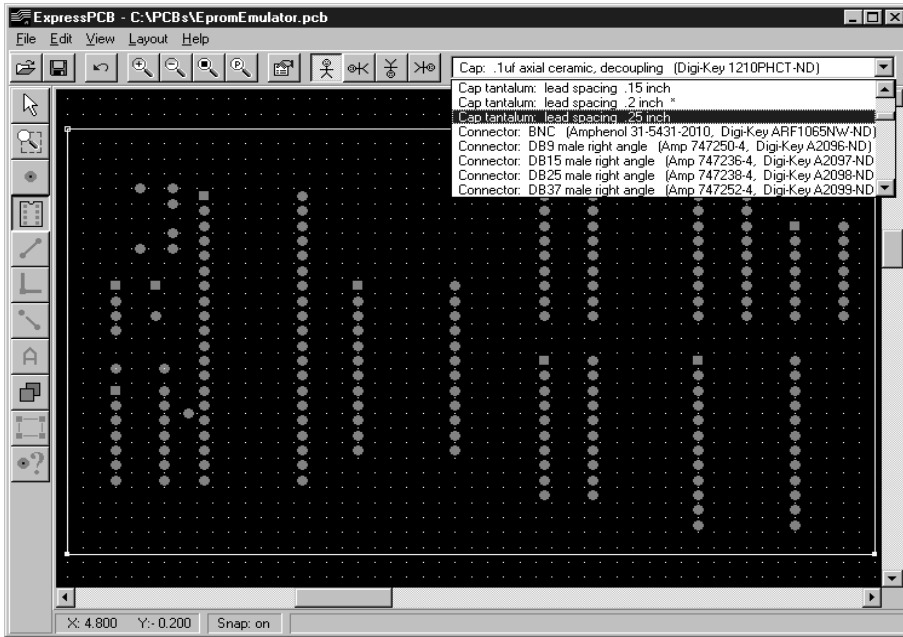http://www.quickroute.co.uk/qrs007.htm
Size: 3 MB

Windraft and Winboard
These Windows programs from Ivex are suitable for drawing schematic diagrams and doing circuit board layouts, respectively. The demo versions can only accommodate a limited number of pins (maximum 100).
http://www.ivex.com/
Size: 3.4 MB (Windraft) and 4 MB (Winboard)

Simulation

AIM Spice
This simulation program is based on Spice, as the name indicates. Evaluation versions are available for Windows 3.1 and Windows 95.
http://www.aimspice.com/download.htm
Size: 1.3 MB (Windows 3.1 version); 1.9 MB (Windows 95 version)

Designlab Evaluation Version 8.0
This package consists of several modules from PSpice, the well-known simulation program from Microsim. PSpice is currently available under the OrCAD banner. The evaluation version is exceptionally well suited for the simulation of relatively small circuits. The number of components is limited to roughly 50, but that still allows quite substantial circuit diagrams to be simulated.
http://www.orcad.com/products/pspice/eval_f.htm

Digital Simulator 1.1
This simulation program for digital circuits is free for educational institutions and students. A large number of digital components are available, and the size of the schematic diagram is unlimited. Signals can be traced in the circuit diagram using a logic analyzer function.
http://www.mit.edu/people/ara/ds.html
Size: 1.7 MB (Windows 3.1 version); 1.8 MB (Windows 95 version)

Digital Works
This freeware program is a simulator for digital circuits. All basic functions (AND, OR, flip-flop etc.) are present, and it is possible to create macros to simulate more complex ICs. There are separate versions for Windows 3.1 and Windows 95.
http://www.scm.tes.ac.uk/users/d.j.barker/digital/digital.htm
Size: 1.5 MB

ICAP/4
An evaluation version of this well-known simulation program is available for Windows 95. Only a demo version is available for Windows 3.1. You will also find demo versions of the Intusoft programs Test Designer, Magnetic Designer, FilterMaster and SpiceMod at this web site.
http://www.intusoft.com/demos.htm
Size: 6 MB

Micro-Cap V Student Version
This is a mixed-mode simulation program with a modern interface and lots of features. The working demo/student

version is limited only in the number of nodes that can be simulated.
http://www.spectrum-soft.com/demo.html
Size: 1.75 MB

PC-ECAP

This is an analysis program for calculating and plotting the amplification, phase, delay, impedance and VSWR characteristics of a circuit. It is even possible to calculate the transient response, with a choice of eight waveforms.
http://www.ourworld.compuserve.com/homepages/circuitsys/PCECAP.HTM

SIMetrix Intro

This simulation program for analogue circuits runs under Windows 95/NT and offers a schematic drawing module, advanced waveform analysis functions and a scripting language. The only limitation of the intro version is in the simulation time.
http://www.newburytech.co.uk/Pages/download.html
Size: 2.7 MB

Smash 4 Evaluation Version

The French firm Dolphin Integration provides an extensive simulation program for Windows 95/NT, called Smash. The only limitation of the evaluation version is in the number of nodes that can be simulated (25 analogue nodes and 50 digital nodes). Other than this it is fully functional.
http://www.dolphin.fr/

Miscellaneous

CyberCircuit

This is a Windows program that simplifies finding circuit diagrams for specific applications (and other electronics information) in an associated library. The free demo version contains a library with only 100 entries, while the regular version of CyberCircuit contains 650 entries and the Plus version has 1100. There are no other limitations on the demo version.
http://www.members.aol.com/cybercir/demo.htm
Size: 600 kB

DADiSP Student Edition

This data analysis program is easy to learn and to use. It has numerous functions for processing data and presenting it in a variety of forms. DADiSP runs under Windows, and the student version can accept a maximum of 8192 measurements.
http://www.dadisp.com/studntdl.htm

Your SweetHaven Online Interactive Tutor
Basic Electronics, Part 2
Elements of AC Electricity

Unit 2: Inductance
Module 2: Self-Inductance

CONTENTS   FEEDBACK

Before starting this module, you should be able to:

- Cite the meaning of each term in the mathematical expression of Faraday's Law.
- Cite the meaning of each term in the mathematical expression of Lenz's Law.

When you complete this module, you should be able to:

- Explain *self-inductance*.
- Define *inductance* in terms of induced voltage.
- Cite the units of measure for inductance.
- Describe the voltage waveform across an inductor when a sine waveform of current is being applied.

Elements of AC Electricity

This not exactly a program, but it is still worth mentioning. This is a free English-language course in electricity and electronics that you can follow via the Internet. The current lesson is basic electronics, part 2. The firm that came up with the idea, Sweethaven Publishing Services, wants to show how educational programs can be presented on the Internet.
http://www.sweethaven.com/acee/

Equation Grapher

This is a Windows program for plotting all sorts of equations and graphics.
http://www.mfsoft.com/equationgrapher/

Flimmer

This is a handy little Windows utility for measuring the video display frequency. It is a German-language program, but it is so clearly laid out that it can be easily used without a complete mas-

tery of German.
http://www.systron.ch/portrait.htm
Size: 27 kB

KyPlot

This is a professional-looking Windows program for plotting graphics and characteristic curves. The beta version is free in 16-bit and 32-bit versions.
http://www.qualest.co.jp/Download/KyPlot/kyplot_e.htm

Ntest

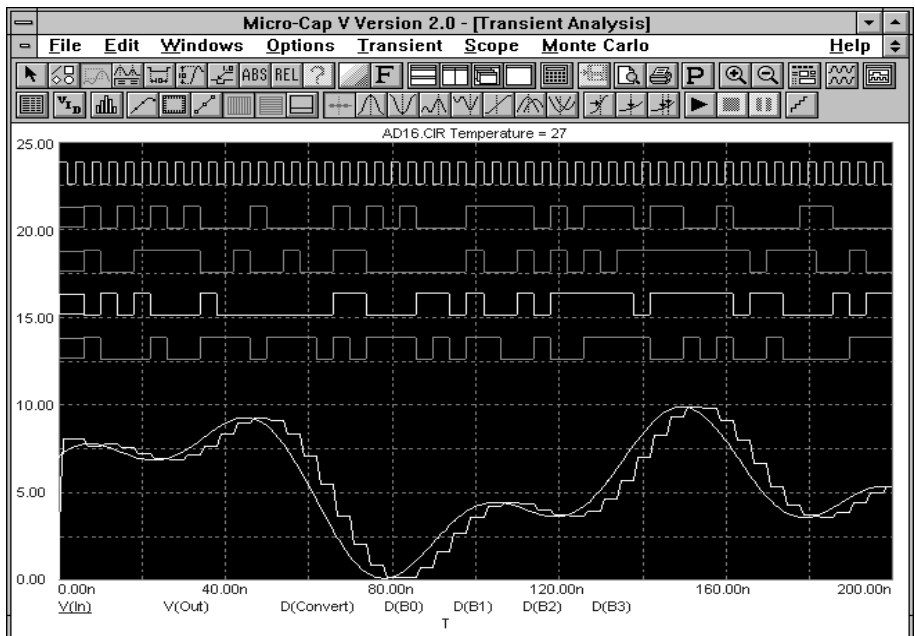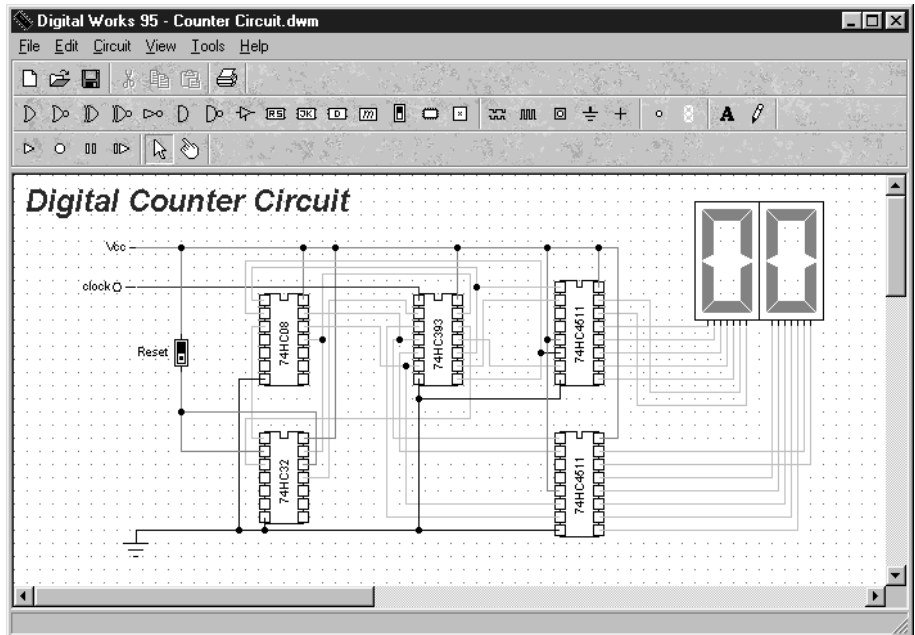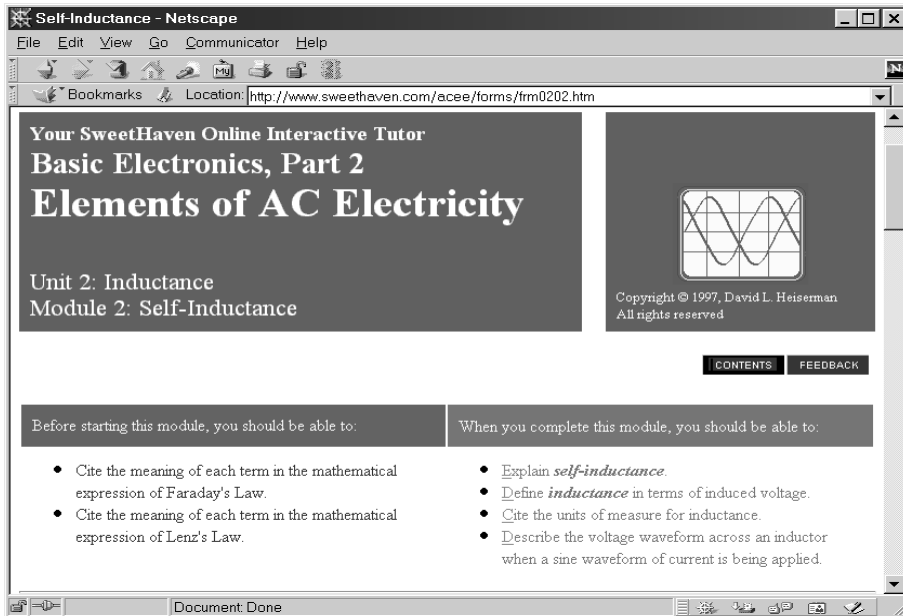This handy monitor testing program from Nokia provides many functions that can be used to investigate the quality of your monitor and adjust it for the best possible display. This program has been around for several years, but it is still one of the best of its type.
http://www.nokia.com/products/monitors/monitor_test.html
Size: 1.2 MB

Oscilloscope for Windows

This is a small, handy program that displays a dual-channel oscilloscope on the monitor, with all the important controls. It displays the signals present at the inputs of the sound card.
http://www.polly.phys.msu.su/~zeld/oscill.html
Size: 42 kB (Windows 3.1 version); 90 kB (Windows 95 version)

Freeware for radio amateurs

A vast potential of free software is available to licensed radio amateurs, short-wave listeners (SWLs) and other RF design enthusiasts. Remarkably, most freeware programs are a bit rusty and consequently run under DOS and/or Windows 3.11 only. Not surprising, really, because many radio amateurs will insist on using an older computer — in these circles, the 386 is still going strong and nothing to be ashamed of…

Because the radio hobby is marked by countless sub-specialisms, it is almost impossible to mention all available freeware for each 'sub-interest'. A couple of popular modes and ham activities, however, are difficult to avoid: packet radio, SSTV, DXing, contest logging, ATV, antenna design, QTH locator/distance calculations. Apart from the widely used WinPack, the packet radio fraternity is served by lots of other less ominous programs. A neat division based on PC operating system may be found at
www.telebyte.nl/~jeepee/softham.htm
Here you find links to WinPack (V. 6.4 for Windows), SP 9.75 (for DOS, an excellent replacement for the almost vintage BayCom), TNT (for Linux) and FlexPacket (for OS/2). The creators of packet radio, the Tucson Amateur Packet Radio Club (TAPR) may be found at
www.tapr.org/tapr/html/software.html
It has to be said that most freeware for radio amateurs may be found on **ftp servers**. In case these are new to you, we recommend getting started with Fast FTP Search at
http://ftpsearch.lycos.com
and put this url in your Favourites folder. This search engine will faith-

fully locate servers holding evergreens like Mininec (antenna design), BayCom (packet radio), RFTools (RF circuit design), QTH, Wefax, Coil (inductor design), Coilbuilder (ditto) Wxfax (weather satellite reception) and WinOrbit (satellite tracking), to mention but a few. In most cases, it is a good idea to type '.zip' behind the filename, for example, 'rftools.zip'. This will prevent the search engine from spewing out too many 'hits'. A couple of suggestions for ftp servers containing tons of ham software:
ftp://ftp.nhl.nl/hamradio
ftp://ftp.uscd.edu/hamradio
ftp://oak.oakland.edu/pub/hamradio/
ftp://ftp.qrz.com/pub/
ftp:ftp.fh-coburg.de/pub/freeware/hamradio
A 'must' with every visit to an ftp server is to read the index file which should be available at any level in the directory structure. If you don't, figuring out what a program does is pure guesswork if you haven't gone through the trouble of actually loading and using it.
Finally, there are many radio amateur societies, organisations, special-interest groups and, of course, individual hams with their own website. These sites are often great resources for freeware, or links to freeware. For example, take a look at what Geoff Brown GJ4ICD does at
http://user.supernet.uk/equinox
Happily surfing the net we also came across a splendid collection of ATV testcharts, a perfect DTMF generator using the soundcard and a QTH distance calculator, all at
http://www.arcadeshop.demon.co.uk/atv

Psimath

Everyone who works with electronics occasionally needs a pocket calculator with scientific functions — even when using the computer. This free program has a graphic display in addition to the usual functions, and even allows the user to program his or her own functions.
http://www.psido.exp.univie.ac.at/psimath/
Size: 2 MB

SmartDraw

This is an easy-to-use drawing program that is suitable for generating flow charts, organization charts, technical illustrations, diagrams and so on. There are separate versions for Windows 3.1 and Windows 95/NT
http://www.smartdraw.com/freecopy.htm
Size: 1.8 MB

Wiring Diagram 2000

This is a handy application for drawing
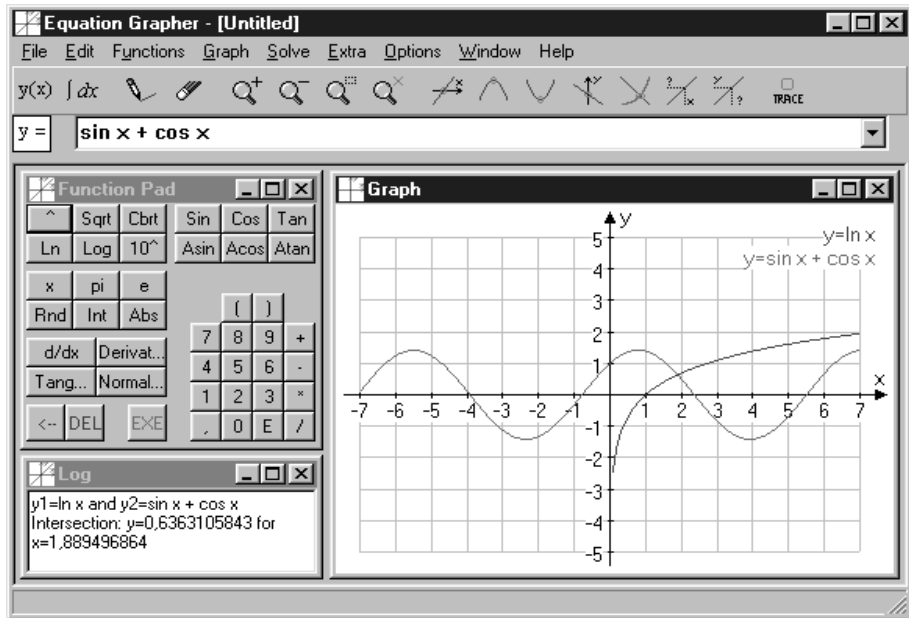
wiring diagrams. It takes up only 256 kB on the hard disk and works under Windows 3.1 and above.

http://www.geocities.com/SiliconValley/Park/5228/apps.htm
Size: 49 kB   (990011-1)

WHEN ELECTRONICS WAS YOUNG (3)

It is remarkable how many discoveries came about by accident (although it should be borne in mind that these 'accidents' were normally preceded by much hard work on allied research). One of these happened to the Danish physicist, Hans Christian Oersted (1777–1851). He was applying a potential across a metal wire to measure the current, when he noticed to his amazement that a compass that happened to be near the wire deflected when the voltage was switched on.

Hans C. Oerstedt (1777...1851).

Since he was aware, of course, of the interaction between two magnetic poles (laid down in the 1785 Law of Coulomb),he concluded that an unknown magnetic force was active in his experiments. An important conclusion, because until then nobody had connected electricity and magnetism. Until the middle of this century, the electromagnetic unit of magnetic fieldstrength was the oersted (2π oersted is the field at the centre of a circular coil 2 cm in diameter carrying a current of 1 ampere). It was replaced by the SI unit A^{m-1} ($= 4\pi \times 10^{-3}$ Oe).

Oersted's discovery was the spur to further research by other scientists. Around 1820, the French physicist Dominique Francois Jean Arago (1786–1853) discovered that an iron rod can be made magnetic by winding a current-carrying (insulated) conductor around it. The magnetism disappeared when the current was switched off. Today, Arago is better known by the experiments he conducted before the discovery of electromagnetic induction by Michael Faraday in which a rotating copper disk was made to cause rotation of a pivoted magnet (Arago's rotation).

Another scientist fascinated by electromagnetism was the French physicist and mathematician André Marie Ampère (1775–1836), who discovered that two wires carrying direct currents flowing in the same direction attract one another and repel each other when the direction of one current is reversed. The force with which this happens is directly proportional to the level of current and inversely proportional to the distance between the wires. From these findings, he formulated the law named after him: $nHdl = i$ (where H is the field around the conductor, l is the length of the conductor, and i is the current through the conductor) He also worked out the principle of a moving-coil ammeter, which depends for its action upon the force on a current-carrying coil in the field of a permanent magnet.

André Marie Ampère (1775...1836).

In the early part of the 19th century there were not yet standardized units for current, voltage and resistance. Although the British chemist Sir Humphrey Davy (1778–1829) had already discovered that the electrical resistance of metals increases when the temperature of the metal is raised, it was not until some years later that the German physicist Georg Simon Ohm (1787–1854) found that the current through a conducting wire is directly proportional to the potential across the wire and inversely proportional to the resistance of the wire. This was formulated in the well-known Law of Ohm: $I = E/R$.

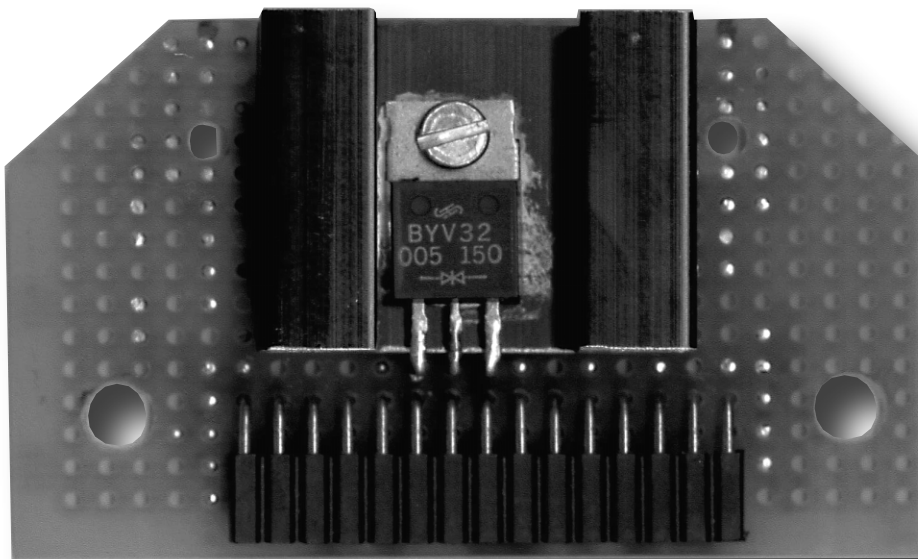**Georg S. Ohm (1787...1854).**

[995024]

With the introduction of the AMD K6, Cyrix 6x86 and Pentium MMX processors, a second supply voltage is required on the motherboard in addition to the primary voltage of 3.3 to 3.5 V. This additional voltage can be generated using a special voltage regulator, but there is an easier approach. The circuits presented here solve the problem in an especially simple and inexpensive manner.

Design by K. Viernickel

simple CPU voltage regulator

use K6, Cyrix and Pentium MMX processors in older-model computers

ply voltage.

It must be said at the outset that the circuit presented here is relatively simple, which naturally means that it has certain limitations. One of these is that the output voltage level may differ slightly from the desired value. It is thus important that you check what the supply voltage tolerance is for the processor used, and use a DVM to measure the actual output voltage of the regulator after switching on the computer, to verify that it is within the allowed range. You should also check the voltage whenever an energy-saving program, such as Waterfall, is active. The reduced current consumption in the energy-saving mode can cause the output voltage to increase slightly. You need not be unduly concerned about small variations in the voltage level, but it is important to be sure that everything is proper.

Two options, two circuits

Figure 1 shows the approach used to reduce a 3.5 V supply voltage to 2.8 V. This approach is needed when a Pentium processor with MMX technology is used, among others. The dual diode used here (Philips BYV32/100) has a forward voltage drop that is slightly more than 0.7 V across the PN junction, as can be seen from the characteristic curve in **Figure 2**. If the CPU supply voltage on the motherboard is set to 3.5 V,

Before the time of the Pentium MMX processor, all CPUs used a single supply voltage (3.3 to 3.5 V). However, designers then decided to use a lower supply voltage (2.2 to 2.7 V) for the core of the processor, in order to reduce the amount of heat generated. In the transition period between these two types of CPUs, various motherboard manufacturers provided special expansion connectors on the motherboard to

allow an extra voltage regulator to be fitted for CPUs that require two supply voltages. However, these special voltage regulator modules are rather difficult to obtain, especially since modern motherboards have a double supply voltage as a standard feature.

If you want to upgrade a moderately old computer by installing a new CPU, then it's handy to be able to provide your own solution for the second sup-
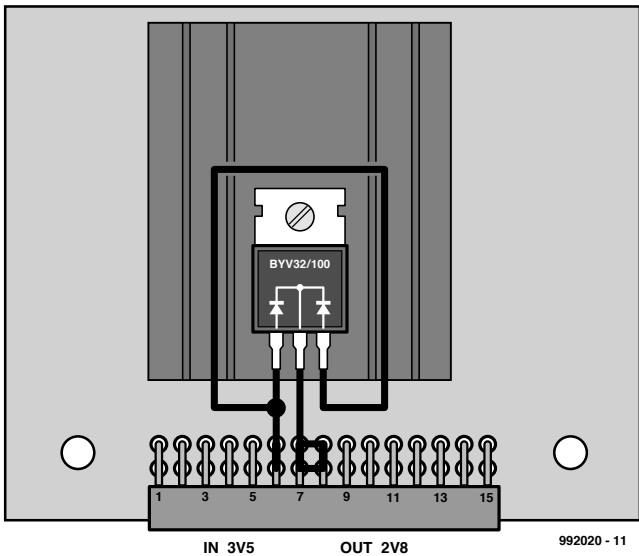
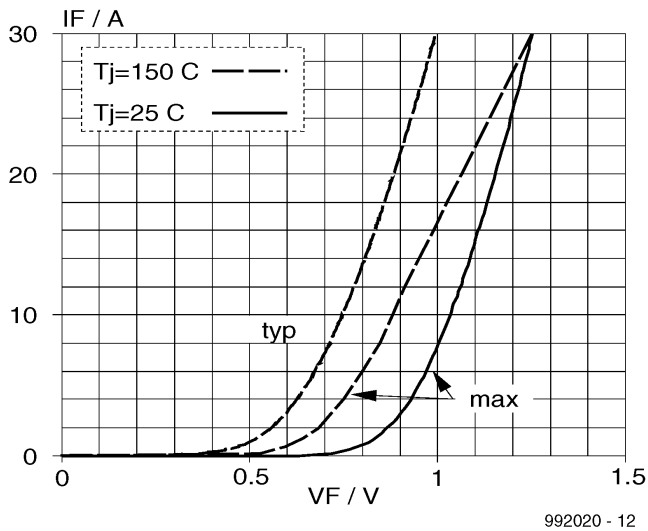Figure 1. This circuit can be used to generate the additional supply voltage for a Pentium MMX processor.

Figure 2. Conduction characteristics of the BYV32 diode. The forward voltage is shown on the horizontal axis and the forward current on the vertical axis.
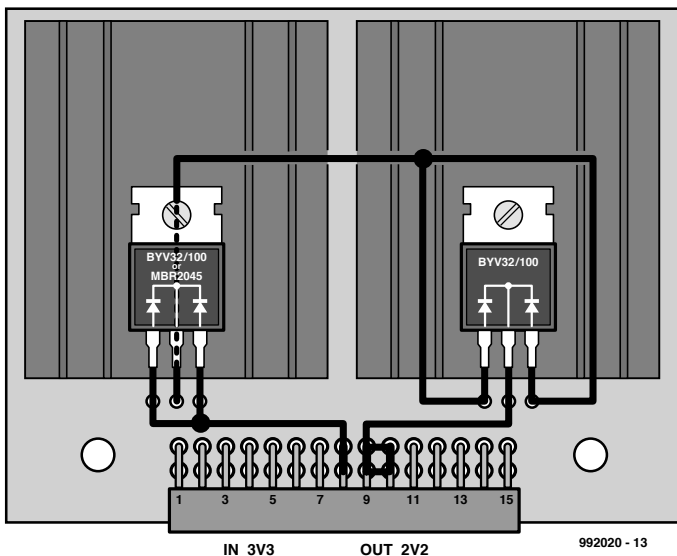

Figure 3. This circuit can be used if you decide to use an AMD K6-2.

then the output voltage will indeed be reduced to the desired level of 2.8 V. The diodes can together handle up to 20 A, which is more than enough for the job at hand.

A pair of diodes can be used in a similar manner to reduce the supply voltage from 3.3 V to 2.2 V, as shown in Figure 3. This approach can be used with an AMD K6-2 processor. In this case the basic idea is that the 3.3 V voltage is dropped to roughly 2.2 V by means of two diode voltage drops in series. Here we use either two BYV32 devices or one BYV32 plus one MBR1035/1045. The latter is a Schottky diode whose maximum forward voltage drop is 0.57 V at 10 A. The voltage drop is even less at lower current levels. The series connection of a BYV32 pair and am MBR1045 provides a voltage drop of 1.1 to 1.2 V, which is exactly what is needed in this case.

Connecting the two PN junctions of the BYV32 in parallel causes the relatively high current to be split between the two diodes, which results in a smaller voltage drop per diode.

The two circuits work with two different input voltages (3.3 and 3.5 V). The voltage level can usually be selected by means of a jumper on the motherboard. In practice, it does not matter all that much to the processor whether it works with 3.3 V or 3.5 V, but the level of the second supply voltage is clearly more critical.

Construction

It's easy to build the circuit and connect it to the motherboard. Mount the diode(s) together with a heat sink on a piece of prototyping board, and add a two-row, 30-pin right-angle connector. The wiring diagrams of **Figures 1 and 3** indicate the necessary connections. The photo in **Figure 4** shows the prototype build by the author. Once you have fitted the regulator board to the motherboard connector and set the jumpers correctly, your PC is ready for a second (and faster) life.

(992020-1)

Table 1. Processor operating voltages.		
type	Core voltage	I/O voltage
Pentium (P54C)	3.3 - 3.5 V	3.3 - 3.5 V
Pentium MMX (P55C)	2.8 V	3.3 - 3.5 V
AMD K5 PR75 - PR300	3.3 - 3.5 V	3.3 - 3.5 V
AMD K6 PR166 - PR200	2.9 V	3.3 V
AMD K6 PR233	3.2 V	3.3 V
AMD K6 PR266 - PR300	2.2 V	3.3 V
AMD K6-2 PR266 - PR400	2.2 V	3.3 V
Cyrix 6x86 P120+ - P200+	3.3 - 3.5 V	3.3 - 3.5 V
Cyrix 6x86MX PR166 - PR266	2.9 V	3.3 V

Many hobbyists use their PCs to control circuits via an
I2C interface. In this article, we show how the neces-
sary programming can be made considerably easier
with the help of a simple interface card and a spe-
cial Visual Basic DLL. Now you can control all your I2C
hardware via Visual Basic under Windows.

Design by R. Van Lier

I²C interface for the printer port

easily programmed with Visual Basic
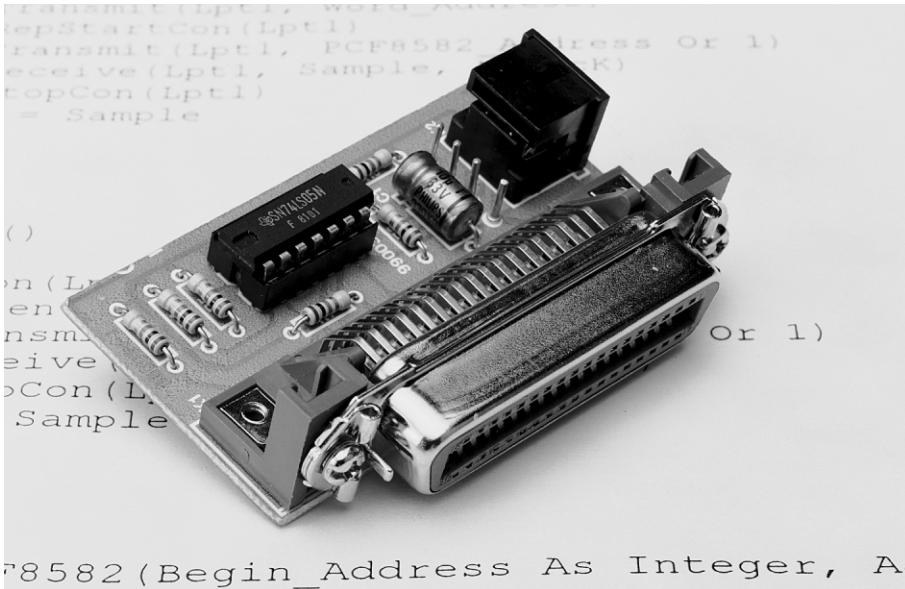
I2C, the Inter-IC bus, was developed
by Philips to allow ICs to communicate
with each other. Many modern pieces
of equipment, such as tuners, televi-
sion sets and video recorders utilize
this interface. Nowadays, the major
microcontroller families support this
interface, and driving the I2C bus is
furthermore not all that difficult.

If the I2C bus is used to control equip-
ment via the PC, then things are quite a
bit more complicated. A special hard-
ware interface card that allows external
equipment to be controlled has been
described in a past issue of *Elektor
Electronics*. The associated software
was limited to simple device drivers at
the DOS level. Presently, with practically
every PC running with Windows, this
approach is a bit outdated.

There's another way

Many programmers these days utilize
Visual Basic, which is a graphical
development environment for pro-
gramming in BASIC under Windows.
The most significant limitation of Visual
Basic is the fact that memory locations
cannot be directly addressed. Filling in
the contents of hardware registers in
special chips is thus out of the ques-
tion. Fortunately, there is a way to work
around this problem, based on using a
special DLL.

The DLLs presented here contain a
number of special functions, including:
- generating the start condition,
- generating a stop condition,
- sending a byte,
- receiving a byte.

There are two types of DLL available.
The first is IIC.DLL, a 16-bit version that
is suitable for use with Visual Basic 3
(Windows 3.1x), and the second is
IIC_32.dll, a 32-bit version that is suit-
able for use with Visual Basic 4 and
above (Windows 95 and later). These
DLLs must be copied to the
Windows/System folder or the
Windows/System32 folder, respectively.
Users of Windows NT should in principle
also be able to use the 32-bit DLL, but
they encounter a problem in that
Windows NT does not allow the user to
directly write to hardware addresses.
In this case a solution is available in
the form of the program TotalIO, which
is distributed via the Internet.
Interested parties can find it at
*http://www.ise.ufl.edu/esi4161/
files/direct_io/*
Once this driver has been installed, it is
no problem to access the I/O hard-
ware directly from the software.

A complete concept

Support for the PCF8591 IC is already
built into the DLLs. This IC contains both
an A/D and a D/A converter and is
used in many projects. The example
program IIC.BAS (which is located on
the diskette along with the drivers)
shows how both the PCF8591 (A/D and
D/A) and the PCF8582 (EEPROM) can
be used with the interface card of this
project, supported by Visual Basic.
Based on these examples, you can
see that using the I2C interface has
become very easy indeed. The only
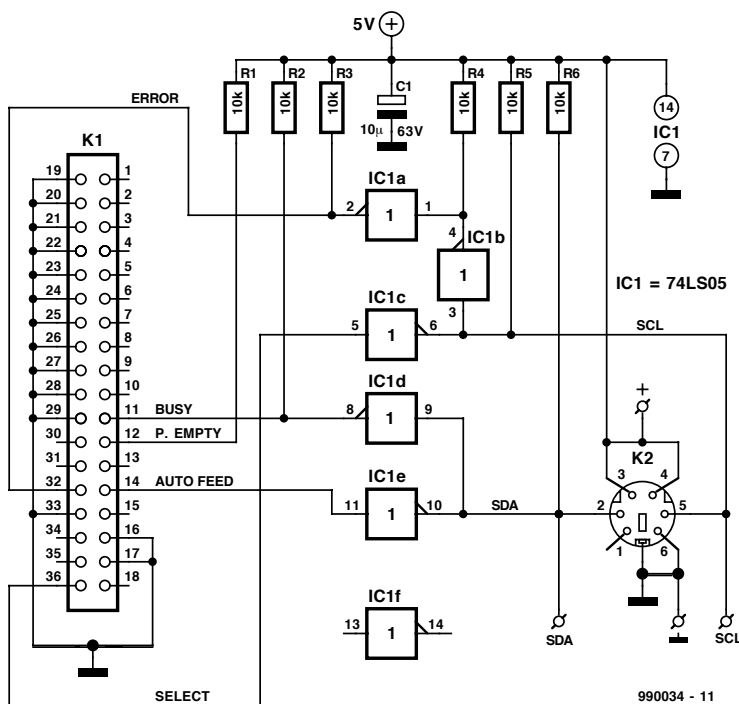limitation with this approach is that

Figure 1. Schematic diagram of the I2C interface, which can be connected to the PC Centronics port.

there can be only one master in the system, namely the PC.

The hardware

The DLL is based on a special I2C interface that is connected to the printer port. The circuit diagram is shown in **Figure 1**. The interface is based on the standard PC Centronics port, and connects five buffers of a 74LS05 to the port. It utilizes the printer port connections Error, Busy (inputs), Paper Empty and Auto Feed (outputs). These four connections are used to generate

the two I2C bus control signals SCL and SDA. Both of these signals are provided via combined input/output connections, since they are both bi-directional. The two control signals and the supply voltage are routed to connector K2. The target hardware can easily be connected to the interface via a cable and a mini-DIN plug.

Regular *Elektor Electronics* readers will undoubtedly recognize the circuit, since it was already presented in the Summer Circuits issue in 1993. Only marginal changes have been made to the original circuit design.

The pull-up resistors used here are required, since the buffer and the I2C driver are both open-collector devices. If R5 and R6 are the only pull-up resistors on the I2C side, it is better to use a value of 3.3 kΩ.

The copper track layout and component overlay of the circuit board are shown in **Figure 2**. This board is not available through our Reader Services, so you will have to make it yourself. Fortunately, this is not difficult since the board is quite simple.

(990034-1)

DLL functions

InitPCF8591	: initialise PCF8591
ReadPCF8591	: read byte from ADC
ReadbufPCF8591	: read n bytes from ADC
WritePCF8591	: write n bytes to DAC
StartCon	: generate start condition
RepStartCon	: generate repeated start condition
Transmit	: transmit a byte
Receive	: read a byte
TestFree	: test if bus free
TestConnected	: check if interface and supply present

Error reports

0 Error 0000 : No errors
1 Error 0001 : IIC bus not free
2 Error 0002 : No acknowledge received
3 Error 0003 : Could not generate a stop condition
4 Error 0004 : IIC interface has no power supply
5 Error 0005 : IIC interface not connected
6 Error 0006 : Undefined error occurred

Figure 2. The copper track layout and component overlay for the interface board.
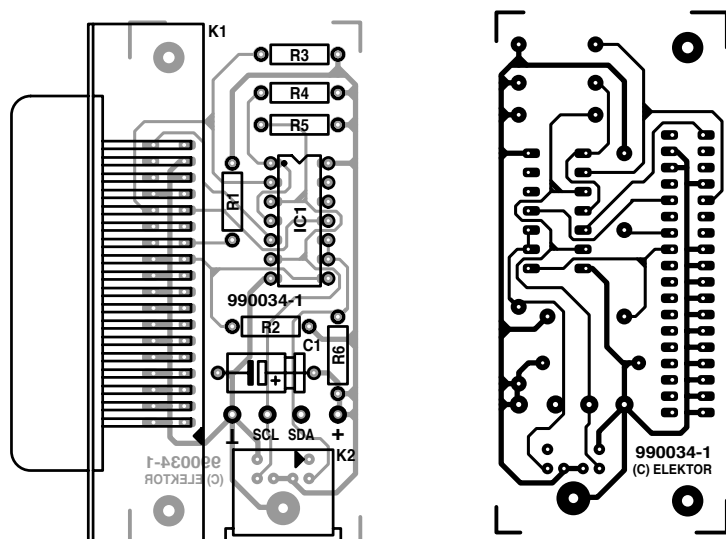
The eye pattern diagram is a proven means of judging the quality of a digital transmission channel or storage medium. It can normally be acquired from every type of CD-ROM player/recorder and can be displayed using remarkably simple equipment.

Design by W. Foede

eye pattern meter

measure the quality of home-made CDs
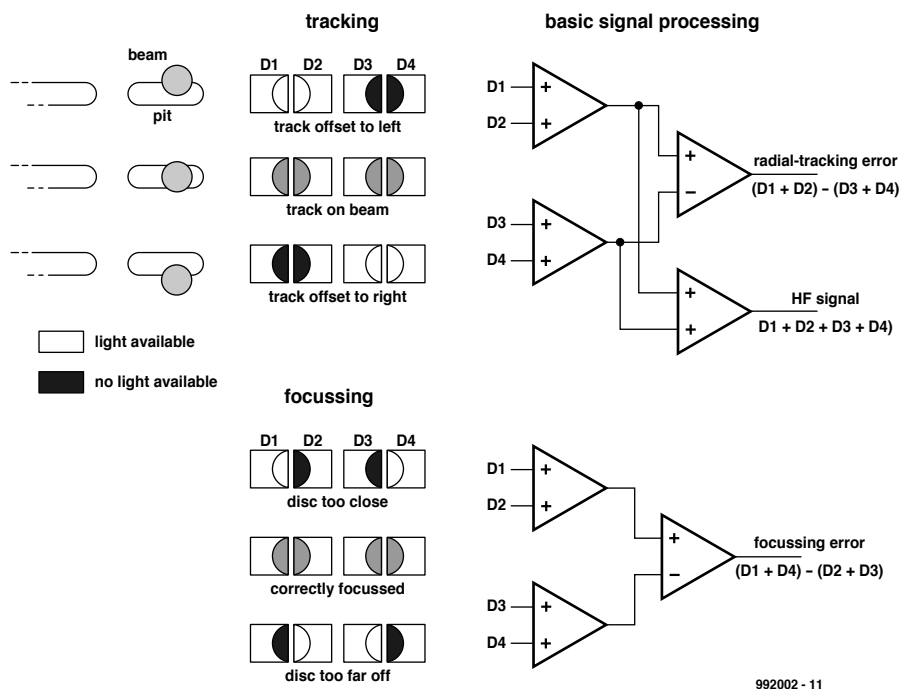
Figure 1. The four photodiodes D1 through D4 provide both the data signal HF and information that is used for adjusting the focussing and tracking.

Nothing is perfect, not even digital data transmission. No matter whether we are dealing with audio data or 'normal' computer data, the error gremlin is always present. Possible sources of errors in digital data transfers can be found both in the system components (such as a CD-ROM player/recorder) and the storage media (such as the CD). Some types of system-related errors, in particular those with electronic sources such as aliasing, nonlinearity and noise, can be minimized by suitable circuit design, and other types can be dealt with by error-protection measures. In the latter case, errors are detected using parity checking or cyclic redundancy checking (CRC) and corrected by means of encoding schemes (such as cross-interleaved Reed-Solomon coding). And if this all fails, the corrupted signal can be restored by interpolation.

Other types of system-level errors are purely mechanical in nature. The causes of the most frequent, commonly-occurring errors with the CD medium are well known: soil and scratches on the surface of the CD itself. These obvious errors usually affect a large number of bits and are referred to as 'bundle errors'. Of course, single-bit errors can also occur, for example due to an asymmetric pit or a material defect.

Errors also occur due to faulty tracking and incorrect focussing of the laser beam. It is by no means a simple task to keep the laser beam within micrometer tolerances in spite of often demanding environmental conditions. To ensure a good-quality playback signal, the laser beam should follow the centre line of the track within ± 0.1 micrometre. This requires a sophisticated control system and a mecha-

nism that responds quickly and accurately, even after years of service.

There are many possible ways to build a laser read or write head assembly, but all of them have one thing in common. This is the fact that the signal received by the photodetector (that is, the laser detector assembly with its four photodiodes) delivers both the data signal and important information that is used to control the laser head. This information is produced by interpreting the signals from the four photodiodes, as illustrated in **Figure 1**.

The FE signal is used by the focussing actuator to correct for focussing errors, the radial error signals RE1 and RE2 are employed by the tracking control sub-assembly, and the sum of the signals from all four diodes produces the data signal, designated HF. The latter signal is passed through an automatic gain control stage and converted to a balanced signal before being output from the servo electronics assembly.

There is no need to be concerned about the data signal being affected by the relatively low-frequency control signals. The bandwidth of the data signal is limited to the range of 20 kHz to 1.5 MHz by the eight-to-fourteen modulation scheme (EFM), so it is completely separated from the control signals.

The eye-pattern diagram

One way to judge the quality of a digital data transfer is to observe its eye-pattern diagram. This is produced (in the case of a CD-ROM player) by connecting the HF signal to the Y input of an oscilloscope while connecting the clock signal recovered from the HF data stream to the X input. This causes an eye-shaped pattern to be displayed. When a large number of such patterns are displayed superimposed, the result is an eye-pattern diagram as illustrated in **Figure 2**. In the ideal case, all of the eye patterns lie exactly on top of each other, but in practice distortions occurs due to radial and focussing errors. Several factors relating to the quality of the digital data channel and the storage medium can be read from the eye pattern diagram. The inner width of the eye is equal to the minimum separation between successive pulse edges of the binary data stream. The difference in the widths of the eye patterns indicates the amount of jitter, and the amount of variation in the pulse amplitude can be read from the difference in the heights of the eye patterns. The inner height of the eye-pattern diagram indicates the noise margin of the digital signal.
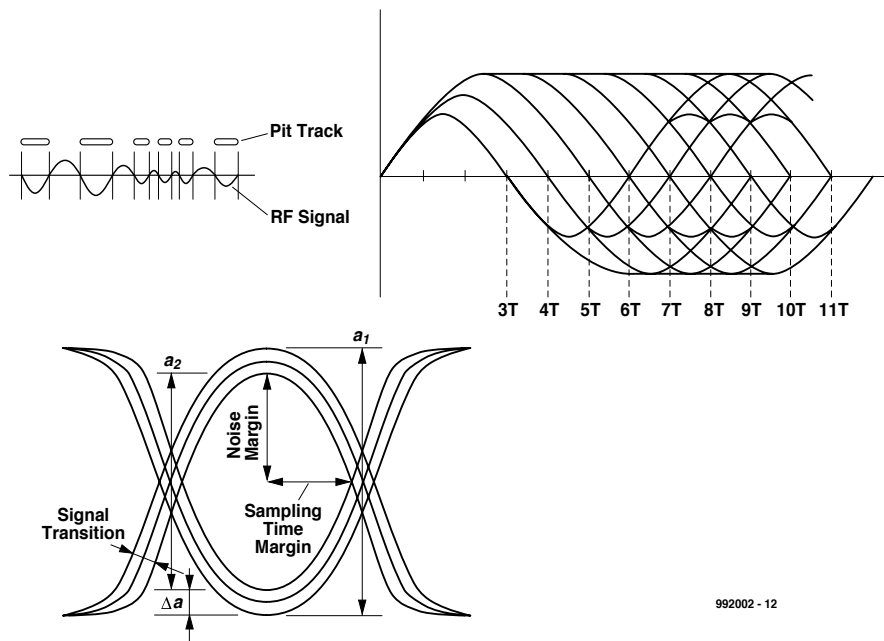
Figure 2. The eye-pattern diagram shows the overall 'health' of the data signal.

Applications

No matter how highly integrated a given CD-ROM player/recorder may be, it is always possible to access the HF and data clock signals somewhere inside the unit. The most interesting application for these signals is to use them to generate eye-pattern diagrams on an oscilloscope, as just described. However, it is possible to do something useful with the HF signal alone (together with an earth reference). The HF signal – once the DC component has been removed – provides in fact an exact indication of the relationship between pit and non-pit signal levels, the 'pit-to-land ratio'.

You can connect an ordinary moving-coil meter to the HF signal as shown in **Figure 3**, with a capacitor to block the DC voltage and a variable series resistance (R1 plus P1). The Schottky diode D1 acts as a rectifier. The HF signal can easily tolerate this load.

Adjust the resistance so that the meter indication is about 90% of full scale with an arbitrarily selected, pre-recorded CD. The meter can be used to optimally adjust a laser head (for a maximum meter indication). This is especially worthwhile for three-beam assemblies, since their mechanisms are not all that robust. However, it can also be used for comparative testing of various makes of CD-R drives (which was the author's original intention). In this way you can answer questions such as 'is an inexpensive no-name CD-R drive just as good as an expensive top-brand product?' and 'can I find the best brand of CD-R disk to use with a given CD-R drive?'

(992002)
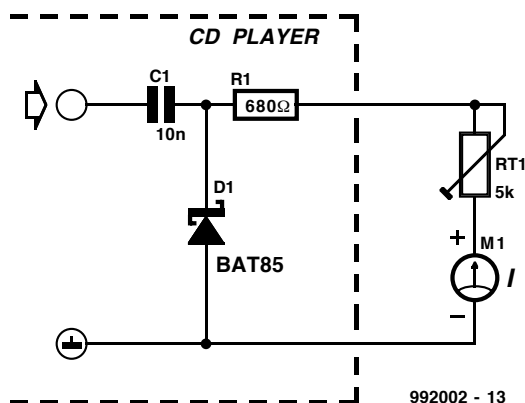
Figure 3. A very simple circuit can be used to show the quality of the data transfer.

CORRECTIONS & updates

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

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

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

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

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

0.45 / I [ohms].

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

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

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

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

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

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

If a PIC is used for example in a timer application, such as a programmable clock timer, the majority of the circuit is taken up by the user interface with its switches, pushbuttons and display hardware. This expense can be avoided if the settings are entered via a PC, but operating the device is then made even more inconvenient by the required connecting cable. In this article, the author describes a simple interface that requires almost no additional hardware and allows a PIC application to be configured from the PC without a connecting cable.

Design by H. Bärnthaler

PC screen data flasher

a wireless interface
between the PC and a PIC
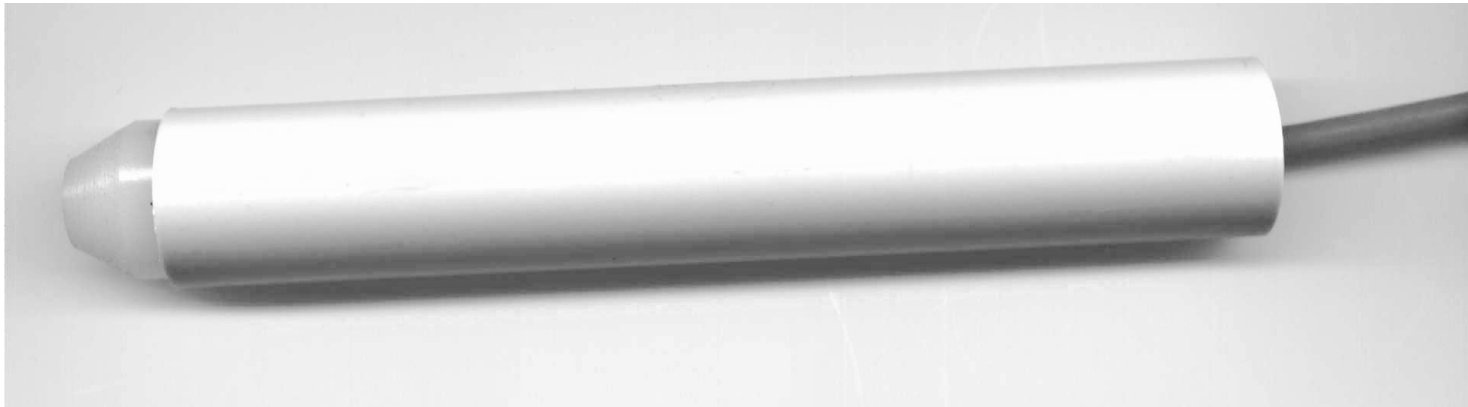
As an example, let's suppose that you want to build a convenient timer using a microcontroller. All that you need for the timer function is a counter that engages or releases a relay at certain times. This function can be realized with a few lines of software.

However, you will need significantly more software and hardware (pushbuttons and a display) to be able to configure the timer. You must be able to set the current time and define the various switching times, you have to specify which relay is to be controlled, and of course you will have a choice of several options. For the benefit of the user, you compose four pages of verbose text in order to explain how to

set up the timer using its three pushbuttons and three-character display.

A better solution

Instead of all this, you can write an easy-to-use C program on your PC, with attractive screen windows and a help menu, and use this to enter the necessary data for the timer. Then you hold a simple probe, resembling a ball-point pen and containing a phototransistor sensor, against a certain portion of the monitor screen where a blinking point of light appears. This transfers the required 20 bytes of configuration data to the microcontroller. The advantages of this approach are

obvious. Only one port lead is used for the entire key entry and configuration management functions of the timer. The display and pushbuttons are made fully redundant, since all data are entered at the PC and graphically edited. No cable need be connected to the PC, and the PC and the PIC system are fully electrically isolated. Finally, a small amount of simple code in the PIC is sufficient for handling the data, so that more memory is available for the actual application.

The configuration data are managed in a convenient and easily-understood manner using the PC, and the complete PC keyboard is effectively made available to the PIC. This procedure

can be used with even the most antique PC, since practically every PC can display an alternating black and white rectangle on its monitor. Since none of the PC ports is used, the common problem of an incorrectly configured serial connection disappears entirely, and special PC hardware expertise (which is often needed with serial interfaces) is not required.

Of course, we should not neglect to mention the disadvantages: data can only be transferred from the PC to the PIC, and not in the other direction, and the data transfer rate is slow (around 40 bytes/minute). However, this is not a problem for many applications, where the amount of data to be transferred is anyhow very small.

How it works

A blinking rectangle is generated and displayed on the PC monitor, with pulse-width modulated brightness. This carries the data words in serial form. A phototransistor passes the signals to the microcontroller, which reconstructs the data words.

As can be seen from the schematic diagram in **Figure 1**, the necessary hardware is very simple. Any standard type of phototransistor can be used for the receiver; two common types are specified on the schematic. The phototransistor is followed by a single amplification stage using a BC548B, which increases the signal level so that it will reliably activate the Schmitt-trigger input of the following monostable. The pulses produced by the monostable are connected directly to the microcontroller port RB0 pin for evaluation within the PIC. The PIC shown in the sample circuit uses a 455-kHz ceramic resonator and is wired only to the extent necessary to test the interface program.

Software

A Pascal program that can be used for sending the data bytes from the PC is available on a diskette through the *Elektor Electronics* Readers Services, together with a commented assembly-language program listing for the PIC (order number 996038-1).

The sample program 'ScreenDataFlasher', shown in **Table 1**, demonstrates the function of the screen data interface and transfers a total of 20 bytes with alternating values of FF_H and 00_H. An init bit is sent before each data byte; the microcontroller measures the length of this bit. The following data bits are pulse-width mod-
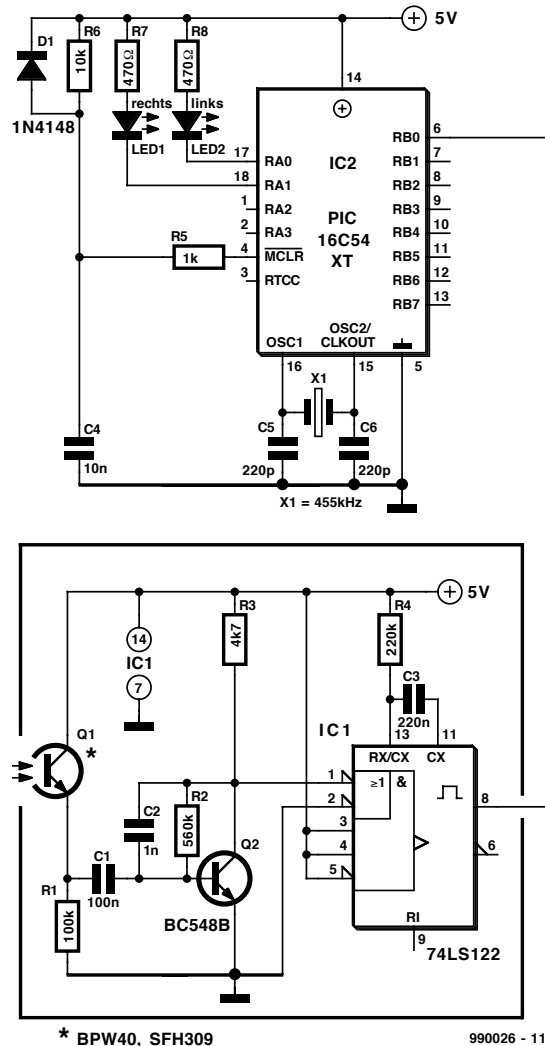
Figure 1. The hardware required for the interface is very simple, consisting of a phototransistor, an amplifier stage and a monostable.

Table 1. Test and demonstration program for the interface.

```
Pascal Listing
**************************************************************}
Program PCScreenDataFlasher (Input, Output);
Uses   Dos, CRT, Graph;

type
     PointType = record
               x, y: Word;
          end;

Var  Var1               : Integer;
     Var2,  Var3         : Integer;
     GraphMode,  GraphDriver    : Integer;
     x1,  y1,  Width,  Height    : Integer;
     MeasInstant        : Integer;

const
     Pentagon: array [1..4] of PointType =
     (( x:  50;  y:50),
      ( x:  50;  y:100),
      ( x:  100;  y:100),
      ( x:  100;  y:50));
     Dark:  FillPatternType = ($00,  $00,  $00,  $00,
                                $00,  $00,  $00,  $00));
     Bright:  FillPatternType =    ($FF,  $FF,  $FF,  $FF,
                                    $FF,  $FF,  $FF,  $FF));

     HighLength   = 2000;   {length of high pulse}
     LowLength    = 1000;   {length of low pulse}
```

ulated. All pulses that are longer that the init bit are decoded as '1', and all pulses that are shorter than the init bit are decoded as '0'. The size of the data word is adjustable, with a minimum value of one bit. The actual setting must of course be taken into account in the microcontroller.

The specified time delays may have to be modified to accommodate the PC used and the monitor's vertical repetition rate. Start testing with relatively long delay times and gradually reduce the delays until the data are no longer correctly transferred. If you have questions, you can contact the author via e-mail: Ing. H Bärnthaler at hbaernthaler@mail.carinthia.co.at.

(990026-1)
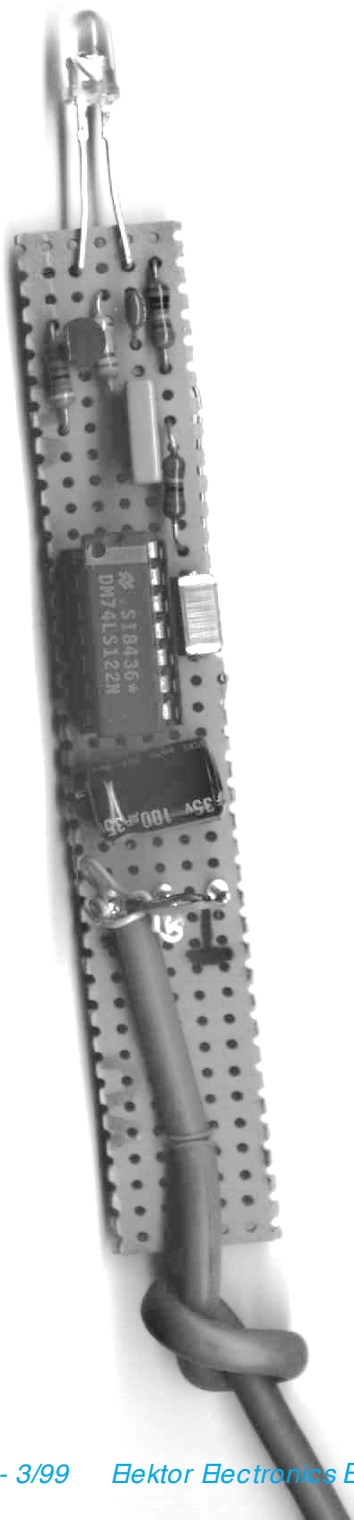
```
        WaitLength    = 1500;   {time between bits}
        InterByteTime = 1000;   {time between bytes}


{*****************************************************************
{  In this subroutine the start bit is flashed, its length is
{ measured by the microcontroller.
*****************************************************************}
Procedure InitBit;
Begin
     {transmit Init bit length calculation}
     MeasInstant : = LowLength + ((HighLength-LowLength) div 2);
     SetFillPattern (Bright, White);
     FillPoly (SizeOf (Pentagon) div SizeOf(PointType),  Pentagon);
     Delay (MeasInstant);
     SetFillPattern (Dark, Black);
     FillPoly (SizeOf (Pentagon) div SizeOf(PointType),  Pentagon);
     Delay (WaitLength);
End;


{*****************************************************************
  Program start
*****************************************************************}
Begin
     GraphDriver : = Detect;
     InitGraph (GraphDriver, GraphMode, 'c:\pascal\graphix');
     readln;   {Wait for key pressed}
     For Var1 : = 1 to 10 do
          Begin
                     InitBit;
                     {supply 8 High Data bit}
                     For Var2 : = 1 to 8 do
                          Begin
                                {supply High}
                                SetFillPattern (Bright, White);
                                FillPoly (SizeOf (Pentagon) div
                                SizeOf(PointType),  Pentagon);
                          Delay (HighLength);
                                SetFillPattern (Dark, Black);
                                FillPoly    (SizeOf    (Pentagon)    div
SizeOf(PointType),  Pentagon);
                          Delay (WaitLength);
                          End;
               { wait until next data byte transmitted }
                    Delay (InterByteTime);
                    InitBit;
                     {supply 8 Low Data Bit}
                     For Var2 : = 1 to 8 do
                          Begin
                                {supply Low}
                                SetFillPattern (Bright, White);
                                FillPoly    (SizeOf    (Pentagon)    div
SizeOf(PointType),  Pentagon);
                                Delay (LowLength);
                                SetFillPattern (Dark, Black);
                                FillPoly    (SizeOf    (Pentagon)    div
SizeOf(PointType),  Pentagon);
                                Delay (WaitLength);
                                End;
                          {wait until next data byte is sent}
                    Delay (InterByteTime);
          End;
          { display dark again}
     readln;
     CloseGraph;


End.
```

Beyond 2000

Predictions anyone?

By Gregg Grant

INTRODUCTION

No? I can't say I'm surprised. Nothing – someone once said – dates so rapidly as the future. When Aldous Huxley's Brave New World came out in 1932, most people thought it was a terrifying view of what lay ahead. In retrospect, it forecast nothing so much as the soma-phoric drug culture of today.

George Orwell's bleakly depressing 1984 predicted neither computer control nor the re-emergence of the Spiv – tarted up for the 1980s – as the Yuppie. It did however tell its readers a great deal indeed about immediate, post-war Britain.

On another level the television series Star Trek is as good a guide as you can get to the hemlines of the 'swinging sixties' this side of a 60s revival edition of Vogue magazine. As to the realities of space travel…let that be!

This, you may say, is all very well. You've chosen some easy targets for a bit of good, knock-about journalism. OK, point taken. Now let's see if scientific technology has fared any better in the prediction game.

TRUST ME, I'M A SCIENTIST

When looking into the future, it seems logical to go to those who, the majority of us feel, are best placed to judge such matters: scientists and engineers. Sadly the record of scientists in the prediction business has been outstandingly undistinguished, to put it mildly. This appalling track record was encapsulated in a law in 1982, by no less a person than the science fiction writer and futurologist Arthur C. Clarke. This law states that 'when a distinguished but elderly scientist states that something is possible he is almost certainly right. When he states that something is impossible, he is very probably wrong.'

The evidence for this began to accumulate much earlier, the first inventor-originator to come up against the law being Galileo, in 1610. Under investigation by the Church for dar-
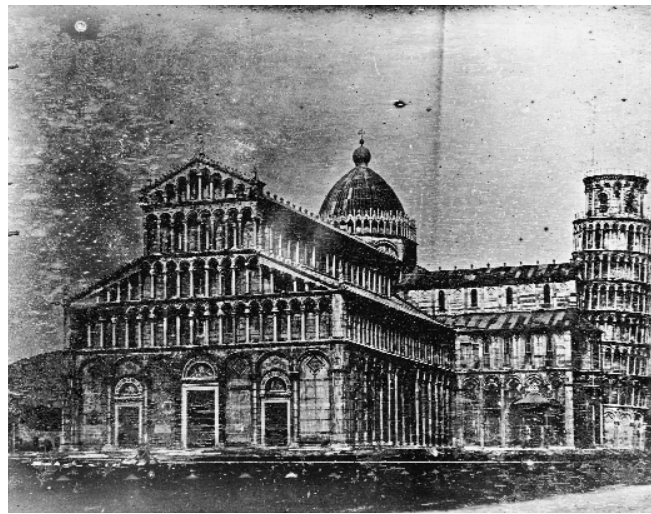

Figure 1. An early Daguerreotype illustration of Pisa, featuring the leaning tower, by Ellis, 1841. (Science & Society Picture Library)

TECHNOLOGY AND THE NEW MILLENNIUM

The advent of a new era is usually a time for reflection and stock-taking. The millennium currently approaching Platform Earth is no different. Reflecting on the progress of electronic technology over the second half of the millennium now passing away is sobering, to say the least.

To the Victorians and their successor, the Telegraph was the epitome of technical progress, along with the Trans-Atlantic cable system that was its highway. To pre-World War II Britons, the Television was no less marvellous. Yet, one has passed away, and the other is being changed significantly.
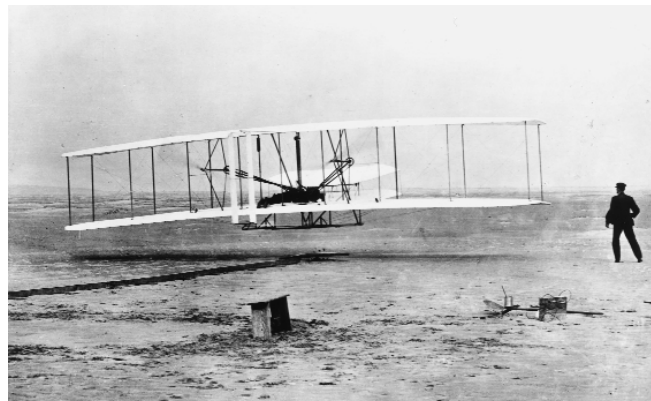

Figure 2. Orville Wright 1871–1948) making the first powered and sustained flight at Kitty Hawk, North Carolina, 17 December 1903. (Science & Society Picture Library)

ing to suggest that Jupiter had moons, his views were forwarded to some professors of astronomy for their views. They replied to the Inquisition that since these so-called moons were invisible to the naked eye, they couldn't possibly have any influence on planet Earth. They obviously, therefore, didn't exist!

In 1827, the German physicist Georg Simon Ohm published the law called after him, the first such law to link voltage and current to resistance in an electrical circuit. It was immediately denounced by a number of physicists and so-called electrical 'experts.' Indeed it would be 1841 before Ohm's work was vindicated, when the Royal Society awarded him its Copely Medal. Shortly thereafter, he began to be recognized for what he was: a clear-thinking original.

Just as the learned professors refused to look through Galileo's telescope, so would Louis Daguerre suffer from the arrogance of the 'experts' of his day. In 1839, he announced his process for creating a silver image on a copper plate, termed a daguerreotype. An early example of this is shown in Figure 1. This photograph, a view of Pisa, featuring the Leaning Tower, was dismissed by a variety of authorities, none of whom took the trouble to either talk to, or examine, the inventor or his method and process.

In 1896, that Victorian scientific icon Lord Kelvin – he of the temperature scale all scientists know and prefer – stated bluntly that he had 'not the smallest molecule of faith in aerial navigation other than ballooning.' Seven years later, this view became dated, to say the least.

As the Wright Brothers – shown in Figure 2 with the younger one, Orville, at the controls – were taking to the air in their earliest proving flights, they were attacked from another quarter. The Canadian-American astronomer Simon Newcomb – who knew a considerable amount about the earth's atmosphere – wrote an

article whose ending was far from encouraging for what would rapidly become a new form of transport.

Newcomb explained that no conceivable combination of materials, machinery or motive power could be brought together in a vehicle that would lift into the air with a human being on board. A fortnight after his death in 1909, Louis Blériot became the first man to fly across the English Channel and the Englishman Henri Farman had completed the first flight of 100 miles duration.

Nor did matters improve as the century progressed. In 1937 Lord Rutherford – laden with distinctions and probably the greatest living experimental physicist – proved that his skills as a prophet were every bit as underwhelming as that of his predecessors. When a journalist asked what the effects of splitting the atom would be, Rutherford replied that if anyone jumped to the conclusion that a power source lay within the transformation of atoms, then that person was talking moonshine. Less than 20 years later the British nuclear engineer Christopher Hinton opened Calder Hall, in Cumbria, the world's first nuclear power station.

Nothing, perhaps, epitomizes the last half of the present century in quite the same way as spaceflight does. Yet it too had its detractors, not least the British Astronomer Royal, Sir Richard Woolley. In 1956, he stated that spaceflight was 'utter bilge'. In the following year Sputnik, the world's first satellite, was launched.

Later Woolley, through his official position, became a member of the committee advising the United Kingdom (UK) government on - wait for it – space research! It need hardly be observed here that, by and large, the UK has never had anything that could be remotely termed a space programme.

ENGINEERS ARE NO BETTER

If scientists can hardly be said to be prescient, engineers are equally as lacking in foresight, as the development of electrical power shows.

By the final quarter of the nineteenth century, the inventive gifts and technical initiative of a number of individuals were making significant advances in
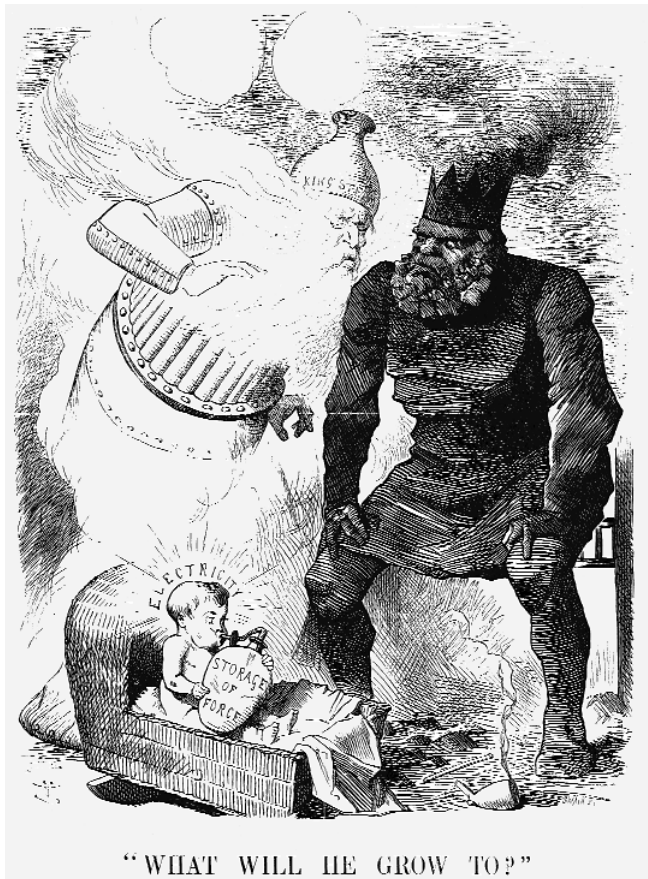

Figure 3. The Punch cartoon referred to in the text (25 June, 1881, reproduced with permission of Punch Ltd)

developing electrical power for commercial and public utility applications.

One of these developments would be roundly dismissed by no less a person than the Engineer-in-Chief of the British Post Office, Sir William Preece. His béte noir was the newly invented Electric Light of Thomas Edison, which, Preece thought was an absolutely fatuous development. In fact the

humorous magazine Punch displayed far more foresight in its 1881 cartoon, shown in Figure 3, than Preece appeared capable of.

Nor was Thomas Alva Edison much better as a prophet of future trends, despite his 1,093 patents. Whilst well aware that his Phonograph for example could record music, he nevertheless thought that it would really come into its own

Figure 4. Five printed-circuit boards illustrating the various stages of manufacture in the 1980s. (Science & Society Picture Library)

as a device for recording the last words of the dying!

In 1943, Thomas J. Watson, the founder of the International Business Machine (IBM) Corporation stated that, in his anything but humble opinion, the world market for computers would be small indeed. He envisaged no more than five being sold, world-wide.

Six years later, technical journalists proved that they too were just as disastrous at forecasting the future as everybody else had been. The American magazine Popular Mechanics, whilst acknowledging that ENIAC – the world's first general purpose computer – had 18,000 valves and weighed 30 tons, those of the future would be far more versatile. They'd probably require no more than 1,000 valves and weigh as little as 1.5 tons.

And this at a time when the valve was known to be cumbersome, inefficient and power-hungry to a degree. However, a replacement for the valve was being actively sought in a number of research laboratories, resulting in the transistor and integrated circuit. Today, most electronic circuits are made up of vast numbers of integrated circuits mounted on a printed-circuit board as illustrated in Figure 4

Sadly, it gets worse. In 1961, some 12 months before the launch of the world's first communications satellite, Telstar, the United States Federal Communications Commissioner T.A. Craven said that the chance of launching satellites to provide better television and telephone services was virtually nil!

And this, some 16 years after a former Royal Air Force (RAF) communications officer, one Arthur C. Clarke, had prophesied that the first use of satellites would be in the communications field.

So, how is it that science fiction writers are far better at the prediction game than scientists, engineers and technical journalists? After all very few of them – Arthur C. Clarke excepted – have had an engineering or scientific training.

That fine practitioner of the genre, Ben Bova, hinted that such a training was, in all probability, the least satisfactory background for a futurologist. Bova observed that no scientist
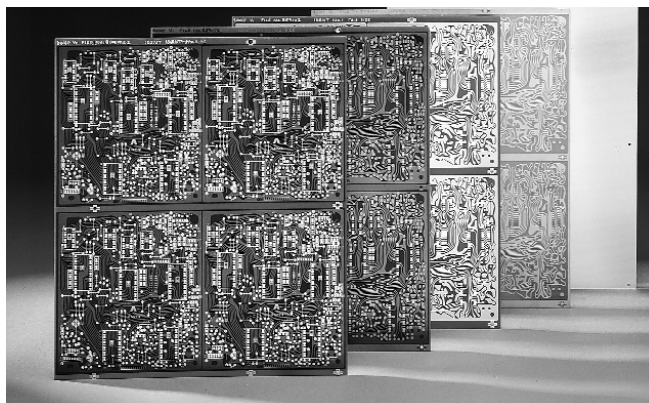
or engineer, working for the majority of Western governments, would predict the sort of semi-accidental discovery – a good example of which is the integrated circuit – that would change the world. He highlighted the electronics industry circa 1950 as an illustration.

If, as Bova pointed out, a journalist had asked any government-employed engineer or scientist at this time how they saw the future of electronics evolving he – or she – would have got a fairly predictable reply. Far smaller valves, working at increasingly lower voltages added to an increasing use of plastic for the enclosures, would have been the limit of their imaginations.

At this time, however, science fiction writers were talking of two-way wrist radios and pocket-sized computers, not because they'd had an insight that silicon and germanium would subsequently prove to be the way ahead, nor because they had a hotline to Bell Labs. It was simply that their instincts told them that something had to be done about the sheer bulk of the electronic devices of the day.

History played a part too. The earliest steam engines – a good example of which is shown in Figure 5 – were massive, noisy and gluttonous of whatever fuel they used.

This was what could be called – indeed was – first generation technology. Compare Figure 5, however with Figure 6, the latter representing about a century of engineering progress.

To men like Bova, 1950s radio gear was the first generation technology of the electronics business. It seemed obvious therefore that progress would – broadly – follow much the same pattern as it had previously done with the steam engine, the internal combustion engine and a number of other machines.

Aware of the technology all around them – and the science underpinning it – they used both to drive their imaginations forward.

For scientists, engineers and technical and scientific journalists – the latter pair almost always coming from a scientific technology background – such everyday devices act as constraints, an advanced braking
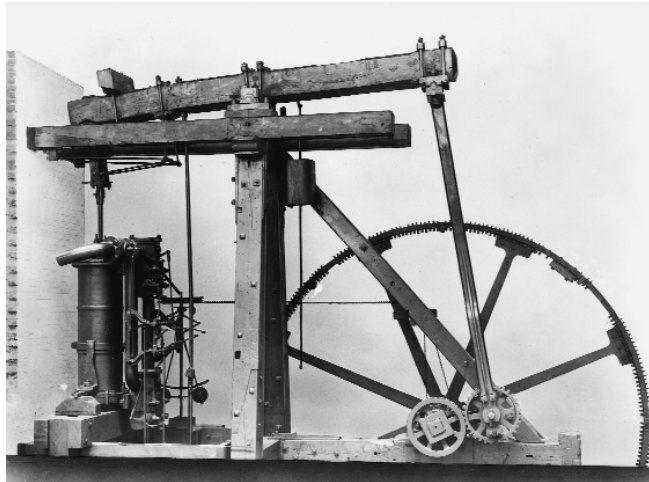

Figure 5. Boulton and Watt rotative engine of 1785. (Science & Society Picture Library)

system on too vivid an imagination. Research funding, government patronage, career prospects and other forms of advancement all conspire to ensure that scientists, engineers and – yes ––even technical and scientific authors stay within the long established guidelines of their fields and/or professions. Little wonder therefore that no government or academically-employed researcher, engineer or scientist will upset this steadily trundling applecart.

THE FUTURE

We are – generally speaking –

made by our materials and the machinery we fashion from them. Not for nothing have historians termed certain periods in our past the Stone Age, the Bronze Age and so on. Currently, we're in the Silicon Age and the major machine of our time is the computer.

When Isaac Newton published his *Principia* in 1687, the sophisticated machinery of the day was the clock. Newton looked on the workings of nature as an example of superb and elaborate clockwork. As the clock came to dominate everyday life, so the concept
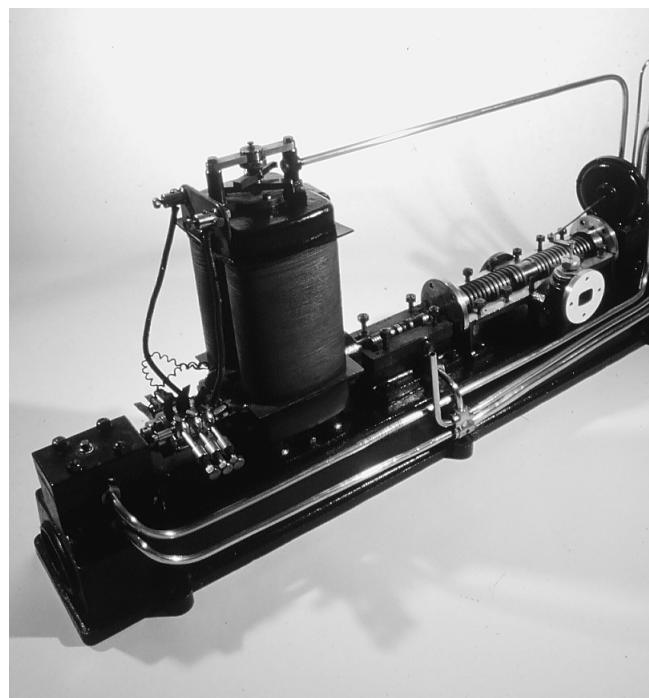
struck a powerful chord in the mind of man, one that took a great deal of shifting when, later, it became obvious that nature's clockwork was less than perfect.

When John von Neumann put forward his concept of the series computer, arranged in what's come to be known as the von Neumann architecture in 1945, he created a machine which has dominated all our lives since. Look again at Figure 4: circuit cards such as these are familiar to virtually everybody who has a home computer. The device and its peripherals such as the Visual Display Unit (VDU) and laser printer, have had a profound effect on late twentieth century human beings: we have been conditioned by its structure, operating technique and general ergonomics.

Given this, I sense that a number of powerful factors – and people for that matter – will ensure that they become, if I can put it this way, the Newtonian clock paradox of the next couple of hundred years or so.

Therefore, when looking into the future – no matter how far – we should be aware of being too influenced by our present, by what we're familiar and comfortable with. One modern example of how attached we've become to what's familiar, what's part of our mindset, is the shape and size of the TV and VDU screens we use.

Indeed if any area is ripe for improvement this is it. Already the Laptop computer has pointed the way to a far smaller, slim-screen future. Shortly, too, we'll have to find a successor to silicon for there is – at most ––about one more order of magnitude to be had from present-day integrated circuit manufacturing techniques.

Will we succeed in these and other developments, many of which we can only vaguely envisage? Of course we will! Why? Simply because, as Arthur C. Clarke pointed out long ago, if something is desired by a sufficient number of people, however unlikely the 'something' may seem at present, it will be achieved eventually. And we have proof of this: simply look back at the twentieth century!

[995019]

Figure 6. Parson's steam turbine and high-speed dynamo of 1884. (Science & Society Picture Library)

VGA display tester

check those computer displays

The portable test instrument described in this article supplies RGB test signals for VGA colour displays as used in many of today's computer systems. The tester supports line frequencies of 31-83 kHz, and raster frequencies of 55-114 Hz, with selectable sync polarity as a useful extra. The VGA tester not only allows 'suspect' displays ('super bargains') to be tested on the spot, it is also great for computer service and repair shops.
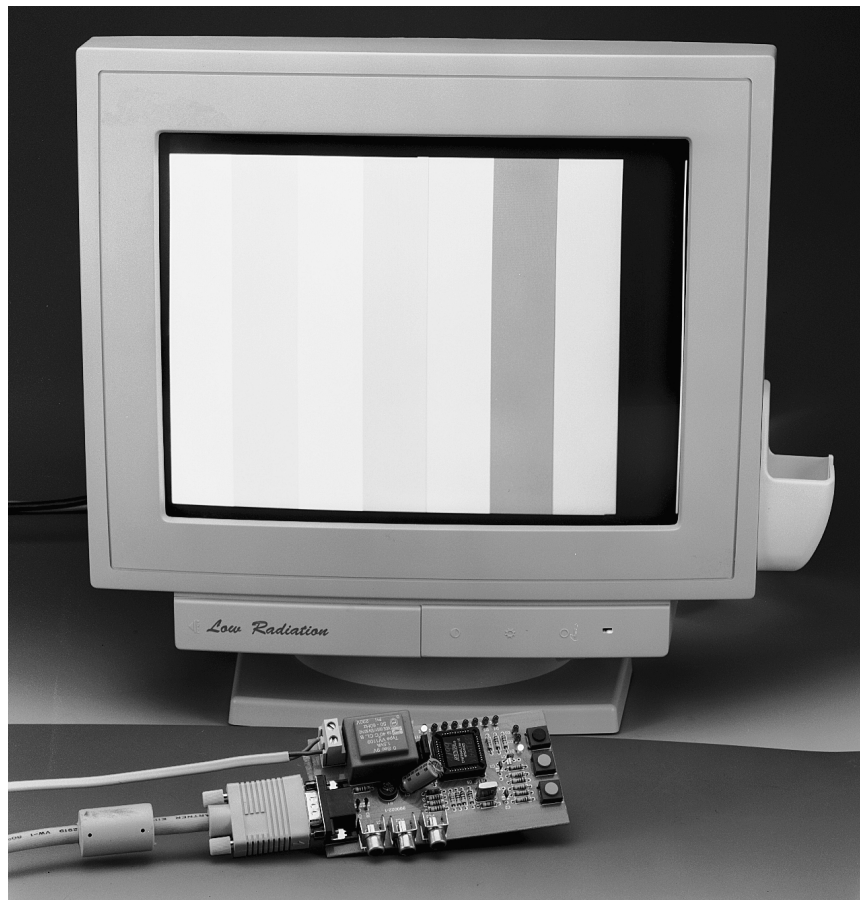
Features

8 Horizontal frequencies from 31-83 kHz
8 Vertical frequencies from 55-114 Hz
8 Testcharts
- Any combination of horizontal, vertical frequencies and testchart
- All frequencies at crystal stability
- Mode selection using 3 pushbuttons
- Display: 8+ 3 LEDs

Classic construction using discrete parts, or integrated programmable logic, well that is not an issue in this case. If a an 'all-discrete-design' strategy were followed, a test instrument like the one described here would require one or two dozen integrated circuits and a massive amount of passive components. By contrast, the use of a programmable logic component (like a PLD) results in a compact and extremely useful instrument that is eas-

Design by W. Foede

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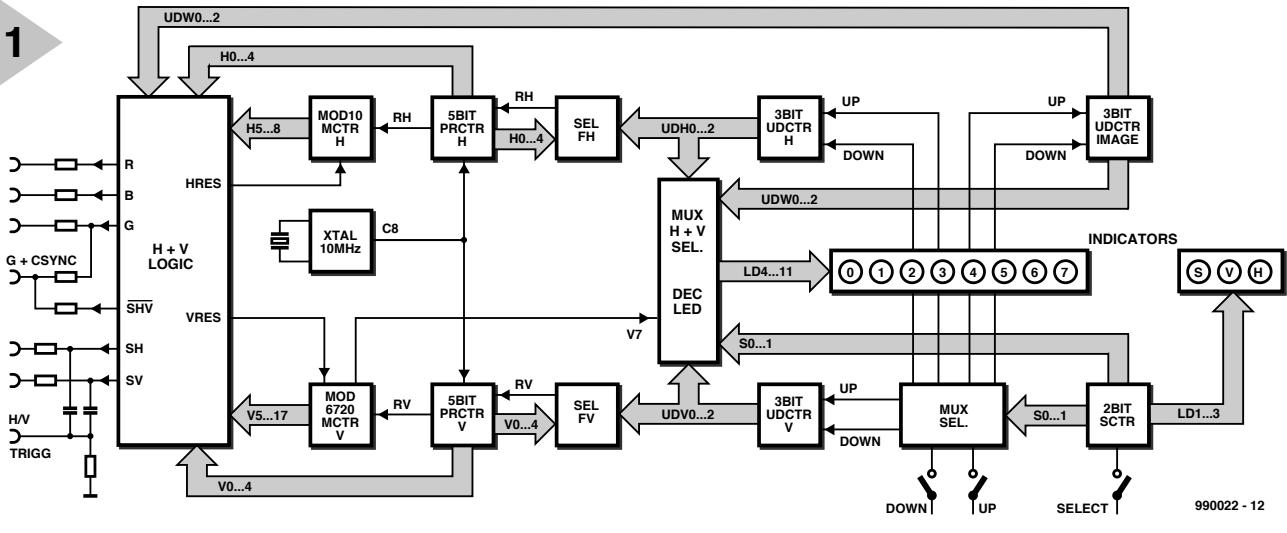
Figure 1. Block diagram of the VGA Tester, with special attention given to the logic blocks in the EPLD.

ily reproduced at a reasonable price.

On the downside, the programmed logic component 'hides' its activity, so that its function is not apparent at first blush, and modifications, well they are almost impossible to implement. Because of this, we will give a fair amount of attention to the contents of the EPLD used in the VGA Tester.

EPLD, INTERNALLY

For a change, the block diagram of the VGA Tester, **Figure 1**, may be said to provide more information than the actual circuit diagram! The upper part deals with the horizontal sync frequency (also called line frequency), the lower part, with the raster (picture refresh or simply 'vertical') frequency. The central clock

Figure 2. Circuit diagram of the VGA Tester.

2

990022 - 11
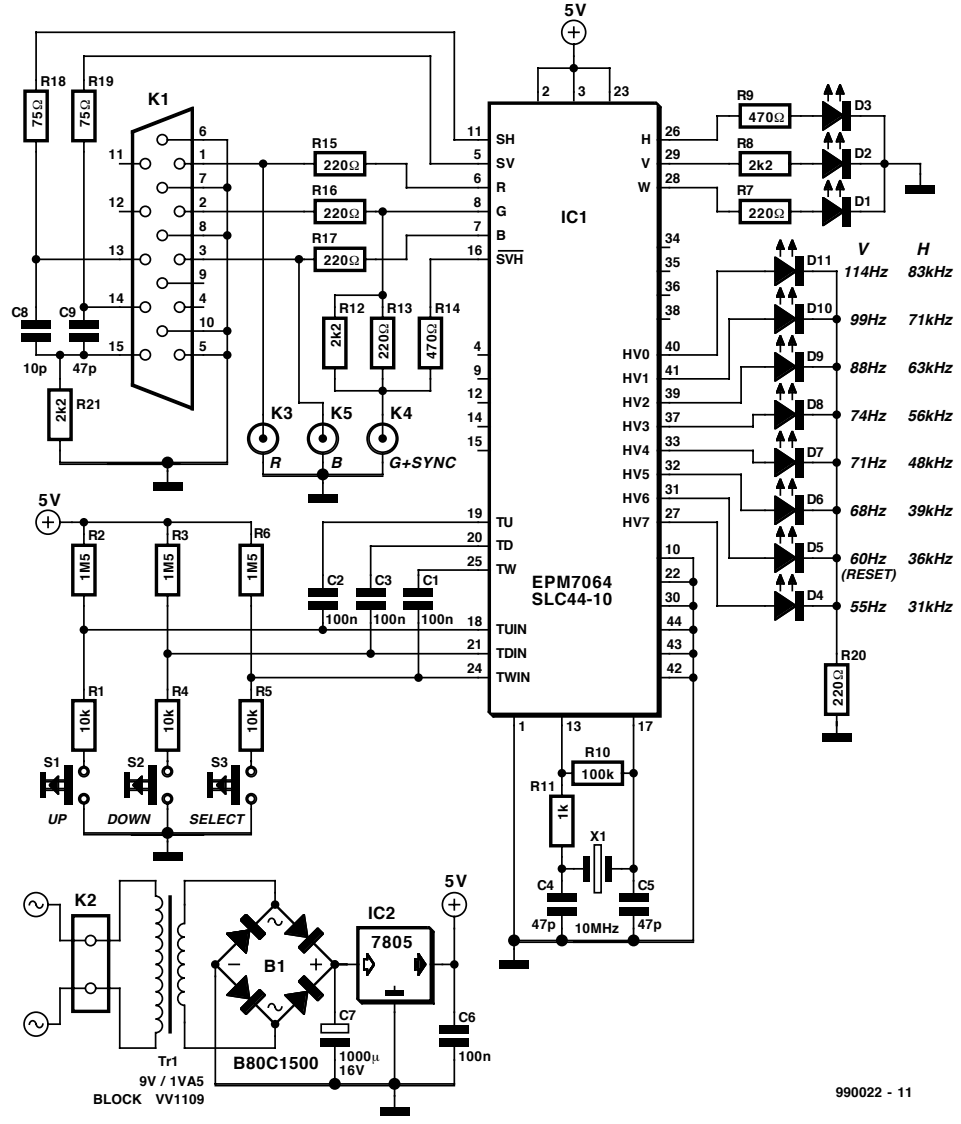
Table 1. Modes and indicators

Mode 1: Setting: *line frequency (H)*
Display: *LED on, bright*
Operation: UP: *frequency up,* DOWN: *frequency down*

	Line frequency in kHz		Mode LEDs	
Divider	**(exactly)**	**Display**	**S V H**	
10k÷12	*83.333*	*83*	*o o x*	
10k÷14	*71.429*	*71*		
10k÷16	*62.500*	*63*		
10k÷18	*55.556*	*56*		
10k÷21	*47.619*	*48*		
10k÷26	*38.462*	*38*	*interlaced*	
10k÷28	*35.714*	*36*		
10k÷32	*31.250*	*31*	*reset*	

Mode 2: Setting: *raster frequency (V)*
Display: *LED on, dim*
Operation: UP: *frequency up,* DOWN: *frequency down*

	Raster frequency in Hz		Mode LEDs	
Divider	**(exactly)**	**Display**	**S V H**	
6720÷13	*114.47*	*114*	*o x o*	
6720÷15	*99.21*	*99*		
6720÷17	*87.54*	*88*		
6720÷20	*74.40*	*74*		
6720÷21	*70.86*	*71*		
6720÷22	*67.65*	*68*		
6720÷25	*59.52*	*60*	*reset*	
6720÷27	*55.11*	*55*		

Mode 3 Setting: *testcharts*
Display: *LED on, bright*
Operation: UP: *next testchart*, DOWN: *previous testchart*

| Picture		Mode LEDs	
		S V H	
Colour bars	*reset*	*x o o*	
Crosshatch			
Red			
Green			
Blue			
White			
Dots			
Lines			

Mode 0 Setting: *sync pulses*
Display: *bright: horizontal; dim: vertical*
Operation: UP: *–SH inverted;* DOWN: *–SV inverted*

Mode LEDs	
S V H	
o o o	

Reset Setting: *FH= 31 kHz, FV= 60 Hz, testchart = colour bars, Mode 0*
Operation: *SEL + UP or SEL + DOWN (in all selections)*

MCTR V. **Table 1** lists the adjustable divisors, the associated exact values, and the resulting frequencies as printed on the front panel of the instrument. The line frequencies are between 31 kHz and 83 kHz, the raster frequencies, between 55 Hz and 114 Hz.

The two blocks marked SEL FH and SEL FV provide two sets of 8 reset pulses for PCTRH and PCTRV. They are switched using 3-bit counters UDC-TRH and UDCTRV.

Counter UDCTR is the only up/down counter which is blocked for the direct transition from 31 kHz to 83 kHz Under certain circumstances, this jump could cause severe damage to the VGA display under test!

For still testcharts, we need an even-numbered ratio of lines per picture. With 64 possible frequency combinations, things become very difficult indeed, because all frequencies are derived from a single quartz crystal. Moreover, the frequencies should roughly match the usual resolutions offered by videocards on the one hand, and VGA displays, on the other — see the data in **Table 2**.

The H:V ratio of the two 'fixed' modulo counters has been chosen such that horizontal picture sections only appear interlaced at 38 kHz. With all other pictures, line jumps occur. For these to be eliminated one would need a much more extensive circuit.

UP AND DOWN

The VGA Tester is controlled with just three pushbuttons. The SEL(ect) button is sued to pick one of four modes. In Mode 1, the horizontal (line) frequency is selected; in Mode 2, the vertical (raster) frequency, and in Mode 3, the testchart. The Mode you have selected is indicated by three Mode LEDs: S, V and H.

Table 2. Outputs

**Socket K1: DC15-HD,
pinout to VGA standard**

Pin	Symbol	Signal
1	*R*	*0.7 V_{pp}/75 Ω*
2	*G*	*0.7 V_{pp}/75 Ω*
3	*B*	*0.7 V_{pp}/75 Ω*
13	*-SH*	*TTL/75 Ω*
14	*-SV*	*TTL/75 Ω*
15	*H/V*	
	Trigger-Signal	*2.2 kΩ*

Cinch outputs

R	*0.7 V_{pp}/75 Ω*
B	*0.7 V_{pp}/75 Ω*
G + Scomp	
(SH/SV)	*1 V_{pp}/75 Ω*

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source is a 10-MHz oscillator around X1, which generates the signal marked 'C8'. This signal is applied to two counter chains, each consisting of a fixed-modulo counter and a counter with a programmable divisor. Of course, the counters do not actually divide, they merely count a fixed number of pulses before reverting to zero.

The horizontal (line) frequency is determined by an 5-bit counter, PRCTR H) with 8 adjustable steps, and

the modulo-10 counter, MCTR H. All picture contents, the sync signal and the blanking (picture retrace) signal are derived from the modulo-10 counter. This is done to make sure the testcharts remain independent of the programmable divider frequency. Basically the same applies to the raster (V) frequencies. Here, too, we find a 5-bit counter (PRCTR V), which reduces the oscillator frequency in eight steps, together with the modulo-8060 counter

COMPONENTS LIST

Resistors:
R1,R4,R5 = 10 kΩ
R2,R3,R6 = 1MΩ5
R7,R13,R15,R16,R17,R20 = 220Ω
R8,R12,R21 = 2kΩ2
R9,R14 = 470Ω
R10 = 100kΩ
R11 = 1kΩ
R18,R19 = 75Ω

Capacitors:
C1,C2,C3,C6 = 100nF
C4,C5,C9 = 47pF
C7 = 1000μF 16V radial
C8 = 10pF

Semiconductors:
B1 = B80C1500 (round case)
D1 = low current LED, 3mm, green
D2-D11 = low current LED 3mm, red
IC1 = EPM7064SLC44-10, programmed, order code 996501-1
IC2 = 7805

Miscellaneous:
S1,S2,S3 = pushbutton type ITC D6-R-RD, optionally with cap type D6Q-RD-CAP
TR1 = PCB mount mains transformer 9V/1VA5 (e.g., Block type VV1109)
K1 = 15 pin VGA connector, angled, PCB-mount
K2 = 2-way PCB terminal block, raster 7.5mm
K3, K4, K5 = cinch socket, PCB mount, angled
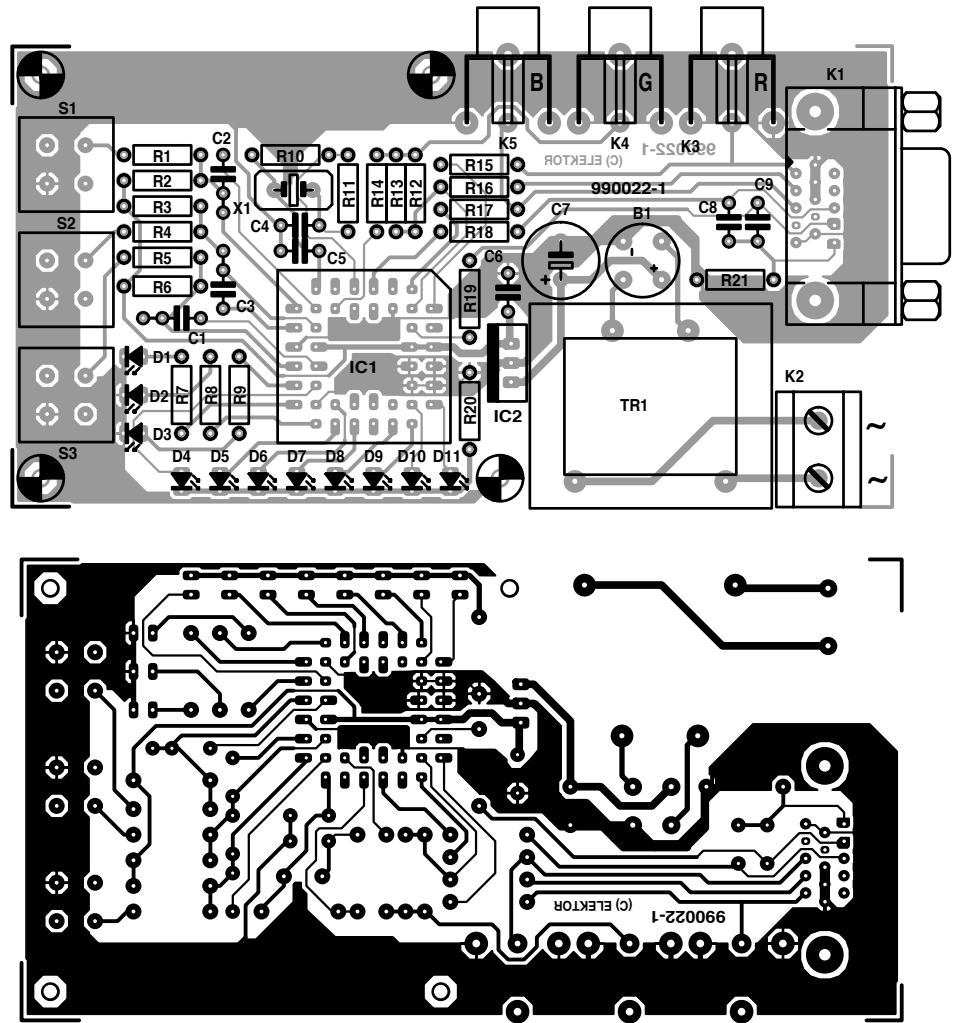X1 = 10MHz quartz crystal
44-pin PLCC-socket
PCB, order code 990022-1

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

The SEL pushbutton clocks a 2-bit ring counter (2BIT SCTR), which drives a dual 4-to-1 multiplexer (MUX SEL) as well as the three Mode indicator LEDs via LD1, L2 and LD3. Depending on the switching position of the multiplexer the pulses generated by the UP and DOWN switches are taken to up/down counters (3BIT UDCTR, V and H). These counters in turn copy the binary equivalents of the 'up' and 'down' pulses to the counter cascades which perform the frequency setting.

In Mode 3, the up/down pulses arrive at counter 3BIT UDCTR PICT, which serves to select the testchart selection in the output stage.

The information from the three up/down counters and the 2-bit ring counters are accepted by the MUX H+ V SEL block, and used to control the eight LEDs (0-7). This readout provides an indication of the currently set frequencies (H and V) and testchart. In Modes 1 and 2, one LED lights brightly to indicate the selected line frequency and one LED lights weakly to indicate the vertical frequency selection. In Mode 3, finally, one LED lights brightly to indicate the testchart selection.

At this point, we should not forget to mention the fourth mode, which is

Table 3. VGA-Tester display resolution

Horizontal / Vertical	31 kHz	36 kHz	38 kHz	48 kHz	56 kHz	63 kHz	71 kHz	83 kHz
55 Hz	640x480	800x600	800x600	1024x768	1280x960	1280x1024	1280x1024	1600x1280
60 Hz	**640x480**	640x480	640x480	1024x768	1152x900	1280x1024	1280x1024	1600x1280
68 Hz	640x480	640x480	640x480	800x600	1024x768	1152x900	1280x1024	1280x1024
71Hz	640x480	640x480	640x480	800x600	1024x768	1024x768	1280x960	1280x1024
74 Hz	640x400	640x400	640x480	800x600	800x600	1024x768	1152x900	1280x1024
88 Hz	640x400	1024x768	640x400	1280x1024	800x600	800x600	1024x768	1152x900
99 Hz	800x600	640x400	640x400	1152x900	1280x1024	800x600	800x600	1024x768
114 Hz	640x400	800x600	640x400	1024x768	1152x900	1280x1024	800x600	800x600

bold: *value at power-on*

actually Mode 0. It is indicated by all four Mode LEDs remaining off. The up/down counters cannot be switched in this state. However, the UP key may then be used to change the polarity of the H sync signal from negative to positive. The same goes for the DOWN key and the V sync pulse. Non-standard sync polarity may be required for some display types.

Mode 0 is also active after the unit is switched on. All counters are reset, and the Mode LEDs are off. When the SEL key is pressed, the VGA Tester switches to horizontal-frequency Mode; pressing it again selects vertical-frequency mode, and so on.

A special feature: when the UP and DOWN keys are pressed simultaneously, or SEL and DOWN, all settings of the VGA Tester are returned to those for a standard VGA output signal. The test picture is then 'colour bars' at a resolution of 640x480 pixels.

TESTCHARTS — THE LOGIC WAY

The states (output values) of the frequency counters are available as parallel binary words (H0-H8 and V0-V18) at the block marked H+V LOGIC, together with 'position' of the picture selection counter (UDW 0-2). This information is combined into eight testcharts by the H+V LOGIC block. With all testcharts, the timing ratios Sync/Blanking/Picture are based on those for 'standard VGA' (640x480 pixels, H=31.5 kHz, V=60 Hz).

The modulo-counter states also allow the horizontal and vertical pulses to be derived with simple logic. The RGB and sync outputs are taken to a standard VGA socket (high-density 15-way), which should enable most displays to be connected-up. Besides the regular R and B components, some monitors require a sync-on-green signal (GS) which contains the colour and a combined (H+V) inverted sync signal. For this type of monitor, three cinch sockets are available on the board. The combined signal is also eminently suitable for triggering an oscilloscope. To eliminate the 'green' DC component, you simply use the AC-coupled input on the oscilloscope. **Table 3** provides an overview of the outputs.

In addition to the EPLD and its peripherals (pushbuttons, LEDs and VGA outputs) the complete circuit diagram in **Figure 2** also shows a small 5-volt power supply consisting of a miniature transformer, bridge rectifier, reservoir and smoothing capacitors, and a 5-V fixed-voltage regulator.
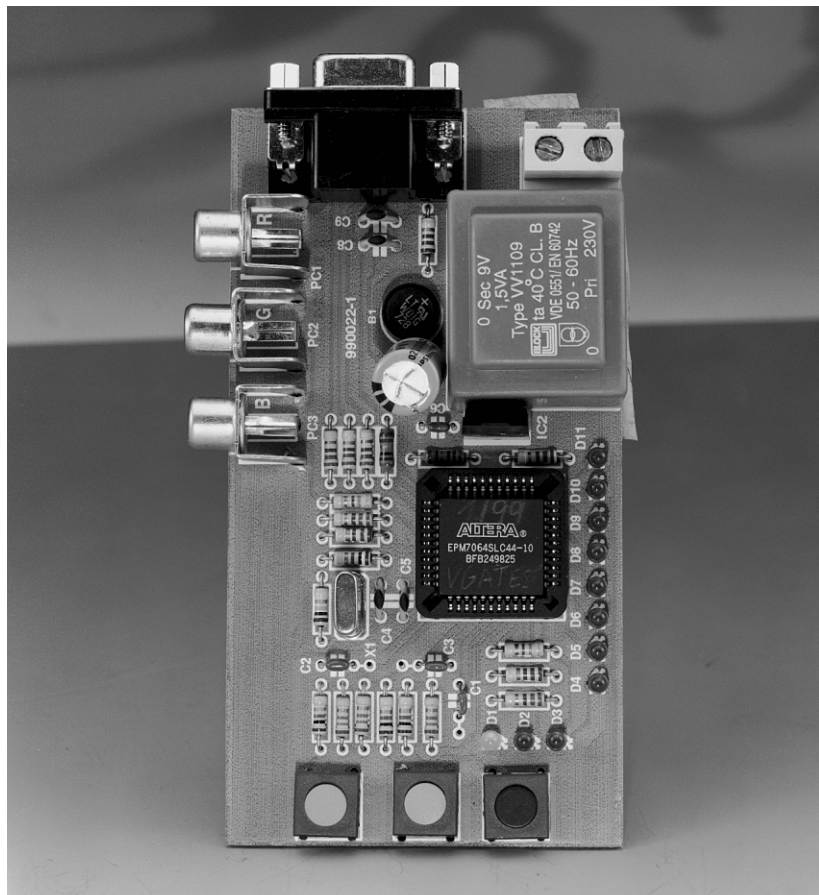
Building the circuit on the printed circuit board shown in **Figure 3** should not present problems, we reckon, and the same goes for fitting the completed board into a suitable plastic enclosure.

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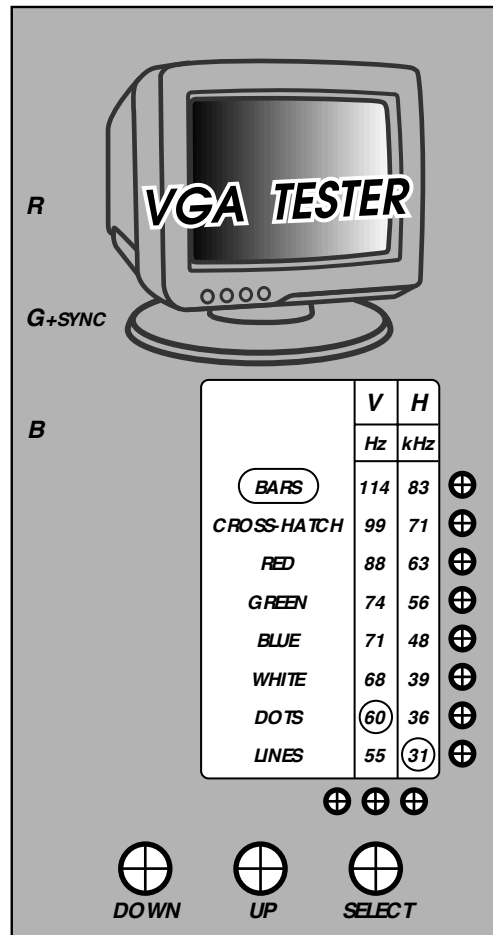
990022 - F

Figure 4. Suggested front panel layout

noise generator

white or pink noise at the flick of a switch

Strictly speaking, noise is a composite of a great number of signals at many, varying frequencies. It is a random quantity which generally has no regular or repetitive character. Although it is usually an unwanted quantity, noise may be used to analyse the performance of an audio system. A noise generator is, therefore, indispensable for much work in an audio workshop. Unfortunately, many amateur audio enthusiasts find the price of noise generators beyond their means. For them, this article describes an affordable, small noise generator that is easy to build.

Design by F. Hueber
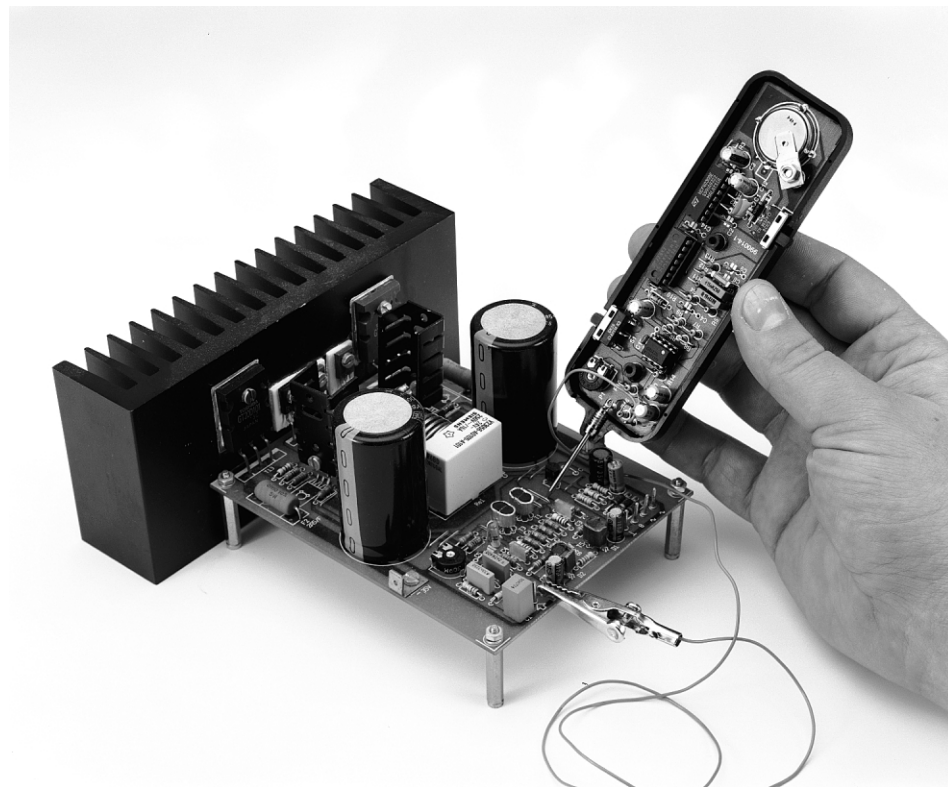
Main parameters

Frequency range	20–20000 Hz
Signal output	White noise or pink noise
Signal source	Pseudo random noise generator
Output voltage	2 V_{p-p} max.
Attenuation	About 10 dB
Power supply	lithium battery
Current drain	About 4.5 mA

INTRODUCTION

Noise is either artificial (man-made) or natural. Man-made noise is normally impulsive and stems mainly from electrical machines.

Natural noise is mainly due to cosmic electromagnetic radiation that invades a system through either an intentional or accidental aerial, Also, all circuit components generate thermal noise. Thermal noise is completely random and occurs over the entire frequency range from d.c.to infinity. For test purposes in audio equipment, only noise in the audio frequency range of 5–20000 Hz is of course of interest.

A distinction must be made between white noise, red noise and

pink noise. White noise has equal energy throughout the frequency range from zero to infinity, but the energy of red and pink noise is inversely proportional to the frequency in a (limited) frequency spectrum. The names white and pink derive from the spectral division of visible colours (white light contains all colours, while red and pink light is filtered)

The power per unit bandwidth of white noise is constant. This means that noise signals of equal amplitude are probable over the entire electro-magnetic spectrum. White noise has an energy distribution that is described statistically by the Gaussian distribution curve.

The power density distribution of red and pink noise varies in inverse proportion to frequency: that of red noise at a rate of 6 dB/octave or 20 dB/decade, and that of pink noise at a rate of 3 dB/octave or 10 dB/decade.

one device to another (of the same type!). As this voltage is small, it becomes difficult to design an amplifier whose output is fairly constant with such a wide spread of input voltages. Another is that many semiconductor devices exhibit so-called popcorn noise, which manifests itself, as the name implies, by short, irregularly occurring peaks in the output, which play havoc with the measurement.

It is therefore clear that a home constructed noise generator needs a much more reliable means of producing noise. The present design uses a digital generator, which not only ensures a well-defined output, but has the added advantage of requiring only a (relatively) small supply voltage.

The present design is based on a rectangular waveform generator whose output is applied to a series of shift registers. An XOR gate is used to produce a reset pulse that initiates the

cuitry associated with IC_{3a} forms the (analogue) amplifier and filter section.

The rectangular generator operates at a frequency of 50 kHz. Its output is applied to the clock input of IC_2, which is an 18-stage register. These stages are interconnected in a loop with the output of one linked to the data input of the next. Gates IC_{1c} and IC_{1d} provide the requisite sequence of operation.

Network R_3-C_3 provides a power-on reset. To ensure that the registers in IC_2 start working correctly on power-on, it is essential that pin 8 of IC_1 is then logic low.

The level of the output at pin 1 of IC_2 is very nearly peak-to-peak, which is too high for operational amplifier (op amp) IC_{3a}. This is, therefore, remedied by potential divider R_4-R_5.

Operational amplifier IC_{3a} functions as a voltage follower that provides the requisite low source impedance for the filter between the op amp
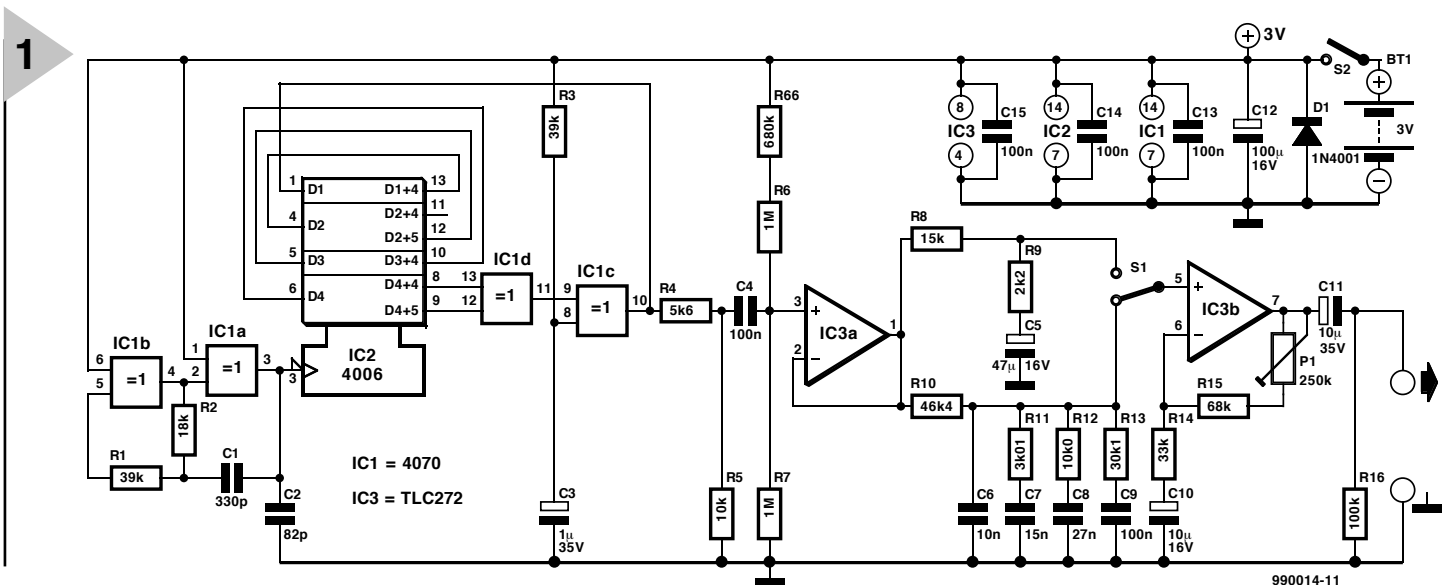

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Figure 1. The circuit of the noise generator consists of a digital signal generator section and an analogue amplifier and filter section.

Because of these properties, white noise is particularly useful for measurements with an oscilloscope or spectrum analyser, and pink noise for measurements that involve a one-third-octave analyser.

DESIGN CONSIDERATIONS
Professional noise generators often operate at the knee of the limiting characteristic of zener diodes, which requires a very stable supply voltage. Other means are reverse-biased diodes or the base-emitter junction of bipolar transistors.

A drawback of most of these methods is that the device used as the noise source has to be selected for several reasons. One is that the generated noise voltage varies substantially from

start of a new count sequence. The signal so generated has a statistically distributed frequency and constant output level, and is therefore similar to white noise. The difference between the two is that normal white noise is random in the time domain, whereas the noise produced by the shift register is a pseudo random noise, that is, a noise that repeats itself regularly. For the present design, this presents absolutely no difficulties whatsoever.

CIRCUIT DESCRIPTION
In **Figure 2**, IC_{1a} and IC_{1b} form the rectangular waveform generator, IC_2 contains the shift registers, and the cir-

and switch S_1.

The supply for IC_3 is single and resistors R_6, R_7 and R_{66} therefore shift the operating point of the op amp slightly below $U_B/2$. This arrangement ensures that the op amp can be driven symmetrically. In spite of the low supply voltage (3 V), the op amp provides an output signal of about 2 V_{p-p}.

The output of IC_{3a} is a pseudo random noise signal. Pink noise is obtained by putting the white noise signal through a filter that has a slope of –3 dB/octave. This roll-off is obtained by a four-section *RC* filter consisting of resistors R_{10}–R_{13} and capacitors C_6–C_9. The filter covers a frequency range of ten octaves and, because 1% resistors and 2% capacitors are used, has an error of only 0.5 dB. If the capacitors are not selected appropriately, the error
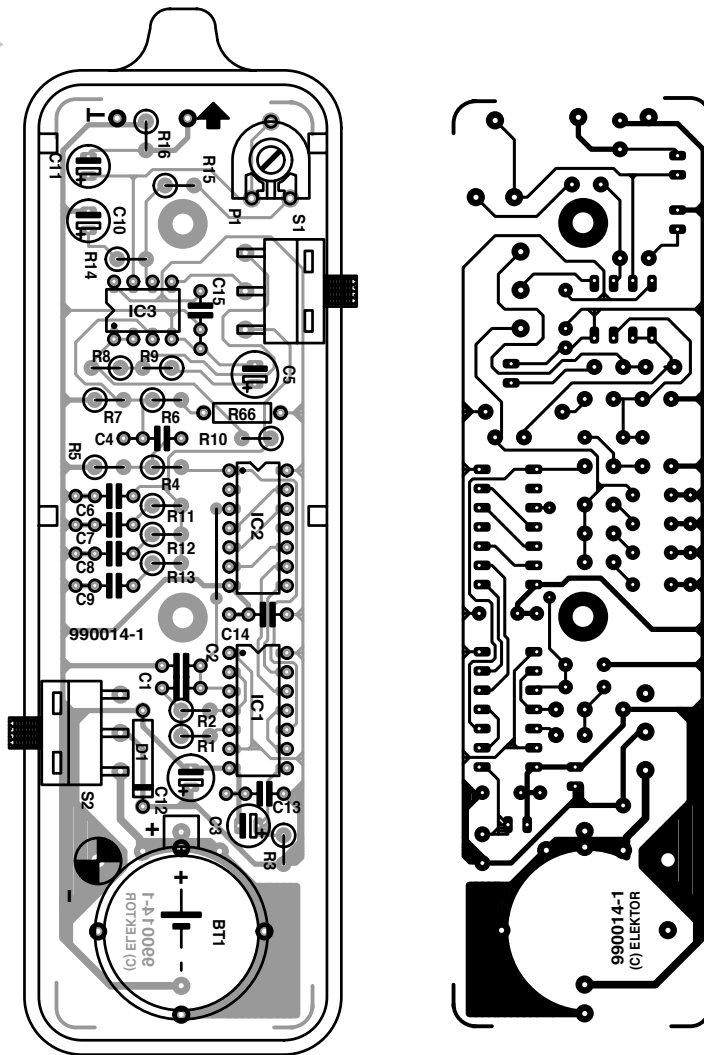
Figure 2. The single-sided printed-circuit board fits exactly in a probe enclosure.

may rise to 2 dB. Whatever, the noise amplitude is suitably attenuated by the filter.

The output of the filter is applied to switch S_1 which enables either white noise or pink noise to be selected. The amplitude of the white noise signal is made equal to that of the pink noise by divider R_8-R_9.

The voltage drop across capacitor C_{10} is equal to the direct voltage at the operating point of IC_{3a}.

Op amp IC_b amplifies the signal arriving from the switch to give an output signal at a level of 2 V_{p-p} across terminals PC_1, PC_2.

Resistor R_{16} ensures that even when the output is open-circuit, the polarizing voltage for C_{11} is maintained.

The generator is powered by a 3 V lithium battery. A polarity protection diode is not used, since this would lower the battery voltage unnecessarily. If readers want protection, diode D_1 may be used as shown. This will short-circuit the battery if it is connected with wrong polarity and so protect the generator from damage. The generator draws an operating current of about 4.5 mA.

CONSTRUCTION

The generator is best built on the printed circuit board in **Figure 2**, which is available through our Readers Services – see section toward the end of this magazine.

Virtually all components should be mounted vertically. Since the board cannot be screwed down, it is advisable to fit it tightly into the enclosure with the aid of some pieces of foam rubber. The specified enclosure is normally intended for a probe.

The output voltage may be adjusted with a screwdriver through an appropriate aperture in the lid of the enclosure or the spindle of the relevant potentiometer may be made to protrude through the lid.

Do not overlook the wire bridge near IC_2 and do mind the polarity of the electrolytic capacitors, ICs and

diode D_1 if used.

A test prong, which is readily made from a 25–50 mm (1–2 in) length of stout copper wire, must be connected securely to terminal PC_1; the earth connection is best made from a short length of stranded, insulated circuit wire soldered to PC_2.

TESTING THE GENERATOR

The generator cannot really be tested properly without an oscilloscope. Check that the signal at pin 3 of IC_1 has a rectangular waveform and a frequency of 50–55 kHz. When that is so, the signal at pin 1 of IC_2 should be a pseudo random noise signal. This is seen on the scope as two limiting (horizontal) lines separated by a distance equal to the supply voltage. When the time base of the scope is adjusted appropriately, there appear between

these two lines at irregular distances level jumps, visible as faint lines, which represent the actual noise signal.

It is advisable to check the operating point of IC_3, since this may stray from device to device. To this end, remove IC_1 and IC_2 from their socket and apply a sinusoidal voltage at a mid-range frequency and at a level of $1 V_{rms}$ between pin 1 of IC_1 or IC_2 and earth. This signal should be visible undistorted at pin 1 of IC_3. Increase the level of the sinusoidal signal until the peak of the voltage at pin 1 of IC_3 begins to flatten. This flattening should be absolutely symmetrical at both the positive and the negative peaks. If this is not so, the operating point should be adapted slightly by altering the value of R_{66} as required. This procedure is essential to ensure maximum undistorted output voltage. In the prototype, the combined value of $R_6 + R_{66}$ is exactly 1.7 MΩ.

Set S_1 to white noise output and turn P_1 fully clockwise, whereupon the noise signal should be clearly visible on the scope connected to the output of the generator.

O P E R A T I O N

The spectra of white noise and pink noise are shown in **Figure 3**. The frequencies contained in the white noise signal are evenly distributed over the audio range up to about 20 kHz. The response dips a few dB towards 30 kHz, but the actual level of the spectrum is, of course, not important.

In practical operation, the output signal of the generator can be applied to any accessible point in the equipment on test by simply touching it with the test prong. Take care, however, not to overload the equipment on test. Note that noise signals contain very high peaks that may damage tweeters. A white noise signal enables, for instance, testing the operation of a volume control or a sound level control.

Pink noise may be used to check room acoustics or the effect furniture or curtains have on the performance of loudspeakers. This enables the loudspeaker to be trimmed to the room requirements.

In any case, it is advisable to carry out a number of experiments with the noise generator before using it in practical testing.

[980014]

Figure 3. Spectra of white noise and pink noise.
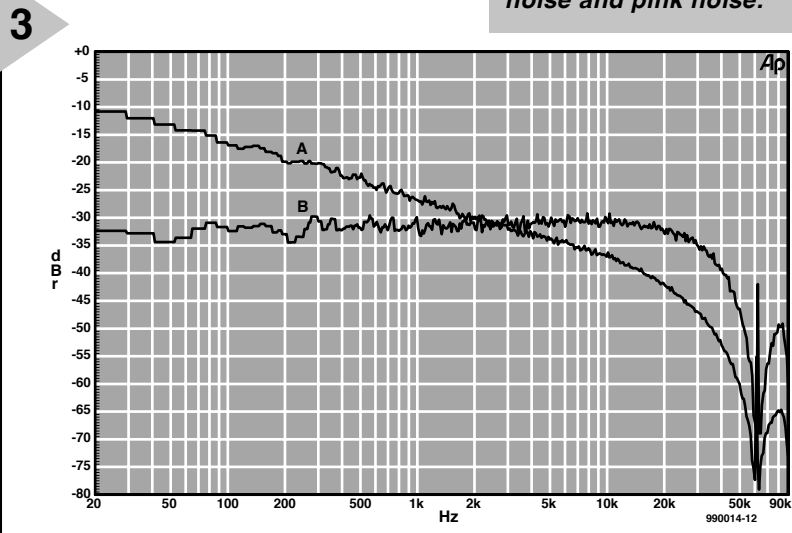
evaluation system for 80C166 (1)

part 1: introducing the 16-bit SAB80C166

This is the first time *Elektor Electronics* presents a development system for a 16-bit microcontroller. We've chosen the SAB80C166, which is generally known as the 'generic device' in the C166 series of microcontrollers manufactured by Siemens. This the first instalment of an extensive, multi-part article covering hardware, software and application examples, all aimed at introducing you the world of 16-bit microcontrollers.

Design by K.-H. Domnick
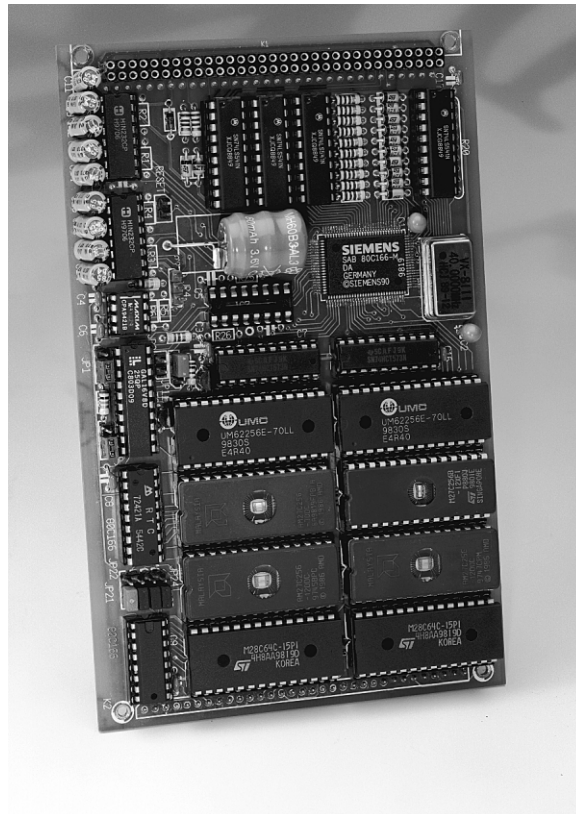
In the field of microcontrollers, product diversification has been evident for many years. In the early days of microcontroller technology, only a couple of different types were available. Initially, these chips were packed with just about anything technically feasible at the time (still not much by today's standards). Soon, however, the combined forces of market and user demands brought about a change from general-purpose to specialized products. This resulted in whole families of microcontrollers, with 'members' having preciously little in common except the instruction set.

A fine example is the MCS51 family from Intel, with the famous 8051 as the 'generic device' from which dozens of versions were derived over the years. Until recently (well, a few years ago) only a few of these derivatives of the 8051 were generally available, and some of these were at the heart of our best-selling projects like the *Elektor Electronics* 8052 BASIC Computer, 80C32 Single-Board Computer and Match-Box BASIC Computer, to mention but a few.

Meanwhile, however, ultra-fast controllers have become available with 8 to 16 pins, a small instruction set (RISC) and a just a basic complement of I/O functions. Besides general-purpose working horses like the 80C51 you now find state-of the-art controllers with massive memories, tens of interrupt sources, A/D converters, registers and I/O lines. And they're fast, too!

THE 80C166: YOUR TAILOR-MADE CONTROLLER

The SAB80C166 from Siemens has been with us for about five years now and certainly belongs in the latter category of high-speed number-crunching beasts. Its clock frequency of 20 MHz and vast number of interrupt sources enable the 80C166 to act as the brains of applications requiring flexibility and very high speed. Typical examples include real-time embedded control

systems (as used in vehicles), and complex industrial control systems. Because the price of the SAB80C166 recently dropped to less than £10, the device is also a good candidate for advanced applications in the hobby and semi-professional fields. For example, the 80C166 is ideal for simultaneous control of several stepper motors, as the 'brains' in a professional object surveillance system, at the heart of a really extensive model-railway system, and many other applications.

However, to most of you, the interesting thing about the 80C166 will be that it is a 16-bit microcontroller, for which a complete and affordable development system is described.

This fist instalment of the article deals mainly with the controller itself, and the things it can do. Obviously, only a small selection can be made from the vast amount of information available on the 80C166. Datasheets and a user handbook are available free of charge from the Internet — both are supplied as PDF files.

The C166 series has three basic types. Whereas the family members designated 83C166 and 88C166 have 32 kBytes of ROM or Flash memory respectively, the 80C166M comes without this memory. No problem, because the evaluation system to be described provides a much larger external memory.

As shown in **Figure 1**, the SAB80C166 sports 256 kBytes of addressable memory having the 'Von Neumann' architecture. The device can use one of four bus modes: 8-bit, 16-bit, multiplexed or non-multiplexed. On the development board, the 16-bit multiplexed mode is used. The bus timing is adjustable in many ways, including the insertion of up to 15 wait states. Two different bus mode configurations may be used at the same time. Support for multi-master operation in multiprocessor systems is also possible.

The internal dual-port RAM has a capacity of 1 Kbytes, and is found in the address range 0$FA00h through 0$FDFFh. Of this memory, 255 bytes are bit-addressable.

The 80C166 offers five ports with a total of 66 bit-addressable input/output lines or special functions, as well as a port comprising 10 TTL or analogue inputs.

The microcontroller has 98 Special Function Registers (SFRs) and 16 General Purpose Registers (GPRs) per register bank. Changing between 16 register banks is possible, though limited by the internal RAM.

There are 32 freely programmable interrupt sources, of which 19 are implemented as port pins. Interrupts can be assigned 16 prior-

ity levels, each having four group levels. The response time to interrupt events (in the external memory) is only 600 ns. The interrupt inputs may be programmed to respond to events consisting of a negative or a positive pulse edge.

The Peripheral Event Controller (PEC) comprises eight freely programmable units, and allows 8- or 16-bit data traffic between memory and peripherals in a single cycle. The array of five universal 16-bit timers with a resolution of 400 ns or 200 ns may be employed as timers, gated timers or counters. Two more 16-bit timers, also independently programmable, are used by the 16 Capture/Compare units.

The 80C166 has two serial ports with separate baudrate generators. The ports can operate in synchronous mode or asynchronous full-duplex mode at up to 625 kbit/s. The ten available D/A converters are marked by a resolution of 10 bits, a conversion time of 9.7 μs and a sampling period of 1.58 μs. These converters should enable single, continuous and group conversions to be performed without problems.

The watchdog timeout may be programmed to any value between 25.6 μs and 419 ms.

The 80C166 features two power saving modes for battery operation: Power Down and Idle. About 90% of all commands are executed in one cycle, which takes 150 ns at a clock speed of 20 MHz and zero wait states. 16-times-16 multiplication is completed in five cycles, 32-by-16 division, in ten cycles.

The instruction set is remarkably consistent with all commands made up of either two or four bytes. Powerful word, byte and bit commands are also included.

80C166 Board Main features

- Microcontroller: SAB80C166M
- 40-MHz quartz crystal = 20-MHz clock speed
- 16-bit mode, multiplexed, segmented
- 64-kBytes RAM (with optional battery backup)
- 64-kBytes EPROM for user program
- 2 serial interfaces, RS232
- 16 TTL outputs, buffered
- 16 TTL inputs, buffered, interrupt-ready
- 10 analogue/TTL inputs, protected
- 2 inputs/outputs, protected
- Extension bus

Options:
- 64 kBytes RAM or EPROM
- 16 or 32 kBytes EEPROM
- Battery for RAM and RTC supply
- Watchdog / battery switchover
- Real-time clock

AROUND THE 80C166

Because the generic 80C166 has only limited internal memory resources, our development system, of which the block diagram is shown in **Figure 2**, must have a minimum amount of external hardware around the microcontroller. The board contains the following hardware components:
- 64 kBytes RAM (optionally battery-powered)
- 64 kBytes EPROM containing the program
- 16 or 32 kBytes EEPROM
- 16 buffered TTL outputs
- 16 buffered TTL inputs with interrupt ability
- 10 protected TTL/analogue inputs
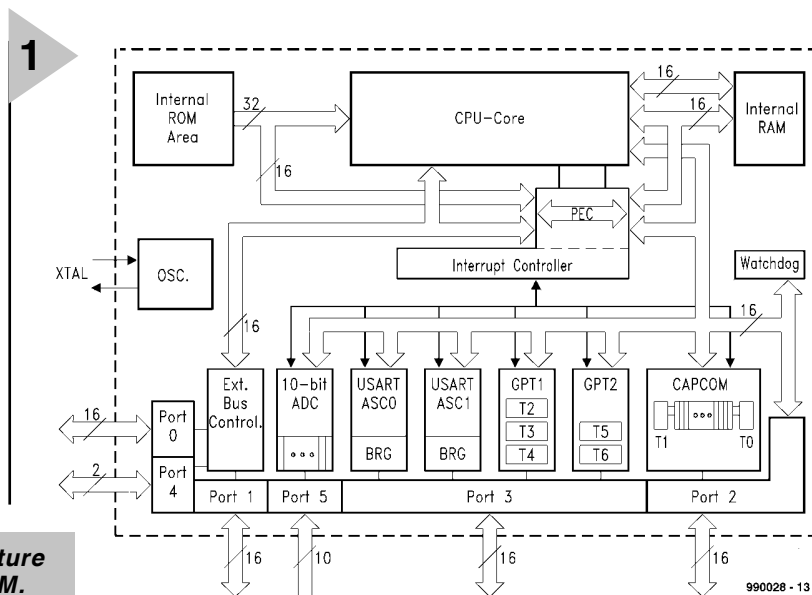- 2 RS232 interfaces
- 2 protected bidirectional in/out-

Figure 1. Architecture of the SAB80C166M.

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puts
↪ extension bus for add-on cards
↪ battery for RAM and clock supply
↪ watchdog/battery switchover
↪ real-time clock

BUS TIMING

Of the four available bus modes, the development system only employs the multiplexed 16-bit version. The 16 address bits 0-15 are only available for 50 μs at the address/data port, and have to be 'extracted' with the aid of latches IC9/IC10 and the ALE (Address Latch Enable) signal. Bits 16 and 17 are available at another port for the duration of a cycle. After the address has been supplied, the 16-bit data transfer process is completed.

A data transfer operation takes 850 ns after a reset (100 ns + 15 wait states of 50 ns). By reducing the number of wait states to zero, this may be reduced to just 100 ns. Consequently, the memory access time can be anything between 50 ns + data access time = 900 ns, or just 150 ns if no wait states are programmed. Gate propagation times of 15 ns to 35 ns occurring in the chip select circuitry should be deduced from these values. At zero wait states, memory chips with an access time of less than 120 ns should be used. The 50-ns steps are the result of the 20-MHz clock signal, which is derived from a 40-MHz source.

For the program code, the memory is divided into four segments of 64 kBytes each. All chip select signals for the memory are produced by a GAL type 16V8 (IC4), as well as the write signals for all 8-bit memory access operations. Programming details of the GAL will be published in part 2 of this article.

The program start address may be set to any of the following addresses:

Figure 2. The controller is surrounded by a plethora of peripheral functions.

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Table 1. Segment configurations

JP2	JP1	Segment	Address
0	0	1	1$0000h - 1$FFFFh
0	1	2	2$0000h - 2$FFFFh
1	0	3	3$0000h - 3$7FFFh
			0$8000h - 0$F9FFh
1	1	0	0$0000h - 0$F9FFh

In this way, different programs may be installed, loaded, or called up whenever required. Other memory configurations are possible by changing the GAL contents.

Programs always start at address 0. Because the development board contains volatile memory (RAM) at this address, random bytes are found when the system is powered up. Program code is therefore stored in an EPROM resident segment which is 'mirrored' to segment 0 after a reset, or when power is applied. When initialisation is finished, the mirror is disabled by the instruction EINIT (End Initialisation), and segment 0 is returned to RAM. During a reset, controller output RSTOUT# is pulled logic low. It returns to logic high when the EINIT instruction is executed. This signal controls the segment mirror operation as described above.

INPUTS/OUTPUTS

The board offers you 16 outputs, all buffered via TTL components type 74LS541 (or inverted when using the 74LS540). After a reset, all controller pins are set to act as inputs. If output functions are required, you have to declare them as such in your program.

TTL buffers from the 74LS541 take 16 inputs to the controller. All inputs are interrupt-ready, and five of them may be used as counters. If the input signals have to be inverted, the buffer IC may be replaced by a type 74LS540.

It is strongly recommended to stock to the use of LS-TTL components at the inputs and outputs, because they are far more resilient against short-circuits and overvoltage than CMOS components. In general, a short-circuit on one of the output pins of the 80C166 means instant demise of the controller.

Ten inputs may be programmed to act as TTL or analogue inputs, the latter with a resolution of 10 bits, and protected against voltage surges or reverse input voltages by simple resistor/zener diode networks. Two similarly protected bidirectional inputs/outputs are available for clock and data signals as required by a serial keyboard or an I²C bus, to mention but two examples. The clock input is interrupt-ready.

There are two RS232 interfaces for communication with the user. SIO # 2 is required when the system is used with a monitor program. The reset and NMI (non-maskable interrupt) input are also bonded out to pins.

All inputs, outputs and the 5-volt supply voltage connection are available on three rows of solder pads. Here, different connector types may be mounted:
↪ 2 x 32-pin pinheader (plug) for flatcable;
↪ 2 x 32-way socket to enable you to plug on boards containing control

elements, switching elements, displays, power drivers, power supplies, and so on.

☞ 2 x 32-pin (a-c or a-b row) or one 3 x 32-pin (a-b-c row) DIN connector as used in 19-inch rack systems.

MEMORY

Six sockets are available on the PCB to hold 64-, 128- and 256-kbit memory components, besides two sockets for 64- or 128-kbit EEPROMs. Memory devices always have to be inserted in pairs (2 x 8 bits = 16 bits). A minimum memory configuration requires RAM (IC11/IC12) in the range 0$000h-0$F9FFh, and a monitor or user program in EPROM (IC13/IC14) starting art 1$0000h. The internal memory and the register array of the 80C166 are located between 0$FA00h and 0$FFFFh.

tents (16 kBytes or 32 Kbytes of data) after the power supply or battery is disconnected. Because the access time of these components will be of the order of 200 ns or longer, the necessary number of wait states has to be programmed when accessing the EEPROM memory range.

Real-time clock (RTC)

When the real-time clock unit type RTC-72421 is used, decoder IC6 (a 74HC138) has to be fitted. The real-time clock continues to 'tick' when the development system is switched off.

Extension bus

The data/address bus, control signals and six chip select signal of the 74HC138 (IC6) are made available on a 32-way array of solder pads. Single-row connector systems may be used to

MAX690

This IC in position IC3 has two more functions:

☞ If WDI (WatchDog Input) remains open, the watchdog is disabled. If WDI is at TTL level via J3, the watchdog is active. After about 100 ms, a level change should occur at CS6; if not, the MAX690 issues a reset pulse.

☞ If the voltage at the PFI pin (Power-Fail Input) drops below 1.34 V, the PFO pin supplies a logic low level. Using JP4 this signal may be employed to generate a reset or an NMI.

FINALLY

That concludes our short description of the 80C166 microcontroller and the basic possibilities of the evaluation board. Whenever you feel this article provides insufficient information, that is entirely due to the practical limitations of a magazine article. Note, however, that anything you may want to know about the SAB80C166 can be found in the (free) databook and datasheets, which you will find indispensable anyway. The book, datasheets and lots of other useful information may be downloaded from this address

Table 2. Memory allocation			
RAM	64.0 kB	2 x RAM 62256	0$0000h-0$F9FFh
Controller	1.5 kB	80C166 RAM and Register	0$FA00h-0$FFFFh
EPROM	65.5 kB	2 x EPROM 27C256	1$0000h-1$FFFFh
RAM or EPROM	65.5 kB	2 x RAM 62256 or 2 x EPROM 27C256	2$0000h-2$FFFFh
EEPROM	32.8 kB	2 x EEPROM 28C64 / 28C128	3$0000h-3$7FFFh
Decoder	16.4 kB		3$8000h-3$BFFFh
CS0#		CS 0 for extension cards	3$8000h-3$87FFh
CS1#		CS 1 for extension cards	3$8800h-3$8FFFh
CS2#		CS 2 for extension cards	3$9000h-3$97FFh
CS3#		CS 3 for extension cards	3$9800h-3$9FFFh
CS4#		CS 4 for extension cards	3$A000h-3$A7FFh
CS5#		CS 5 for extension cards	3$A800h-3$AFFFh
CS6#		Watchdog (MAX 690)	3$B000h-3$B7FFh
CS7#		Real-Time-Clock (RTC-72421)	3$B800h-3$BFFFh
Free	16.4 kB	Free range	3$C000h-3$FFFFh

extend the 80C166 board at both sides.

OPTIONS

The printed circuit board we've developed for the 80C166 development system offers a number of optional functions.

Memory extension 1

Positions IC15/IC16 accept RAMs and EPROMs. Because these devices are not pin compatible, the relevant selection must be set on jumpers JP22, JP23 and JP24. The first, JP21, selects between battery power or 5-V supply. Evidently, EPROMs should only be powered by the 5-V supply — they would drain the battery in a couple of minutes.

Memory extension 2

Positions IC17/IC18 on the board are reserved for 64-kbit or 128-kbit EEPROMs. These devices retain their con-

Wait/Ready signal

With the Ready input activated, it is possible to make the controller wait for a period determined by R25-C5. This is only possible via access to certain parts of the GAL, and via IC7 (74HC123). This option should only be used by experts!

The other half of the 74HC123 may be set for the duration of R26-C7 under the control of P1.13. The output is freely available for control and timing purposes.

Battery backup

A 3.6-volt battery is provided on the board to enable the RAM devices to retain their contents. Jumpers JP11/JP21 allow you to select between unbuffered and buffered powering of the RAMs. A MAX690 (IC3) arranges the switch-over between 5-V and battery voltage.

The second instalment of this article will deal mainly with building the evaluation board, and in particular, fitting the 100-pin controller. In case the board does not work spot-on, practical advice and help is provided in the section 'faultfinding'.

Part two will also discuss connecting-up the PC and your first steps in the world of 16-bit programming. Finally, there's useful information on where to obtain free or low-cost software for 80C166 program development.

(990028-1)

Evaluation System for 80C166 (parts 1 and 2)
March & April 1999, 990028

Errors in Components List
IC9 and IC10 should be type 74HC573, not HCT573.

C1 and C2 should be 10μF 16 tantalum bead.

R20 should be an 8-way SIL array, value 4kΩ7.

The crystal frequency mentioned with C18, C19 should be 40MHz, not 100MHz.

IC3, MAX690 should be listed as MAX690 (BATT), not MAX690 (I/O)

Miscellaneous
Pull-up resistors R1-R4 need not be mounted with the serial channels.

When a 40-MHz crystal is used for X1, it may oscillate at the fundamental frequency (13.333 MHz) instead of the third overtone. If this happens the system baudrate will not be correct and the serial communication will fail to work as described. Suggested solutions are (1) to use a 40-MHz crystal oscillator module, (2) use a different 40-MHz crystal or (3) adapt the value of C18 and C19 until oscillation occurs at the third overtone.

The battery may be a 3.6-V NiCd type, but note that this is very slowly charged by the MAX690. A better solution is to use a Lithium battery.

The circuit diagram does not make it clear how the serial connection is made via D9. Pins 2 and 3 of this connector should not be connected TxD1 and RxD1 (i.e. the TTL side of the MAX232), but to the other (RS232) side of the MAX232. Pin 2 of D9 is therefore connected to pin 2BC via

bus K1. Likewise pin 3 of D9 is connected to pin 3BC via bus K1. The correct connections are shown in the illustration.

990028-11

Development System for 68HC11F1
June 1999, 990042

JP1 is a simple jumper. In the text and parts list, it is erroneously referred to as K3.

Part K3 is a 4-way SIL pinheader. In the text and parts list, it is erroneously referred to as JP1

R4 is erroneously listed as a SIL array with a value of 10kΩ. The PCB however only accommodates eight discrete resistors. These are numbered R4 and R6-R12. Resistor R13 in the circuit diagram equals R4 on the PCB.

PC-Controlled Model Railway: EEDTS Pro
June 1999, 990082-2

On page 60, the text references t S3, D1 and S4 should read S2, D2 and S1 respectively.

EVALUATION SYSTEM FOR 80C166 (PARTS 1 AND 2)
March & April 1999, 990028

Errors in Components List

IC9 and IC10 should be type 74HC573, not HCT573.

C1 and C2 should be 10μF 16 tantalum bead.

R20 should be an 8-way SIL array, value 4kΩ7.

The crystal frequency mentioned with C18, C19 should be 40MHz, not 100MHz.

IC3, MAX690 should be listed as MAX690 (BATT), not MAX690 (I/O)

Miscellaneous

Pull-up resistors R1-R4 need not be mounted with the serial channels.

When a 40-MHz crystal is used for X1, it may oscillate at the fundamental frequency (13.333 MHz) instead of the third overtone. If this happens the system baudrate will not be correct and the serial communication will fail to work as described. Suggested solutions are (1) to use a 40-MHz crystal oscillator module, (2) use a different 40-MHz crystal or (3) adapt the value of C18 and C19 until oscillation occurs at the third overtone.

The battery may be a 3.6-V NiCd type, but note that this is very slowly charged by the MAX690. A better solution is to use a Lithium battery.

The circuit diagram does not make it clear how the serial connection is made via D9. Pins 2 and 3 of this connector should not be connec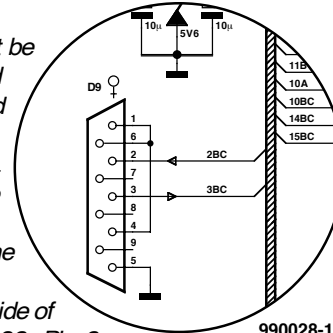ted TxD1 and RxD1 (i.e. the TTL side of the MAX232), but to the other (RS232) side of the MAX232. Pin 2 of D9 is therefore connected to pin 2BC via bus K1. Likewise pin 3 of D9 is connected to pin 3BC via bus K1. The correct connections are shown in the illustration.

990028-11

Titan 2000

Part 2: protection network

This second of four parts deals primarily with the protection network incorporated in the amplifier. This indispensable network safeguards the amplifier and the loudspeakers connected to it against all kinds of error that may arise. The network is an independent entity with its own power supply.

Correction. In last month's first part of this article, it was stated erroneously that the article consists of two parts, whereas in fact it will be described in four parts.

Design by T. Giesberts

INTRODUCTION

As mentioned briefly in Part 1, extensive and thorough protection is a must in an amplifier of this nature. It may well be asked why this is so: is there such a likelihood of mishaps arising? Or is the amplifier so vulnerable? On the contrary: extended tests on the prototype have shown that the Titan 2000 is a very stable and reliable piece of equipment. In fact, unusual means had to be used to actuate the protection circuits during these tests, since not any standard test prompted the amplifier into an error situation.

The extensive protection is necessary because by far the largest number of mishaps occur owing to actions by the user, not because of any shortcomings in the amplifier. For example, the most robust and reliable amplifier can not always cope with extremely high overdrive or overload conditions.

SIX FUNCTIONS

The integrated protection network consists of six sub-circuits:

* power-on delay
* transformer voltage sensor
* temperature sensor
* current sensor
* direct-current sensor
* overdrive sensor

The power-on delay ensures that the relays in the amplifier are energized 50–100 milliseconds after the supply has been switched on to prevent switch-on clicks.

The transformer voltage sensor reacts to the cessation of the secondary voltage of the mains transformers to prevent switch-off clicks and crackles.

The temperature sensor responds to excessive heat sink temperatures, but it should be noted that this works only in

Figure 4. The protection network consists of six sensor circuits each of which causes the input and output relays of the amplifier to be deenergized when a fault occurs.

conjunction with the fan drive, which is reverted to later in this article.

The current sensor monitors the output current, while the direct-current and overdrive sensors form a combined circuit that monitors differences between the input and output signals, and reacts to excessive direct-current levels or distortion. This circuit is the most important and 'intelligent', but also the most complex of the six.

All sensors, when actuated, react in the same way: they cause the output relays and the mute relay at the input of the amplifier to be deenergized immediately. This action causes the

input signal and the output load to be disconnected from the amplifier. After the fault causing the sensor action has been removed or remedied, the relevant protection circuit is disabled, whereupon the amplifier relays are reenergized after a short delay.

When the protection network is actuated, a red LED lights to indicate an error. When the fault has been removed or remedied, the red LED remains on, but a yellow LED flashes to indicate that the amplifier will be

reenabled shortly. The red LED then goes out, shortly followed by the yellow, whereupon a green LED lights to indicate that all is well.

COMMON SECTION AND POWER-ON DELAY
The circuit of the integrated protection network, including the + 5 V and ± 12 V power supplies, is shown in **Figure 4**.
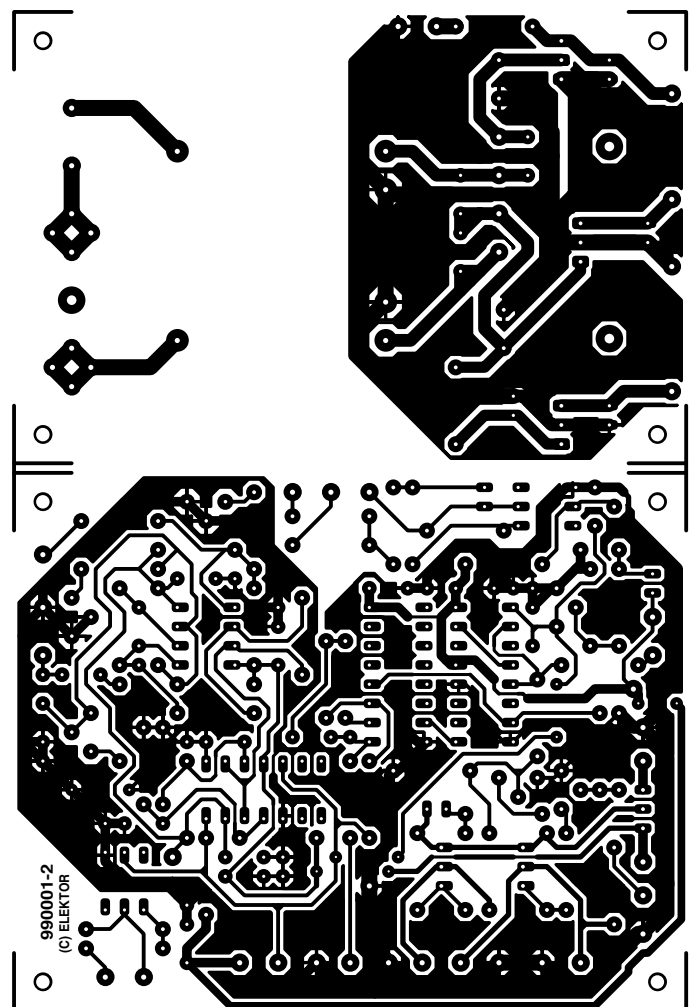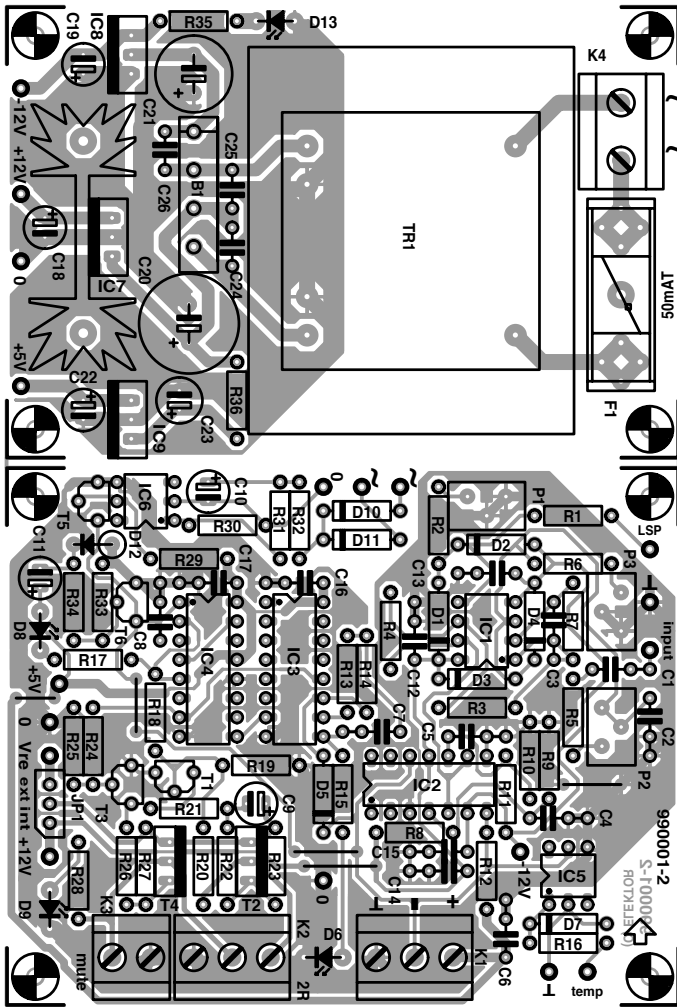
Parts lists

Protection network

Resistors:
$R_1, R_{33}, R_{34} = 100\ k\Omega$
$R_2 = 1.05\ k\Omega$
$R_3, R_4 = 10.0\ k\Omega$
$R_5 = 680\ \Omega$
$R_6 = 820\ k\Omega$
$R_7 = 1\ M\Omega$
$R_8, R_{11}, R_{18}, R_{19}, R_{24}, R_{25}, R_{29} = 47\ k\Omega$
$R_9, R_{10} = 470\ \Omega$
$R_{12}, R_{21}, R_{22} = 2.2\ k\Omega$
$R_{13} = 470\ k\Omega$
$R_{14} = 2.2\ M\Omega$
$R_{15}, R_{17} = 1\ k\Omega$
$R_{16}, R_{23}, R_{26}, R_{27} = 4.7\ k\Omega$
$R_{20} = 2.7\ M\Omega$
$R_{28} = 3.9\ k\Omega$
$R_{30}, R_{35} = 3.3\ k\Omega$
$R_{31}, R_{32} = 15\ k\Omega$
$R_{36} = 22\ \Omega$
$P_1 = 250\ \Omega$, multiturn preset (upright)
$P_2 = 500\ \Omega$, multitun preset (upright)
$P_3 = 500\ k\Omega$, multiturn preset (upright)

Capacitors:
$C_1, C_3 = 0.1\ \mu F$
$C_2 = 0.001\ \mu F$
$C_4, C_5, C_6, C_8, C_{12}–C_{17} = 0.1\ \mu F$, ceramic
$C_7 = 0.47\ \mu F$
$C_9, C_{18}, C_{19}, C_{22} = 4.7\ \mu F$, 63 V, radial
$C_{10} = 10\ \mu F$, 63 V, radial
$C_{11}, C_{23} = 47\ \mu F$, 25 V, radial
$C_{20} = 1000\ \mu F$, 25 V, radial
$C_{21} = 470\ \mu F$, 25 V, radial
$C_{24}–C_{26} = 0.047\ \mu F$, ceramic

Semiconductors:
$D_1, D_2 = $ BAT82
$D_3, D_4 = $ BAS45A
$D_5, D_7 = $ 1N4148
$D_6, D_8, D_9, D_{13} = $ 3 mm high-efficiency LED (yellow, red, green, green respectively)
$D_{10}, D_{11} = $ 1N4007
$D_{12} = $ 1N4001
$T_1, T_3, T_5, T_6 = $ BC547B
$T_2, T_4 = $ BD140

Integrated circuits:
$IC_1 = $ OP249GP (Analog Devices)
$IC_2 = $ LM319N
$IC_3 = $ 74HC4060
$IC_4 = $ 74HC175
$IC_5, IC_6 = $ 4N35
$IC_7 = $ 7812
$IC_8 = $ 7912
$IC_9 = $ 7805

Miscellaneous:
$JP_1 = $ 2.54 mm pin strip and pin jumper
$K_1, K_2 = $ 3-way terminal block, pitch 5 mm
$K_3 = $ 2-way terminal block, pitch 5 mm
$K_4 = $ 2-way terminal block, pitch 7.5 mm
$B_1 = $ bridge rectifier, rectangular, Type B80C1500
$F_1 = $ fuse, 50 mAT and fuse holder
$Tr_1 = $ mains trasformer, 15 VA, with 2×15 V secondary
Heat sink (for IC_7) = e.g. Fischer SK104, 50 mm
Mains interference filter

The network is linked to the input and output of the amplifier via terminals 'input' and 'LSP' respectively (to terminals 'P-IN' and 'P-LS' on the amplifier board).

Terminals '50 V≈' are connected to the secondary windings of the mains transformers.

The three output relays and the mute relay in the amplifier are linked to the protection network via K_2, and K_3 respectively.

The current sensor is connected to the output of optoisolator IC_2 in the amplifier ('I-> ' on the amplifier board) via K_1.

The terminals marked 'temp' are intended to be linked to the output of the fan control circuit.

As mentioned earlier, the action of each sensor results in the deenergizing of the output and mute relays in the amplifiers. This implies that the outputs of the the various sensor circuits are interlinked. This is effected by combining the open-collector outputs of these circuits into a wired OR gate with R_{12} functioning as the common pull-up resistance. The combined output signal serves to reset a number of
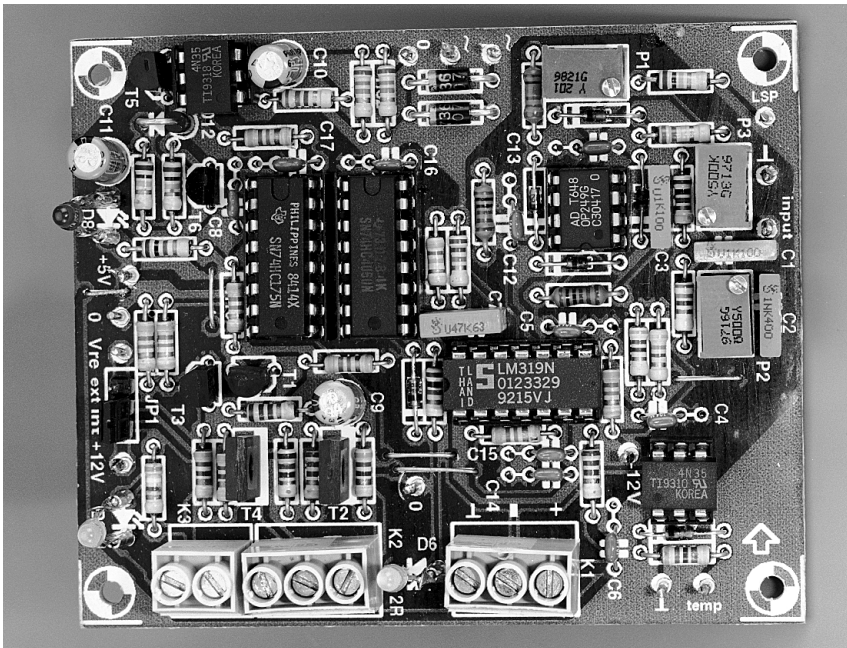
D-type bistables (flip-flops), contained in IC$_4$, which are interconnected to form a shift register. Note that D-type bistables are essential since these can be set and reset in a defined manner.

The outputs of IC$_4$ are used to drive two level converters, T$_1$-T$_2$ and T$_3$-T$_4$ respectively, which bridge the difference between the 5 V level of the logic ICs and the 12 V supply for the relays. Jumper JP$_1$ enables a different, external supply voltage (V_{RE}) to be used if 12 V relays are not employed.

Transistors T$_1$ and T$_2$ drive Re$_1$ and Re$_2$, which are the first to be energized (synchronously). On switch-off, capacitor C$_9$ ensures that T$_2$ remains on for some milliseconds longer during which period Re$_3$ and Re$_4$ are deenergized (see Part 1).

The power-on delay, which also operates after a fault situation, is more complex than usual. To start with, after the supply voltage us switched on, input CLR of IC$_4$ is held low (active) for a few seconds by the circuit around T$_6$. When, after this period, CLR is made high by R$_{12}$ –which happens only when there is no error situation (any longer)–the internal oscillator of IC$_3$ is enabled via D$_5$. This results after a few seconds in a clock pulse appearing at the CLK input of IC$_4$, whereupon Q$_4$ goes high. The period between the oscillator being enabled

and the appearance of the first clock pulse is not defined since, owing to the presence of T$_6$, a power-on reset is purposely not provided. To ensure a minimum delay in the energizing of Re$_1$ and Re$_2$ in spite of this, a high level is clocked into Q$_4$ after IC$_3$ has been enabled. The precise moment at which this happens varies, therefore, only when the supply voltage is switched on for the first time.

A period of IC$_3$/Q$_3$ later, Q$_1$ of IC$_4$ goes high, whereupon Re$_1$ and Re$_2$ are energized. After another period, Q$_2$ of IC$_4$ becomes high, whereupon Re$_3$ and Re$_4$ are energized. At the same time, IC$_3$ is disabled since its reset is interlinked with Q$_2$ of IC$_4$.

The red LED, D$_8$, in parallel with Q$_1$ of IC$_4$ lights when the relays in the amplifier are not energized, either because the amplifier is (not yet) switched on, or owing to an error.

The yellow LED, D$_6$, is linked to the output of the oscillator in IC$_3$, causing it to flash until IC$_4$ is clocked.

The green LED, D$_9$, is connected in parallel with Re$_3$ and Re$_4$, so that it lights only when the amplifier is fully switched on.

TRANSFORMER VOLTAGE SENSOR
The 50 V≈ secondary voltages of the mains transformers in the amplifier are rectified by diodes D$_{10}$ and D$_{11}$, and

smoothed by R$_{30}$-R$_{31}$-R$_{32}$-C$_{10}$. The values of these components ensure that the LED in optoisolator IC$_6$ lights sufficiently to hold the associated photo transistor on. This transistor pulls the base of T$_5$ to ground, causing T$_5$ to cut off. When the secondary voltages fail, T$_5$ is switched on immediately via R$_{29}$, whereupon the D-type bistables in IC$_4$ are reset.

Use is made of an optoisolator purposely to avoid any risk of earth loops between the supply return and the ground of the protection network, which is linked to the input ground of the amplifier.

TEMPERATURE SENSOR
The temperature sensor works in a manner similar to that of the transformer voltage sensor. The optoisolator in this circuit is IC$_5$, which, in contrast to IC$_6$, is normally cut off and comes on only when the heat sink becomes excessively hot.

The sensor reacts to the fan control circuit switching the fan speed to maximum (because the heat sink is getting too hot). A comparator in the fan control circuit then toggles, whereupon IC$_5$ is actuated via the 'temp' input and resets the D-type bistables in IC$_4$. This situation changes only after the heat sink has cooled down to an acceptable temperature (although the fans may still be rotating).

CURRENT SENSOR
To nullify high common-mode voltages and to prevent any risk of earth loops, the current sensor also uses an optoisolator, IC$_2$ (**Figure 5**). However, this is not located on the protection board, but directly at the output of the amplifier.

The values of the relevant components cause the sensor to be actuated when the output current is about 40 A. This may appear a very large current, but this is due entirely to the specified requirement that the amplifier must be capable of delivering 60 V into a load of 1.5 Ω without the protection circuit being actuated. The current level may be lowered to some extent by increasing the value of R$_{74}$ in the amplifier.

Output resistor R$_{78}$ is in parallel with R$_{12}$ by linking terminals 'I', '+ 5 V' and ground on the amplifier board to K$_1$ on the protection board via three lengths of insulated, stranded circuit wire twisted together. This arrange-

990001-3

TR1

K1

TR2

D1 D2
F1 0.16AT
K3

C1
C3

D3 D4
R1
K2

D5 D6
R2

C2
C4

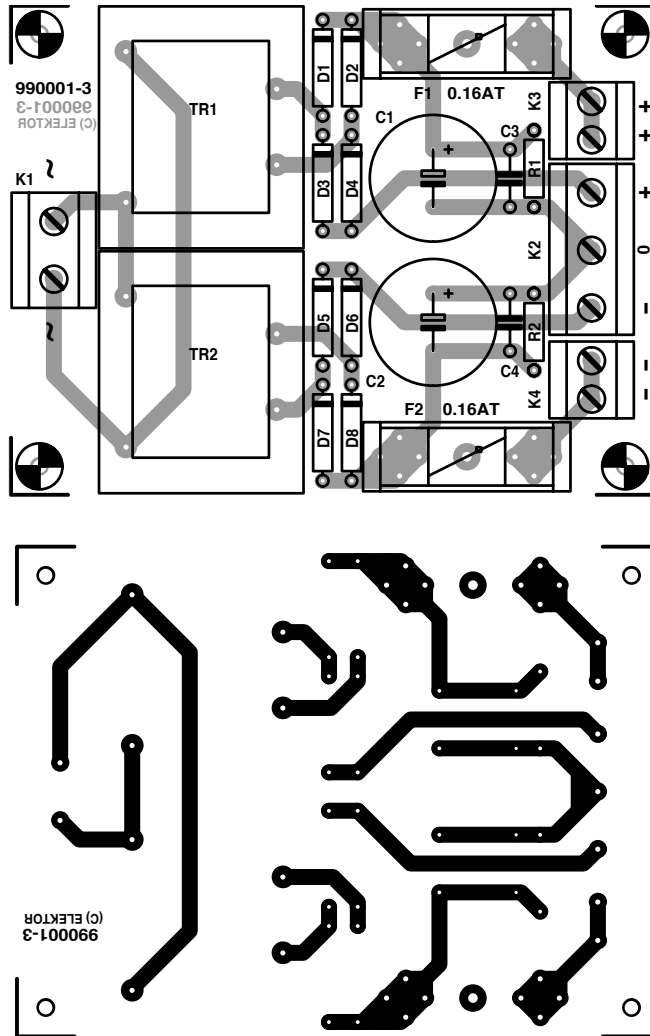D7 D8
F2 0.16AT
K4

+
+
+
0
1

990001-3 (C) ELEKTOR

Figure 7. Printed-circuit board for the auxiliary power supply described in Part 1.

ment ensures a low impedance to any interference and a high reaction speed.

DIRECT-CURRENT AND OVERDRIVE SENSOR
The d.c. and overdrive sensor constantly compares the input and output signals of the amplifier and reacts when the difference between the two is too great. The comparison is effected with the aid of operational amplifier IC_1 which has a very low bias current and a very low offset. It is, of course, essential that during the comparison of the two signals by differential amplifier IC_{1b} the differences in phase and transit times do not lead to error detection. At the same time, the voltage amplification (×43) of the amplifier must be taken into account.

The amplification is compensated by potential divider R_1-R_2-P_1 at input LSP. The potentiometer is a multiturn type to ensure accurate adjustment.

The phase difference is compensated by the circuit based on IC_{1a}. The transit at high and low cut-off points is simulated by first-order networks that can also be adjusted very accu-

rately with multiturn potentiometers P_2 and P_3.

The inputs of IC_{1a} and IC_{1b} are protected by diodes. Since any leakage current of these diodes, combined with the high input impedance (≈ 1 MΩ) of IC_{1a}, might lead to an appreciable offset, and therefore to an unwanted error detection, the diodes, D_3 and D_4, are special types with a leakage current of only 1 nA.

The output of differential amplifier IC_{1b} is monitored by a window comparator formed by IC_{2a} and IC_{2b}. The value of the components used in potential dividers R_8-R_9 and R_{10}-R_{11} ensures that the protection circuit is actuated when the direct voltage reaches a level of ± 5 V or the distortion becomes 2.5 per cent. Such distortion will normally be the result of overdrive, but the circuit reacts equally well to oscillations or other spurious signals that cause too large a difference to be detected.

CONSTRUCTION AND SETTING UP
The integrated protection network is best built on the printed-circuit board shown in **Figure 5**. Populating this board should not present any undue

difficulties, but it should be noted that diodes D_6, D_8, D_9 and D_{13}, are not located on the board, but are linked to it via flexible, stranded circuit wire. They are fitted to the front of the enclosure.

Jumper JP_1 will normally be in position 'intern' unless relays with a coil voltage other than 12 V are used.

A prototype of the completed protection board is shown in **Figure 6**.

All input and output terminals of the board are clearly marked with the same symbols as shown in Figure 4. Most interconnections can be made in thin, stranded hook-up wire to DEF61-12, but the input and output links ('input' and 'LSP') must be screened audio cable.

Although the power supply for the protection network can be fitted on the same board, the relevant section may be cut off and fitted elsewhere. Of course, the supply lines must then be linked to the relevant terminals on the protection board via insulated, stranded hook-up wire.

The power supply is straightforward. From the secondary output of the specified mains transformer, Tr_1, a symmetrical ± 12 V supply is obtained with the aid of regulators IC_7 and IC_8. From the same secondary, a + 5 V supply for the digital circuits is obtained with the aid of regulator IC_9. Since the relays are fed by the + 12 V line, regulator IC_7 must be fitted on a heat sink.

To ensure that the protection network is not actuated by interference on the mains supply, it is advisable to precede the power supply by a suitable noise filter. This may be made from a 30 μH choke and two 0.1 μF, 300 V≈ capacitors as shown in dashed lines in Figure 4.

The network is set up by maximizing the common-mode suppression

with the aid of an oscilloscope or a multimeter with sufficient bandwidth. Measurements need to be made at 1 kHz, 20 kHz, and 20 Hz. The open-circuit amplifier is driven as far as possible by a suitable sine-wave generator or CD player with a test CD.

With a signal of 1 kHz, set P_1 for minimum signal at the output of IC_{1b}, follow this with a signal of 20 kHz and adjusting P_2, and finally, with a signal of 20 Hz, by adjusting P_3. Since the settings influence one another to some extent, the potentiometers should be set a couple of times, perhaps also at some different audio frequencies.

POWER SUPPLY

The auxiliary power supply described in Part 1 is best constructed on the printed-circuit board shown in **Figure 7**. The mains voltage is linked to K_1, the ± 70 V to K_2 and the + 85 V and –85 V lines to K_3 and K_4 respectively. Since all currents are low level, the wiring may be made in thin, insulated, stranded hook-up wire. A completed prototype board is shown in **Figure 8**.

The main supply for the amplifier is a straightforward, unregulated type, providing an output of ± 70 V. Its circuit diagram is shown in **Figure 9**.

Since the specified requirements call for a 2 Ω load, the supply must be rated at 1000 VA, which necessitates two toroidal transformers. To prevent unforeseen equalizing currents, the dual secondaries are not linked in parallel, but are individually connected to a bridge rectifier. The outputs of the rectifiers can be connected in parallel without any problem. The rectifiers need to be mounted on a suitable heat sink such as a Type SK01.

It should be clear that the wiring of

Figure 8. The auxiliary power supply is small enough to fit in most enclosures.

the power supply must allow for the large output currents of the amplifier. In the prototype, the electrolytic capacitors are linked by 3 mm thick strips of aluminium. The remainder of the wiring should be in insulated, high-current wire to BS6231 with a conductor size of 50/0.25 mm (2.5 mm²) or better. The use of car-type connectors is recommended.

Note that the power supply as described is intended for use with a mono(phonic) amplifier that can deliver 800 W into 2 Ω and should remain stable with loads of 1.5 Ω. If you are certain that you will always use 4 Ω or 8 Ω loads, the power supply requirements may be relaxed to some extent. A reasonable relaxation is the use of 2×50 V/300 VA transformers and 10,000 μF/100 V smoothing capacitors. The rating of the primary fuses may then be reduced to 1.5 AT.

MAINS-ON DELAY

The use of a mains-on delay is recommended when heavy loads are to be switched on, as in the case of the present amplifier. Such a delay circuit switches on the mains to the load gradually to ensure that the switch-on current remains within certain limits and to prevent the mains fuses from blowing.

The most recently published (in this magazine) mains-on delay is found in the July/August 1997 issue (p. 74), whose circuit diagram is reproduced in **Figure 10**. Its printed-circuit board is readily connected with the primary windings of the two mains transformers. The board is not available ready-made, however, and its diagram is, therefore, reproduced in **Figure 11**.

Figure 9. The main power supply for the amplifier is a heavy-duty entity in which the six capacitors are particularly impressive.
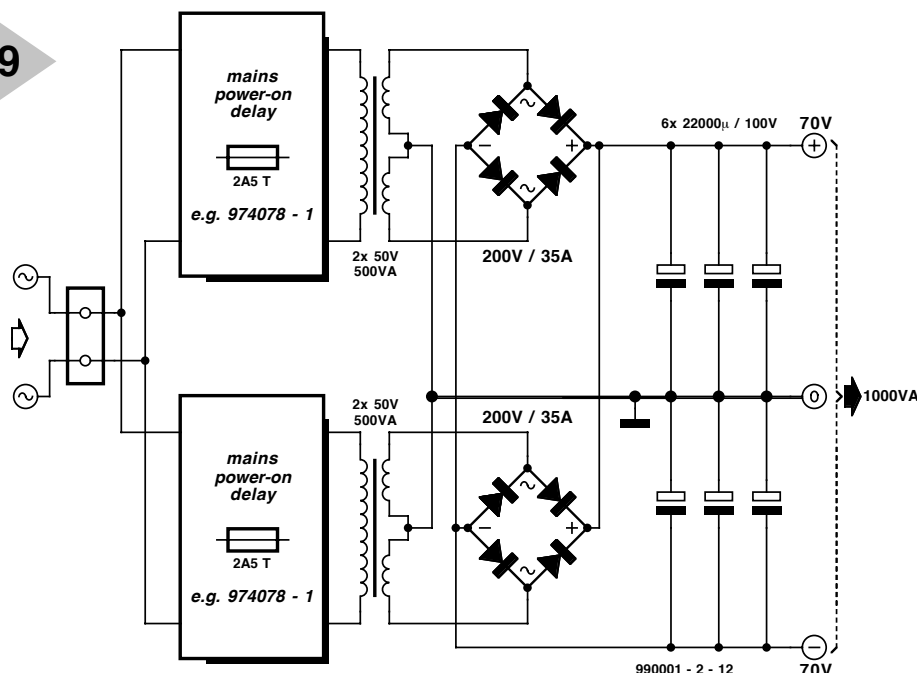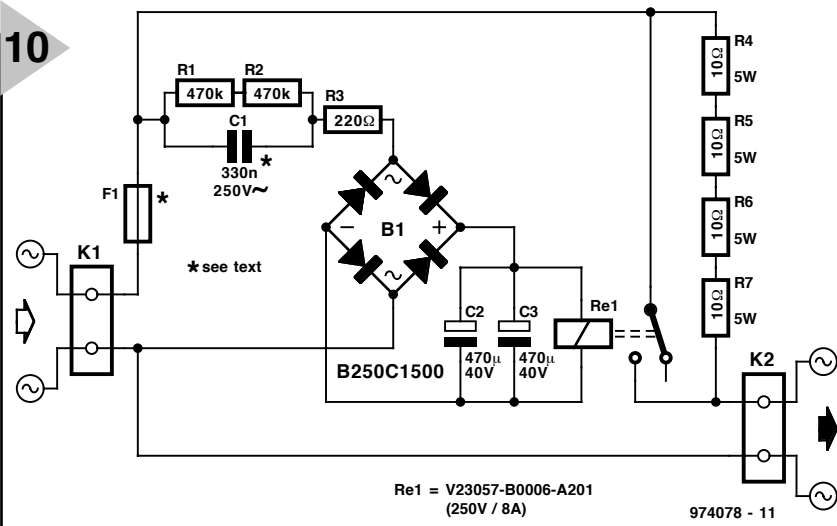
Figure 10. The mains-on delay ensures that the switch-on current remains within certain limit. Two of these delays are required for each Titan 2000.

The delay arranges for the load, that is, the Titan 2000, to be switched on in two stages. In the first of these, the switch-on current is limited by series network R_4–R_7. After the delay determined by capacitors C_2 and C_3, the series network is shorted by a relay contact, whereupon the full current flows between K_1 and K_2.

Relay Re_1 can switch up to 2000 VA. Its supply voltage is obtained from the mains with the aid of rectifier B_1, capacitor C_1 and resistor R_3.

Since the amplifier power supply uses two mains transformers, two mains-on delay circuits are needed.

Fuse F_1 functions as a primary mains fuse for the amplifier.

Capacitor C_1 is a metallized paper type intended especially for use with mains voltage applications.

Bear in mind that the circuit is linked directly to the mains supply and thus carries lethal voltages.

Next month's third instalment of this article deals with the construction of the amplifier, a few other practical matters, and some measurements.

[990001-2]
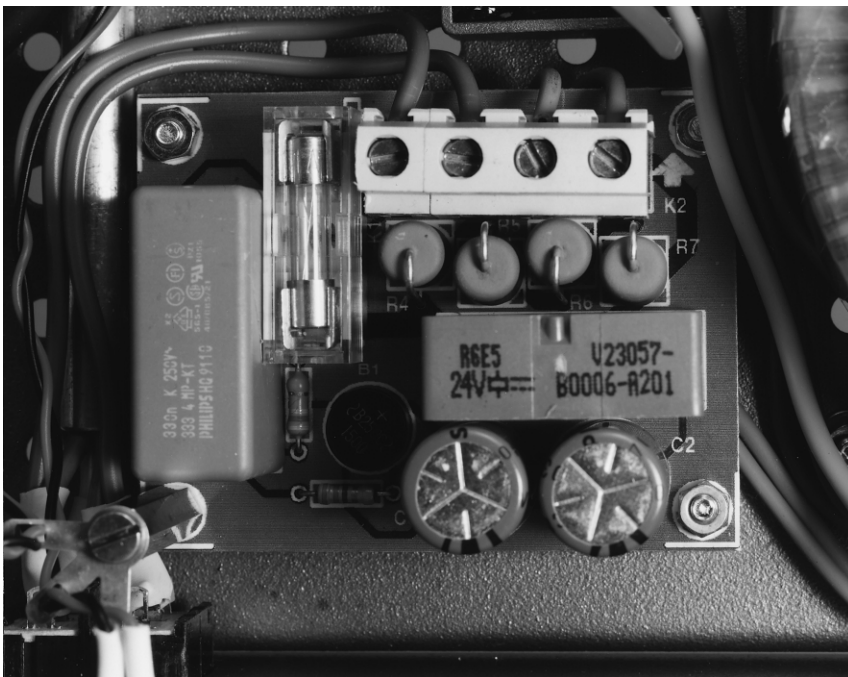
Figure 11. Printed-circuit board for the mains-on delay circuit, which is not available ready made.

Parts lists

Mains-on delay circuit

Resistors:
R_1, R_2 = 470 kΩ
R_3 = 220 Ω
R_4–R_7 = 10 Ω, 5 W

Capacitors:
C_1 = 0.33 µF, 300 V a.c.
C_2, C_3 = 470 µF, 40 V

Miscellaneous:
K_1, K_2 = 2-way terminal block, pitch 7.5 mm
B_1 = bridge rectifier, round, Type B250C1500
Re_1 = relay, coil 12 V, 1200Ω; contact rating 250 V, 8 A
F_1 = see text
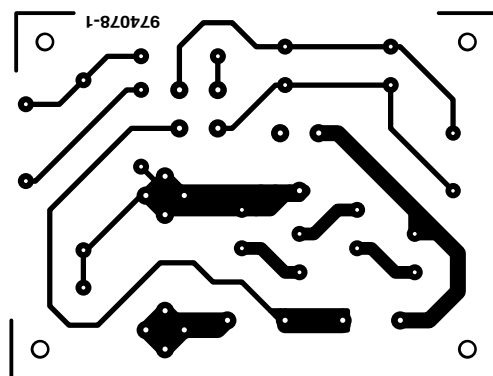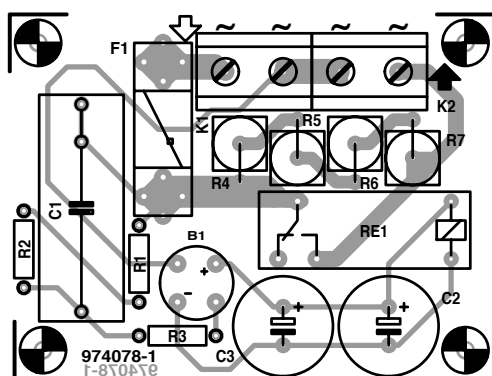
SX-microcontroller evaluation system (2)

part 2: the programming adaptor

In this second instalment of the series we present the PICK-ALOCK programming adaptor, which acts as the link between the programming software on the PC and the SX-microcontroller on the prototyping or application board. In this configuration, a high-speed Atmel controller acts as a protocol converter.

Design by M. Ohsmann
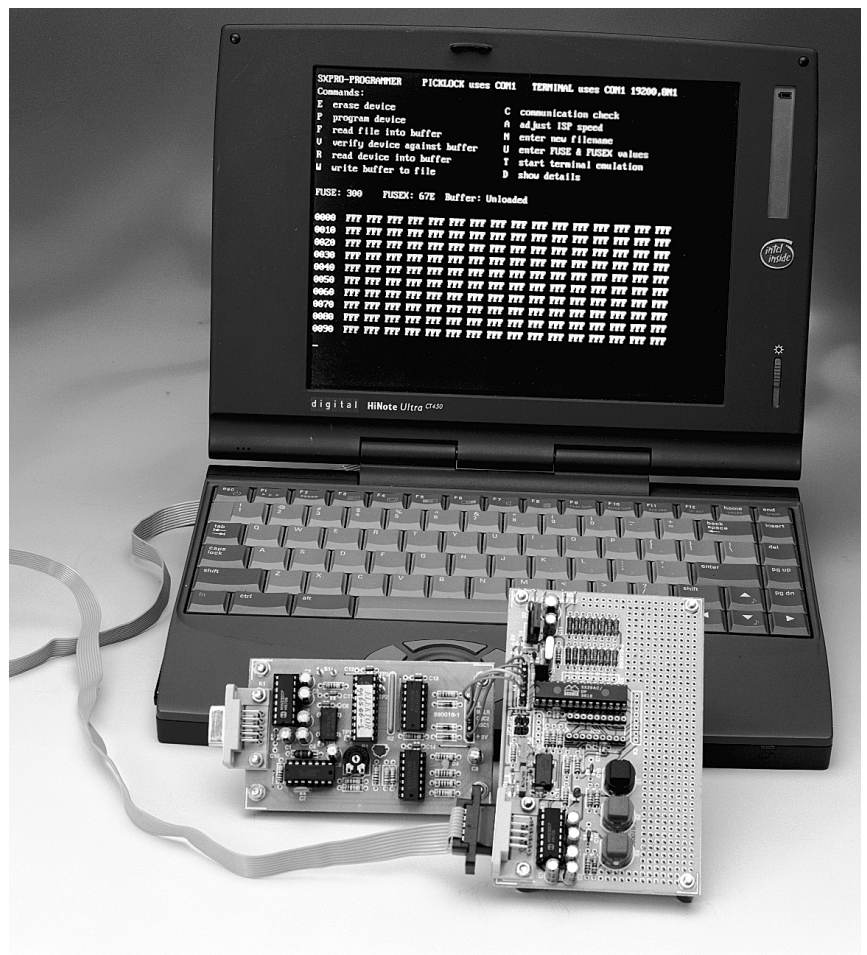
Last month we showed you that the timing of the SX chips is pretty rapid when serial programming is used, and that the timing protocols are fairly strict. After due consideration, the designer came to the conclusion that an 8051 micro clocked at 18 MHz should really be able to handle all communication with the SX chip. The result of the design work is the PICK-ALOCK programming adaptor, whose circuit diagram is shown in **Figure 1**. Microcontroller IC3 is the heart of the circuit. Instead of the 'generic' 8051, a more up to date version, the Atmel 89C2051 is used in the circuit. Regular *Elektor Electronics* readers should know this chip from quite a few earlier publications. The link with the PC is established by serial interface driver IC1. The serial protocol is 19200,8,N,1. A switching regulator around IC6 supplies the
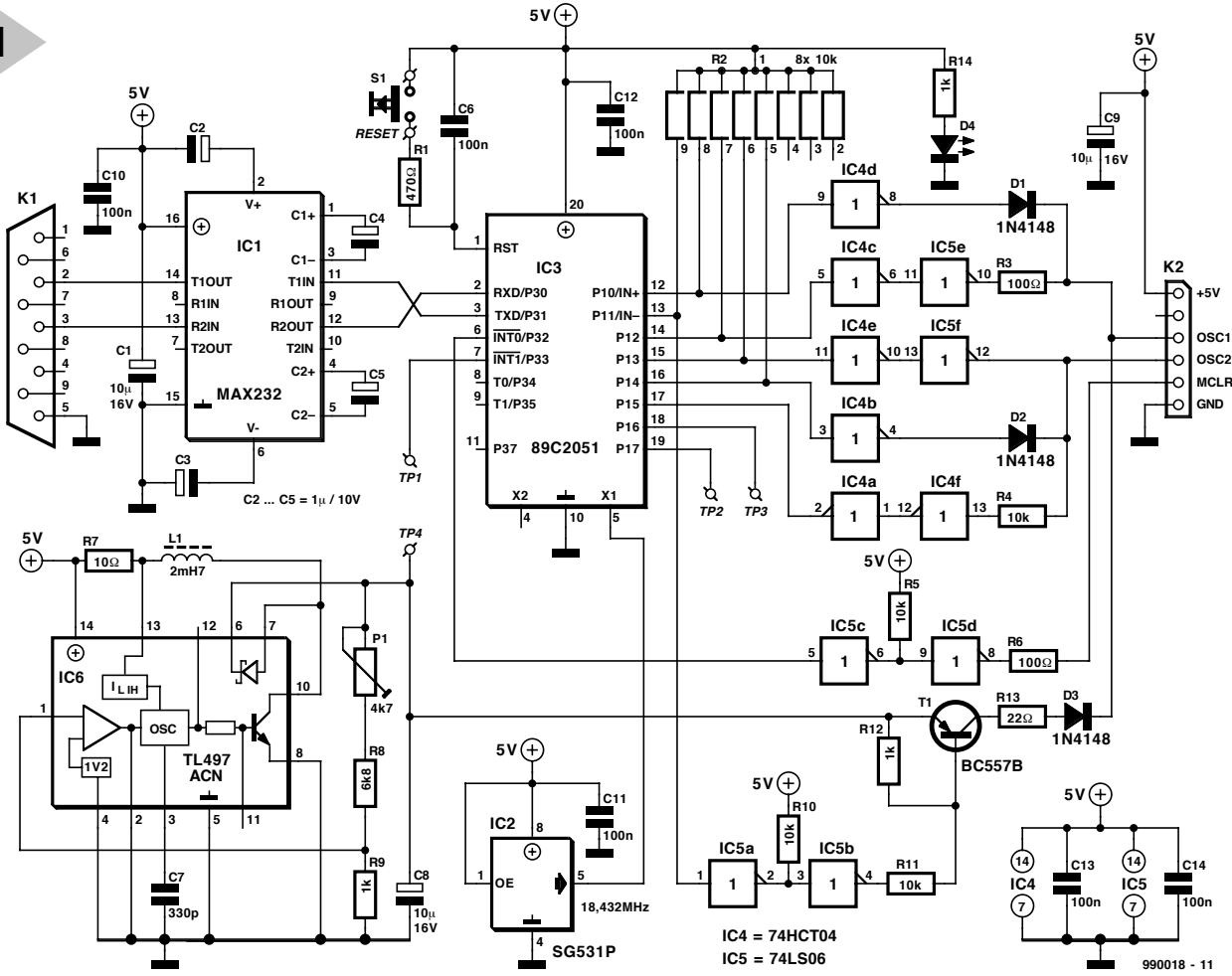
Figure 1. Circuit diagram of the PICKALOCK programming adaptor for SX microcontrollers.

12.5 V which is necessary to switch the SX processor to 'programming' mode. An integrated clock oscillator, IC2, is employed, operating at 18.432 MHz. Circuits IC4 and IC5 form the link between IC3 and the SX chip. The programming voltage may be connected to the OSC1 line by way of transistor T1. The same line may be switched to 5 V with the aid of IC4d and D1. The open-collector output of IC5e and resistor R3 enable the OSC1 line to be pulled to ground. A similar system is used on data line OSC2. Via IC4a and IC4f, processor IC3 is able to read the level on the line. The complete interface to the SX chip is configured in such a way that lines OSC1 and OSC2 are at high impedance during the reset state of IC3 (for example, after switching on). In this way, a quartz crystal oscillator circuit (as described in part 1) is allowed to oscillate on OSC1 and OSC2. The SX chip may also be reset by way of IC5c and IC5d. The +5-V supply voltage is borrowed from the SX-circuit to be programmed, via the 5-V pin on connector K2.

The photograph shows the SX evaluation board. The connections between the SX-PICKALOCK and the

SX chip should be kept as short as possible, because stray capacitance and inductance (introduced by long wires) will degrade the oscillation behaviour of the SX quartz oscillator circuit in the frequency range 10 MHz and higher.

CONSTRUCTION AND FIRST USE

The copper track layout and component mounting plan of the single-sided printed circuit board developed for the programming adaptor are shown in **Figure 2**. As a matter of course, all ICs should be fitted in sockets. On pinheader K2, it is recommended to cut off the non-used pin between OSC1 and +5 V. By inserting the pin in the mating socket, the socket can not be fitted the wrong way around — a simple trick that can prevent a lot of problems.

While you build up the board, do not forget the wire links. Also note that K1 (RS232 interface) is a sub-D socket (i.e., a female connector). After a thorough visual inspection of the board, the circuit may be connected to 5 volts by way of the 5-V pin on K2. Next, check the operation of the switching regulator IC4, and if TP4 can be set to 12.7 V by adjusting preset P1. Then, having connected a PC running a terminal emula-

tor program set to 19200,8,N,1 communication, the SX-PICKALOCK should produce a start-up message when IC3 is reset by pressing S1. Not much can go wrong, we'd say, provided you've done a proper soldering job.

FUNCTION OF THE SX-PICKALOCK

Actually, the programming adaptor only acts as a protocol converter. For that purpose, the PICKALOCK software stashed away in IC3 provides a number of functions. Although functionally essential, they are not terribly important to you, the user, mainly because the actual programming software runs on the PC, with the code in IC3 just acting as 'glue' between the PC software and the SX chip to be programmed. None the less, a description of the interface control software may be found on the diskette supplied for this project. It should be noted that some of the available commands can also be used to perform tests on the PICKALOCK hardware. These tests are remnants of the design work, and they are obviously not required once the hardware is fully functional. For example, routines are available that enable the ports of IC3 to be read and controlled as part of an integral hardware test procedure.

Figure 2. PCB artwork (board available ready-made).

USING THE SX-PICKALOCK

Scenix SX microcontrollers may be programmed by launching the PICALOCK control program, SXPRO.EXE, on the PC. These microcontrollers may also be read, erased and reprogrammed. The FUSE and DEVICE words may be set up as required if that has not been done already in assembler code.

The simple user interface offered by the SXPRO program is shown in **Figure 3**. Files generated by our SX assembler are processed directly. Although this may appear a ready to go situation, you should not forget that you first have to build a test board with the new processor.

SX DEMO BOARDS AND PROGRAMS

An SX experiment/prototyping board will be discussed in next month's instalment (part 3 of the series). Originally, there were two separate boards, one for the SX18 version and one for the SX28. The final product, however, is a single board that can be used by both processor versions. This board is already shown on a couple of photographs.

Apart from the construction of the prototyping board, next month's instalment will also deal with programming the SX controllers.

(990018-1)

Figure 3. SXPRO user interface.

```
SXPRO-PROGRAMMER    PICKLOCK uses COM2    TERMINAL uses COM1 19200,8N1
Commands:
E   erase device                     C   communication check
P   program device                   A   adjust ISP speed
F   read file into buffer            N   enter new filename
V   verify device against buffer     U   enter FUSE & FUSEX values
R   read device into buffer          T   start terminal emulation
W   write buffer to file             D   show details

FUSE: 265    FUSEX: 973   Buffer: Unloaded

0000   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0010   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0020   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0030   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0040   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0050   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0060   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0070   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0080   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
0090   FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF FFF
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circuit testing with a sawtooth

audio measurements in theory and practice

Many experts in the field query the use of sinewave signals to test amplifiers and other audio gear. Although a rectangular signal is in principle suitable for many measurements, the sawtooth is believed by many to be a much better test signal. The combination of this test signal and an oscilloscope should enable you to give an expert opinion about audio equipment performance.

Design by F. Hueber
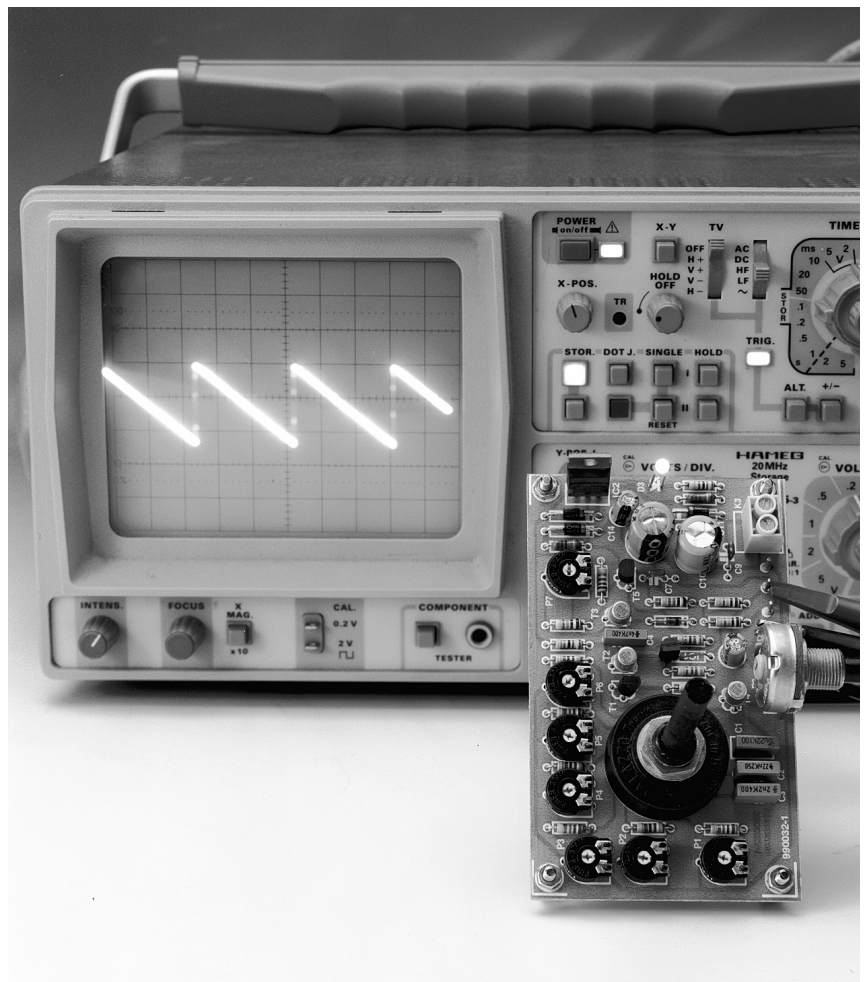
Specification

Waveform:	inverted sawtooth
Frequencies:	100 Hz; 315 Hz; 1 kHz, 3.15 kHz, 10 kHz, 31.5 kHz
Rise time	< 1% of period
Linearity error	< 1%
Output voltage:	max. 3.5-4 V_{pp}
Sync pulse:	positive, max. 4 V_{pp}
Power supply:	12 V, approx 1.3 W

When it comes to testing audio equipment with the aid of a sinewave signal, you first require a generator with very low distortion. Unfortunately, most function generators have a distortion between 1 and 3%, which makes them unsuitable for this particular application. AF generators of the Wien bridge type are to be preferred here because of their much better specification (distortion typically 0.01%). And yet, this distortion level may well be much higher than that of the equipment under test. What's more, measuring distortion and frequency response often equates to lots of individual measurements. Thing become even more complicated when you want to determine the dynamic range or overall stability of an amplifier under test. A simple sinewave signal, clean as it may be, is simply not suitable for that purpose. Likewise, judging the 'sonic quality' of, say, a power amplifier, is almost impossible with just a sinewave signal.

A pure sin-wave has a *crest factor* of 2 or about 1.41. The crest factor is the ratio of the peak value to the effective value. However, with music signals, or noise (percussion), this value can easily rise to 10 or higher. Consequently, an amplifier that performs very well under sinewave testing conditions may produce mediocre results when music or speech signals are applied.

This is due to the fact that a high-performance amplifier should be able to handle very fast signal rise times (often in the μs range) and still supply a clean output signal.

For music reproduction a frequency that just about covers the audible range (upper limit 16-20 kHz) is obviously too narrow. Good amplifiers these days go up to about 100 kHz, provided the slew rate is adequate. Again, these qualities are almost impossible to measure with just a sinewave.

Consequently, rectangular test signals are often used to put audio amplifiers through their paces, and subject them to some pretty gruelling tests. In practice, the response of an amplifier to rectangular signals says a lot about its sonic qualities. An advantage of the rectangular wave over the sinewave is its higher harmonics content. Consequently, you can do tests at the fundamental frequency of the rectangle signal as well as at much higher frequencies. It should be noted, however, that besides the fundamental frequency a rectangular wave contains only odd-numbered harmonics (3rd, 5th, 7th, etc.). So, a sawtooth signal would be even better. In principle, the sawtooth contains all harmonic frequencies (2nd, 3rd, 4th, 5th, etc.), again in addition to the fundamental frequency, so that the complete spectrum is always available.
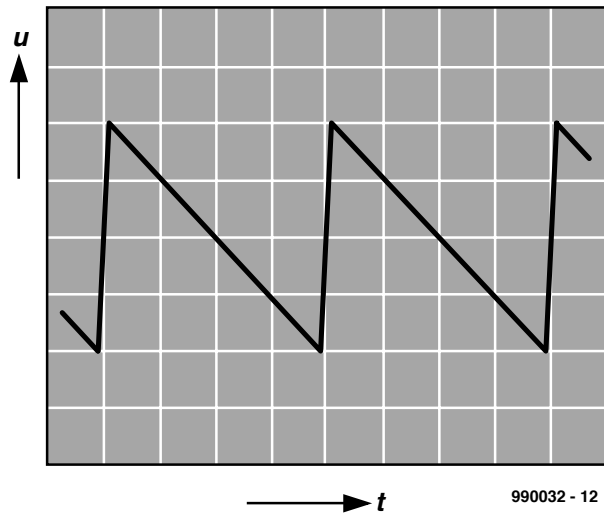
Figure 1. Negative (inverted) sawtooth.
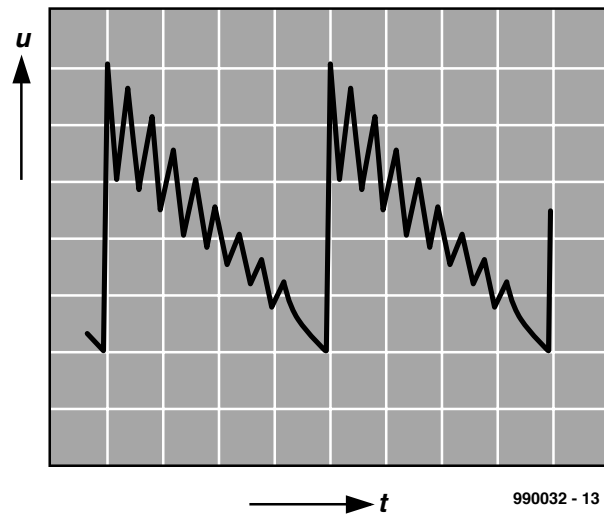
Figure 2. Amplifier suffering from a tendency to oscillate.
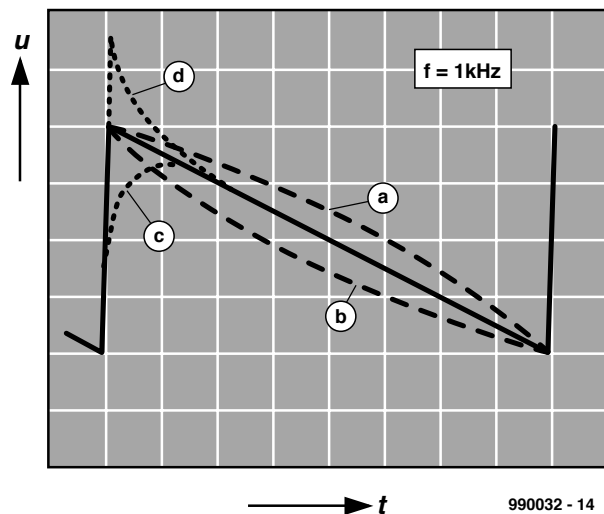
Figure 3. Effect on the frequency response.
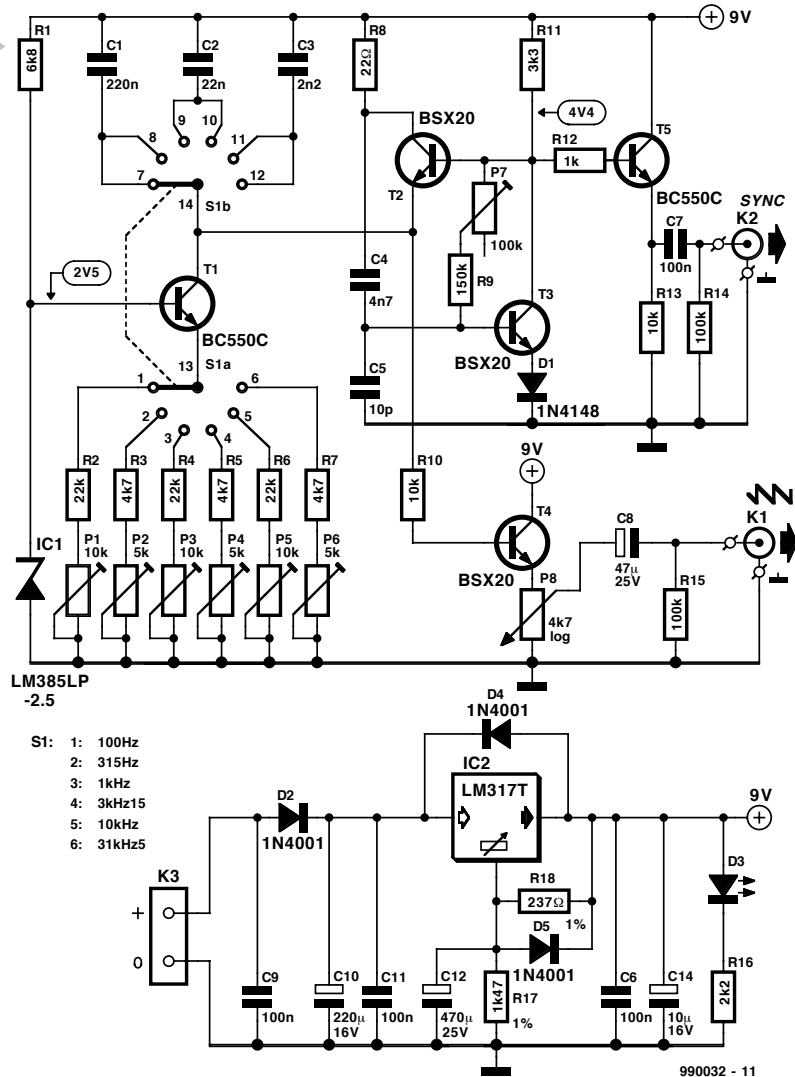
Figure 4. Circuit diagram of the simple sawtooth generator.

the frequency response is reasonably flat. After all, irregularities in the frequency response are also easily noticed if you use a sawtooth test signal. As shown in **Figure 3**, the effect is easily demonstrated on a tone control section when using a sawtooth test signal with a not too high frequency. If an amplifier or any other audio circuit has a (hidden) bass boost, the falling edge of the signal is slightly curved upwards (dashed line marked 'a'). If the low-frequency amplification is reduced, the falling edge 'droops' (b). If, by contrast, the equipment attenuates high frequencies, the upper part of the edge will be less steep, and the 'front' part of the signal becomes slightly curved (dotted line 'c'). Similarly, unwanted high-boost is indicated by this part being pulled up.

With a little practice, this measuring method can provide many interesting viewpoints concerning the functioning of amplifiers, filters and similar circuits. The sawtooth is also useful for those of you interested in testing and 'grading' cassette decks and other tape recording machines. For example, recording and playing back the 3.15-kHz test signal will provide lots of information on the optimum 'bias' level (pre-magnetisation) for a particular tape brand.

Another example is the compensation adjustment on a typical 10:1 oscilloscope probe — here, too, a sawtooth test signal results in easier and more accurate calibration than when the

BETTER NEGATIVE THAN POSITIVE

Unfortunately, the 'regular' (positive) sawtooth as supplied by many function generators is still not ideal when it comes to testing a wide range of audio equipment. One period of such a positive sawtooth signal consists of a slowly rising slope followed by a sharp falling edge. For our specific purpose, however, the inverted form, a 'negative' sawtooth, is better suited. Its shape is shown in **Figure 1**. Each period starts with a sharp rise, followed by a slow and gradual downward slope.

The main advantage of this waveform is that its fast edge will disclose any instability of the equipment under test. The oscilloscope picture in **Figure 2** shows the output signal of an amplifier with insufficient compensation for inductive loads. The tendency to oscillate is clearly visible.

Using a sawtooth test signal, only the best amplifiers will produce a faithful copy of the input signal, provided

Figure 5. PCB design.

flaky square wave from the oscillo-scope itself is used.

Interesting and sometimes surprising facts may also be learned by first examining and comparing the output signal of an amplifier connected to a dummy load (i.e., a pure resistance), and then connect the output to a real-life load, that is, a loudspeaker. The results will clearly indicate why the combination (amplifier and loud-speaker) may not achieve a certain sonic quality, while there is nothing ostensibly wrong with the performance of the individual units.

An obvious requirement with all tests is that the equipment under examination is not overdriven. On the oscilloscope, overdriving is indicated by rounded signal tops ('clipping'), just as with any other waveform. The saw-tooth waveform is then transformed in a trapezoid voltage, and everything

mentioned so far is then subject to more than one serious limitation.

The desired waveform called 'negative sawtooth' may, of course, be obtained from any generator with a positive sawtooth output, simply by inverting the signal. However, doing so may cause problems with the signal linearity and rise time. In general, it will be better to use a purpose designed generator, and such an instrument is described here.

A SIMPLE SAWTOOTH GENERATOR

Although a negative sawtooth is emi-nently suited as a test signal, this par-ticular waveform is rarely found on commercial function generators and similar instruments. The simple gener-ator described here requires only a handful of commonly available parts, yet guarantees excellent performance.

As shown in **Figure 4**, the generator proper is built from discrete parts only,

including transistors. Together with voltage reference element IC1, transis-tor T1 acts as a constant-current source. Depending on the frequency range selected with switch S1, one of the potentiometer-resistor combinations causes a certain constant current to be generated in the emitter line of T1. This current is used to charge capacitors C1, C2 and C3. Each of these is responsible for two frequency ranges. Once the voltage across the capacitor reaches the turn-on level of T2, this transistor starts to conduct, the collector current gener-ating a 'dip' at current limiter resistor

Harmonics

Harmonics are oscillations of a periodic quantity, present in a complex signal, having a frequency that is an integral multiple of the fundamental frequency. A sinewave signal should be as pure as possible, which means that it should have as few as possible harmonics. If harmonics are present, they should have the lowest possible level (small distortion). The actual number of harmonics associated with a sinewave, and in particular their level, is strongly dependent on the elementary design of the generator, as well as on components used, and is difficult to predict. By contrast, the waveform supplied by rectangular-wave and sawtooth generators is accurately determined by the number of harmonics, at least the lower-order ones, and the harmonic levels may be calculated approximately. As a rule of thumb, the discrete level of a harmonic is the reciprocal of the number of harmonics, multiplied by the level of the fundamental signal. In an equation,

$$V_H = (1/n) \times V_F$$

where

V_H = *level of harmonic*
n = *number of harmonic (2, 3, 4, …)*
V_F = *level of fundamental signal*

For example, assuming you have a available a 1-kHz signal with a level of 3 V, the level of the 4th harmonic equals

$$V_H = (1/4) \times 3 = 0.75 \ V$$

Expressed in decibels (dB) this equates to

$$20 \log (3/0.75) = 12 \ dB$$

below the level of the fundamental frequency.

R8. Via capacitor C4 this dip arrives at transistor T3, causes it to block, so that its collector and the base of T2 will be pulled to a high potential. This potential change causes T2 to conduct abruptly, allowing the selected capacitor to be rapidly discharged.

The sawtooth generator employs an old faithful: the BSX20 transistor, a fast switching device which has been with us for more than 25 years. General-purpose AF transistors are used in the constant-current source and the synchronisation driver stage. Thanks to the above mentioned feedback, the sawtooth is characterised by extremely short rise times.

Diode D1 lifts the emitter potential of T3 by a constant level above ground, enabling the base to become more negative than the emitter. In this way, the transistor can be switched off rapidly and completely. For proper functioning of the circuit it is necessary to have a defined potential at the collector of T3. Preset potentiometer P7 allows this potential to be adjusted, independent of the current gain of T3.

By way of decoupling resistors R10, the sawtooth voltage at the emitter of T2 is fed to emitter follower T4. The output voltage is taken from the wiper of potentiometer R8 in the emitter line. Via C8, the output signal arrives dc-free at output socket K1. To enable small output voltage levels to be set with sufficient accuracy, pot P8 should be a logarithmic type.

The feedback pulse supplied by T3 is fed to sync output socket K2 by way of another emitter follower, T5. The sync signal appears at the same time as the rising edge of the sawtooth, and is useful to keep an oscilloscope triggered.

The mains power supply is a conventional design. Because of the low current drain, a small (single-winding) transformer is sufficient, together with a single-phase rectifier and a fairly large smoothing capacitor, C10, for ripple suppression. Alternatively, the transformer and rectifier may be replaced by a low-power mains adaptor (cheaper and safer).

Because the stability and purity of the supply voltage affect the quality of the output voltage, the voltage regulator section is a bit more extensive than usual. The stabilising element, an LM317, is set to supply an output voltage of 9 V by means of R17 and R18. The Adj(ust) input of the LM317 has an additional decoupling capacitor, C12. The resulting output voltage is cleaner and much more stable than would be possible when using, say, a 7809 fixed-voltage regulator. The LM317 has to be fitted with a small heatsink.

Without LED D3, the circuit draws about 3.5 mA. Include the LED and the current still remains low at about 13.5 mA. Because the generator can work off a 5-V supply without major modifications to the circuit, battery-powering using a 9-V PP3 block is a feasible option. Resistors R17 and R18 then have to be changed accordingly. Also, because the indicated frequencies are roughly doubled at a supply voltage of 5 V, resistors R2-R6 have to be suitably modified (i.e., their value has to be increased).

CONSTRUCTION AND ADJUSTMENT

To keep unwanted signals out of the circuit, the generator is best fitted in a metal enclosure with (approximate) dimensions 150x60x100 mm.

Building up the circuit board shown in **Figure 5** should not present problems, we reckon, because only a few common parts are involved. However, do make sure you fit the polarized components the right way around; these include the electrolytic capacitors, diodes and transistors in TO18 case (emitter marked by a small locating tab). The circuit is powered by a small mains adapter capable of supplying at least 12 V d.c.

Having switched on the circuit, the first thing to do is check the presence of the reference and supply voltages. Next, P7 is adjusted to give a collector voltage of between 4.3 V and 4.5 V on T3. This is an important adjustment because it determines to a large extent the frequency calibration, output signal level and the total functioning of the generator.

Next, adjust P1-P6 to give the desired frequencies, using a frequency meter connected to output K1. Preset P7 should not be adjusted again at this stage because all frequency settings depend on it.

(990032-1)
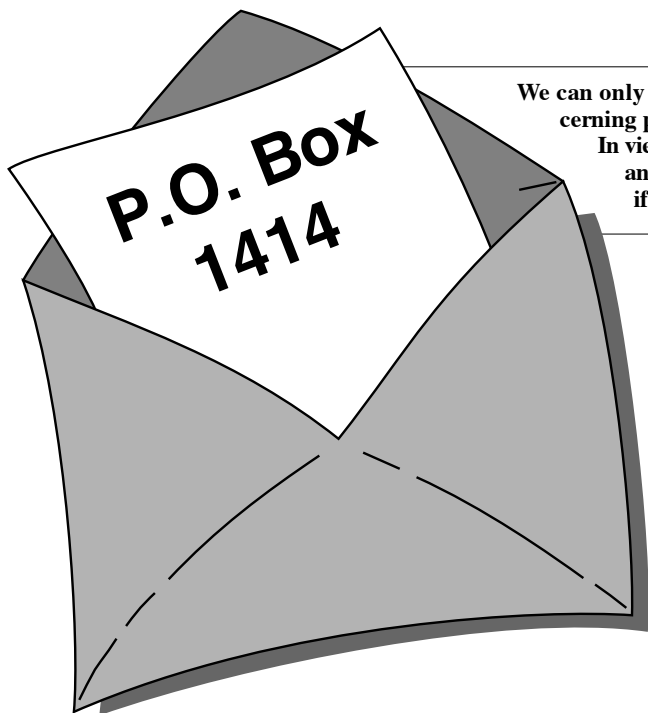
P.O. Box 1414

Memory change-over tip

Dear Editor — with reference to L. Lemmens' useful tip (005, page 57, December 1998), I wonder if you've noticed you can do the same thing using + /– in, say, BASIC:

A=A+B
B=A−B
A=A−B

You can extend the idea to swap strings:

A$=A$+B$
B$=LEFT$(A$, LEN(A$−LEN (B$))
A$=RI GHT$(A$, LEN(A$) −L EN(B$))

Danny Langton, by email

Elektor Electronics — Contents

Dear Editor — as one of your long term subscription readers I feel it is about time to air some of my views concerning the type of projects currently being featured in the magazine. Firstly then, the complaint. It may well not surprise you to learn that I think you are producing far too many projects for, and features on, computers. Most of the projects have rather limited use an appeal to the average reader, how many of your readers who own a computer actually use their machine to perform tasks more technical than a word processor, a game player or to surf the net(?) — and oh yes, we must not forget using a computer to reproduce some very awful holiday photographs in an equally awful digital form. Perhaps some help in actually learning how to operate and get the best of the average PC would be in order, particularly in the case of some of your more mature readers. As a Windows 95/Coraldraw 8 operator (take the word 'operator' with a pinch of salt, please) I think I am on the rung below the one listed as 'illiterate'.

Now to some suggestions for future projects:

A stereo PA slave amplifier with the basic spec of 200/300 W rms into 8R, using easily obtainable FET output transistors (BUZ series), simple rugged design (similar to your advertiser's BK Electronics' products), a volume control, soft start. LS protection and an LED output meter calibrated in watts — this last feature would make a good stand-alone project as I can't remember the last time an audio output meter was featured. If you decide to do the meter project it should be versatile to show outputs from say 100 to 400 or 500 watts (there are a lot of very high power amps out there these days).

A four channel lighting controller for DJ's featuring a user controllable and auto display with channel repeater LEDs on the front panel. I think I'm talking a microcontroller circuit here with audio connections as it should be bass beat clocked via an internal microphone.

A sound clocked stepper motor controller for use in disco lighting effects. There are two possibilities here, one a simple version stepping the motor to the sound beat, and secondly a version controlled by an inexpensive microcontroller, again sound clocked. This type of circuit could be used for colour and gobo lighting effects.

My final comments concern the components used in projects. There is still a tendency to use ICs that are difficult to source in the UK unless one knows where to look. It is all very well to name the component manufacturer but it would be very much better to name a UK stockist. For example, I was recently looking for a Phillips (sic, *Ed.*) IC, the heart of one of your recent projects and not one of the six Phillips franchise holders that I spoke to could supply the part — that is unless I was prepared to order 100 off and wait six weeks for delivery, and then only two of them could offer that! Capacitors are the other problem. Normally in the parts listing you only state the type of capacitor to use for critical parts of the circuit, but what about the less critical parts, should they be polyester, polycarb, MKT, ceramic or what? I think it would also be a good idea to state the ripple value of high value electrolytic capacitors, as this would aid the selection of the correct capacitor for the circuit.

I hope that these observations and suggestions will be regarded as constructive and I look forward to seeing the results in future editions of the best practical electronics mag on the market.

David Jones

This rather long letter is reproduced unabridged here because it contains valuable points for discussion.

Regarding the number of computer-related items, we can only say that the content of a magazine which attempts to be in the forefront of technology has to be an accurate reflection of readers' interests and their ways of dealing with the subject at hand: modern electronics. Our latest Readership Survey indicates that the majority of readers find the balance between computer and non-computer-related projects just right. With this in mind, we strive to keep the amount of computer stuff in each magazine within reason, although many of our younger readers are clamouring out for more. As you may have noticed, our computer articles are always related to electronics in the widest sense of the word, and nearly always about hardware and software you will not easily find in the highstreet computer shop.

Suggestions for future projects are always welcome and yours have been copied to our design department. A high-power audio amp, — well your wish is our command as you can see from the Titan 2000 article of which the second part is included in this very issue.

Some of the components used in our projects are, admittedly, rather special. However, mentioning one UK supplier would provoke letters from half a dozen others claiming to have supplies also, and always after publication of the relevant article! Two of our advertisers, C-I Electronics and Stippler Elektronik, supply kits for many of our projects, as well as 'difficult to source' individual components. Arguably, their exact

function is to buy the 100 components you mention from, say, Philips Semiconductors (not 'Phillips'), and then sell them to you. You may object to this, but it is the simple and whole purpose of retail business: buy in volume quantities, sell as one-off. Stippler Elektronik have a UK outlet also: Viewcom Electronics, so if you prefer to Buy British that is the way to go. C-I Electronics are fully set up to deal with credit card payment, advertise and correspond in English, so with them too borders are virtually non-existent (within the EU). By the way, you do not mention the type number of the IC you were after — we may have been able to help you with pointers in the right direction. Capacitors, then. Our design department advises that where no particular make, style or

dielectric material is mentioned, the part is indeed so uncritical that any one the types you mention will work without problems. In case of doubt, guidance may be obtained from the photographs included in the article, or simply ask us!

Tachometer — inductive pick-up?

Dear Editor — your article covering a DIY tachometer (*Elektor Electronics* October 1998) states that ignition pulses are picked up inductively. I think this is misleading. To be able to generate a voltage inductively, a changing magnetic field has to be sent through the inductor. There is no such field. The magnetic field caused by the ignition current does not pass through the coil but

appears at a right angle from it. So in fact we are looking at capacitive coupling at the 'hot' side of the coil.

K. Williams

If we doze off from time to time, there's always someone to prod us awake! Of course you are right. Our apologies for this slip of the pen.

PC-Controlled light Dimmer — watt's up?

Dear Editor — I was delighted to see the PC-controlled 32-channel light dimmer in the December 1998 magazine. With some surprise I noticed that the maximum power per channel is only 275 watts. As far as I know, the smallest theatre spotlight weighs in at 500 watt. Are you aware of any opto-triacs for higher power, or

is there another way to increase the power in each channel?

K. Verstraeten

The problem is not caused by the opto-triacs, because with sufficient cooling these are capable of passing up to 8 A (approx. 1900 W). However, suppressor choke L1 has a highest rating of 10 A, and this value is also the safe limit for the PCB tracks and the PCB terminal block. The 500-watt lamps you mention may be controlled by adding not more than four opto-triacs per PCB, and increasing the fuse ratings to 2.5 A (slow).
To still be able to use 32 channels, simply use more PCBs (in this case, eight), connected in parallel to RS232 port on your computer.

EL lamp driver Type IMP803

high voltage on chip

990005 - 11

EL (electroluminescent) lamps are used primarily for the background lighting required by liquid-crystal display panels used in much battery operated equipment where low current drain is a prime requirement. The IMP803 driver for such lamps contains the requisite basic circuits: a switch-mode power supply using a high-frequency oscillator and a high-voltage H-bridge output driver using a low-frequency oscillator. It can drive lamps of up to 30 nF (10 in^2) to high brightness.

Main parameters

➜ *Low power:*   *420 µA typical input current*
➜ *Wide operating voltage range:*   *2.0–6.0 V*
➜ *180 V peak-to-peak typical a.c. output voltage*
➜ *Large output load capability: drives lamps with up to 30 nF capacitance to full brightness*
➜ *Adjustable output lamp frequency for control of lamp colour, lamp life, and power consumption*
➜ *Adjustable converter frequency to minimize power consumption*
➜ *Device can be enabled/disabled*
➜ *Low quiescent current:*   *20 nA (disabled)*
➜ *High-voltage CMOS process*

An IMP, Inc. Application
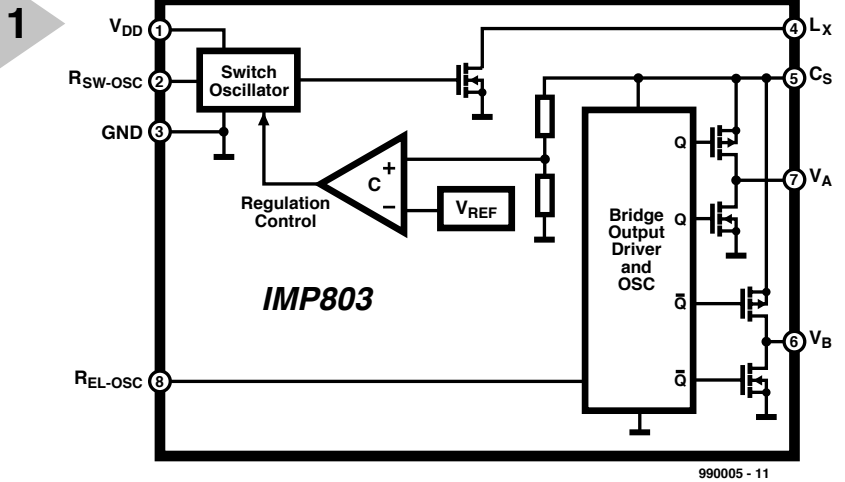
INTRODUCTION

Although the IMP803 is intended for driving EL lamps of up to 30 nF capacitance to high brightness, it can drive lamps with greater capacitance, but not to full light output.

The typical regulated output voltage that is applied to the EL lamp is 180 V$_{p-p}$ The device requires few external components as shown in **Figure 2**: a single inductor, a single catch diode, two capacitors, and three resistors. Two of these resistors set the frequency for two internal oscillators.

The IMP803 operates over supply voltage range of 2.0–6.0 V. A regulated, low-power source can supply the low quiescent current of the device. The inductor may be driven from a higher supply voltage in dual supply applications.

An internal circuit shuts down the switching regulator when the lamp drive voltage reaches 180 V p-p. This

conserves power and extends battery life.

The IMP803 can also be operated from a single battery when a regulated voltage higher than 2.0 V is available.

The dual supply configuration shown in Figure 2 uses the regulated voltage to operate the IMP803 while the energy for the high-voltage boost comes from the battery. The current to run the internal logic is typically 420 µA. The circuit in Figure 2 can also be used with batteries that exceed 6.5 V as long as V_{DD} does not exceed 6.0 V.

EXTERNAL COMPONENTS

The function of the external components shown in Figure 2 are described below.

The catch diode is a fast reverse recovery type with a reverse bias voltage greater than 100 V. A Type 1N4148 meets these requirements.

Capacitor C_S is a high-voltage type that stores the inductive energy transferred through the catch diode. Its recommended value is 0.01–0.1 µF at a voltage rating of 100 V.

Capacitor C_{SW} is a noise-suppression component connected between ground and the R_{SW-OSC} pin. It has a recommended value of 0.001 µF

Resistor R_{EL} is the frequency setting component for the EL lamp oscillator. Connected between the R_{EL-OSC} pin and V_{DD}, it provides an oscillator frequency that is inversely proportional to its value, that is, when R_{EL} increases, the EL lamp frequency decreases along with the current drawn by the lamp. Lamp colour is also determined by this frequency. A resistance value of 2 MΩ results in a lamp frequency of about 350 Hz; a value of 1 MΩ gives a frequency of around 700 Hz. When the resistor, together with R_{SW}, is linked to ground instead of to V_{DD}, the IC is disabled.

Resistor R_{SW}, connected between the R_{SW-OSC} pin and V_{DD}, sets the frequency of the switch-mode oscillator. The switching frequency is inversely proportional to the resistance value, dropping as the resistance increases.

Inductor L_X provides the requisite voltage by inductive flyback. The internal MOSFET switch alternately opens and closes the ground connection for the inductor at the L_X pin. When this internal switch opens, the inductor potential will forward-bias the catch diode and the current will pass through the storage capacitor, C_S, charging it to a high voltage. The recommended type of inductor is a Murata LQH4N561K04, which has a d.c. resistance of 14.5 Ω and an inductance of about 500 µH.

Lower value inductors are preferred to prevent saturation. As the value of the inductor rises (and the

series d.c. resistance of the inductor decreases), the switching frequency set by R_{SW} should be increased to prevent saturation. In general, lower value inductors that can handle more current are desirable when larger area EL lamps are to be driven.

The size of the lamp is important to the operation of the IMP803. Larger lamps will draw more current requiring more power dissipation in the IMP803. An external resistor in series with the lamp, R_{CL}, will protect the output drivers from high transient currents during lamp commutation.

The capacitor across the battery has a preferred value of 0.1 µF. It serves to compensate for the impedance of the battery. Its value may have to be increased depending on the impedance of the battery.

The IMP803 may be enabled and disabled by a CMOS gate connected between V_{DD} and the junction of R_{EL} and R_{SW}. The device is enabled when

R_{SW} is linked to V_{DD} and disabled when R_{SW} is connected to V_{DD}. Resistor R_{EL} may be connected to V_{DD} or to the output of the gate.

[990005]

Figure 2. Standard circuit for dual supply operation of the IMP803 with high battery voltages.

Source: Data sheet 'IMP803 high-voltage EL lamp driver' (IMP, Inc.) (www.impweb.com)

Applications

→ GPS units; pagers, cellular phones
→ Handheld computers
→ Safety illumination
→ Portable instrumentation
→ Battery-operated displays
→ Liquid-crystal display (LCD) panels

Pin descriptions

Nr.	Name	Function
1	V_{DD}	Positive voltage supply for the IMP803. Inductor L may be connected here or to a separate unregulated supply.
2	R_{SW-OSC}	Switch-mode resistor pin. Switching frequency is determined by an external resistor, R_{SW}.
3	C_S	Boost converter storage capacitor. The voltage across the EL lamp is equal to twice the voltage at C_S.
4	L_X	Connection to flyback inductance L.
5	GND	Ground pin.
6	V_B	EL lamp drive. The lamp is connected in a high-voltage bridge circuit with V_B providing the complementary connection to V_A. The peak-to-peak a.c. voltage across the EL lamp is thus two times V_{CS}
7	V_A	EL lamp drive (see above).
8	R_{EL-OSC}	The EL lamp oscillator frequency setting pin. The oscillator frequency is controlled by external resistor R_{EL}.

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MAX280

Integrated Circuits
Analogue, Special Functions (1)

MAX280
5th Order, Zero DC Error, Lowpass Filter

Manufacturer
Maxim Inc.
http://www.maxim-ic.com

General description
The MAX280 is a 5th-order all-pole instrumentation lowpass filter with no DC error. The filter uses an external resistor and capacitor to isolate the integrated circuit from the DC signal path, thus providing excellent DC accuracy.
The resistor and capacitor, along with the on-chip 4th-order switched capacitor filter, form a 5th-order lowpass filter. Two MAX280s can be cascaded to form a 10th-order lowpass filter.
The filter cutoff frequency is set by an internal clock which can be externally driven. The clock to cutoff frequency ratio is 100:1, allowing clock ripple to be easily removed.

Application Example
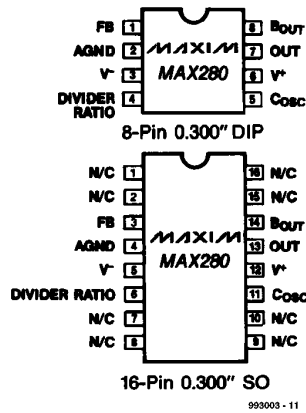Weather satellite decoder,
Elektor Electronics April 1999.

Features
➤ Lowpass filter with no DC error
➤ Low passband noise
➤ DC to 20 kHz cutoff frequency
➤ 5th-order all-pole filter
➤ Internal or external clock
➤ Cascadable for higher-order rolloff
➤ Buffered output available
➤ 8-pin DIP or 16-pin SOIC

Basic operation
Figure 1 illustrates the architecture of the circuit. The output voltage is sensed through an internal buffer, then applied to an internal switched capacitor network which drives the bottom plate of an external capacitor to form a 5th-order lowpass filter. The input and output appear across an external resistor and the IC part of the overall filter handles only the AC path of the signal. The DC offsets of the buffer and the switched capacitor network are blocked by the capacitor and do not

Top View

8-Pin 0.300″ DIP

16-Pin 0.300″ SO

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Pin configurations

Pin #	Name	Function
1	FB	External capacitor couples to the chip through this pin.
2	AGND	Ground. Connect to the system ground for dual supply operation or mid-supply for single operation. This pin should be well bypassed using a large capacitor for single supply operation.
3	V–	Negatative supply voltage
4	DIVIDER RATIO	The oscillator frequency is divided by either 1, 2 or 4 depending upon the voltage to this pin. This in turn gives a clock to cutoff ratio when tied to V+ of 100:1; when tied to GND of 200:1; and when tied to V– of 400:1.
5	C_{OSC}	Clock input pin for external clock applications. For internal clock operation, connect an external capacitor between this pin and V–.
6	V+	Positive supply voltage
7	OUT	Input to on-chip buffer amplifier
8	B_{OUT}	Output of buffer amplifier

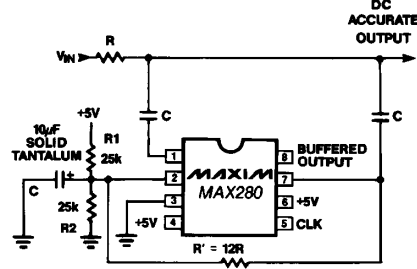# MAX280

Integrated Circuits
Analogue, Special Functions (3)

Electrical Characteristics (V+ = + 5V, V– = –5V, TA = 25ºC, unless otherwise specified, AC output measured at pin 7, Figure 1)

Parameter	Conditions	Min.	Typ.	Max.	Units
Operating Supply Voltage					
Dual Supply		±2.375		±8.0	V
Single Supply		4.75		16.0	
Power Supply Current	C_{OSC} (pin 5 to V–) = 100pF				
	$T_A = 25ºC$		5.0	7.0	mA
	$T_A = T_{MIN}$ to T_{MAX}		5.0	10.0	
Input Frequency Range				0-20	kHz
Filter Gain at	$f_{CLK} = 100kHz$, pin 4 at V+				
	C = 0.01μF, R = 25.78kΩ				
$f_{in} = 0$			0		
$f_{in} = 0.5f_C$ (Note 1)			–0.02	–0.3	dB
$f_{in} = f_C$	$T_A = T_{MIN}$ to T_{MAX}	–2	–3		
$f_{in} = 2f_C$	$T_A = T_{MIN}$ to T_{MAX}	–28	–30		
$f_{in} = 4f_C$	$T_A = T_{MIN}$ to T_{MAX}	–54	–60		
Clock to Cutoff Frequency Ratio	$f_{CLK} = 100kHz$, pin 4 at V+				
f_{CLK}/f_C	C = 0.01μF, R = 25.78kΩ	100±1			
Filter gain at fIN = 16kHz	$f_{CLK} = 400kHz$, pin 4 at V+ C = 0.01μF, R = 6.5kΩ $T_A = T_{MIN}$ to T_{MAX}	–46	–52		dB
f_{CLK}/f_CTempco	Same as above		10		ppm/ºC
Filter Output (pin	Pin 7 buffered with an external opamp, $T_A = T_{MIN}$ to T_{MAX}	±3.5	±3.8		V
Clock Feedthrough			10		mVpp
INTERNAL BUFFER					
Bias Current	TA = 25ºC		2	50	pA
	$T_A = T_{MIN}$ to T_{MAX}		170	1000	
Voltage Swing	R1 = 20kΩ, $T_A = T_{MIN}$ to T_{MAX}	±3.5	±3.8		V
Short Circuit Current Source/Sink			30/2		mA
CLOCK (Note 2)					
Max. Clock Frequency			4		MHz
C_{OSC} Input Sink/Source Current	$T_A = T_{MIN}$ to T_{MAX}		25	80	μA

Note 1: f_C is the frequency where the gain is –3dB with respect to the input signal.

Note 2: The external or driven clock frequency is divided by either 1, 2, or 4 depending upon the voltage at pin 4. When pin 4 = V+, $f_{CLK}/f_C = 100$, when pin 4 = GND, $f_{CLK}/f_C = 200$, pin 4 = V–, $f_{CLK}/f_C = 400$.
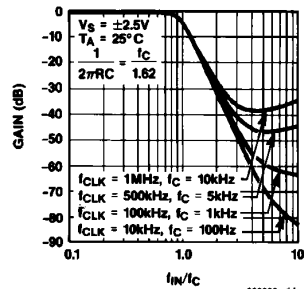
DC ACCURATE OUTPUT

V_{IN} — R

10 µF SOLID TANTALUM
+5V
C

R1 25k

MAXIM
MAX280

R2 25k
+5V
+5V

1
2
3
4

8 BUFFERED OUTPUT
7
6 +5V
5 CLK

R' = 12R

C

FOR A 10Hz FILTER R = 29.4kΩ, C = 1µF, f_{CLK} = 1kHz

THE FILTER IS MAXIMALLY FLAT FOR $\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.84}$

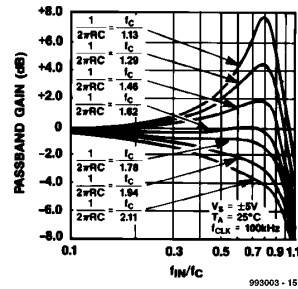*Single 5V supply 5th order LP filter*

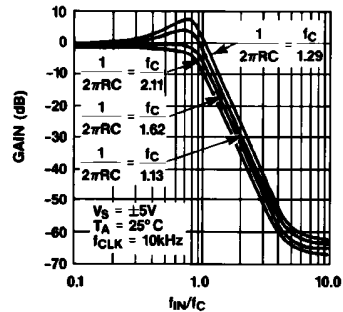**GAIN NORMALIZED TO CUTOFF FREQUENCY (V_S = ±2.5V)**

V_S = ±2.5V
T_A = 25°C
$\dfrac{1}{2\pi RC}$ = 1.62

f_{CLK} = 1MHz, f_C = 10kHz
f_{CLK} = 500kHz, f_C = 5kHz
f_{CLK} = 100kHz, f_C = 1kHz
f_{CLK} = 10kHz, f_C = 100Hz

GAIN (dB)

f_{IN}/f_C

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PASSBAND GAIN vs. INPUT FREQUENCY

$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.13}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.29}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.46}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.62}$

$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.78}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.94}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{2.11}$

V_S = ±5V
T_A = 25°C
f_{CLK} = 100kHz

PASSBAND GAIN (dB)

f_{IN}/f_C

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GAIN vs. INPUT FREQUENCY

$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.29}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{2.11}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.62}$
$\dfrac{1}{2\pi RC} = \dfrac{f_C}{1.13}$

V_S = ±5V
T_A = 25°C
f_{CLK} = 10kHz

GAIN (dB)

f_{IN}/f_C

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CUTOFF FREQUENCY vs. C_{OSC}

V^+ = 5V
V^- = -5V

DIVIDER RATIO PIN TO V^+
DIVIDER RATIO PIN TO AGND
DIVIDER RATIO PIN TO V^-

C_{OSC} CAPACITANCE (nF)

f_C (Hz)

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① **MAX280 DC ACCURATE LOWPASS**

IN — R

C

1 FB
SWITCHED-CAPACITOR NETWORK
A = 4
OUT 7

ZERO OFFSET OUTPUT

+V (÷1)
(÷2) 4 ÷
-V (÷4)

CLK OSC

B_{OUT} 6
C_{OSC} 5

BUFFERED OUTPUT (2mV MAX V_{OS})

C_{OSC}

$C_{OSC} = \left[\dfrac{140\text{kHz}}{f_{OSC}} - 1\right] 33\text{pF}$
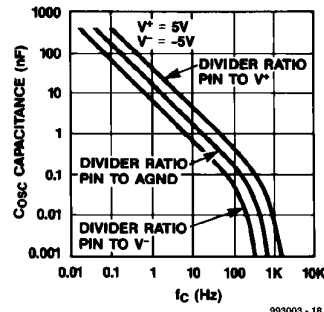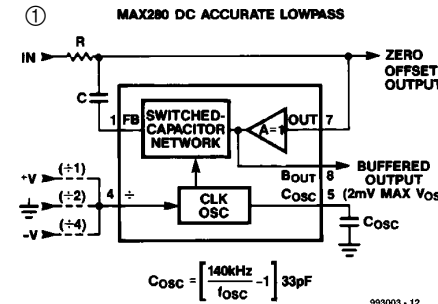
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appear at the zero offset output pin.
Use of this external resistor and capacitor also automatically provides the required anti-aliasing filtering for the sampled filter. Further, low frequency noise in the filter IC is attenuated by the external capacitor since any noise at the FB pin goes through a highpass path to the filter output. The filter output pin is unbuffered. This signal can be buffered by the on-chip buffer or by a high accuracy opamp (such as a chopper stabilized opamp) to obtain a buffered DC accurate system. The on-chip buffer has an offset voltage of 2 mV. The offset voltage tempco is typically 1 µV/°C.

Clock requirements
Using Divider Ratio
DIVIDER RATIO sets the ratio between the internal f_{CLK} (supplied by the MAX280) and f_{OSC} (the output at the DIVIDER RATIO pin). Connect DIVIDER RATIO to V+ for a 1:1, to GND for a 1:2, and to V− for a 1:4 f_{CLK}/f_{OSC} ratio.

Using Internal Oscillator
The internal 140 kHz (nominal) oscillator frequency can be modified by connecting an external capacitor in parallel with the on-chip 33pF capacitor, from the C_{OSC} pin to GND (or to V− if the capacitor is polarized). The clock frequency can be calculated by:
f_{OSC} = 140 kHz (33pF/(33pF+ C_{OSC}))   (1)
Due to process tolerances, f_{OSC} can vary by ± 19.5%. The oscillator frequency can be adjusted by adding a series potentiometer between the capacitor and the C_{OSC} pin. The new frequency can be computed as:

$f'_{OSC} = f_{OSC}/(1-4RC_{OSC}f_{OSC})$ (2)
where f_{OSC} is the value of the oscillator frequency when R= 0. When an external potentiometer is used, the new value of the oscillator frequency is always higher than the one calculated in Eq. (1). To achieve a wide tuning range, calculate (Eq. 1) the ideal f_{OSC}, C_{OSC} pair, then double the value of C_{OSC} and use a 50k pot to adjust f'_{OSC}. The internal oscillation frequency can be measured directly at the C_{OSC} pin using a low capacitance probe.
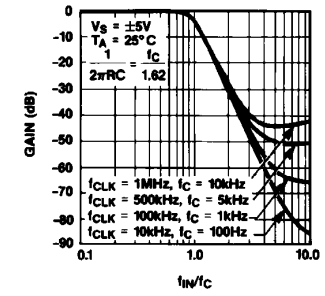
Using External Clock
The internal switched capacitor filter requires a clock 100 times higher than the desired cutoff frequency. The external resistor and capacitor is used as part of a feedback loop for the filter and also forms one pole. The internal 4-pole switched capacitor filter is driven by a clock which also determines the filter cutoff frequency. For a maximally flat amplitude response, the clock should be 100 times the desired cutoff frequency and the resistor and capacitor should be chosen such that:

$(f_C/1.62) = (1/2\pi RC)$

where f_C is the filter cutoff frequency (−3dB point). Typically R is chosen to be around 20kΩ. For wide temperature range applications, NP0 ceramic capacitors are recommended. Mylar, polystyrene and polypropylene capacitors all provide acceptable performance.
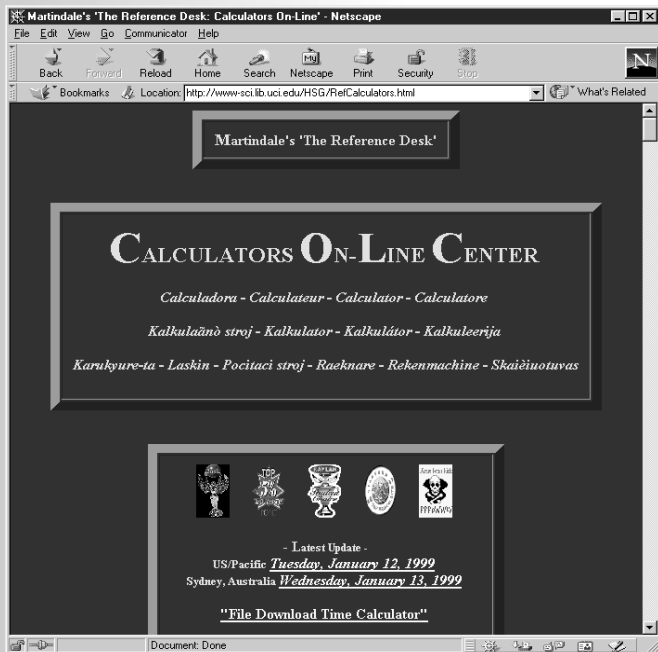
GAIN NORMALIZED TO CUTOFF FREQUENCY (V_S = ±5V)

V_S = ±5V
T_A = 25°C
$\dfrac{1}{2\pi RC}$ = 1.62

f_{CLK} = 1MHz, f_C = 10kHz
f_{CLK} = 500kHz, f_C = 5kHz
f_{CLK} = 100kHz, f_C = 1kHz
f_{CLK} = 10kHz, f_C = 100Hz

GAIN (dB)

f_{IN}/f_C

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electronics on line

calculators on the Internet

Calculators come in many shapes and sizes, but you don't have to go to a department store to get one. Ferreting the Web we found more than 7,800!

At a very early age, most of us learned that one and one equals two. Ever since, we do not need calculators for simple sums. But complex calculations for specific fields of interest are a different kettle of fish. Often, even the most advanced calculator supplied by the high street electronics store is inadequate when scientific problems have to be solved. The only solution in such cases is to write your own program for a programmable calculator. Internet users, however, have an additional option. At the **Calculators On-Line Centre** they find a vast collection of advanced calculators for an equally vast number of widely different applications. The Centre may be found at

http://www-sci.lib.uci.edu/HSG/RefCalculators.html

Apart from these stand-alone calculators, the site also includes emulators ('all-software-lookalikes') of famous scientific calculator models once produced by Casio, Texas Instruments and Hewlett Packard.

Some of these emulators may be downloaded, others only run as Java Applets or Java Scripts within your Internet browser.

The collection is divided into four sections, of which section number four (IV) is of particular interest to electronics designers and engineers. Under the heading 'Section IV Engineering Electrical & Computer' we found a big collection of calculator functions that may be applied to many aspects of electronics and computer technology. Special calculators may be found for such specialisms as PCB design, integrated circuit design, antenna dimensioning, waveguide signal transmission, loudspeaker enclosure design, J-FET amplifier calculations, or, indeed, your common-or-garden oscillator.

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