THE ELECTRONICS & COMPUTER MAGAZINE

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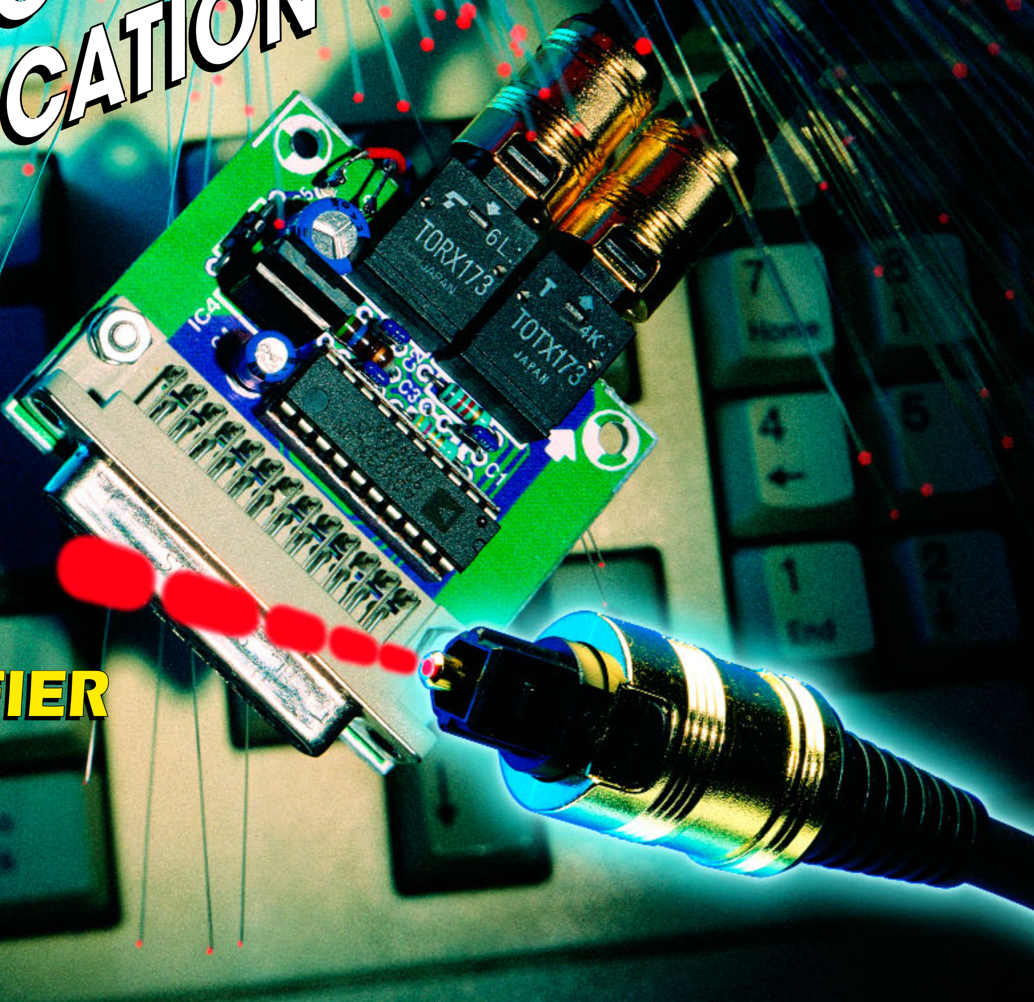

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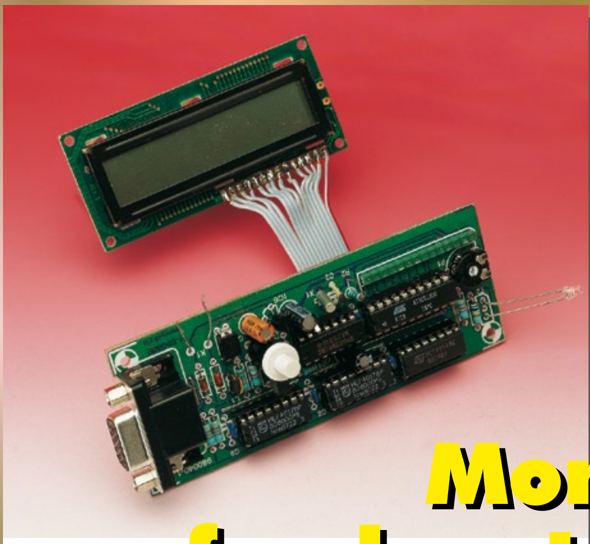

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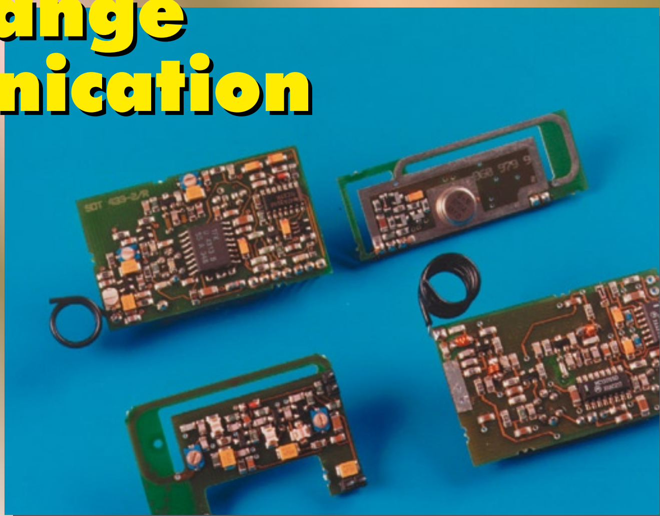

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In computer land there is no such thing as a globally standardised system. Over the years many manufacturers have come up with software which only runs on their specific systems, and many of you have witnessed the rise and demise of many computer types. Fortunately, a fair number of emulation programs is available these days, allowing software written for other computer systems to be run on an IBM PC or compatible. This article aims at presenting an overview of a miscellany of emulators which in most cases may be obtained at no cost from the Internet.

computer emulators

Using a PC to mimic other systems

Figure 1. The main purpose of most emulators is to enable you to play those immensely popular games. This page shows some screenshots of C64 games.

A lot has happened in the relatively short history of computing. Over the past 20 years or so, many different systems have been designed, some soaring from nothing to immense popularity in just a few years time, others failing miserably and dropping out of the market only months after their introduction.

Today, the situation is not as bad as in those early years of computers for the masses. Apart from the IBM PC and the Mac, and including all their clones, there are hardly any other systems left, although we should hasten to add that that applies to the average home or small-office user, and we do close our eyes to mainframes and high-end workstations.

The annoying thing about all these different systems is that they all run their own specific software. For example, If you decide to change from a Mac system to a PC system, nearly all your valuable software has to be replaced.

So, over the past twenty years we saw a lot of programming activity, the results of which would appear to be unsuitable for use on today's computers. However, to enable you to continue using the mass of software written for these 'old' systems, emulators have been designed. Basically, an emulator is a program that uses software to mimic the operation of another computer system. In this way, it is still possible to keep using those faithful old programs.

You may raise an eyebrow now and question the purpose of it all. You could argue that we have come a long, difficult way since those early days, and we can now enjoy exchanging lots of software and sitting in front of the latest multimedia PC. Who then would want to mimic a relic like the Commodore C64?

Well, in many cases the main interest is in games rather than 'serious' software. For example, wagonloads of popular games were produced for the C64, and people still want to play them! Although the graphics detail and sound may be primitive compared to what we have come to expect from today's games on CD-ROM, playing those old games is still great fun.

Hobbyists and other computer amateurs, who offer the fruit of their programming efforts as freeware or shareware, have written many of the emulators we mentioned above. The scope of emulators is by no means limited to ordinary personal-computer systems — emulators are also available for game stations ('consoles') like the Atari 2600, enabling games which used to require a TV set to be run on a PC.

Before discussing a number of emulators currently circulating on the Internet, some remarks must be made on emulators in general.

A good emulator provides a near-perfect imitation of the original computer. Programmers achieve this by making use of the original system ROMs. The general idea is to copy the contents of the original ROMs, and then link this data to the emulator program. To be able to do so, you obviously need to have the original computer. Of course, ROM copies also circulate on the Internet, but this reflects an illegal situation because the original manufacturers do not usually make the ROM contents available for general use. Incidentally, the same applies to many games that may be found here and there on the Internet: the original reproduction rights are still held by the program producers!

Many different computers

Once you start looking around on the worldwide web, it soon transpires that an emulator is available for practically any machine. Below is a quick rundown of erstwhile famous systems; the order in which they are discussed is rather arbitrary.

CP/M

The CP/M operating system was hugely popular around 1980. Originally, it was written for computers based on the Z80 processor. Later, versions appeared for the 8086 and the 68000. CP/M was the foundation for DOS.

On the site
www.seasip.demon.co.uk/Cpm/index.html
you will find John Elliot's **CP/M Main Page**, which provides a number of links to technical information, software, emulators and newsgroups. The **Simtel** page at
www.simtel.net/simtel.net/msdos/emulate.html
also holds a number of freely downloadable Z80 CP/M emulators for MS-DOS computers. Incidentally, this site is also great if you are looking for emulators enabling you to relive your TRS-80 and Vic-20 days.

Apple II

The Apple II computer, based on the 6502 microprocessor, is generally considered the world's first 'personal computer' which was graced with a vast number of popular programs. To be able to run these programs on an MS-DOS machine you need to have, for

Figure 2. There are still lots of people who just can't say goodbye to antiquated game computers like the Atari 2600 shown here.

example, Appler, an emulator written in '386 assembly code. The home page of one of the program writers, **Emil Dotchevski**, supplies ample information. Both the program and the complete source code file are freely available. Go to
www.geocities.com/SiliconValley/Bay/3577/appler.html

Sinclair ZX81 and Spectrum

Many of you will remember them fondly, those tiny Sinclair computers you could connect directly to your TV. Emulators are now available to relive the great feelings often associated with playing ZX81 games. The successor of the Zx81, called Spectrum, had a more mature look, sporting 'real' (actually, rubber) keys instead of membrane ones.

A collection of emulators for these computers may be found at **Dave's Classics**:
www.davesclassics.com/spectrum_emu.html
as well as at **Stephan's Retro-Computing** site:
www.gm.fh-koeln.de/~it048/emulator/zx81/zx81.html
A nice bit of history on Sinclair computers may be found at the German (!) web site
www.zock.com/8-bit/D-Sinclair.html

Figure 3. This beautifully designed HTML page for the PaCifiST emulator shows the characteristic features of the Atari ST computer.

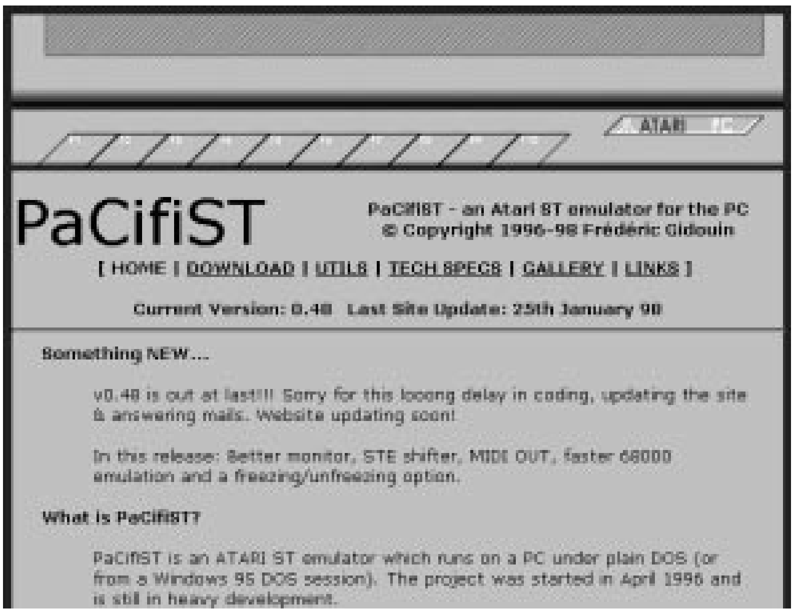

Figure 4. Yes, there are video-console addicts! On Paul's Emulator Pages *www.cs.tamu.edu/people/pforeman/emualtor/index.shtml?* they find what they want.

Atari
Atari has an eventful history and has gone through a lot of changes, producing various computer models. A tremendously popular games computer was the type 2600 video computer. This was basically a game console with two joysticks. The unit had two joysticks, no control buttons (blissful days), and it could be connected directly to a TV set. A cartridge containing the game program had to be inserted in a slot in the top cover of the case.

This machine proved to be a milestone in the history of game computers. The good news is that emulators are available to once again play the original version of Pacman and many other famous games. Such an emulator may be downloaded from **Classic Gaming** at
www.classicgaming.com/pcae/main.html
which, if you are interested, also supplies the source code file.

The regular personal computers from Atari also received a lot of interest in those days. Some great games derived from arcade blockbusters were also available for the type 400 and 800 8-bit models. The Atari 5200 game computer was based on these computers, and most 8-bit Atari emulators will be able to emulate this game console. Here, too, we would refer you to **Dave's Classics**, because Dave collected a respectable amount of Atari emulators, which may be found at
www.davesclassics.com/atari8emu.html
The 'ST' was the last really successful computer from Atari — a pretty advanced machine built around a Motorola 68000 processor. And yes, an emulator for the ST may be found at
www.pacifist.fatal-design.com/

Figure 5. Free64 is a Commodore C64 emulator written in C by a 16-year old American pupil.

Acorn computers
The British-designed Acorn Atom was one of the earliest 6502-based computers sporting a few *kilo*bytes of memory. Its emulator may be found at
wwwis.cs.utwente.nl:8080/~faase/Ha/Atom
In 1981 Acorn introduced a much more powerful computer, the BBC 'B'. Later, the Electron appeared, this was basically a BBC B with lower specifications. The BBC B computers were immensely popular, but in their home country only. For die-hards and addicts there's BeebEm, an emulator for the model B. As opposed to many other emulators using plain DOS, BeebEm runs under Windows. The source code is also available from
members.aol.com/mikebuk/beebem/index.html
Another BBC emulator may be found at a web site run by **Tom Seddon**:
www.ncl.ac.uk/~n5013784/bbc-emu.htm

Commodore C64
Looking around on the Internet for information on the C64 it would appear that this is the most popupar computer ever made. This is partly true, of course, the C64 was affordable and designed to do interesting things at home. By the end of the eighties, Commodore sold more C64's than IBM and Apple sold PCs *together*.

The C64 at its time was endowed with an ample amount of memory (64 kB RAM), and excellent graphics and sound specifications. All of this contributed to the fact that games did very well, while the more serious applications played a lesser role. No wonder a lot of C64 emulators have been written.

A shareware version of the emulation program CCS64 may be found at
www.fatal-design.com/ccs64
'Free64' also deserves a mention because it was written by a 16-year old who set his mind on getting hand-

on experience with programming in C++. Go to *www.inormatik.tu-muenchen.de/~ortmann/uae/*

MSX
The MSX computer appeared on the market in 1980 and was based again on the Z80. The MSX specification was the unified effort of a number of manufacturers to establish a new standard in the home-computing market.

Hard work, clever designing, brisk marketing and the odd success in some countries could not forestall the demise of MSX after a couple of years. None the less, some really fine software was produced for this platform. 'FMSX' is an emulator capable of running under DOS and Windows. Because it appears to be around in a fair number of versions, we once again turn to Dave's Classics where a 'best of' collection is available: *www.davesclassics.com/msxemu.html*

Macintosh
Broadly speaking, today's computer scene has two large camps: Mac and PC. Of course, emulators are around to mimic a Mac on the PC. Using 'iMac', for instance, enables you to use your PC to emulate an Apple Macintosh Plus computer. The program may be found at Leb.net/vmac/main.html

As already mentioned (and this goes for several of the emulators discussed here), a ROM image of the original Mac SE is required to be able to use the emulator!

Game computers

So far the discussions were mainly about emulators for older computers. Programmers, however, are also very much interested in the latest game computers! The results of their programming efforts may be found on the Internet; emulators for the Nintendo Gameboy, Sony Playstation, Super Nintendo, and many others. Apart from these emulators you also find the associated games. The suppliers of these games assume that you have bought the game yourself, which, they claim, entitles you to use a copy of it for running on your PC. That, in our opinion, is a very doubtful claim, and possibly illegal.

One site on the Internet, Dave's Classics, which was already mentioned a couple of times, has both emulators and games for practically all computer types. The site is found at *www.davesclassics.com*

Figure 6. Dave's Classics is the most interesting site if your are after emulators and games. Dave has one of the largest collections in this area.

The MAME (Multiple Arcade Machine Emulator) site deserves a special mention in this article. MAME was developed by a team of programmers. This wonderful program is capable of mimicking a vast number of arcade machines, and available in a DOS and a Windows version. Here, too, you have to note that the ROM images may not be copied if you are not the rightful owner of the relevant computer. So far, some 350 games are available for MAME. The address of the MAME home page is *www.media.dsi.unimi.it/mame*

Experiment!

A number of emulators are, regrettably, not 100% compatible with the original computer. This is often the case if the designers of the original computers used hardware tricks and other hidden features. So, if you are after an emulator for a particular computer brand and type, it is always worthwhile to try out a number of different emulators. In this way, you can do a few experiments to see which emulator works best (or, better).

Some computers are followed in the wake by ten or even more emulators. There are also commercial suppliers and producers of emulators, but they are not mentioned here. Fortunately, if your are looking for a specific emulator to relive the feeling of your first little computer, the Internet usually offers plenty to choose from.

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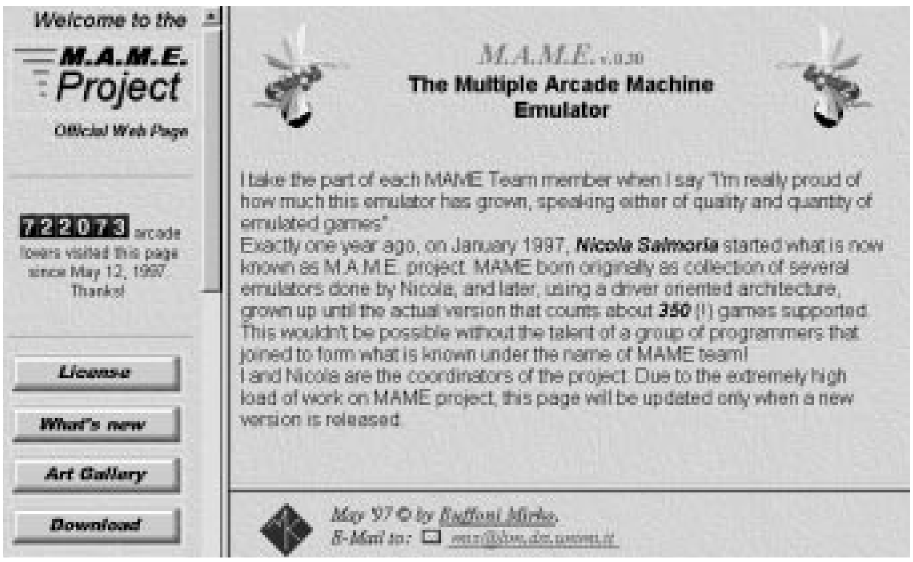
Figure 7. The MAME emulator allows different arcade-style games to be mimicked on a PC. Mote than 350 games are available!



SCSI remains one of the most underrated interfaces in the PC world. Although Apple Macintoshes cannot manage without it, and RiscPCs and Amigas use it to the utmost, Windows machines accept it only grudgingly. What is SCSI actually, where does it come from and what can you do with it? Come with us on an exploratory journey into a realm which many still find dark and mysterious…

By our Editorial Staff

SCSI

Fast, flexible and versatile

A lot of computer users are not familiar with the SCSI interface and thus do not appreciate it. And yet, SCSI (Small Computer System Interface) is one of the oldest interfaces in the computer industry. It is also characterized by a high degree of flexibility, true ‘plug-and-play’ capability and the fact that it is designed to avoid saddling the user with difficult configuration problems. “Buy a SCSI device, select a free device ID number, connect it to the SCSI bus and switch on the power”: if everything is in order, which is almost always the case, the peripheral device is now ready for use. Many a PC user would find this statement hard to believe, but it is certainly true. The SCSI interface is without doubt one of the most user-friendly interfaces to be found in the computer world.

History

The history of SCSI starts in 1979, when Shugart, an American manufacturer of hard-disk drives, developed a new interface for its drives and called it the SASI interface (for Shugart Associates System Interface). This newcomer to the world of computer interfaces included a number of fundamentally novel concepts. Such a radical change was urgently needed, since at the time the pace of development of both PCs and peripheral devices was rapidly accelerating. The most important advantage of the SASI concept was that it decoupled the internal structure of the peripheral device from its interface to the PC. This meant that it was no longer necessary to develop new driver software for every new technical development in the peripheral device. In addition, Shugart made SASI an open standard, which meant that it could be freely used by anyone who wanted to do so. In 1982 an ANSI (American National Standards Institute) working group started working on an improved version of the SASI standard, which resulted in the SCSI standard first seeing the light of day in June 1986. The overall structure of a SCSI system is shown in **Figure 1**.

Since SCSI is a device-independent I/O bus, it has the advantage that the internal structure of a SCSI device is totally immaterial to the computer. This is because the SCSI protocol hides the device's internal structure. Each piece of SCSI equipment presents itself as 'SCSI device' consisting of a number of logical blocks. The driver software thus does not have to deal with storage structures such as the surfaces, heads, cylinders and sectors of a hard disk drive. But there is more: a device can also provide information about itself to the computer. This information, which includes the category, size and equipment class of the device, can be used by the software to initialize the proper sort of driver. In this way the drivers can remain device-independent. A hard-disk driver can in principle work with any SCSI-bus hard disk drive, without requiring any modifications.

Just a little tweaking

Unfortunately, the theory here turned out to be yet again better than the practice. Although the developers of the SCSI standard did their best to keep the structure as transparent as possible, a compatibility problem arose due to the fact that certain aspects of the interface protocol were not fully worked out.

Luckily, it was not too late to learn from the experience and fill in the last gaps. The ANSI working group got together again and issued an extension to the SCSI standard, called SCSI-2. The SCSI-2 standard specifies a set of 18 subcommands (the Standard Command Set) which allow devices to be driven in an unambiguous manner. Every manufacturer of a SCSI-2 compatible device must integrate these subcommands in the device. The writing of drivers on the computer side of the interface is considerably simplified by the guaranteed availability of the Standard Command Set.

The SCSI-2 standard defined a total of eleven device classes. In addition, it opened the door open for more demanding applications by including definitions for Fast SCSI and Wide SCSI.

With the SCSI-2 standard the ultimate goal of a fully device-independent software interface was fully realized.

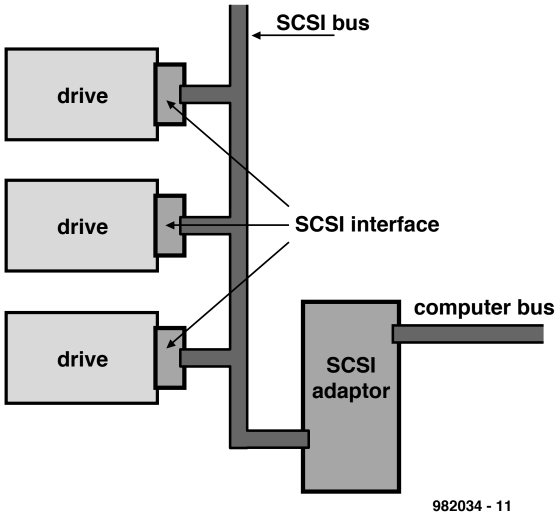


Figure 1. The overall structure of a SCSI system. It consists of three main elements: the adapter, the bus and the connected devices.

Structure

The SCSI bus makes no distinction in principle between a peripheral SCSI device and the SCSI interface adapter. Instead, the terms 'controlled element' and 'controlling element' are used, where an 'element' can be a system or a device. The initiator of a communication process receives access to the SCSI bus and selects the target device with which it wishes to communicate. Once the selection process has been completed, the target device takes over control of the communication process. In order to clarify how the communication process works, it is necessary to first examine the bus in more detail.

The standard SCSI bus consists of 50 lines, of which all odd-numbered lines (1,3,…,49) plus lines 20, 22, 24, 28, 30 and 35 are tied to earth. Line 25 is not used. **Table 1** lists the signals and shows how they are assigned to the pins of a 50-pin connector. Nine of the signal lines are used for data transport (DB0…DB7 and DBP), and an additional nine lines are used for control sig-

Figure 2. The quality of the SCSI cables and connectors contributes to the quality of the overall system. The three types of connectors shown here are used for most standard configurations.

Figure 3. The rear panels of three external SCSI devices (Zip and Jaz drives, and a CD-ROM player). The differences in the connectors can be clearly seen. Also note the switches for setting the device identifier numbers.

nals. The TERMPWR line (pin 26) carries 5 V DC power, which can be used to supply bus terminators, which will be described shortly.

The 8-bit-wide data bus supports data rates of up to 5 Mbyte/s. The actual data rate is strongly dependent on the mode used. Although in principle only one type of signal is used on the bus, there are various modes available. These modes can be classified in the following manners:

single-ended versus differential signals

asynchronous versus synchronous operation

The first two classifications (single-ended and differential) relate to the form of the signal. These two modes are in practice mutually exclusive. The single-ended mode uses TTL signal levels, while the differential mode uses RS-485 signal levels. The same cables are used for these two modes, but the utilization of the signal lines is different. The assignments listed in Table 1 refer to the single-ended mode. Differential mode is an 'exotic' mode which is not important for the average computer user. It is primarily employed in professional systems such as servers, since it allows much longer cables to be used. In single-ended mode the total cable length is limited to 6 metres, but with differential mode it can range up to 25 metres. **Figure 2** shows a number of cables that can be used for connecting SCSI devices. Note that three different types of connectors are commonly used.

The second two classifications (asynchronous and synchronous) relate only to differences in the handshaking process. In asynchronous operation a handshake signal is expected in response to every received signal, while with synchronous transmission a complete block of data is transferred before a handshake signal is expected in return. For this reason, the amount of time lost in confirming the correct reception of the transmitted data is much less with synchronous transfers. This is reflected in the respective performance levels. Although 5 Mbytes/s can be realized over the bus with synchronous communication, the data rate drops to at most 1.5 Mbytes/s with asynchronous transfers.

Asynchronous communication is always the default mode after a system reset, and all commands and status reports are processed in this mode. If a SCSI device supports synchronous communication and its partner device also proves to be capable of synchro-

Table 1. Signal line assignments for a 50-pin SCSI connector.

Pin	Signal	Name
2	DB0	Data Bus Line 0
4	DB1	Data Bus Line 1
6	DB2	Data Bus Line 2
8	DB3	Data Bus Line 3
10	DB4	Data Bus Line 4
12	DB5	Data Bus Line 5
14	DB6	Data Bus Line 6
16	DB7	Data Bus Line 7
18	DBP	Data Bus Parity
26	TERMPWR	Terminator Power
32	ATN	Attention
36	BSY	Busy
38	ACK	Acknowledge
40	RST	Reset
42	MSG	Message
44	SEL	Select
46	C/D	Control/Data
48	REQ	Request
50	I/O	Input/Output

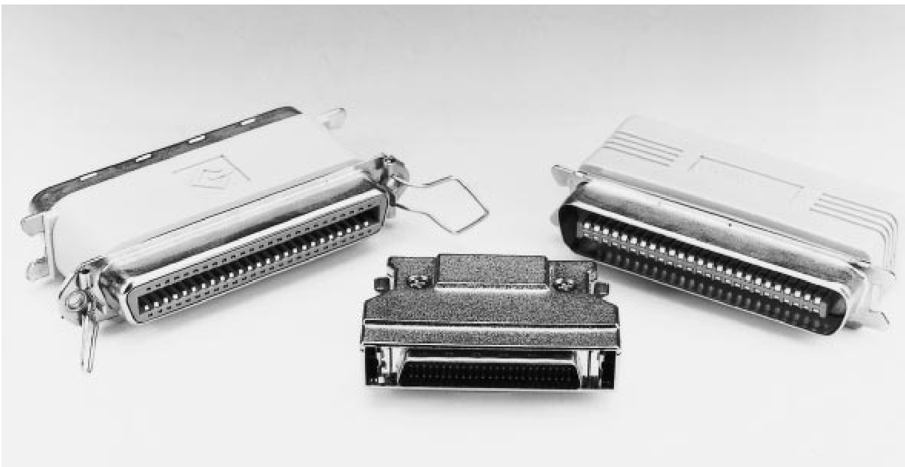


Figure 4. A terminator must be used at the end of the SCSI cable. The photo shows three types of terminator: one for a Centronics connector, one for a high-density connector and a feed-through type.

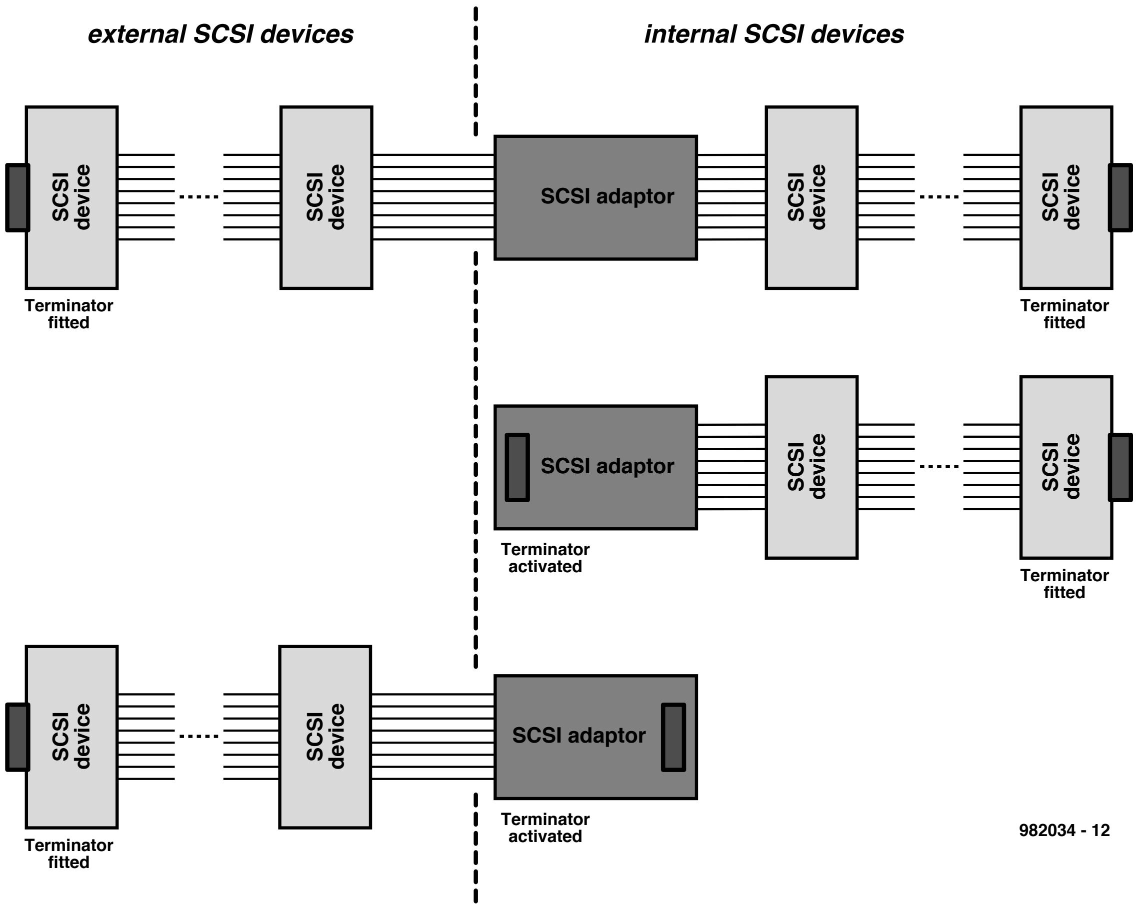


Figure 5. This is how the terminators are used in a SCSI system.

nous communication, then the initiator and target devices switch over to synchronous mode.

Fast SCSI and Wide SCSI

Fast-SCSI and Wide-SCSI are both extensions of SCSI-2 which make significantly higher data transfer rates possible.

Fast-SCSI is an optional variant of normal 8-bit SCSI, in which the synchronous data rate is increased from 5 Mbytes/s to 10 Mbytes/s by reducing the durations of the REQ and ACK signals. The higher data rate is only possible if the interface adapter and at least one of the peripheral devices supports Fast-SCSI. Normal SCSI devices operate at their usual data rates on a Fast-SCSI bus. A disadvantage of Fast-SCSI is that the maximum total cable length is reduced to 3 metres.

Wide-SCSI increases the data transfer rate by expanding the width of the bus to 16 or 32 data bits. If in addition an improved communication protocol is employed on such a bus, the data transfer rate can reach 40 Mbytes/s.

Obviously, different cables and connectors must be used for buses that are 16 or 32 bits wide. Both 8-bit and 16-bit devices can be used with modern 16-bit Wide-SCSI cards, internally as well as externally. Wide-SCSI allows up to 32 devices to be connected to a single bus (four times as many as standard SCSI).

Identification

When more than one device can be connected to a single bus, there must be some system allowing each device to be identified. For this reason, each device connected to a SCSI bus must be assigned a unique identifier number. On an 8-bit SCSI bus, identifier numbers can be assigned to up to 8 devices (including the bus adapter). For this reason, each device can be configured with an identifier number ranging from 0 through 7. Since number 7 has the highest priority, it is usually assigned to the adapter or host

Table 2. A 'well-loaded' SCSI bus.

Device	Type	Capacity	Vendor	Product	Rev	Level
0	Processor	Unknown	EPSON	FilmScan 200	1.01	SCSI-1
1	Processor	Unknown	EPSON	SCANNER GT-5000	1.07	SCSI-1
2	Read-Only	Unknown	TOSHIBA	CD-ROM XM-3801TA	1047	SCSI-2
3	Direct Access	3090 MBytes	QUANTUM	FIREBALL ST3.2S	0F0C	SCSI-2
4	Read-Only	Unknown	PHILIPS	CDD2600	1.07	SCSI-2
5	Direct Access	1021 MBytes	iomega	jaz 1GB	H$70	SCSI-2
6	Direct Access	96 MBytes	IOMEGA	ZIP 100	D.09	SCSI-2
7	Host Powertec SCSI Expansion				1.43	SCSI-2

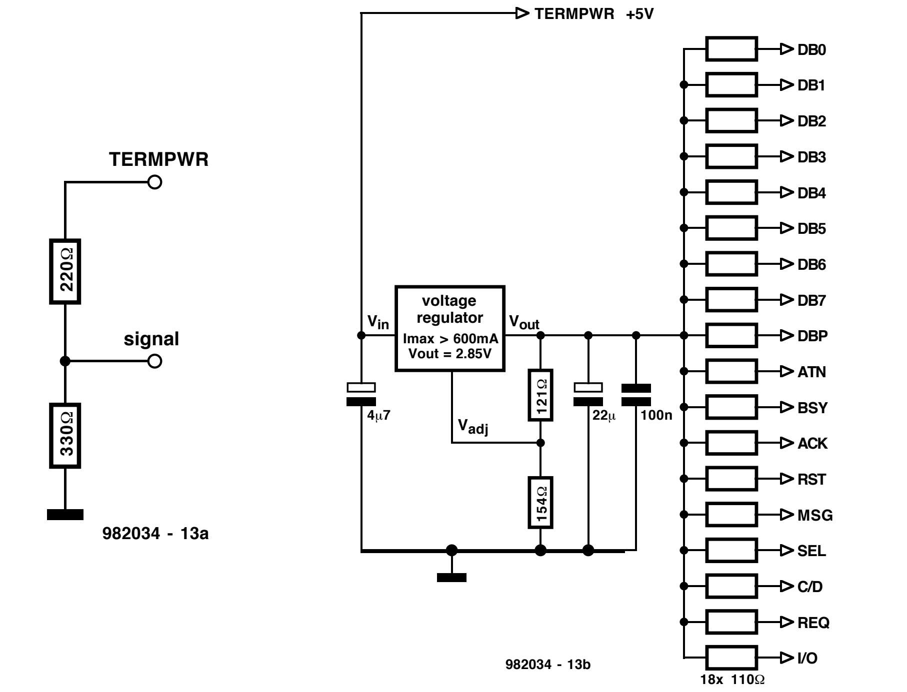


Figure 6. Proper termination is critically important. Two types of terminators can be used: passive (left) and active (right). The illustrated terminators are only suitable for systems with single-ended signals.

system. **Table 2** shows the configuration of a 'well-packed' SCSI bus. It can clearly be seen that each peripheral device can send a lot of information about itself and its origin to the host system.

The selection of an identifier number is very simple, due to the presence of special switches on the rear panels of SCSI devices. **Figure 3** shows various manners in which the identification number selector switch can be implemented on the rear panel. For internally mounted devices the identifier number is selected by positioning a combination of jumpers. If the same identifier number is assigned to two devices a conflict will occur, and in most cases both devices will be rendered inaccessible.

Termination — the key to success

Termination of the SCSI bus deserves just as much attention as the selection of the identifier numbers. If the SCSI bus is not properly terminated at each end, it is unusable. The photograph of **Figure 4** shows three different types of terminator. The pass-through type is rarely used. The most basic type of terminator consists of a simple resistor network which guarantees that each line of the bus always has a well-defined signal level.

If the SCSI adapter takes the form of a plug-in card, then as a rule it has both an internal and an external SCSI bus connector. The peripheral devices located outside of the computer are connected via the external bus connector, and the internal connector is naturally used to connect any devices which are mounted inside the computer enclosure. If either one of these buses is not used, it must be terminated at the adapter. For the internal bus this is done by means of simple resistor arrays. **Figure 5** illustrates where the termination resistors must be installed. Internal terminators are normally located on the SCSI card.

Active and passive

A SCSI bus is a digital bus that carries signal frequencies ranging up to several megahertz. If either end of the bus (that is, either end of the cable) is not properly terminated, undesired signal reflections will occur. These reflections will cause corruption of the data and incorrect operation. In the worst case it will not be possible to send any data at all via the bus.

Figure 6 shows the construction of a passive and an active terminator. A passive terminator contains a resistor network which has a pair of resistors for each signal line, consisting of a 220-Ω resistor and a 330-Ω resistor. Each resistor pair holds its associated signal line at a potential of 3 V, so that its state is well defined even during bus phases when it is not actively being used. The passive terminator is the least expensive and most commonly used type of terminator, and it is adequate in almost all cases.

The active terminator is an alternative to the passive terminator. It contains a constant-voltage source and a series resistor for each signal line. Compared to the passive terminator, the active terminator has the advantage that the voltage levels on the individual data lines are independent of the loads placed on these lines. In addition, an active terminator places a smaller capacitive load on the bus lines, which is primarily important for Fast SCSI. **Figure 6** shows the schematic diagram of an active terminator. According to the SCSI standard, passive and active terminators may be used in combination on a single bus, so that it is possible to have a passive terminator at one end of the bus and an active terminator at the other end. For the user this is an ideal situation, since he or she does not have to be concerned about what type of terminator to use.

Active terminators are always to be preferred if the bus is loaded by many devices, and/or the external cables are relatively long. The edge steepness of the bus signals is considerably improved when active terminators are used.

Plug and play

A SCSI device is connected by means of a SCSI interface. This interface communicates with the SCSI bus on the one side and with the device on the other side. With internally mounted equipment, such as CD-ROM drives and hard-disk drives, the SCSI interface can be recognized by the presence of a 50-pin connector for a flat cable. If the equipment is housed in an enclosure, then the SCSI connection can take the form of a standard D25 connector, a 50-way Centronics connector or a high-density connector. Yet other variations are found with 'professional' equipment, which uses 32-bit-wide busses in addition to 8-bit and 16-bit buses. In ordinary PCs for the consumer market we will never encounter these more exotic variants. Regardless of the type of connector used, there is one common factor for all SCSI connections: they must be constructed from reliable cable material. Of course, the proper termination of the bus is also an absolute prerequisite for success, but you already know that.

(982034-1)

Modern PCs are fortunately much quieter than the models of a few years ago. Better enclosures, quieter fans and temperature-regulated fans, together with better sound deadening measures, have resulted in PCs which are so quiet that they barely disturb the silence of the average office or hobby room. However, even older-model PCs can be made significantly quieter by means of a few judicious modifications, so that they no longer remind one of a vacuum cleaner. Want to know more? Then read on.

a noisy PC

(and what you can do about it)

The modern PC is not only faster than its predecessors, it is also generally less likely to catch your attention.

A few years ago, the hard disk drive was usually the noisiest part of the PC, closely followed by the power supply fan. With these items you right away have the two main rowdies in the PC. The mere fact that a PC is noisy does not mean that you must replace it with a new one. In many cases it is still very well suited to the tasks for which it is most often used, such as writing letters.

Such an old beast can be made quieter by means of a few inexpensive and relatively simple measures, as you will see. Naturally there's a bit of electronics in the solution, since otherwise you wouldn't be reading this in *Elektor Electronics* — but it is not essential!

Mufflers

Quite a bit can be accomplished with the help of a bit of sound-muffling material. Let's start with the enclosure. The side panels of certain tower-model PCs which we have in our offices (yes, even new models) started to vibrate quite noticeably after we mounted high-speed CD-ROM drives. The high rotational speeds of such drives produce a lot of resonances, which principally cause the side panels of the enclosure to vibrate. Firmly tightening the CD-ROM drives in place does not help. The best solution is to attach a few pieces of self-adhesive bituminous lead sheet to the side panels, in order to increase their mechanical inertia and deaden the vibrations. Bituminous lead sheet is available from automotive-parts suppliers (often under the name 'muffling sheet' or 'anti-rumble sheet') and DIY loudspeaker shops. A piece of bituminous lead sheet roughly 10 cm square, attached to the middle of the panel, is usually sufficient (see **Figure 1**). By the way, this trick is also used by manufacturers of audio CD players, primarily to deaden vibrations in the top cover.

The second culprit, the hard-disk drive, is more difficult to deal with. You can of course replace it with a new model, since the current generation of drives (with the exception of the very latest models running at 10,000 rpm) is especially quiet, with an average sound level of roughly 40 dBA.

It is not possible to pack a hard-disk drive in sound deadening material, since it must dissipate a certain amount of heat. A modern drive dissipates between 5 and 10 watts, but older models dissipate quite a bit more than this. These drives become rather warm in operation, which means that there must be adequate airflow past the drive. The only remedy with such a drive is to mount it on a separate frame which is acoustically decoupled from the PC enclosure (remember the 'floating' platform of the old-fashioned gramophone). The specific manner in which this is done depends heavily on the amount of space available inside the enclosure. With a 'midi tower' or 'big tower' enclosure, the hard-disk drive can be placed at the bottom, in the mounting bay for removable drives, with a few rubber blocks underneath it and on either side of it. Be careful when moving the PC afterwards, and take care that the drive always has enough ventilation – otherwise it will be sure to die young.

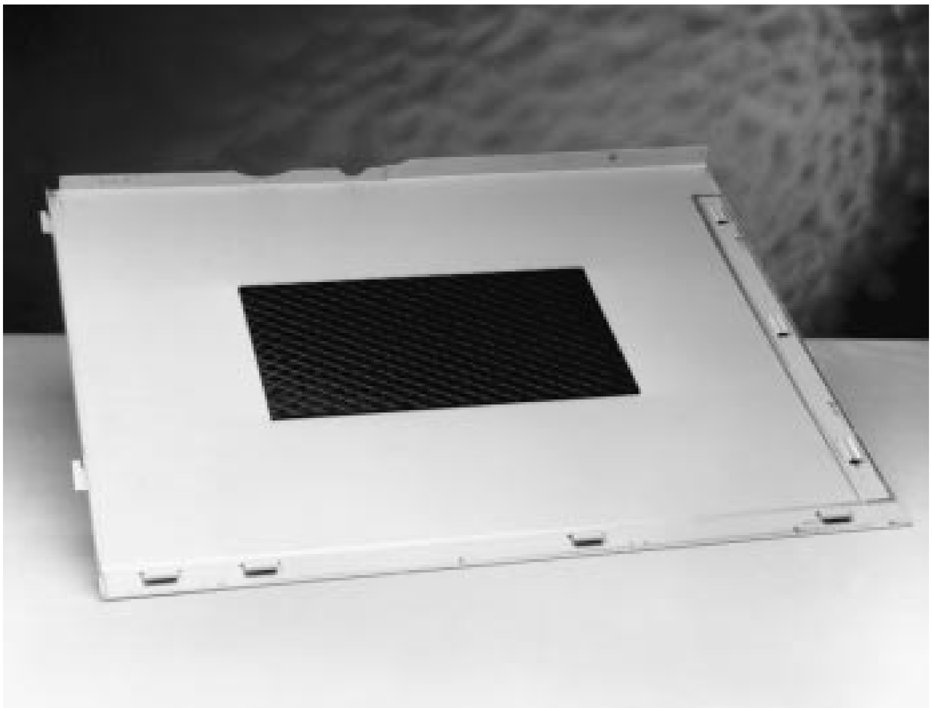
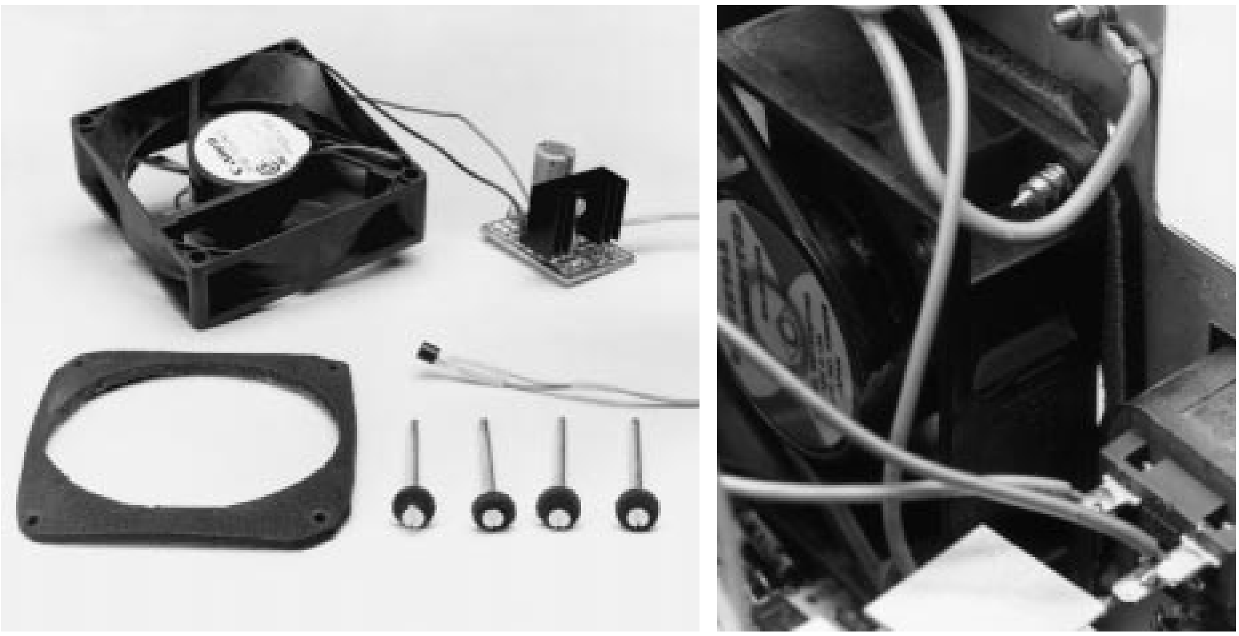


Figure 1. Vibration of a side panel or cover of a PC enclosure can be prevented by sticking a piece of self-adhesive bituminous lead sheet to the inner surface.

Fans

There are usually one or two fans in a computer enclosure: the first one in the power supply and the other one on the processor. The latter fan is only present if the processor is a Pentium type or one of the fast 486 versions. It often happens that the processor fan starts to rattle after it has been in service for some time, due to worn-out bearings. The only remedy is to replace the combination of the heat sink and fan with a new set. If a suitable replacement assembly (for a 486, for example) is no longer available from your supplier, see whether it is possible to dismount the fan and replace it with a fan removed from a different heat sink. If possible, buy a fan with ball bearings, since it will usually last longer than a less-expensive type with bushings. However, ball bearings do not necessarily guaran-

Figure 2. A rubber ring mounted between the fan and the enclosure can significantly reduce the amount of vibration which is coupled from the fan to the enclosure.



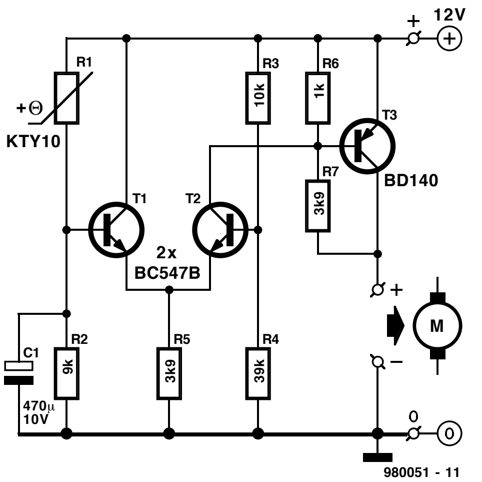


Figure 3. The schematic diagram of the fan regulator. Only three transistors and a few passive components are required.

tee that the fan will be quiet — the ball-bearing CPU fan in a brand-new PC in our office decided to let itself go and started buzzing like a blowfly after only a week of use. It seems like there's no substitute for a bit of luck...

The large fan in the power supply is almost always thermally regulated in modern PCs. A sensor in the power supply measures the supply's internal temperature and controls the speed of the fan accordingly. In older-model PCs the power supply fan always runs at full speed.

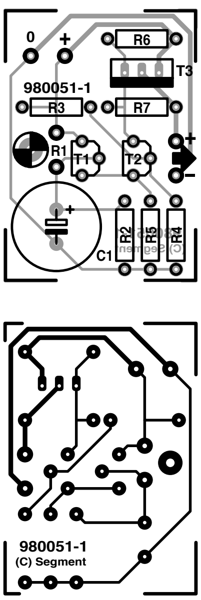


Figure 4. If you set store by neatness, you can etch your own circuit board from this layout (board not available ready-made).

The simplest way to reduce the amount of noise produced by this fan is to mechanically decouple it from the enclosure, by means of a ring of soft rubber or some similar material. First see if you can find a piece of suitable material which is about as big as the fan, either around the house or in a hobby shop. Then dismount the fan so that you can use it as a pattern for cutting a rubber isolator ring to size (see **Figure 2**). Remount the fan using suitable screws, with the rubber ring between the fan and the enclosure.

If you want to go further, you can also add temperature regulation for the fan. The easiest way to do this is to replace the existing fan with a new model with a built-in thermal regulator. The line of fans manufactured by Papst includes models with a separately available temperature sensor. Such fans can truly be as quiet as a whisper.

If you don't mind a bit of extra work, you can also provide a temperature-regulated control for an existing fan. This can be easily constructed using only a few components.

Fan regulator

Figure 3 shows the schematic diagram of a simple fan regulator. This is based on a circuit published several years ago in one of our Summer Circuits issues.

The objective is to make the speed of the fan depend on the amount of heat produced by the power supply. The circuit board of a switching-type power supply is normally housed together with the fan in a separate enclosure. The power semiconductors on the circuit board have thick heat sinks, and these are the components that usually produce the most heat. Your best bet is thus to measure the temperature of the air stream which flows from the heat sinks to the outside of the enclosure. In this way the temperature of the heat sinks will determine how fast the fan rotates.

The circuit we have in mind consists of three ordinary transistors and a few passive components. The regulator is powered from the –12 V supply voltage which is provided for the fan, and the fan is connected to the output of the regulator.

If you examine the schematic, you will see that the heart of the circuit consists of a differential stage formed by T1 and T2. The base of T2 is held at a fixed voltage by the voltage divider R3/R4. T1 is driven by a variable voltage divider formed by a PTC resistor (R1) and the resistor R2. The voltage at the base of T1 thus depends on the temperature, since the resistance of the PTC rises with increasing temperature. The electrolytic capacitor C1 acts to prevent the base voltage from responding too quickly to small, short-term temperature variations. In addition, C1 causes a high voltage to be applied to the fan for a short time after the PC is first switched on, so that it starts up properly.

Transistors T1 and T2 have a common emitter resistor, so that the difference between their base voltages determines which of the two transistors conducts more current. The collector of T2 controls the driver transistor T3, which in turn determines the voltage applied to the fan. If the temperature increases then the resistance of the PTC also increases, and the voltage at the base of T1 decreases. T2 then conducts more, which causes T3 to be turned on harder, so that the fan runs faster.

COMPONENTS LIST

Resistors:
R1 = KTY10
R2 = 9kΩ (2x18kΩ in parallel)
R3 = 10kΩ
R4 = 39kΩ
R5,R7 = 3kΩ9
R6 = 1kΩ

Capacitor:
C1 = 470µF 10V

Semiconductors:
T1,T2 = BC547B
T3 = BD140

Resistor pair R6/R7 connected in parallel with T3 provides a fixed minimum drive level to T3, so that the voltage applied to the fan is never less than roughly 7 V. This prevents the fan from stopping at low temperatures.

Fine tuning

A small printed circuit board (see **Figure 4**) has been designed for the fan regulator circuit, but you can of course also mount the necessary components on a small piece of perfboard, veroboard or stripboard. Constructing the regulator should certainly not present any difficulties. However, before you go ahead and build it into your PC, we would first like to acquaint you with the various 'fine tuning' possibilities of the circuit. This is because the exact component values are strongly dependent on the actual fan used. Temporarily connect the circuit to a separate 12-V supply and connect the fan to its output. When the circuit is switched on, the fan must first run at high speed for a short time and then drop down to a low speed. At the low speed, the fan should rotate fast enough to ensure that it runs properly, but not faster than is necessary. This can be achieved by adjusting the value of R7 with the circuit at room temperature. Once this has been done, replace R2 by a 25-kΩ variable resistor, switch the power on again and heat the sensor to a temperature of 35 to 40 °C. The speed of the fan should increase to nearly its maximum rated value. This can be set by adjusting the variable resistor. Once you have found a good adjustment, measure the value of the variable resistor and mount a resistor with this value in place of R2.

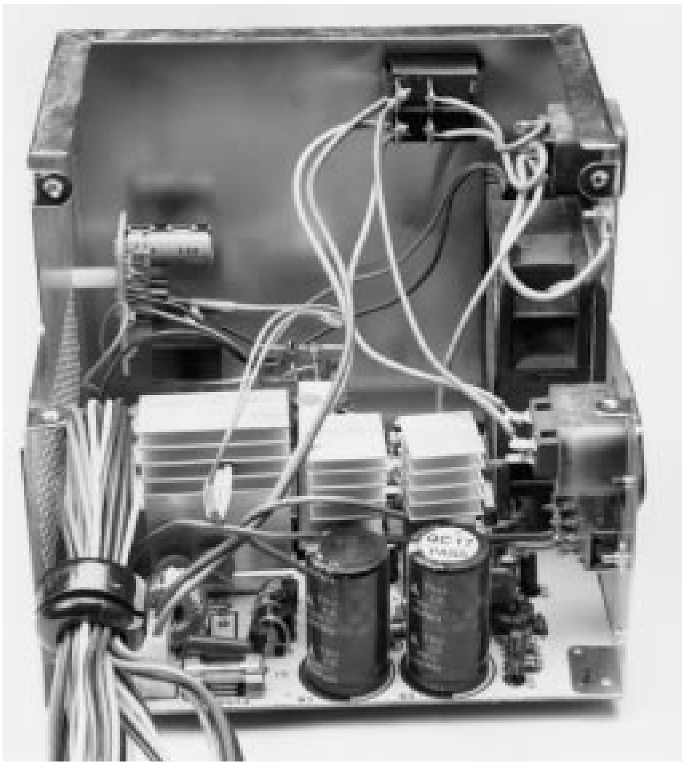
Mounting in the PC

After you have finished tuning the circuit to match the fan, you can mount it in the PC. The circuit board can be attached to one of the sides of the power supply housing such that the PTC sensor is located between the fan and the heat dissipators of the power supply circuit board (it may be necessary to attach it to the circuit board via a short pair of insulated solid copper wires.) To be on the safe side, keep everything well away from the mains side of the power supply (and bear in mind that the heat sinks may be under tension!). Connect the supply terminals of the regulator board to the 12 V fan supply connector on the power supply circuit board, and connect the fan to the output of the regulator board.

Figure 5 shows how we mounted the regulator on the power supply of a old PC. At least this unit will cause a lot less commotion from now on!

(982001-1)

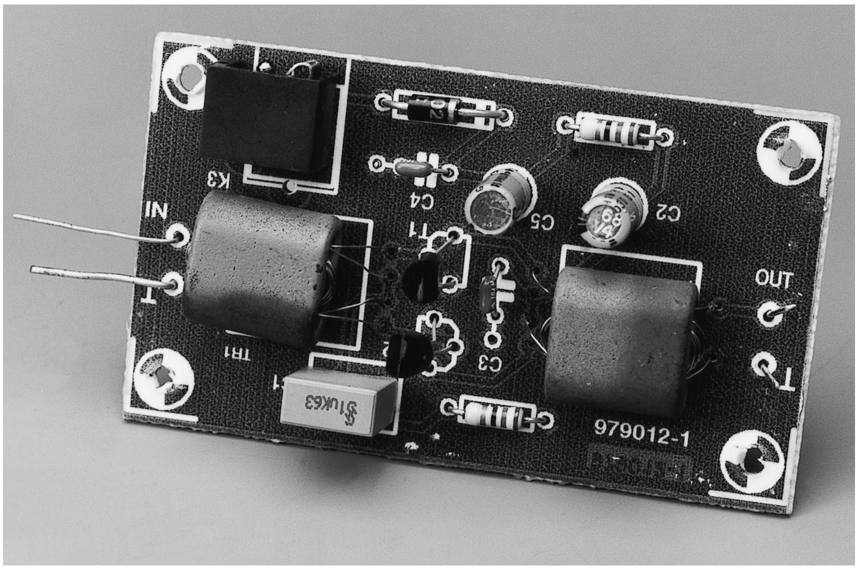
Figure 5. Here you can see how the regulator circuit can be built into a PC power supply.



Broadband RF preamplifier

For LW and MW DX-ing

The preamplifier described is a push-pull type based on a pair of inexpensive JFETs. With a few changes to the circuit, coverage may be extended downwards to VLF and LF, or upwards to 30 MHz and even VHF (150 MHz).



While many designs of broadband amplifiers cover –3 dB frequency response limits of 3 to 30 MHz, or 1 to 30 MHz, the VLF, LF or even the AM broadcast band (BCB, 540 to 1700 kHz) is rarely covered. The preamplifier discussed here does, offering a relatively high dynamic range and third-order intercept point, features which AM BCB Dxers will value highly because of the bone-crunching signal levels put on the air by local AM BCB transmitters. One of the problems of AM BCB is that those sought-after DX stations tend to be buried under multi-kilowatt local stations on adjacent channels.

The present amplifier achieves a decade (10:1) response (250 kHz to 2,500 kHz). It retains the 50-Ω input and output impedances that are standard in RF systems and is is easily modifiable to cover other frequency ranges up to 30 MHz.

As you will soon discover, a good directional antanna is a must for serious LW and MW DX-ing. Some sggested antenna designs are given reference (1).

Design by Joseph J. Carr

A push-pull amplifier

The basic concept of a push-pull amplifier is illustrated in **Figure 1**. Two identical amplifiers, A1 and A2, each amplify one half-cycle of the input sinewave signal. At the input, phase splitting is achieved with the aid of a transformer whose secondary winding has a grounded centre tap (CT). At the output, a similar, but reverse-connected, transformer is used to recombine the signal components. Here, the centre tap is on the primary winding, and used to feed in the supply voltage.

The push-pull amplifier being balanced, it has a very interesting property: even-order harmonics are cancelled in the output, so the output signal will be cleaner than for a single-ended (unbalanced or asymmetrical) amplifier using the same active amplifier devices.

Practical circuit

The actual RF circuit is shown in **Figure 2**; it is derived from a similar circuit found in Doug DeMaw's excellent book *W1FB's QRP Notebook* (2). The active amplifier devices, T1 and T2, are type BF256B JFETs that are intended for service up to VHF. The choice of JFET is not particularly critical — the author originally used the NTE-451, but the general-purpose MPF102, or a rarer bird like the 2N4416, should also work.

The JFETs sit between a pair of similar, back-to-back connected transformers, Tr1 and Tr2. The source bias resistor for the JFETs, R1, and its associated decoupling capacitor, C1, are connected to the centre tap on the secondary winding, B-C, of input transformer Tr1. Similarly, the positive supply voltage (approx. 9 V) is applied through a limiting resistor, R2, to the centre tap on the primary of the output transformer, Tr2. High and low frequency supply decoupling is ensured by C3 and C2 respectively. None the less, the amplifier should be powered by a reasonably stable and filtered 9-V supply. Current consumption will be of the order of a few tens of mA.

Populating the board

The PCB shown in **Figure 3** is unfortunately not available ready-made. Pop-

This article is based on circuit diagram no. 7-12 in the book *Secrets of RF Circuit Design* by Joseph J. Carr, published by TAB Books (McGraw-Hill), ISBN 0-07-011673-3 (pbk), 0-07-011672-5 (hc).

ulating the board should not present problems as only a handful of normal-sized components are involved. The construction of the transformers is discussed below. It is advisable to house the preamp in a metal case. In some cases, particularly at HF and VHF (see further on) a screen may be required between the input and the output so that they can not 'see' each other. In this way, you prevent oscillation or other instability.

Building the transformers

In the case of this project, the key to success is a pair of carefully wound transformers. By comparison, the construction of the rest of the amplifier is far less critical, as long as all connections are kept as short as possible.

The cores used are binocular ('two-hole' or 'pig's snout') ferrite beads type BN-43-202 from Amidon Associates [3], or beads made from 4C6 material (Philips Components).

Each transformer contains three windings. In each case, the 'B' and 'C' windings are 12 turns of 0.3-mm (SWG30; AWG30) enamelled copper wire wound in a bifilar manner. The coupling link on each transformer is winding 'A'. On the input transformer, Tr1, 'A' consists of 4 turns of 0.15-mm (SWG38 or AWG36) lacquered copper wire (CuL), while on Tr2 it consists of two turns of the same wire. The pri/sec ratios of the transformers (1:9 for Tr1 and 36:1 for Tr2) match the source and drain impedances to 50 Ω input and output impedance. For clarity's sake, the winding and connection reference letters and numbers at the output of the amplifier are shown in **Figure 4a**. The other drawing, **Figure 4b**, is for those of you who are interested in higher frequencies, say, up to 30 MHz or perhaps even VHF, when a ferrite (or iron-powder) ring core is used. More about this further on.

First, let's agree on what a 'turn' is. Look at **Figure 5**, which shows what we mean by *one* turn on a ferrite binocular core (left-hand drawing) and *two* turns (right-hand drawing).

Start with the coupling winding, A, on the input transformer, Tr1. Strip, scrape or burn the lacquer for about 5 mm from one end, and tin it with solder. Pass the wire through one of the holes of the core, across the barrier between the two holes, and then back through the other hole. This 'U' shaped turn counts as one turn. To make transformer Tr1, pass the wire through the holes three more times, to make four turns. The wire end should be back at the same core side as the start. Cut the wire to allow a short length to connect to the PCB. Remove the lacquer coating from this free end, and tin the exposed part. Now label these two ends 'A1' and 'A2' using small pieces of paper. The primary of Tr1 is now completed.

1

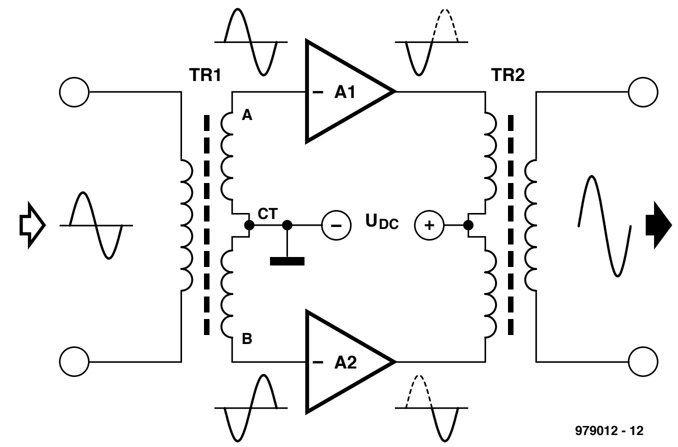


Figure 1. Basic operation of a push-pull amplifier. Thanks to the balanced operation, even-order harmonics are cancelled out at the output.

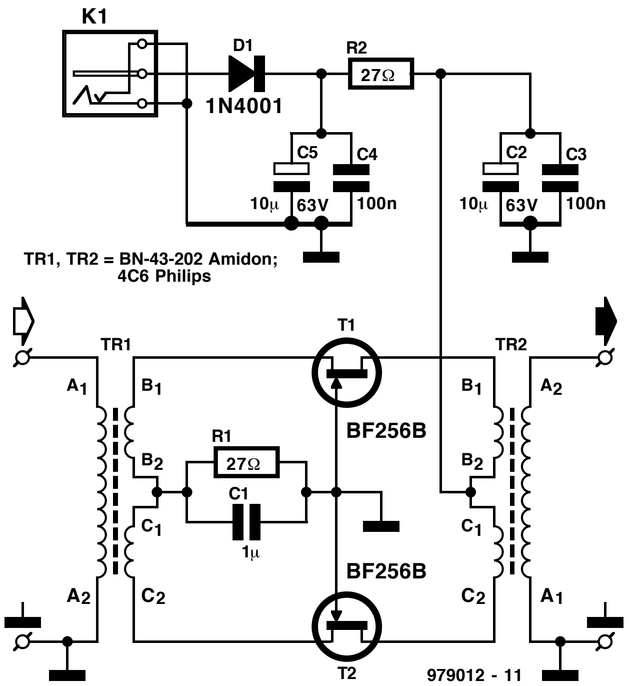
The secondary windings, B-C, are wound together in the bifilar manner, and consist of 12 turns each of 0.3-mm lacquered wire. First, twist the two wires together using an electric drill with speed control. Take two pieces of wire, each approximately 85 cm long, join the ends together and chuck them up in an electric drill. The other ends of the wire are also joined, and anchored in a bench vise. Back off and pull the wire taut. Turning the drill (careful, the wire may break and whip around the drill chuck), causes the two wires to twist together. Keep twisting until you obtain a pitch of about 3 to 5 turns per cm.

To start the secondary winding, remove the insulation of both wires at one end of the twisted pair, and tin the exposed parts. Label one free wire end 'B1', the other, 'C1'. Pass the wire through the hole of the core opposite 'A1', and wind 12 turns. Cut the twisted pair wires off to leave about 1 cm free. Tin the ends as before.

Connecting the free ends of the twisted wire requires an ohmmeter or continuity tester to see which wire goes where. Identify the end that belongs with 'B1', and label it 'B2'. The other pair is 'C1-C2'. 'C1' is connected to 'B2' to make the centre tap.

Figure 2. Circuit diagram of the broadband preamplifier. Provided you pay attention to the design and construction of the transformers (using this month's Datasheets), the preamp can be modified for operation at VLF (down to 10 kHz or less) or VHF (up to 150 MHz).

2



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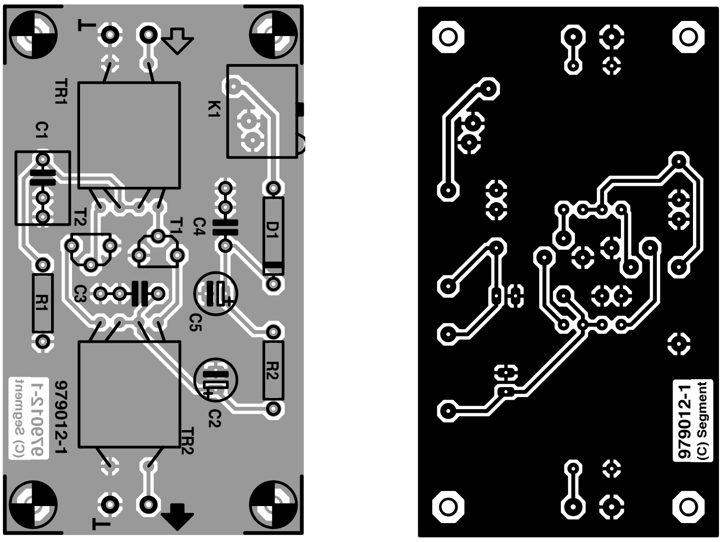

Figure 3. Printed circuit board artwork (board not available ready-made).

COMPONENTS LIST

Resistors:
R1, R2 = 27Ω

Capacitors:
C1 = 1μF solid MKT
C2,C5 = 10μF 63V radial
C3, C4 = 100nF

Semiconductors:
D1 = 1N4001
T1,T2 = BF256B (see text for alternatives)

Miscellaneous:
K1 = mains adaptor socket, PCB mount
Tr1,Tr2 = Binocular core, Amidon type BN-43-202, or Philips core made from type 4C6 material (see text).
Windings:
Tr1A = 4 turns 0.15 mm CuL wire (SWG38/AWG36)
TR1B = 12 turns 0.3 mm CuL wire (SWG/AWG30)
TR1C = 12 turns 0.3 mm CuL wire (SWG/AWG30)
Tr2A = 2 turns 0.15 mm CuL wire (SWG38/AWG36)
TR2B = 12 turns 0.3 mm CuL wire (SWG/AWG30)
TR2C = 12 turns 0.3 mm CuL wire (SWG/AWG30)

Transformer Tr2 is made just like Tr1, but with only two turns on the coupling winding, rather than four.

Before removing the labels and mounting the transformers onto the PCB, subject them to a final, thorough, wire-for-wire check using your ohmmeter.

MODIFYING FOR HIGHER AND LOWER FREQUENCIES

A variation is to build the preamplifier for the shortwave bands (up to 30 MHz). This can be accomplished easily enough. First, reduce C1 to 100 nF. Second, build the transformers on a toroid (ring) core rather than a binocular one. In Dough DeMaw's original design (*op-cit.*) a type FT-37-43 ferrite ring core was used with the same 12:12:2 and 12:12:4 turns ratios. Winding lacquered wire on a ferrite ring core is not difficult — see Figure 4b. Cores made from 4C6 material (from Philips) should also be suitable for use above 50 MHz, but this has not been tested in practice.

Alternatively, select a powdered-iron core, such as the Amidon T-50-2 (red) or T-50-6 (yellow). About 20 turns will be needed for the 'A' winding on Tr2, and seven turns for the 'A' winding on Tr1. You may want to experiment with other core types and turns counts to optimise for the specific section of the shortwave spectrum you wish to cover. A tip: use Amidon's condensed design information on toroid cores found on this month's *Datasheets*.

The third variation is to make the amplifier cover much lower frequencies (e.g., well down into the VLF region). The principal changes needed are the cores for Tr1 and Tr2, the number of turns of wire needed, and the capacitors. The type 43 core (from Amidon) will work down to 10 kHz or so, but requires a lot more turns to work efficiently in that region. The type 73 material, which is found in the BN-73-202 core, will provide an A_L value of 8,500, as opposed to 'just' 2,890 for the BN-43-202 device. Doubling the number of turns in each winding is a good starting point for amplifiers below 200 kHz. The type 73 core works down to 1 kHz, so with a reasonable number of turns should work in the 20 to 100 Hz range as well.

(979012-1)

References:

1. Small loop antennas for MW AM BCB, LF and VHF reception, *Elektor Electronics* June and July/August 1994.
2. Published by the ARRL, 225 Main Street, Newington, CT 06111, USA. Internet: *www.arrl.org.*
3. Amidon Associates, 2216 East Gladwick, Dominguez Hills, CA 90220, USA. Internet: *www.amidoncorp.com.*

Figure 4. Naming the wire ends of the primary and secondary windings (a), and using a toroid core to make the transformers if you want to use the preamp for VHF (b). On a toroid core, too, the bifilar winding technique is used.

4

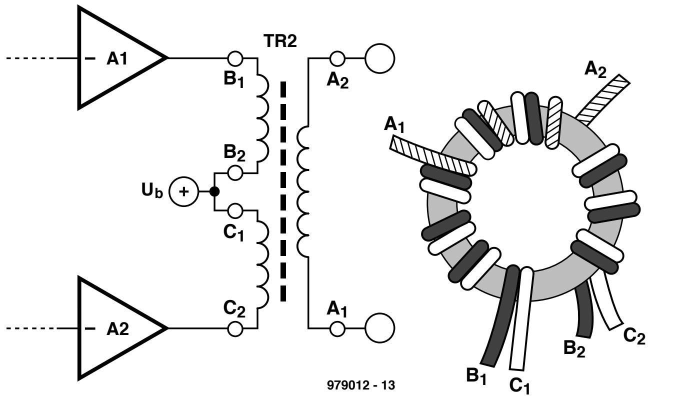

Figure 5. One turn (left) and two turns (right) on a binocular core.

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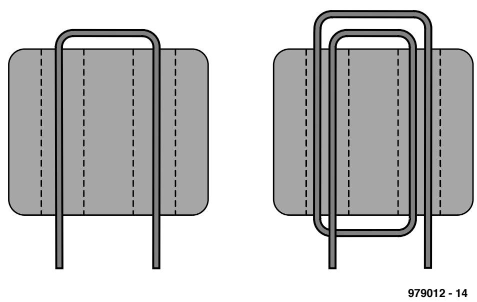


Monitor/TV refresh rate meter

obviates eye strain

The field frequency of a computer monitor or TV screen is a compromise between the requirement for as many horizontal lines as possible and the avoidance of flicker. Such brightness, luminance or colour fluctuations if fewer than 25–30 per second may cause eye strain and headache. It is often possible to increase the field frequency and so prevent such discomforts. The meter described in this article enables the field frequency to be determined.

The number of complete pictures per second on a monitor or television screen is the frame frequency, which is half the number of rasters per second, that is. half the field frequency. European television uses a field frequency of 50 Hz, and American televison one of 60 Hz (these frequencies are the same as those of the mains supply or, in the US, the household AC supply). Since the consequent frame frequency of 25 Hz and 30 Hz respectively is low, most broadcast television companies

** Definition is a measure of the resolution of the system which in turn depends on the number of lines per frame.*

1

Figure 1. Circuit diagram of the refresh rate meter. Measurements may be taken via an electronic eye or via an electrical link.

use a system of interlaced scanning. In this system, the lines of successive rasters are not superimposed on each other, but are interlaced.

In the past, considering the available bandwidth and the then current technology, a frame frequency of 25 Hz (or 30 Hz) was a reasonable value. However, many people can discern fluctuations of 25 per second and they, therefore, experienced eye strain or headache when watching television or an old computer monitor.

Manufacturers of television sets have solved this problem by increasing the frame frequency to 100 Hz with the aid of a digital buffer memory. The result is a stable picture. The solution had to be incorporated in the television receiver because the transmission standard cannot be altered.

The situation was even worse in computer monitors, since users spend many hours a day in close proximity of the screen. Moreover, the definition* of a monitor is much better than that of a television receiver. This means that the frame frequency (sometimes called refresh rate) of a monitor needs to be much higher than in a television receiver†. Whereas in early monitors, modern displays use a frame frequency well in excess of 100 Hz (at the time of writing – early 1998 – a frequently encountered value is 132 Hz). Modern video cards can produce such high-value frame frequencies with a bandwidth of 250 MHz. These values ensure an absolutely stable display.

CIRCUIT DESCRIPTION

The meter, whose circuit diagram is shown in **Figure 1**, is highly suitable for quickly monitoring the frame frequency of a computer monitor. All that needs to be is to hold the unit in front of the display and it will indicate the frame frequency used. It may also be connected to the video output (or VGA output) when it will indicate the line frequency and the field frequency.

The circuit is based on IC_1, an enhanced RISC processor from Atmel's AVR family (see data sheets in our January 1998 issue). The device makes available 15 I/O lines, 1 Kbyte flash memory, and 64 bytes EEPROM. It has a number of other facilities as well, such as an 8-bit timer and a watchdog. Its internal structure is shown in **Figure 2**.

This article is not the place to give a detailed analysis of the operation of the

On the CD-ROM

This project is one of the many contained on the CD-ROM 'μP-μC Hard&Software 97-98'. This CD-ROM contains more than 100 projects resulting from the design competition in our July/August 1997 issue. On the disk can be found all kinds of background information, including source codes of several projects, including the present one. If you wish to program the processor yourself, this CD-ROM is a must. See the Readers Services section

2

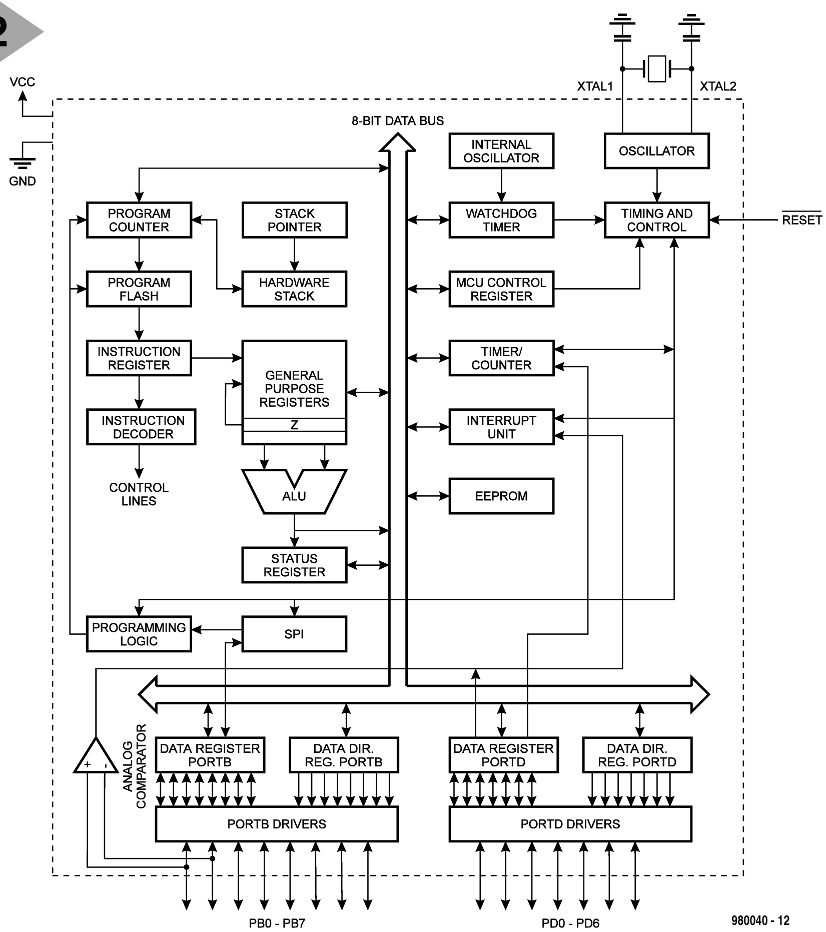


Figure 2. Block diagram of the enhanced RISC processor, which is housed in a DIL20 case.

processor, so the description is restricted to the functions it fulfils in the present meter.

When the processor is clocked at 12 MHz, it achieves an operating speed of 12 MIPS (million instructions per second), which is far more than required for the meter. Consequently, a clock frequency is used that makes simple timing possible. Crystal X_1 is a readily available component with a fundamental frequency of 32,768 kHz. It is used extensively in the watch and clock industry, since its frequency is a multiple of 2 (2^{15}). This simplifies the derivation of a signal of 1 Hz.

An additional benefit of a low-frequency crystal is its low current drain.

The oscillator is designed around two separate inverters to ensure stable operation of the crystal. The clock signal is applied to pin 5 of IC_1 via buffer IC_{2f}.

The B ports of IC_1 (pins 12–19), which contain the signals for driving the liquid-crystal display (LCD), are linked to connector K_3.

The control signals for the LC display, RS, R/W and E, are available at the ports PD_0, PD_1 and PD_3.

The external interrupt input, PD_2, is used for monitoring external signals. Which signal depends on multiplexer IC_3 it is the output of the electronic eye, T_2, the horizontal synchronization signal (reduced to 1/100th via IC_4 and IC_5), or the vertical synchronization signal. The multiplexer is controlled as appropriate via ports PD_4 and PD_5.

Network R_1-C_1-IC_{2a}-IC_{2b} provides a reset pulse when the supply is switched on.

The electronic eye consists of T_2 and digital buffer IC_{2c}.

The power supply is slightly more elaborate than usual since it is provided with an electronic on/off switch. This automatically switches off the supply when the meter has not received any input signal for 30 seconds.

The direct voltage output of the mains adaptor is applied to capacitor C_3 via transistor T_3. Whether this transistor is on or not depends on the potential at its gate. When S_1 is pressed, the gate becomes negative with respect to the source and the transistor comes on. The meter is then actuated. Shortly afterwards, IC_1 enables T_1 via port PD_6, so that, even when S_1 is released, the supply remains on. When port PD_6 is made low, the meter switches itself off again.

CONSTRUCTION

The meter is conveniently built on the single-sided printed-circuit board in **Figure 3**.

The on/off switch, S_1, and the electronic eye, T_2 must be fitted on the enclosure of the meter. All other components are soldered on to the PCB. Mind the polarity of T_3.

The inductor, L_1, is easily made. It consists of two turns of 0.3 mm enamelled copper wire around a small ferrite bead.

Connector K_2 should be fastened to the mother board with screws, nuts and washers before any of its pins are soldered.

There are various ways of linking the motherboard to the LCD board. Ribbon cable is best if a permanent link is wanted. On the prototype, a single-row IC socket with wire wrap pins is used. The LCD has a single row of pins that protrude from the board at two sides. Provided everything is measured accurately, this type of link is easily uncoupled.

The display board must be fitted to the mother board on four 10 mm spacers. The prototype construction is shown in **Figure 4**.

When all construction work is completed, connect a 9 V battery to the meter and press S_1. The display will then read 'searching …' with underneath it 'Hz'. When a measurement value has been established, the display reads 'Refresh Rate'. If the display remains grey, it is possible that the contrast has not been adjusted correctly. Turn P_1 until some text appears on the

Experimentation

The software for the processor was developed with a program that can be downloaded from the Internet: http://www.atmel.com
At this site will be found an assembler, a debugger and software for the development board. The processor is programmed with the aid of a serial programmable interface (SPI). In short, all requisite software is available free via the Internet. The processor may be programmed with the 'Handyman' pub-

Parts list

Resistors:
R_1 = 10 kΩ
R_2 = 1MΩ
R_3 = 100 kΩ
R_4, R_5 = 47 kΩ
R_6, R_7 = 4.7 kΩ
R_8 = 3.9 kΩ
R_9 = 15 kΩ
P_1 = 25 kΩ (27 kΩ) preset potentiometer

Capacitors:
C_1 = 10 μF, 16 V, radial
C_2 = 22 pF
C_3, C_4 = 4.7 μF, 16 V, radial
C_5–C_9 = 0.1 μF

Inductors:
L_1 = 2 turns of 0.3 mm enamelled copper wire on a ferrite bead

Semiconductors:
D_1, D_2 = 1N4148
T_1 = BC547
T_2 = SFH309-4 (do not use -F version)
T_3 = IRFD9120

Integrated circuits:
IC_1 = AT90S1200 (Order no 986510-1)
IC_2 = 74HC04
IC_3 = 4051
IC_4, IC_5 = 4017
IC_6 = 78L05

Miscellaneous:
K_1 = clip for 9 V battery
K_2 = 15-pole HD-sub-D connector, female, right-angled, for board mounting (for link to VGA connector on computer)
K_3 = 14-way SIL header
S_1 = push-button switch, 1 make contact
X_1 = crystal 32,768 kHz
9 V battery
LC module, 2×16 characters
PCB Order no.980040 (see Readers Services towards the end of this issue)
Programmed controller Order no. 986510-1 (see Readers Services towards the end of this issue)

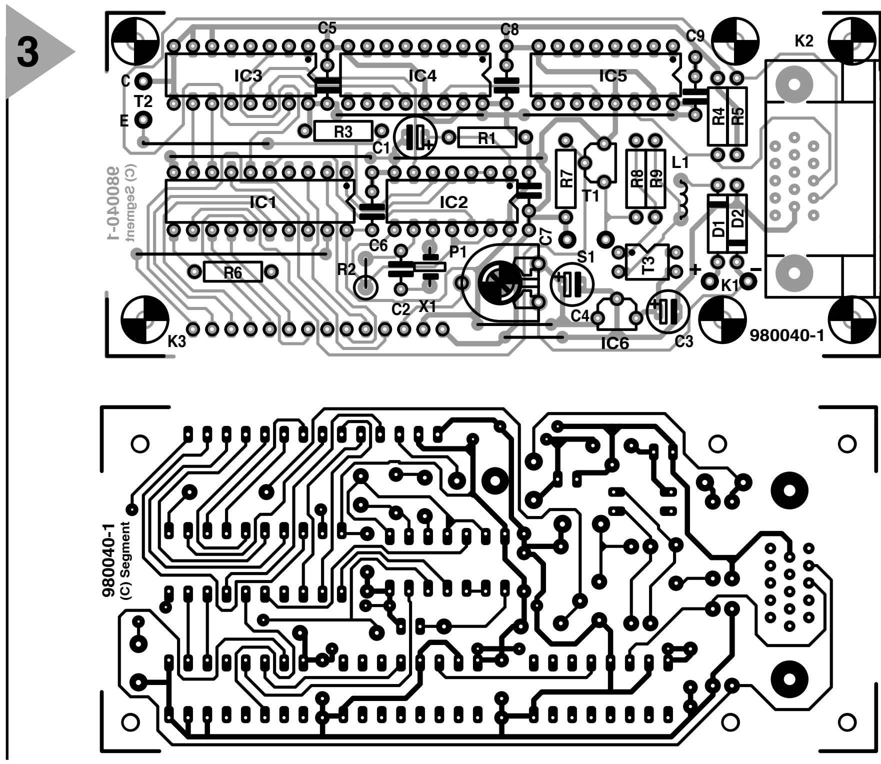


Figure 3. Printed-circuit board for the refresh rate meter.

with the optical sensor is not the only way: measuring direct at the output of the video card is also possible. This is effected by linking the meter via a suitable cable to the output and waiting until the measurement results appear on the display.

software

The software is contained in the processor. Immediately after the meter has been switched on, a routine is started by which the two inputs of the meter are scanned for 250 ms. If the optical sensor detects a signal, or the vertical synchronization appears on the relevant connector, the appropriate on the display. The measurement is continued as long as the signal is present at the relevant input. When it is no longer there, both inputs are scanned again for 250 ms. If no input signal is detected for 30 seconds, the meter switches itself off automatically. Make sure that the switching off occurs only when no light is incident on the meter. It is advisable to cover the meter when it is not in use.

The source code may be found on the CD-ROM 'μP-μC Hard&Software 97-98' in directory NL/01.

[980040-1]

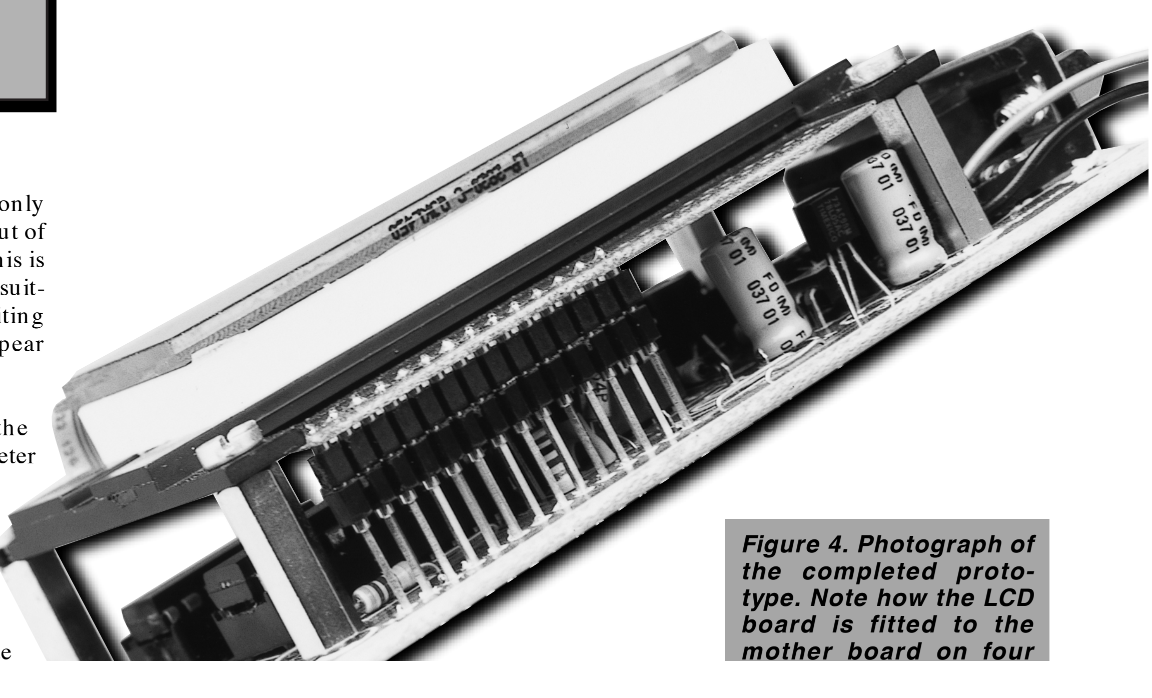
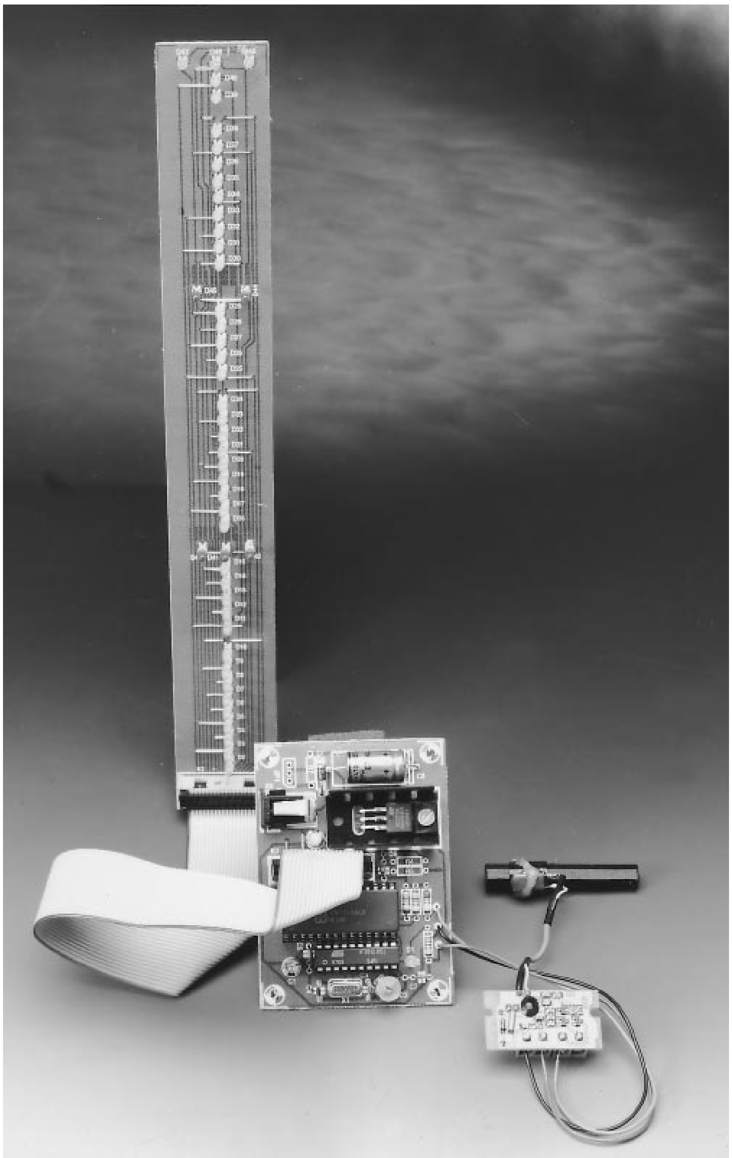


Figure 4. Photograph of the completed prototype. Note how the LCD board is fitted to the mother board on four

DCF-controlled LED clock

Replica of Rhine Tower Clock

Visitors to Germany may have seen the world's largest digital clock which is housed in a 234 metres high transmitter tower on the banks of the Rhine in Düsseldorf. The time is indicated by vertically arranged lamps that shine their light through 'portholes' (glazed round windows). This article describes a miniature replica of this Rheinturmuhr (Rhine Tower Clock). It is controlled by an Atmel processor and synchronized by a DCF module.



Design by D. de Mülder

If you have never visited Düsseldorf (about 35 miles northwest of Bonn and only 27 miles from the Dutch border) you can see photos of the world's largest digital clock on the Internet and download a display version from it (http://www.düsseldorf.de), which is reproduced in **Figure 1**.

Thirty-nine of the sixty-two windows along the height of the tower form the 'clock'. They indicate, from top to bottom, tens of hours, single hours, tens of minutes, single minutes, tens of seconds, and single seconds—see **Figure 2**.

CIRCUIT DESCRIPTION

In the electronic replica of the tower in **Figure 3**, diodes D_2–D_{40} show the time;

1

Figure 1. The Rhine Tower Clock on which the present replica is based.

diodes D_{46}–D_{48} portray the lighting of the revolving restaurant, and diodes D_{41}–D_{45} represent aircraft warning lights.

The arrangement of the light-emitting diodes on the display board shown in **Figure 4** coincides with the diagrammatic representation in Figure 2, so that a faithful small-scale replica is obtained. This arrangement is, of course, not necessary: the LEDs may just as well be arranged as a traditional, horizontal bar.

The use of a programmed Atmel controller saves a lot of components. Apart from the controller, IC_1, and voltage regulator IC_3, only one more IC is needed: IC_2.

Display driver IC_2 is a very useful circuit element, which contains all that is needed to drive an LED display in multi-mode operation under the control of a microprocessor or microcontroller.

The device is linked to the microcontroller via two control lines, $\overline{\text{WRITE}}$ and Mode, which cause either 4-bit control information or an 8-bit (one byte) data word to be displayed. The sequential data words are automatically stored in an 8-byte buffer at each positive $\overline{\text{WRITE}}$ pulse. They may be displayed directly or in decoded form (hexadecimal or binary code-to-7 segment). In the present application the decoder is, of course, not used. The individual LEDs of the clock can be enabled by the microcontroller through direct control of the eight segment drivers.

Normally, IC_2 can control up to eight 7-segment displays with common anode in multiplex. Since the segment and digit lines are all linked to connector K_1, it would be possible to use a standard 7-segment LED display for indicating the time (with suitably modified software in IC_1), but the result would no longer be a replica of the Rhine Tower Clock.

When the tower display is used, K_1 is linked via a length of flatcable to its counter part, K_2, on the display board. On this board, all segment and digit lines are used to drive the LEDs. In the circuit diagram, the groups of LEDs (with interconnected anodes) are connected (from left to right) to the relevant digit line of the display driver as shown in the table.

The horizontal segment lines run

2

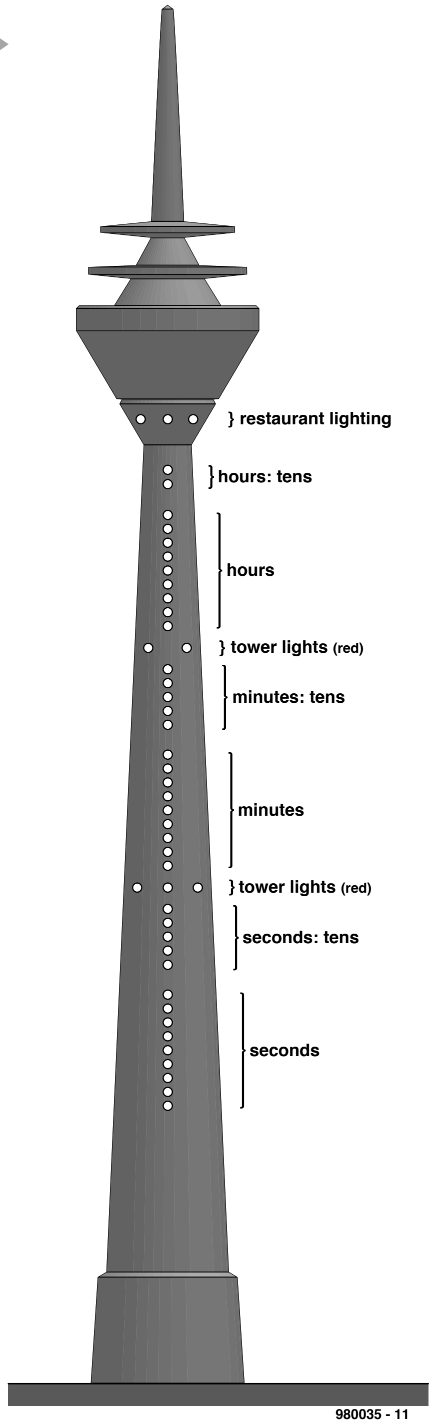


Figure 2. The arrangement of the LEDs on the display board is identical to that of the original clock.

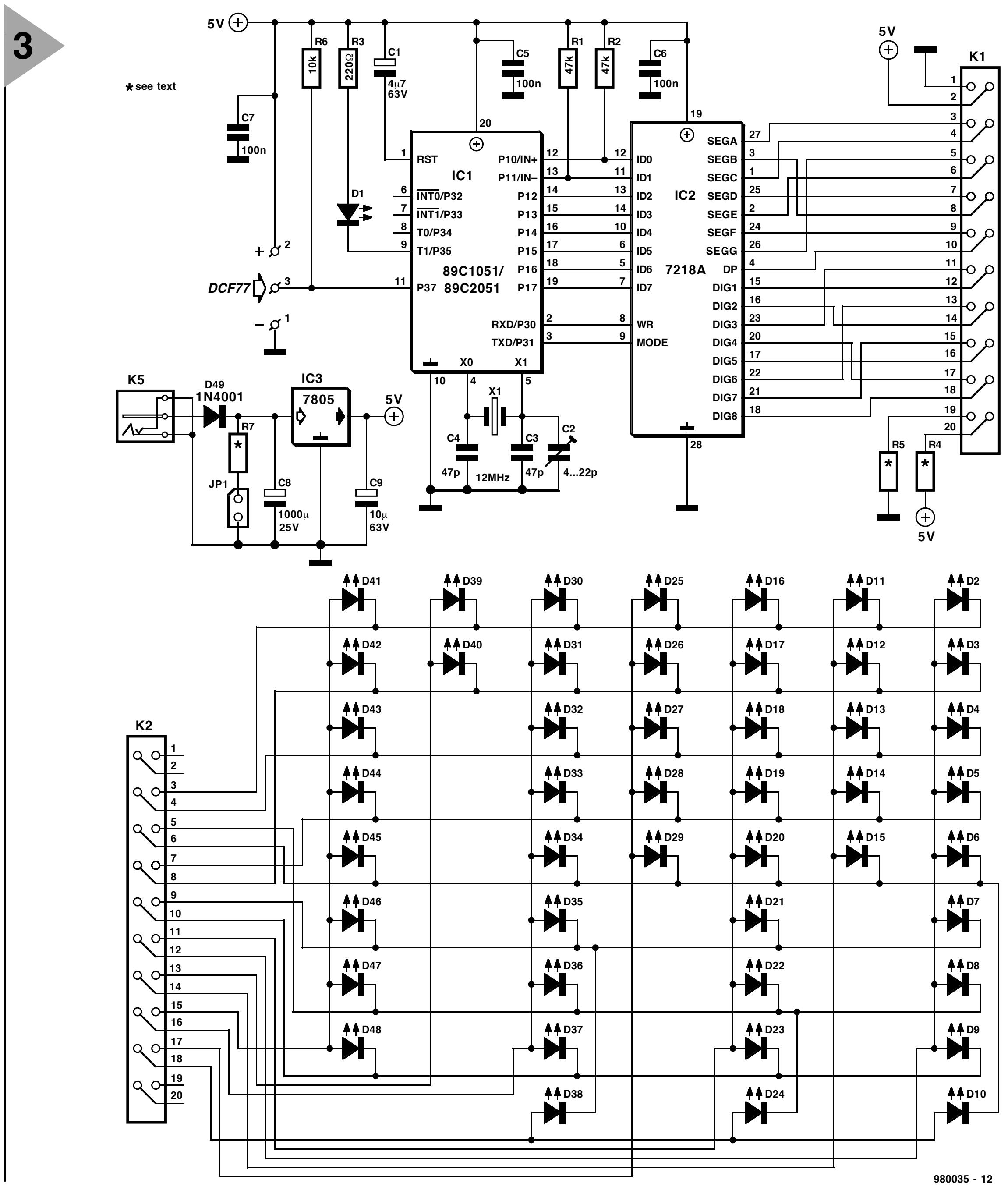


Figure 3. Circuit diagram of the DCF clock. A DCF module is linked to the DCF77 input.

D_{41}–D_{48} (aircraft warning lights and restaurant lighting):	digit line 7
D_{39}–D_{40} (tens of hours)	digit line 6
D_{30}–D_{37} (single hours)	digit line 5
D_{25}–D_{29} (tens of minutes)	digit line 4
D_{16}–D_{23} (single minutes)	digit line 3
D_{11}–D_{15} (tens of seconds)	digit line 2
D_2–D_9 (single seconds)	digit line 1

from top to bottom in sequence A, B, C, …, DP. This is a total of eight lines, which is, in principle, one short in the case of the single (hours, minutes, seconds) LEDs. Therefore, special arrangements have been made for the three bottom diodes in the relevant row, D_{10}, D_{24} and D_{38}. The anodes of these diodes are commoned and then linked to the digit 8 line (pin 18 of K_1, K_2 and IC_2).

On the display board, the sequence is exactly the opposite. There, the three LEDs occupy the top position of the relevant rows.

Diodes D_{41}–D_{48}, whose anodes are linked to the digit-7 line, are driven via the segment lines in such a manner that diodes D_{41}–D_{45} (aircraft warning) flash each second, while the other diodes, D_{46}–D_{48} (restaurant lighting) light continuously.

Resistors R_4 and R_5 may serve as series resistors for the LEDs in case a different display or other kind of experimental circuit is connected to K_1. For the same reason, pin 1 of K_1 is strapped to ground, and pin 2 carries the 5 V supply line. Similarly, resistor R_7 is intended for experimental purposes: it may be used as a series resistor for an LED (in place of JP_1) which shows whether the supply is on or not. If the circuit is used as a replica of the tower clock, the three resistors may simply be omitted.

4

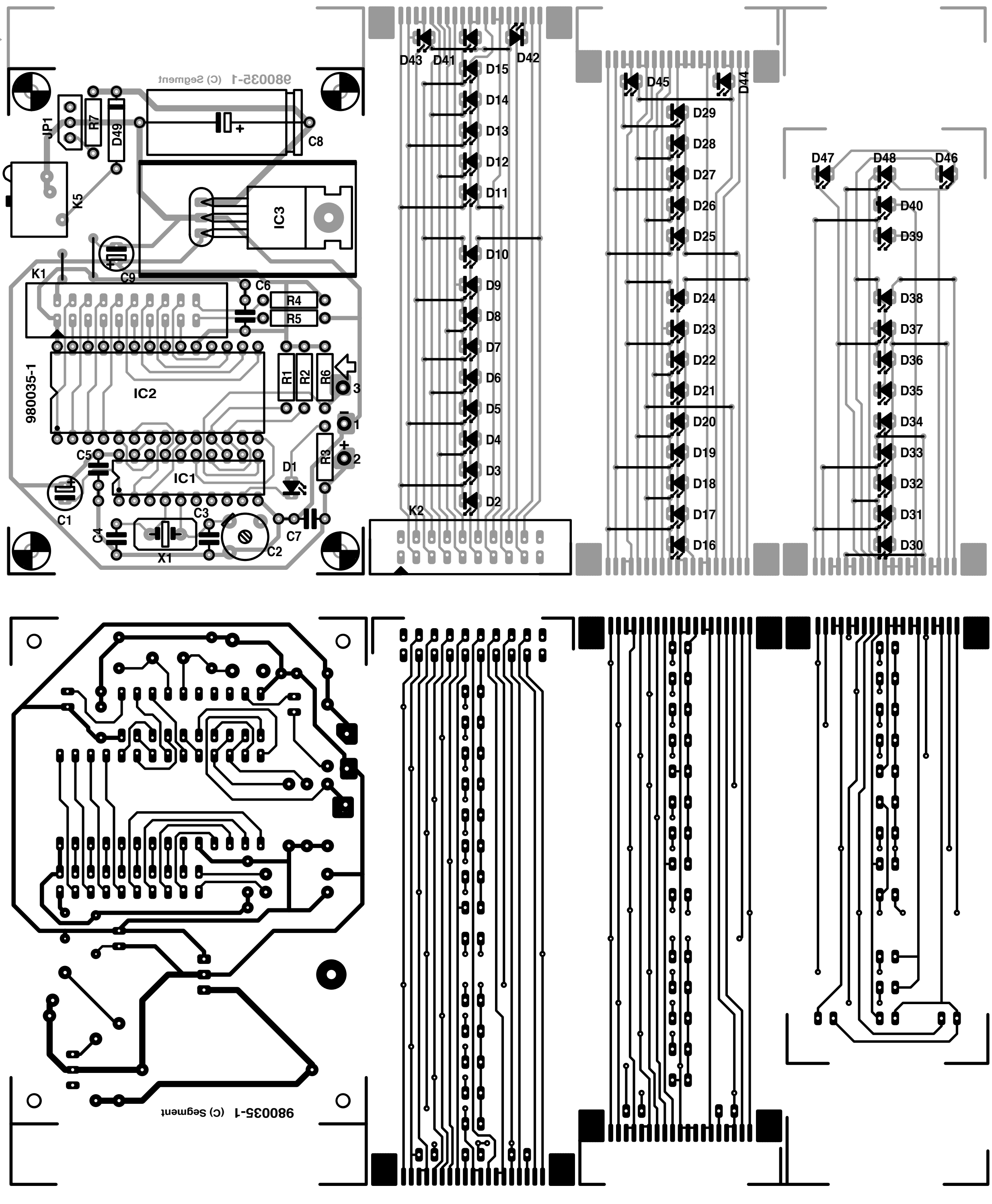


Figure 4. Printed-circuit boards for the clock. The control and display boards are single-sided, not through-plated. The three boards for the display must be cut apart before any work is done.

Apart from decoupling capacitor C_6, the display drivers needs no further external components, but IC_2 does. Capacitors C_5 and C_7 (DCF module) are decoupling elements on the supply line. Capacitor C_1 provides a power-on reset; the resistor in series with it may be omitted when an Atmel controller is used.

Diode D_1 at the output (pin 9) of IC_1 lights at every correctly received DCF pulse and is, therefore, a useful aid in

5

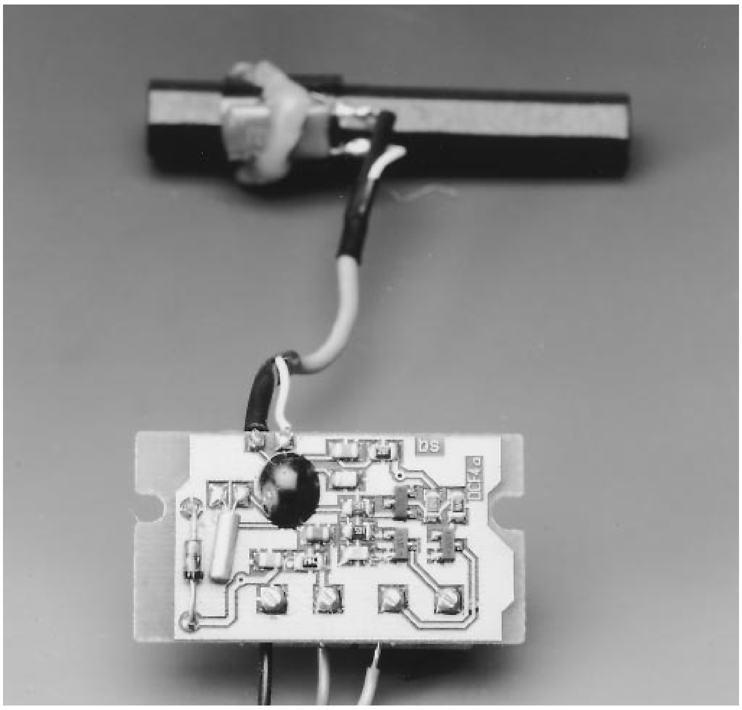


Figure 5. The DCF module board is populated mostly with SMT components. It is linked to the control board via a 3-core (screened) cable.

pointing the ferrite rod antenna of the DCF module in the right direction.

The pulse output of the module is applied to input pin 11 (P3.7) of IC_1, whereupon it is decoded (see box).

The DCF module is linked to the control board via terminals earth (1), + 5 V (2) and DCF pulse (3). Resistor R_6 is a pull-up element for the open-collector output of the DCF module.

Owing to the external 12 MHz quartz crystal, the internal oscillator of IC_2 is so accurate that even when the DCF synchronization fails, the clock continues without discernible error. If necessary, however, the accuracy may be enhanced with trimmer C_2. Note that it is not possible to use the clock without the DCF module since this is needed when the circuit is first taken into use to set the clock accurately.

Power is provided by a 9–12 V mains adaptor rated at 150 mA. The output of this is connected to K_5. The current drawn by the control board, incl. the DCF module, is small: about 18 mA. In operation, the display board draws about 120 mA.

CONSTRUCTION

Before any work on the boards is started, that for the display should be

Parts list

Resistors:
R_1, R_2 = 47 kΩ
R_3 = 220 Ω
R_4, R_5, R_7 = see text
R_6 = 10 kΩ

Capacitors:
C_1 = 4.7 µF, 63 V, radial
C_2 = 4–22 pF trimmer
C_3, C_4 = 47 pF
C_5–C_7 = 0.1 µF
C_8 = 1000 µF, 25 V
C_9 = 10 µF, 63 V, radial

Semiconductors:
D_1, D_{46}–D_{48} = LED, high efficiency, green
D_2–D_{40} = LED, high efficiency, yellow
D_{41}–D_{45} = LED, high efficiency, red
D_{49} = 1N4001

Integrated circuits:
IC_1 = 89C1051 or 89C2051 (Atmel), programmed Order No. 986505
IC_2 = 7218A (Intersil, Harris, Plessey)
IC_3 = 7805

Miscellaneous:
PC_1–PC_3 = soldering pin
X_1 = 12 MHz quartz crystal
K_1, K_2 = 20-way box header with protective shell for board mounting
K_5 = socket for connecting mains adaptor for board mounting
JP_1 = 2.54 mm pin strip and pin jumper
20-way flatcable terminated into mating connectors for box header
Heat sink for IC_3 (e.g., Fischer CK35SA from Dau)
DCF module (see Stippler advert in this issue)
PCB with programmed controller, Order No 980035C

Decoding process

The DCF clock is a compact design: it uses only 829 bytes of machine code. The software is relatively straightforward and consists of two dissimilar blocks. One of these enables the reading of serial data (via P3.7) and storing the information in various registers. Figure 6 shows the make-up of the code word transmitted by the DCF transmitter. When a valid code is read for at least two consecutive minutes, the data is used to set the clock.

The controller maintains its own clock function. After a reset, several registers are erased and then used to store the information as to number of hours, minutes and seconds.

Also after a reset, timer 0 is set to the 8-bit auto reload mode, whereupon it generates an interrupt every 250 µs.

At an interrupt, the content of the accumulator and the program status word (PSW) are stored. Two registers are maintained by this routine: one of them counts from 0 to 100 (250 µs × 100 = 25 ms), and the other from 0 to 40 (40 × 25 ms = 1 s). The resultant 1 s pulse increments the registers, whereupon the clock becomes available.

When valid DCF information has been received, the contents of the hour register and minute register are synchronized.

Reproducing the information on a display requires more arithmetic. First, a byte is split into two digits, after which the hexadecimal code is converted into a position. For in-stance, decimal 7 has the hexadecimal code 0111 and causes the seventh LED to light. The conversion is carried out by successive comparison of the with the digits 0–9. When the position code has been found, it is added to the display code via an instant instruction.

cut into separate boards as indicated by the relevant lines.

Populating the boards should not present undue difficulties. Do not overlook the two wire bridges on the control board and the many on the display board.

Owing to the closeness of the tracks, soldering must be carried with great care.

Make sure that the correct polarity of all diodes and electrolytic capacitors is observed.

The broad tracks at the edges of the display boards serve to interconnect these boards. They are best linked by laying them flat on the workbench with the track layout upward. The connecting wires should be as short as feasible. The boards may be stiffened by soldering stout wire or metal strips at their edges. It is also possible to use small, metal clips available from stationery suppliers.

The DCF module is connected as shown in **Figures 5** and **6**. When the four screw terminals are viewed from above (Figure 6), the terminals from left to right are: DCF output (inverted); DCF output; supply line (+ 1.2–15 V); and earth.

Figure 5 shows the SMD-populated track side of the DCF board and the connecting leads to the control board (from left to right: earth; + 5 V, DCF output). If the connecting leads are long(ish), screened 3-core cable should be used.

The outputs of the module are open-collector outputs of n-p-n transistors that can handle voltages up to 30 V and are able to switch currents of up to 1 mA to ground.

Do not yet insert IC_1 and IC_2 into their respective sockets, and check the completed boards carefully. Then switch on the power and check that the supply lines are as specified. The potential at the junction of IC_3 and C_9, pin 20 of the socket for IC_1, pin 19 of the socket for IC_2, and pin 2 of K_1 must be + 5 V ± 5%.

Switch off the supply, insert IC_1 and IC_2 into their sockets, and connect the DCF module and the display boards.

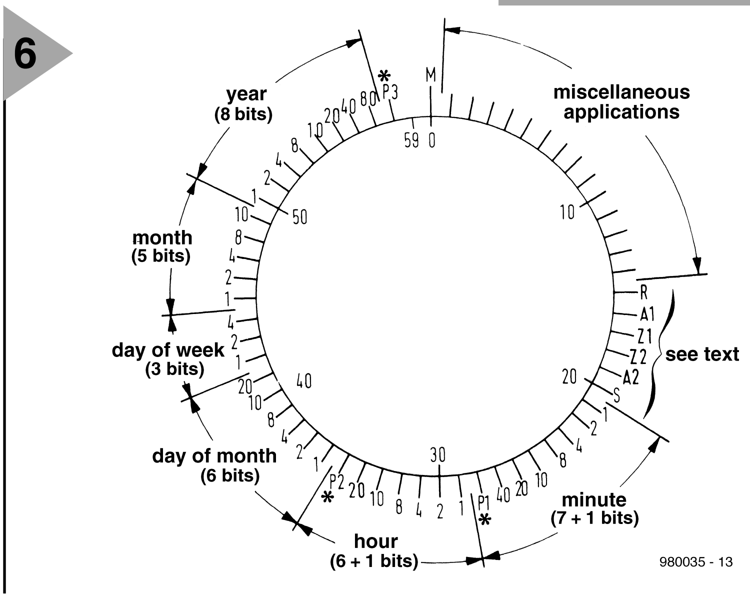
Switch on the supply, whereupon the restaurant lighting should come on and the aircraft warnings lights should start to flash at 1-second intervals. At the same time, the display shows 00:00:00. The clock will set itself to the correct time when the DCF signal has been received flawlessly for at least two minutes. Faultless reception is indicated by the regular lighting of diode D_1 at each DCF pulse.

Owing to the multiplexing of the display the reception in the immediate proximity of the control and display boards may suffer from interference. It may, therefore, be necessary when taking the clock into use for the first time to place the DCF module away from the remainder of the unit. Alternatively, connect the module to the antenna via a longer, screened cable. Reception difficulties may also be encountered when the clock is close (that is, less than one metre) to a television set or similar equipment.

When reception has been satisfactory for more than two minutes, the display will show the correct time. If reception fails during the two minutes, a new period of two minutes is started. Once the clock runs, however, it needs to be synchronized with the DCF signal only once or twice during every twenty-four period.

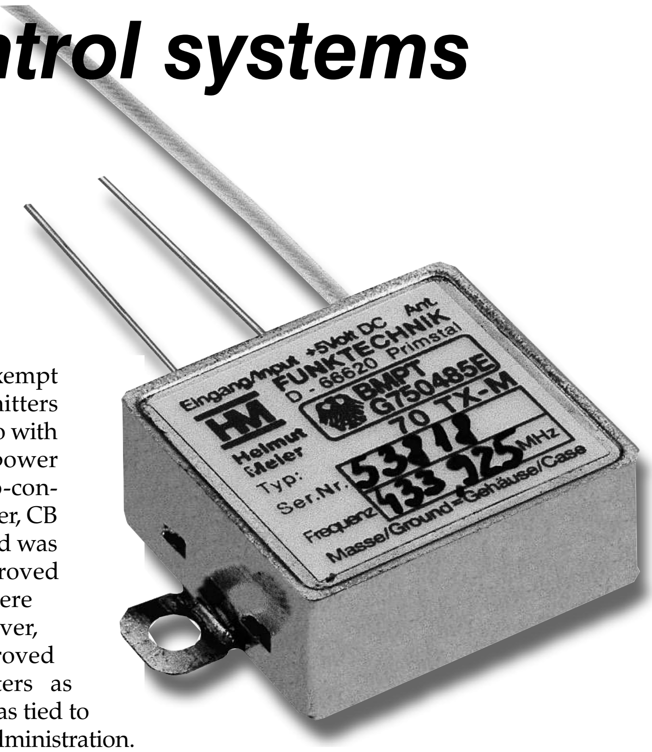
[980035]

Figure 6. Make-up of the 35-bit data word transmitted by DCF.



418/433 MHz short-range communication

licence-exempt data transmission and remote control systems



In the UK, two small sections of the 70-cm band, around 418 MHz and 433 MHz, have been available for some time for licence-exempt wireless communication using type-approved low-power devices (LPDs), also called short-range devices (SRDs). In this article we look at the use of these frequency bands, and some general design considerations for SRD modules.

The history of licence-exempt use of radio transmitters started a few decades ago with the private use of low-power transmitters for radio-controlled models. Much later, CB radio in the 27-MHz band was legalised and type-approved radios for this band were freely available. However, the use of type-approved radio-control transmitters as well as that of CB rigs was tied to a licence fee and some administration. And then, the mere disappearance of the dreaded paperwork and, possibly, a test, to get your licence was hailed as a great liberalisation. The result of this de-regulation on part of the government authorities was a boom in the sales of CB radios. A few years later, the overcrowded CB band was extended with quite a few channels, higher transmit power was allowed, as well as FM (frequency modulation).

Although small sections of the 40 MHz and 173 MHz bands (the latter exclusively in the UK) have long been available for low-power devices like 'stage microphones' and remote controls (for example, for garage doors), nothing was allowed without paying a licence-fee and proof that the equipment was type-approved.

Many of the regulations, but not the type-approvals, have been relaxed or changed radically over the past few years. Initially, licence-exempt remote control systems appeared for the CB 27 MHz (11-m) band. The real activity did not start however until two small sections of the 70-cm band, 418 MHz and 433 MHz, were 'released' for low-power type-approved devices (LPDs), also called short-range devices (SRDs). In Europe, the national radio regulation authorities (in the UK : Radiocommunications Agency, RA) have their own say about the use of the SRD bands. In the UK, the 418 MHz section may be used for telemetry transmitters and receivers, telecommand and in-building security equipment, while the 433-MHz section is only available for in-vehicle equipment including radio keys. This is in contrast with many other European countries, where the section around 433 MHz is much wider and also available for all of the aforementioned applications, and even voice communications using 10-mW FM handhelds.

In the UK, the specification with number MPT1340 is applicable to all LPDs using the 418 MHz and 433 MHz sections of the 70-cm band. The Radiocommunications Agency (RA) is an Executive Agency of the DTI (Department of Trade and Industry) responsible for the allocation, maintenance and supervision of the UK radio spectrum. The RA can be contacted at the following address: Radiocommunications Agency, New King's Beam House, 22 Upper Ground, London SE1 9SA. Tel. (0171) 211 0211, fax 211

0507. Internet: *www.open.gov.uk/radiocom*.

Document number I-ETS 300 220 describes the type-approval requirements for 418/433-MHz SRDs. According to the RA, new equipment can only be type approved to this standard provided parameter limits stated in MPT 1340 are met.

Ex-ISM frequencies

A long time ago, the current SRD band section at 433 MHz was part of a slightly larger section reserved for ISM (industrial, scientific and medical) equipment producing RF radiation. Mainly as a result of pressure from licensed radio amateurs who use this part of the band on a shared and/or secondary basis, the use of ISM equipment has been phased out, and the band section is no longer identified as such, at least not in the UK. Several other ISM frequency bands are defined in the UK, including 167 MHz, 83 MHz and 40 MHz, all subject to strict regulations, the most essential of which being very low ERP (effective radiated power) levels.

The exact frequency allocation of the 418 MHz and 433 MHz SRD bands is shown in **Figures 1a and 1b**. It should be noted that the channel division and channel widths have been adopted by SRD manufacturers, there being no strict RA regulation in this respect.

It is expected from radio amateurs using the 70-cm band to accept the activity of low-power SRD users in this part of the band and not cause interference. Likewise, SRD users have to live with interference caused by radio amateurs, or prevent interference by using low transmission rates, sure codes, high redundancy and selective receivers. All of this is, of course, in the hands of the manufacturers of SRDs, because the users are not allowed to make changes to type-approved equipment.

A new SRD band

Meanwhile, because they are so small, the 418 MHz and 433 MHz SRD bands have become quite overcrowded. A new band, around 886 MHz, is 'identified' by the relevant authorities for use by SRDs (**Figure 2**), with reference to CEPT Recommendation T/R 70-03. In this band, it is planned to reserve several channels exclusively for security applications. Some channels in the proposed frequency range are, however, still in use for analogue cordless telephone sets of the CT2 generation.

For all SRD bands, the intention has always been to arrive at unified regulations. In the UK, however, the Radiocommunications Agency "has not adopted CEPT recommendation TR 01-4 which allows general low-

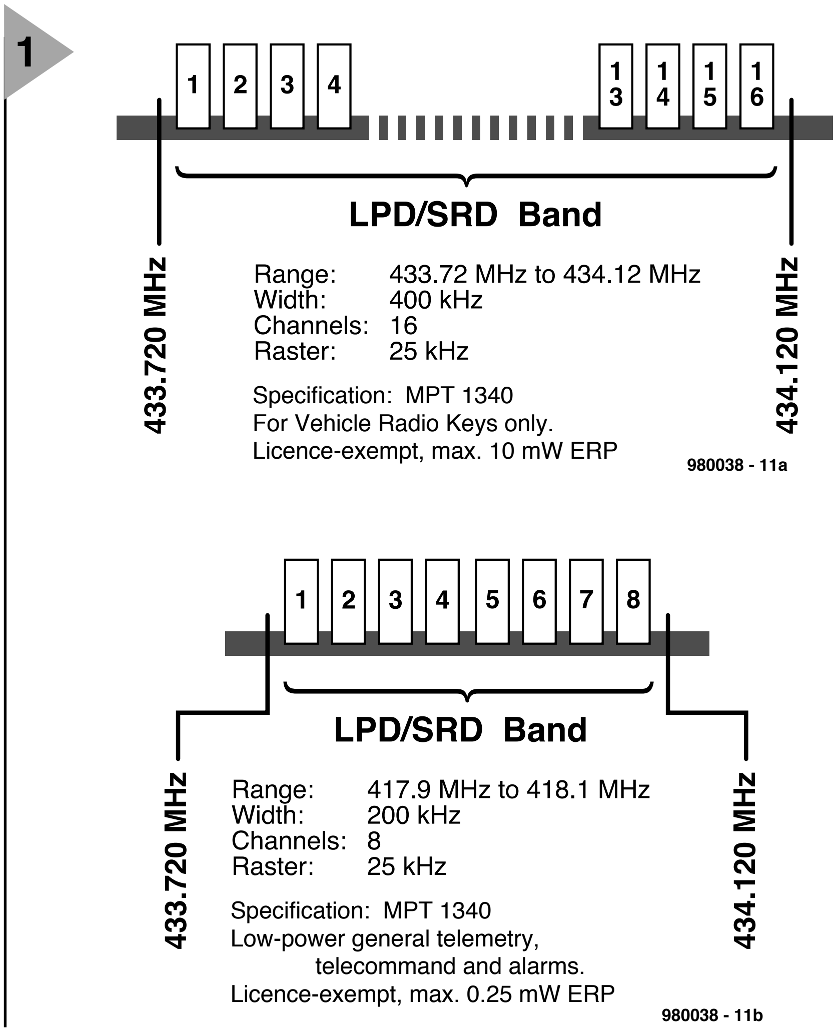
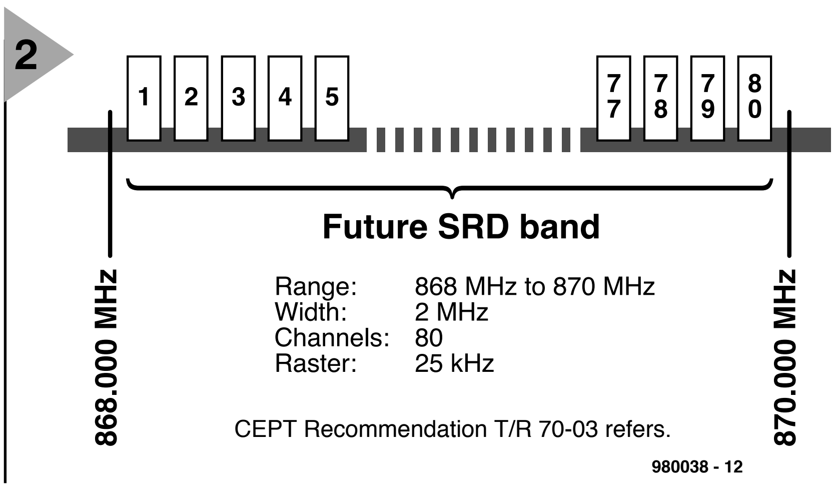


Figure 1. Frequency allocation and (manufacturer-proposed) channel division of the two 70-cm SRD bands available in the UK.

Figure 2. Plans are afoot to open the 886-MHz band for SRD use.



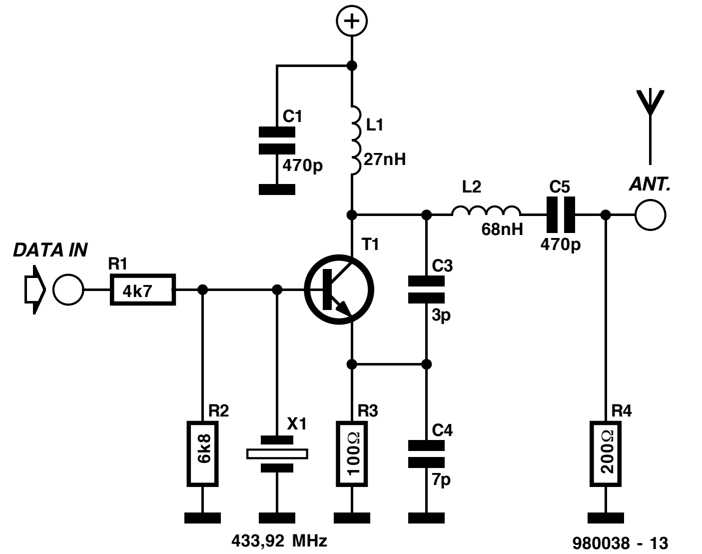


Figure 3. Circuit diagram of an ultra-simple 433-MHz SRD transmitter using amplitude modulation (not type-approved by RA).

Figure 4. Circuit of a simple AM receiver module using a single transistor in the (regenerative) RF section (not type-approved by RA). In some cases, there's an additional preamplifier stage using a second transistor.

power devices to operate in this band". Hopefully, the 886 MHz SRD band will be graced by cross-European standards, and receive an ETS (European Telecommunication Standard).

LPD MODULES

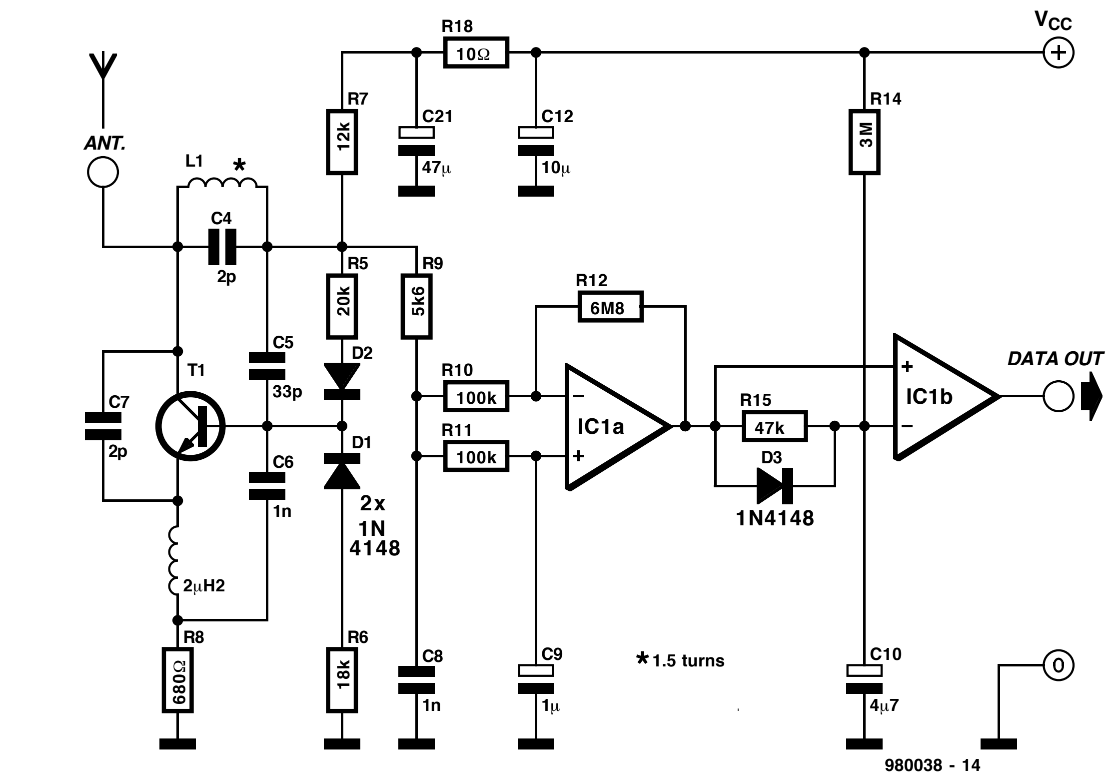
In this country, RadioMetrix and RadioTech are the main suppliers of ready-made, type-approved receivers and transmitters for short-range communications in the 418/433 MHz bands. In this context, we should also mention the activities of the LPRA, the Low-Power Radio Association, who publish an interesting and highly topical newsletter, as well as maintain a fine Internet web site at *www.lpra.org.uk*

The ready-made, UK type-approved LPD modules from RadioMetrix and RadioTech come in a variety of frequencies and transmit powers, depending on your application and country of use. Modules are also available for digital communications between, say, a PC and a printer, the radio link effectively acting as a very long RS232 cable. All LPD modules we have seen so far contain SMD parts to keep the overall size as small as possible.

The simplest versions of SRDs used to rely on an amplitude-modulated transmitter (**Figure 3**) and an associated regenerative receiver (**Figure 4**). Note that such systems are probably no longer allowed under RA specification MPT 1340. The transmitter consists of a one-transistor oscillator. Modulation is obtained by applying the data signal to the base of the transistor. A single surface-acoustic wave (SAW) resonator is used as the frequency-determining element. A highly similar circuit for experimental use was published in *Elektor Electronics* July/August 1993, page 54. Note, however, that this design is based on frequency modulation (FM) using two varicap diodes, while the SAW has a fine-tuning adjustment.

The receiver shown in Figure 4 also contains just one transistor. It is biased to act as a regenerative oscillator, in which the received antenna signal causes the transistor to switch to high amplification, thereby automatically arranging the signal detection. Next, the 'raw' demodulated signal is amplified and shaped-up by opamps. The result is a fairly clean digital signal at the output of the receiver. The logic-high level is at about 2/3 of the supply voltage, i.e., between 3 V and 4.5 V.

The range of the simple system shown in Figures 3 and 4 is much smaller than that of more expensive units, mainly because of the low transmit power (approx. 1 mW) and the rel-



ative insensitivity and wide-band nature of the receiver. Moreover, amplitude-modulated noise is not suppressed in any way.

For more demanding applications, FM (frequency modulation) is the obvious alternative. Block diagrams of an LPD-type 433-MHz FM transmitter and its associated receiver are shown in **Figures 5 and 6** respectively.

The transmitter is automatically actuated by means of pulse edge detection, and uses an accurately defined 4-ms time slot to transmit, as soon as data pulses are detected at the input. When the data signal is removed, the transmitter automatically returns to standby mode after about 200 ms. As in the lower-spec transmitter, the frequency stability is derived from a SAW resonator. The main advantage of these resonators is their low cost. On the down side, they are subject to relatively large production tolerances, and their temperature stability is a far cry from that of a quartz crystal.

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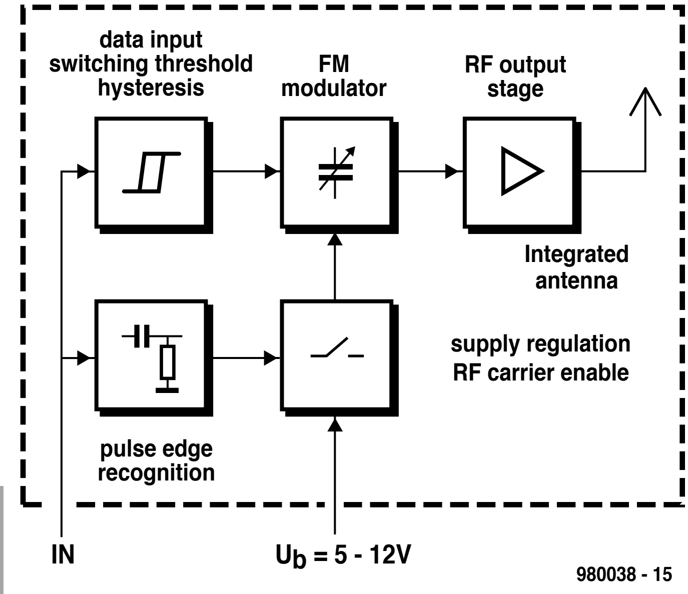

Figure 5. Block diagram of a typical FM transmitter module for one of the 70-cm SRD bands.

To keep the bandwidth of the frequency modulated transmitter output signal within limits, the frequency deviation is limited (±2.5 kHz to ±20 kHz, depending on the SAW type and manufacturer). The input data rate is also limited (low-pass filter). The upshot is that the highest data rate of the FM modules is about 10 kBit/s (using a highest modulation frequency of 5 kHz).

The antennas used for SRDs are traditionally produced in the form of a printed-circuit board track, while ⁄-lambda flexible antennas are also seen occasionally.

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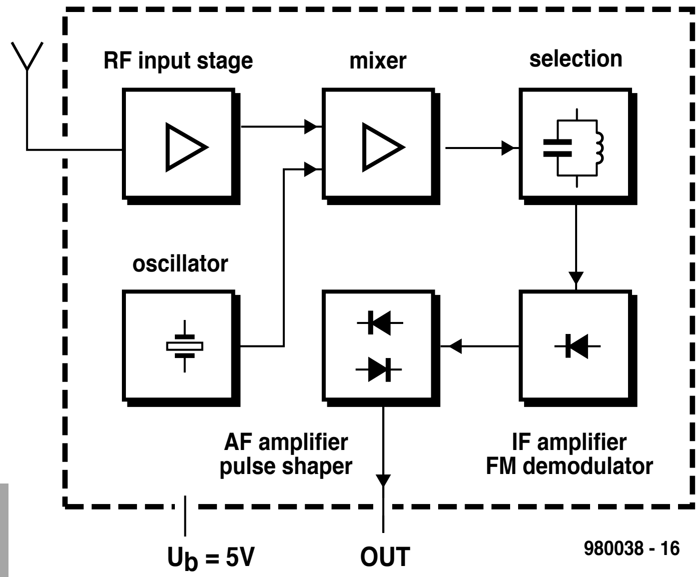

Figure 6. FM receiver modules may be superheterodynes or even double-conversion designs.

The FM receiver module shown in the block diagram (**Figure 6**) is a superheterodyne design. Here, too, an SAW resonator is used in the oscillator to ensure frequency stability. All of the intermediate-frequency (IF) filtering can be done with low-cost 10.7-MHz ceramic filters. Because of the possible frequency offset caused by the SAW resonator, a fairly large bandwidth (approx. 280 kHz) is required anyway. Most ready-made SRD receiver modules are compatible with 5-V or 3-V systems.

Thanks to miniaturisation, SRD modules with even higher specifications are not necessarily larger, but dearer and more complex.

Higher-spec transmitters achieve better frequency stability thanks to the use of a crystal-controlled synthesiser, while the harmonics suppression is also better as a result of extensive filtering at the output.

Likewise, high-end SRD receiver modules are usually double-conversion types using synthesiser tuning and narrow-band IF filters. The technology used to manufacture these modules is the same as found in handhelds for the 70-cm amateur radio band.

Data transmission

For simple data transmission applications, such as a remote control link, you need a suitable encoder at the transmitter side, and a matching decoder at the receiver side. Specially designed integrated circuits are available like the MM57410N from National Semiconductor, the MC145026/MC145028 from Motorola,

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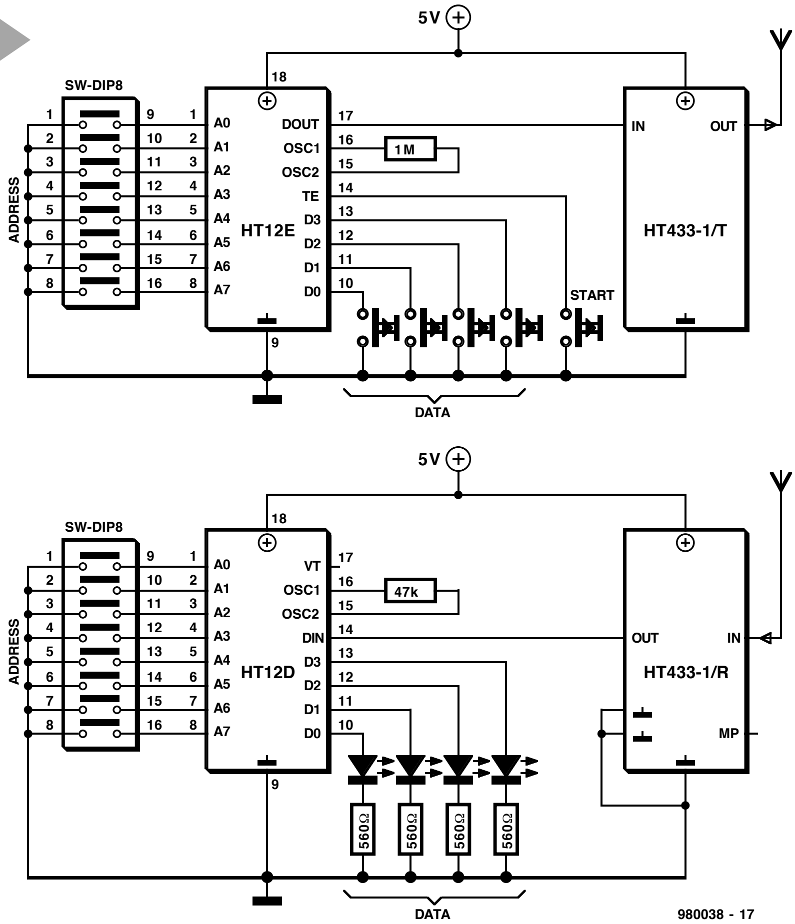

Figure 7. Application circuit for an addressable digital link using an SRD and frequency modulation (FM).

or the HE8 and HT12 from Heiland Electronic (D-48351 Everswinkel, Germany. Tel. +49 2582-7550, fax +49 2582-7887).

An example of an addressable signal transmission link for the 433 MHz SRD band is shown in **Figure 7** (note: this application may not be allowed in the UK). The encoder IC type HT12E supplies its data directly to the modulation input of the transmitter. Similarly, the HT12D decoder IC is found directly at the output of the receiver. On the DIP switches in the encoder you set the same address as in the receiver to be addressed (multiple receivers may be addressed by a single transmitter).

In addition to the receiver address, four data bits may be applied to the input. Here, these four bits come from push-button switches. By applying the transmit-enable signal (/TE), the encoder is prompted to supply a 12-bit serial word (consisting of 8 address bits, and 4 data bits) to the transmitter. The decoder receives the 12-bit word and extracts the first 8 bits as an address, and the remaining 4 bits as data. The four data bits only appear at the output if the received address matches the DIP switch setting in the decoder. The 4-bit dataword is first latched and then used to control external devices (here, LEDs are used).

To make sure the transmission arrives securely at the decoder, the encoder transmits the 12-bit serial word four times each time the /TE input is activated. The decoder withholds the data until three identical, successive, copies have been received. The VT output then flags the availability of valid data.

This process is very well suited to slow data transmission. For higher data rates, a microcontroller is an obvious alternative to special encoder/decoder ICs. Note, however, that opting for a microcontroller (like a PIC) almost always means that you have to write your own software aimed at achieving secure and reliable transmissions.

If data is to be exchanged between equipment having a serial interface, the first solution that comes to mind is often one as adopted in the project 'Long-distance IrDA link' published in *Elektor Electronics* May 1997.

For more demanding telemetry applications, special data modems are employed in combination with high-end 418-MHz SRD modules. A transmission protocol is then used to improve the data security. Often, the AX.25 protocol is employed, a spin-off of the X.25 protocol which has been in use for several years for amateur packet radio.

MODULATION TECHNIQUE — A BOTTLENECK

While most data transmission modules approved for SRD use are usually said to use 'FM', in practice the actual modulation method is FSK (frequency shift keying). Though simple from a design and technology point of view, FSK is burdened by a large bandwidth requirement which is the chief cause of the relatively short distances that can be covered. Assuming a receiver bandwidth of 25 kHz (at –36 dBm) is being used for data transmission, then the highest achievable data rate using FSK would be a measly 500 bits per second! Consequently, professional applications of SRD modules call for special modulation techniques like GMSK (Gaussian Minimum Shift Keying) which reduce the bandwidth requirement by a factor of 15 and more, while considerably improving the transmission security.

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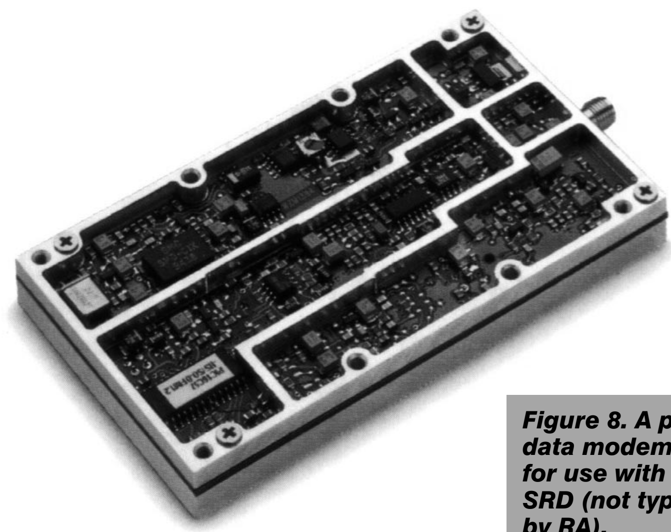

Figure 8. A professional data modem designed for use with a 70-cm SRD (not type-approved by RA).

introduction to digital signal processing

Part 5 – More about filters and modulation

In this instalment, we have another look at filters and their synthesis and then turn our attention to modulation techniques.

By Dr. Ing. M. Ohsmann

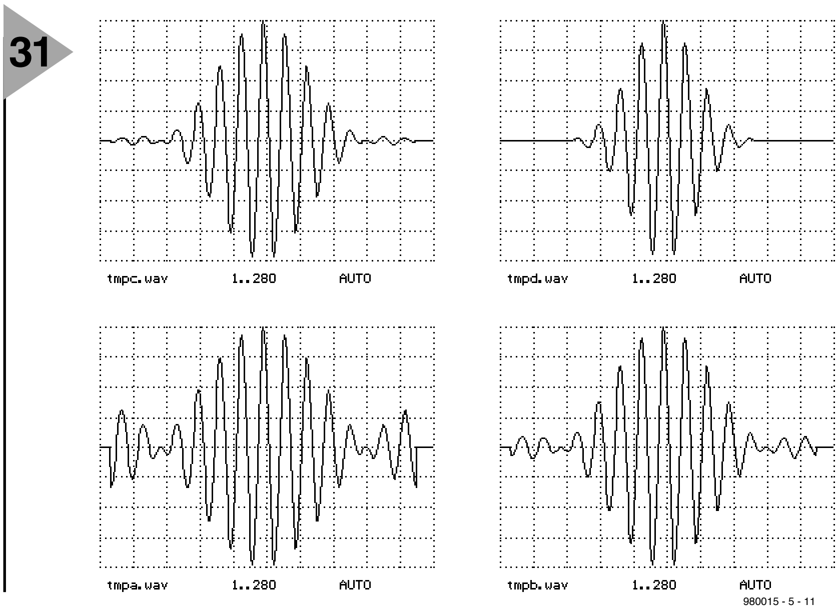

***Figure 31.* Impulse response with various weighting factors (window functions).**

WEIGHTING REVISITED

There is considerable freedom in designing a filter from a predesignated frequency response. The first factor to be decided is the number of samples in the step response, that is, the order, N, of the filter. If too high an order is chosen, the consequent computation becomes enormous. It is, therefore, in general better to choose n as small as feasible. Furthermore, in our program, SPECFIL1.EXE, window parameters, α, have to be chosen. Their influence can be seen in **Figures 31** and **32**. For the oscillogram generated with the program, values of 0.1, 3, 5 and 14 were used for α. A small value for α results in hardly any weighting being applied. The step response shows spikes at either end of the waveform, which may lead to side lobes in the frequency response. A larger value of α will reduce the size of these lobes, but the frequency response is then no longer completely identical with the predesignated response: it becomes more and more rounded. The only alternative to either of these two unfortunate aspects is a higher filter order.

PHASE RESPONSE

The filter design program produces filters with a linear phase response. All frequency components appear to be delayed by the filter for a constant time, which is numerically exactly equal to half the filter order. Entering 'hilbert' instead of 'normal' in the second row of

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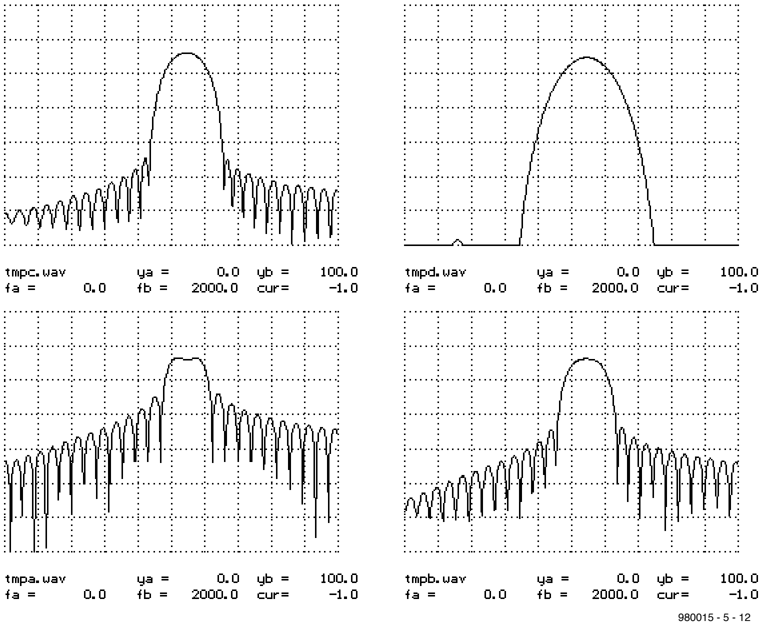

Figure 32. Frequency response with various weighting factors.

the filter specification results in a filter whose frequency response is retained, but shifts all frequency components by 90°. Such a filter is used for specific applications as will be seen later.

BETTER FIR FILTERS

Simple design program SPECFIL1.EXE often does not produce the best possible filter; it is frequently possible to arrive at a design closer to the predesignated one with a lower filter order.

Unfortunately, the design of such a filter is not easy and cannot be dealt with in an introductory article; the reader is referred to the reference works listed at the end of this instalment. There are also a great many commercially available programs which enable the professional designers of DSP systems to design top-of-the-range filters. A section of the design program for an FIR filter contained on a DSP, the ADSP2181 from Analog Devices, is shown in **Figure 33**. When the usual 16.66 MHz crystal is used, an instruction is carried out in 30 ns.

The inner loop, line 3/4, takes about 30 ns per run, so that, if the sampling rate is 48,000 samples per second, only 20 μs are left per sample, and only 10 μs in

Figure 34. Frequency response of a Butterworth filter of various orders.

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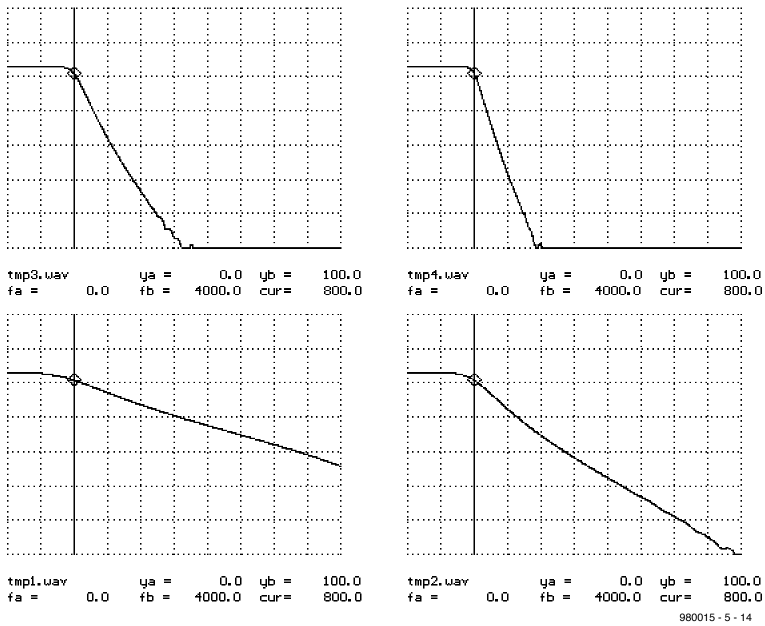

33

```
1 cntre=taps–1;
2 mr=0, mx0=dm(i2,m2),
  my0= pm(i7,m7);
3 do firl until ce;
4 firl:mr=mr+mx0 · my0(ss),
  mx0= dm(i2,m2),
  my0= pm(i7,m7);
5 mr=mr+mx0*my0(rnd);
6 if mv sat mr;
```

Figure 33. Listing of a program for the design of a non-recursive (FIR) filter.

case of a stereo signal. This means that an FIR filter for stereo signals can have a maximum of 10/0.03 = 333 delay elements, that is, $N \leq 333$. This makes it clear that even modern DSPs are not capable of executing a number of long filters simultaneously. This is why in DSP developments, the aim is at all times to use low sampling rates and simple filters. An alternative is the use of an IIR filter instead of an FIR type, but often this cannot meet the specific requirements of the phase response.

FILTERED NOISE

As a final experiment with filters, we will design a simple narrow-band band-pass filter, use this to filter noise and analyse the WAV file so produced on a spectrum analyser. When you listen to this file, you will notice that although the signal can be heard, it can be over a narrow frequency range only. File XFILDES3.SPP provides a suitable band-pass filter about 300 Hz wide with a centre frequency of 1150 Hz.

BUTTERWORTH FILTER

Once you have started designing an FIR filter as just described with steep skirts and narrow pass band, you will notice how tedious and numerous the calculations are.

For low-pass filters, it is best to use the program BUTTER1.PAS, which enables the simulation of steep-skirted IIR filters that are appreciable faster than similar steep-skirted FIR filters. The steepness of the skirts is determined by the filter order (which must be an even number). The second parameter is the cut-off frequency. The frequency responses produced by file XBUTTER2.SPP for a cut-off frequency of 800 Hz, a sampling rate of 11,025 samples/sec and filter orders of 2, 4, 8 and 12 are shown in **Figure 34**. The response is flat up to the cut-off frequency and shows no overshoots, but the attenuation increases in proportion with the filter order. The step response for orders 2, 4 and 8 produced by XBUT-

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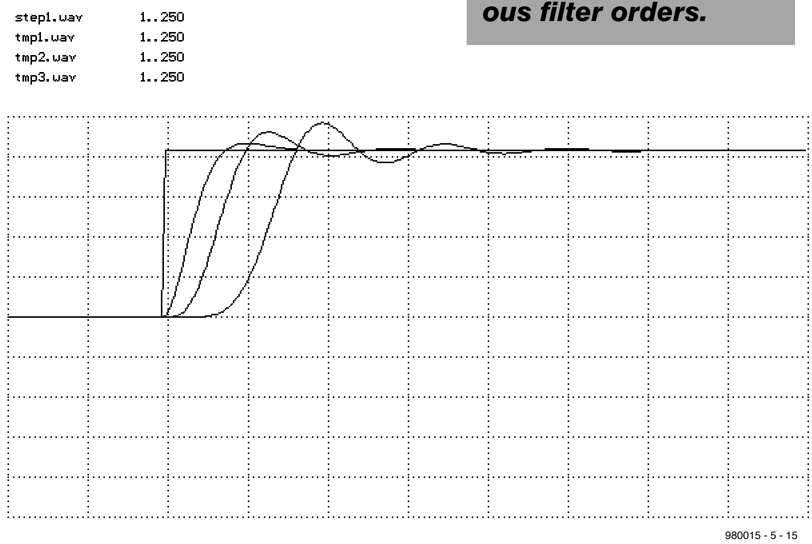

Figure 35. Step response with various filter orders.

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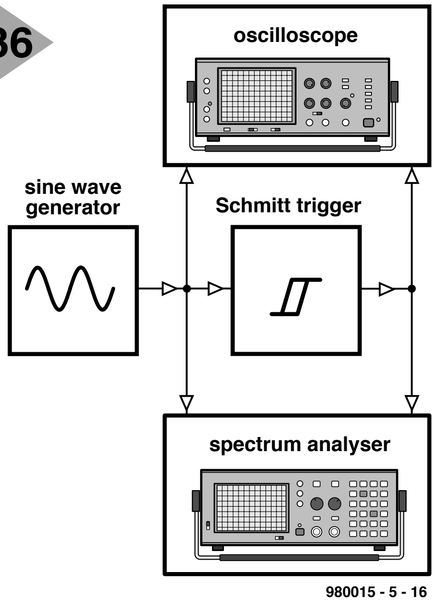

Figure 36. A Schmitt trigger generates a rectangular signal.

Figure 37. Spectra of the sinusoidal and rectangular signals.

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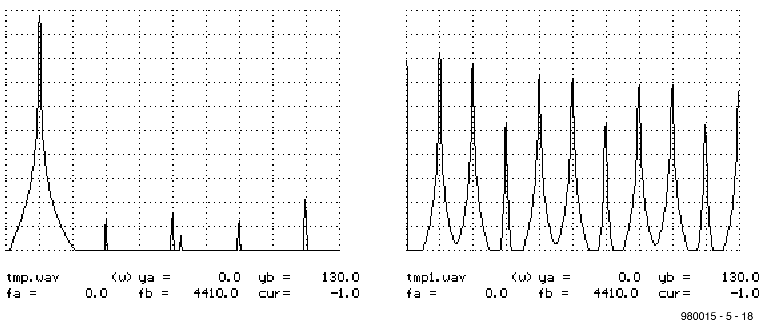

TER1.SPP is shown in **Figure 35**. Note that the amplitude of the overshoots increases with rising filter order to the same extent as the response time.

Other types of filter, such as Chebishev and Butler, encountered in analogue filter designs, are also available in digital filter design. Unfortunately, owing to space considerations, these cannot be discussed here: the reader is referred to the references at the end of this instalment.

PERIODIC SIGNALS

When periodic signals are viewed on a spectrum analyser, it will be noticed that they contain frequency components only at frequencies that are a whole multiple of the fundamental frequency. This is in accordance with the mathematical axiom that a periodic signal is composed of a fundamental frequency and a number of harmonics. Let us carry out an experiment with a setup as shown in **Figure 36**. In this, a Schmitt trigger (SCHMITT.EXE) produces from a sinusoidal signal a rectangular one whose spectrum is shown in **Figure 37** (experiment XFOUR1. SPP). All frequencies contained in the rectangular signal are derived from the sinusoidal frequency. The frequency content of a periodic signal is determined by a Fourier analysis performed by a spectrum analyser.

FOURIER SYNTHESIS

The menu contains a program that computes the relevant signal from a list of frequency components (frequency, amplitude, and phase). For example, for a square-wave signal (duty factor is 1:1), the following table correlates the number of the harmonics (first column) with their constituent value (second column):

1	10	(=10/1)
3	3.3333	(=10/3)
5	2	(=10/5)
7	1.428	(=10/7)
9	1.111	(=10/9)
11	0.9090	(=10/11)
13	0.7692	(=10/13)
15	0.6666	(=10/15)

The result of the Fourier analysis, in which a number of different harmonics are included, is shown in **Figure 38**. The corresponding experiment is carried out by file XFOUR2.SPP.

A HEARING TEST

Experiment XFMSYN2.SPP generates signals TMP1.WAV and TMP2.WAV, which have the same frequency components but with different amplitude. The oscillogram in **Figure 39** shows the significant effect of the phase relations of the frequency components. The first signal has a virtually constant amplitude. During a hearing test, weak frequency modulation may be detected. However, when listening to signal TMP2.WAV a strong amplitude modulation will be discerned. Signal TMP1.WAV is a VHF/FM signal reduced by weak signal components. It has a linear spectrum, but is symmetrical with respect to a given frequency. Thus, we can no longer speak of a fundamental frequency with harmonics.

MODULATION PROCESSES

Digital signal processing is also used more and more frequently in radio receiver technology. For instance, mobile telephones invariably use complex modulation processes. An overview of several modulation and demodulation processes is therefore instructive. Although these processes are in the main classical, the overview gives an interesting picture of the relation between spectra of various signals.

SOURCE MATERIAL

To keep the course as practical as possible, we will use readily available data whenever possible. Signals WD1L.WAV

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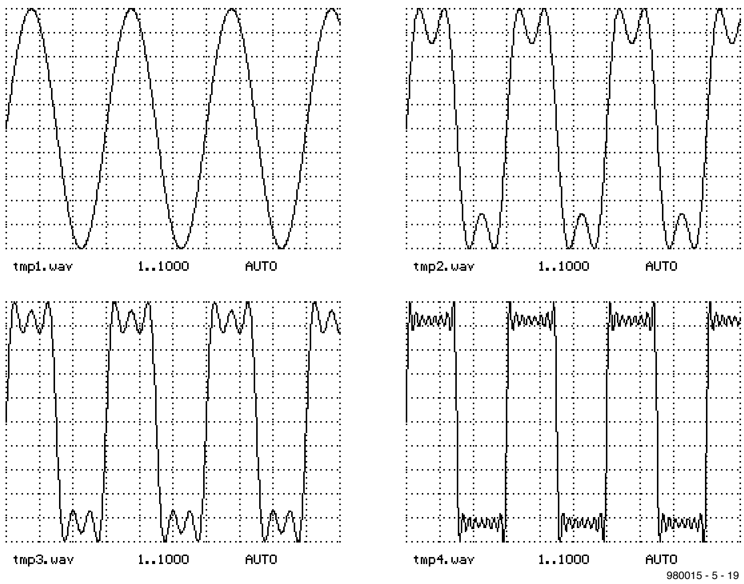

Figure 38. Fourier analysis of a rectangular signal with many harmonics.

Figure 39. Signals with equal amplitude but with different phase spectra.

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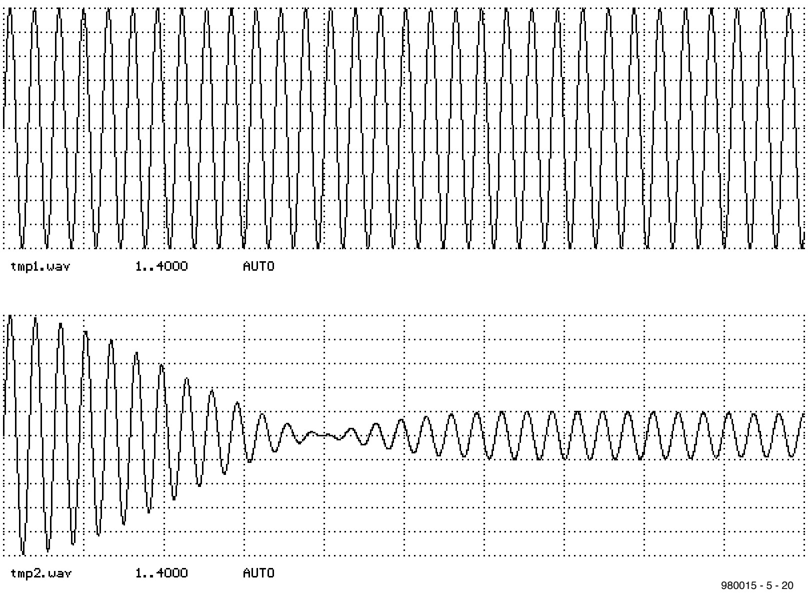

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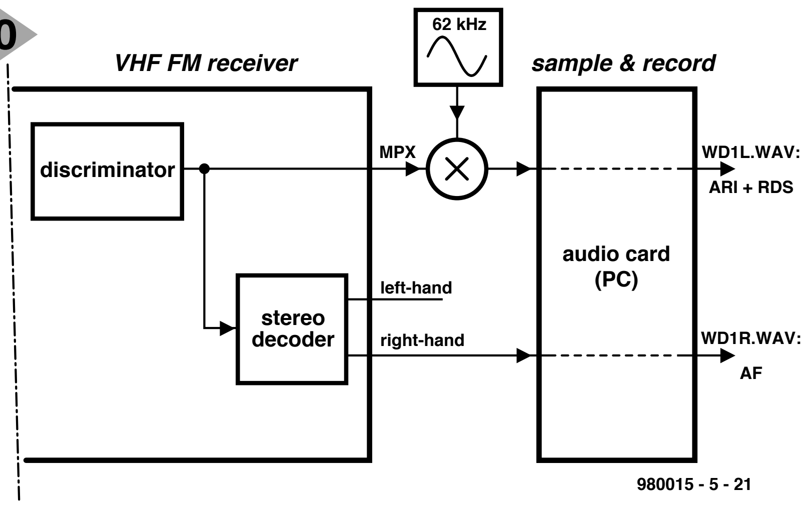

and WD1R.WAV are obtained with the setup shown in **Figure 40**. In several countries, VHF transmitters emit an amplitude-modulated 57 kHz sub-carrier with traffic news (ARI*). At the same time, the sub-carrier transmits, with the aid of phase-shift keying (PSK) digital RDS signals. To be able to sample this signal, it is converted to 5 kHz±2kHz by mixing it with a 62 kHz oscillator signal. The resulting signal, which contains both amplitude modulation and digital phase modulation, is available in file WD1R.WAV.

BBC: AM AND PM

Amplitude modulation may be looked at more closely with the aid of the 198 kHz BBC broadcast transmissions. The carrier of this signal is mixed with a signal of 188 kHz, resulting in an output of 10 kHz (see **Figure 41**), which is readily sampled at 44.1 kHz. This enables amplitude modulation to be tested with a real audio example.

It is interesting to note that the same 198 kHz signal is also phase modulated to enable control data to be transmitted. This is also contained in the file BBC188.WAV.

AMPLITUDE MODULATION

In amplitude modulation, the modulating signal, $s(t)$, is superimposed onto the carrier frequency, f_c.($\omega_c = 2\pi f_c$). In case of a cosinusoidal carrier, the transmitted signal is

$$x(t) = [C+Ms(t)]\cos(\omega_c t),$$

where C is the carrier amplitude and M is the depth of modulation.

Normally, f_c is much greater than the frequencies in $s(t)$. The simulations in this course use relatively low carrier frequencies of about 10 kHz. This means that the modulating frequencies must lie in the low audio range.

In experiment XAM1.SPP in **Figure 42**, a sinusoidal carrier with a frequency of 2 kHz is modulated by a triangular signal at 150 Hz. The triangular signal, $s(t)$, is shown in **Figure 43** (left) with beside it the resulting amplitude-modulated waveform. The spectra of the triangular signal and the AM signal are shown in **Figure 44**. Note that in the AM spectrum at the left and right of the carrier spectral components (sidebands) of $s(t)$ occur. These may be explained by the equation of a cosinusoidal carrier modulated by signal $s(t)$:

Figure 40. Recording a radio signal containing ARI and RDS data. (ARI = Autofahrer Rundfunk Informationen = motorists' broadcast information; RDS = Radio Data System).

$$[C+M\cos(\omega_m t)]\cos(\omega_c t) = C\cos(\omega_c t) + M/2\cos[(\omega_c - \omega_M)\,t] + M/2\cos[(\omega_c + \omega_M)\,t].$$

This shows that the signal consists of three individual cosinusoidal signals: the carrier and two sidebands at a given distance from the carrier.

The modulating signal contains many cosinusoidal frequencies:

$$s(t) = a_0\cos(\omega_0 t) + a_1\cos(\omega_1 t) + a_2\cos(\omega_2 t) + \ldots$$

Each of the terms in this equation provides a spectral line to the left and right of the carrier. To enable AM signals to be investigated, the menu contains a program AMGEN1.EXE for the generation of AM signals with which the various experiments may be carried out.

[980015-5]

References

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

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Notice

Before starting to use the programs, copy the entire folder 'Espresso' from the CD-ROM to the hard disk. The programs may then be run from the hard disk. This procedure is also explained in the 'readme' file on the CD-ROM.

When copying a file or folder under Windows, its read-only setting is also copied. With many Espresso programs, the read-only attribute causes an error report to be displayed, or graphics to disappear. This problem is solved by using the Explorer, selecting all files in the Espresso folder on the hard disk and then clicking on File – Properties. Remove the check mark in the 'read only' square by clicking on it. Close the program by pressing OK after which everything should function correctly.

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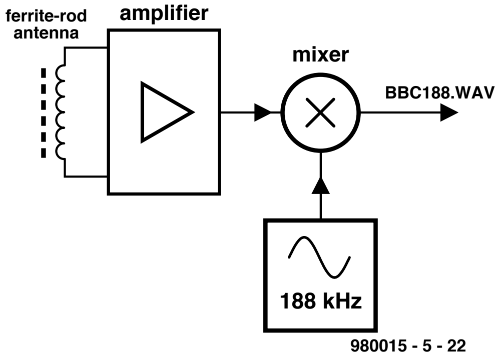

Figure 41. Set-up for generating an AM signal.

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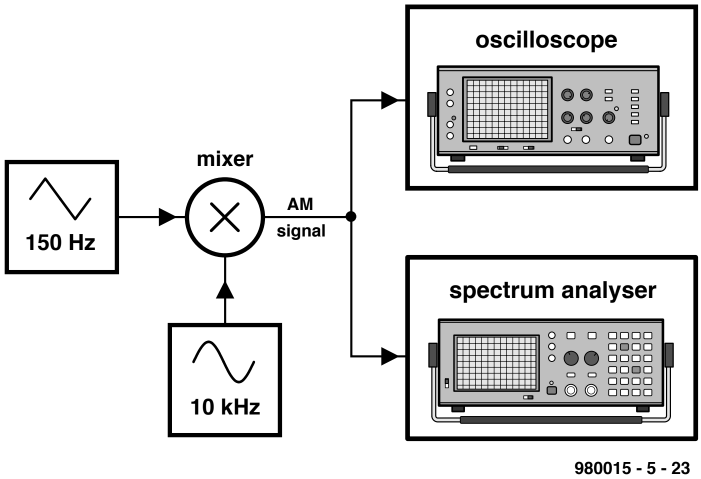

Figure 42. Recording an AM broadcast signal.

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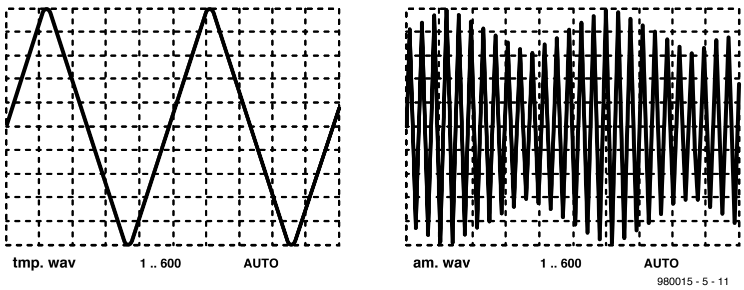

Figure 43. Modulating signal (left) and AM signal (right).

Figure 44. Spectrum of the modulating signal (left) and AM signal (right).

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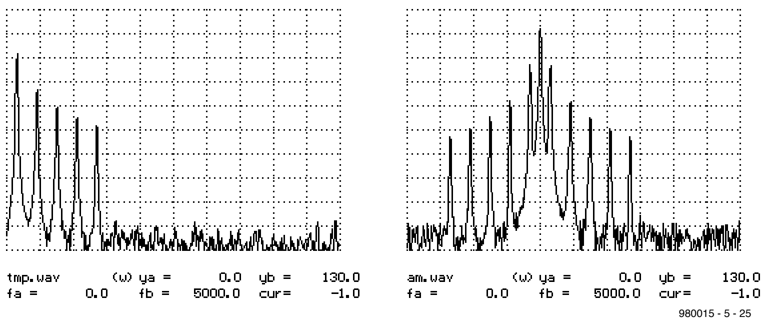
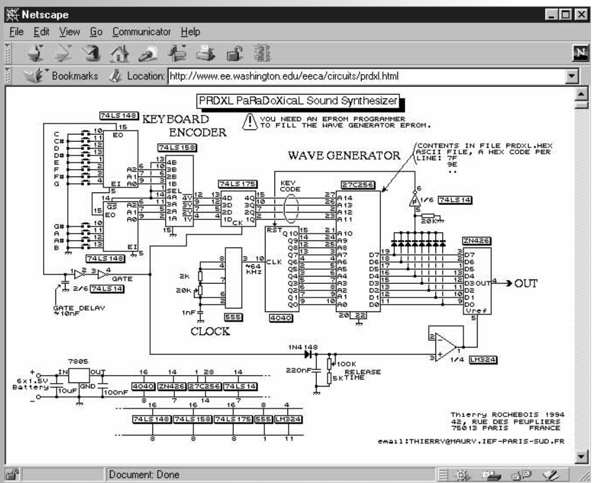
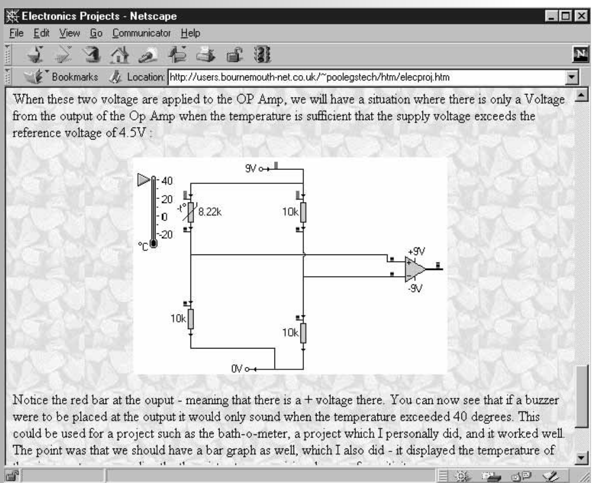
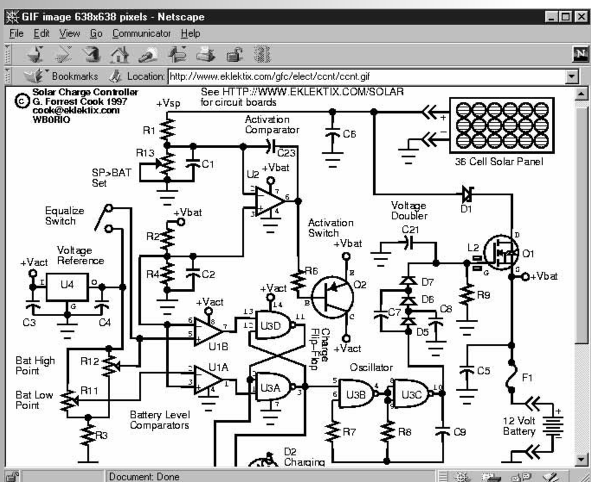


design-hunting

If you are looking for a circuit diagram for a specific application, there is a fair chance that you can find it on the Internet. Hobbyists, technical colleges and universities are just a few sources of that elusive circuit diagram, and, if you are lucky, a complete description to go with it.







What was it again you were looking for? A small motor control circuit or a solar-powered battery charger? Of course, *Elektor Electronics* magazine, our books and CD-ROMs are the best and largest source you'll want to turn to for help, using the invaluable help of our **Item Tracer** on diskette. And yet, there are subjects that have not been covered by Elektor, or you may be looking for a slightly different approach to the project you are working on. In those cases, the Internet can be very useful, because it has a vast number of subjects in store which are offered free of charge to interested readers or aspiring constructors.

Broadly speaking, the sites holding electronics circuit diagrams (also called schematics) may be divided into two classes: educational on the one hand, and hobby-oriented, on the other. Especially on servers at technical colleges and universities vast amounts of electronic circuit diagrams may be found. We launched our browser and paid a visit to some of these sites.

The **Circuit Cookbook Archive** at the university of Alberta *(ftp.ee.ualberta.ca/pub/cookbook/index.html)* contains a respectable number of subjects in various fields, including audio, computers, RF, software as well as Spice files. This is definitely a source that has a lot to offer.

The **Circuits Archive** at Washington University's server (*www.ee.washington.edu/eeca/circuits*) also holds a number of interesting circuit diagrams like a paradoxical sound synthesizer and an RF sniffer (see for yourself what this is all about).

Then there is the technical department of the **Poole Grammar School** which runs a site showing beautifully designed Internet pages (*users.bournemouth.net.co.uk/~poolegstech/htm/circuits.htm*). Although you may find just a couple of circuit diagrams at this site, there are extensive descriptions to go with them, and the pages have an attractive layout. This site is certainly worth a visit!

Private individuals, too, show their circuit diagrams on the web, often using links to other sites containing circuits.

Tomi Engdahl's Electronics Info Page at ***www.hut.fi/Misc/Electronics*** is very extensive. Here you are sure to find diagrams for a wide variety of applications, as well as addresses of electronic-part manufacturers, and even information on subjects like EMC or GPS.

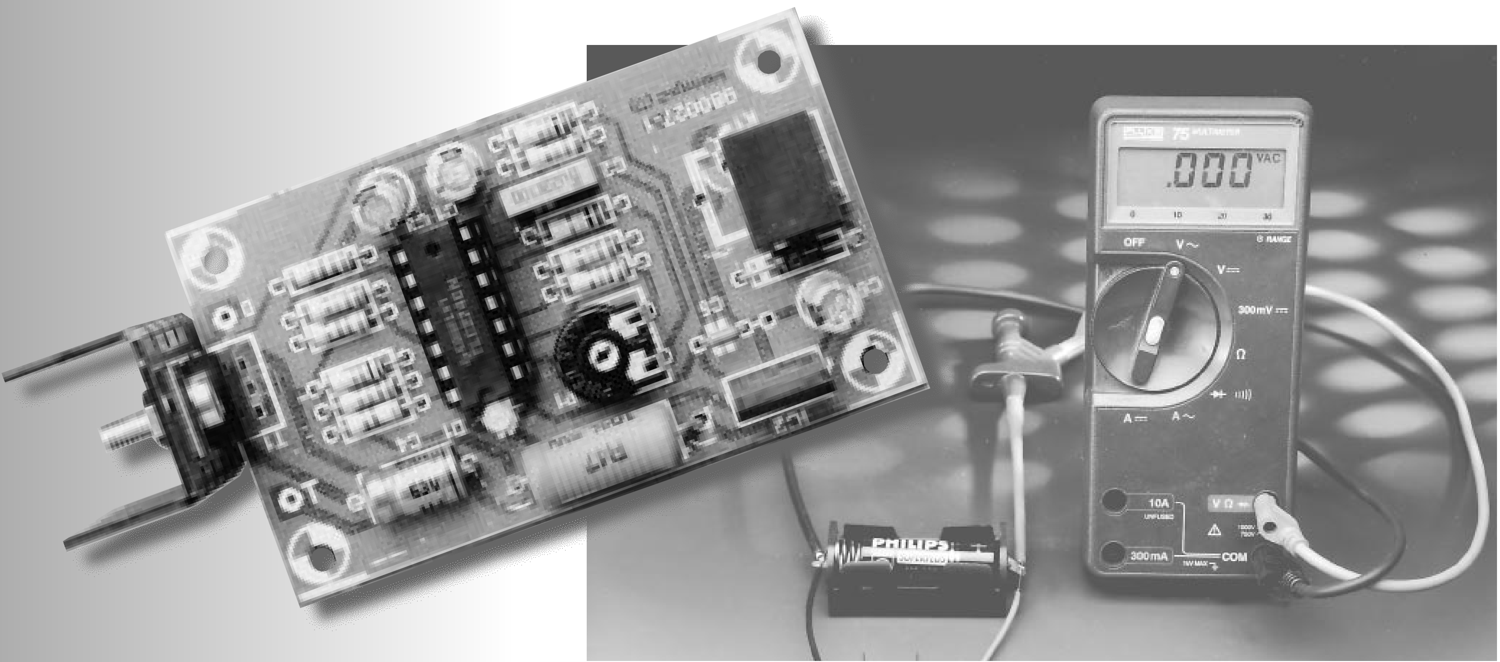
The **Electronics Page** at *www.world-net.net/~muldowne/schems.html* also offers an impressive collection of circuit diagrams for power supplies, RF, audio/video, etc.

Other addresses you may want to turn to for interesting schematics are, among others, **Circuit Land** (*www.uoguelph.ca/~antoon/circ/circuits*), **Electronic Schematics** (*www.web-span.com/pjohnson/schematics.htm*), **FC's Electronic Circuits** (*www.eklektix.com/gfc/elect/*) and **Dr. Bob's Electronics Resource** (*www.drbob.net/*). Note, however, that the references on these pages often point to one and the same circuit diagram, and that many designs are simply copied from databooks. None the less, there's lots of interesting stuff out there, just waiting to be discovered.

(985037-2)

battery-resistance meter

for all kinds of battery



A measurement of the e.m.f. of a battery (dry or rechargeable) does not say anything about the condition of the battery or its constituent cells. To obtain a useful indication of that condition it is necessary to measure the battery voltage under load. The circuit described in this article allows this to be done readily, and goes even further since it enables the extent to which the battery is able to follow rapid changes in the load to be monitored.

Design by K A Walraven

Both dry and rechargeable batteries retain their e.m.f. more or less unchanged over about three quarters of their useful life (dry) or charge/discharge cycle (rechargeable). However, a useful indication of the residual capacity or state of charge can be obtained only when a current is drawn from the battery by a load. If then the terminal voltage changes little, it may be assumed that the battery is in reasonable condition. If, however, it drops appreciably, the battery is very nearly flat or near the end of its life.

In the case of a rechargeable battery, an even better indication of its condition is obtained when it is first fully charged and then discharged at a well defined current. The product of the time taken for the battery to become discharged and the discharge current gives an accurate indication of the capacity of the battery.

Tests like these are useful when the

battery is used for normal applications that draw normal currents. Unfortunately, this is not true for a number of applications; electronic flash devices, for instance, draw fairly large currents. And they are not the only ones.

Many batteries, such as dry alkaline manganese and rechargeable metal hydride types, cannot handle large discharge currents. Nickel-cadmium batteries can, provided they are in good condition. The reason for this different behaviour lies in the internal resistance of the battery. That of a Ni-Cd battery in mint condition is very low, whereas that of an alkaline manganese type is high, as is that of a nearly discharged Ni-Cd type.

The present circuit serves to measure the internal resistance of a battery. It does so by monitoring how well the battery is able to follow rapid variations in the discharge current. This does not give an accurate indication of the capacity of the battery, but it does give a good idea of the condition and quality of the tested battery.

TEST METHOD

A test with a large, constant discharge current does not suffice to get an idea of the quality of the battery, since it does not show how the battery reacts to variations in the load current. It is only when the terminal voltage of the battery is measured under rapidly varying load current conditions that a good picture will emerge of how the battery reacts. The way to do this is to test a new battery (or one of proven good quality) and note the measurement results. Test results on other, probably older, batteries can be compared with those of the new battery from which clear conclusions may be drawn.

The terminal voltage is measured with a common or garden digital multimeter. The varying load is provided by the present circuit. The load current consists of two parts: a 1 A direct current and a 100 mA alternating current. The frequency of the alternating current is 50 Hz, since both the battery and the multimeter can handle this without any problem.

The internal resistance is calculated by simply multiplying the meter reading (with the multimeter in the relevant a.c. range across the battery terminals) ×10.

CIRCUIT DESCRIPTION

The circuit in **Figure 1** consists of two parts: a current source via which the battery is discharged and a generator that controls the current source.

The generator is based on operational amplifiers IC_{1a} and IC_{1b}. Since only the amplitude of the generator output is of essence, and not its shape, the oscillator is a straightforward triangular type. The output voltage may be set, within certain limits, with P_1. The triangular-shaped voltage at the output of IC_{1b} is shaped by low-pass filter R_6-C_3 into roughly a sine wave.

1

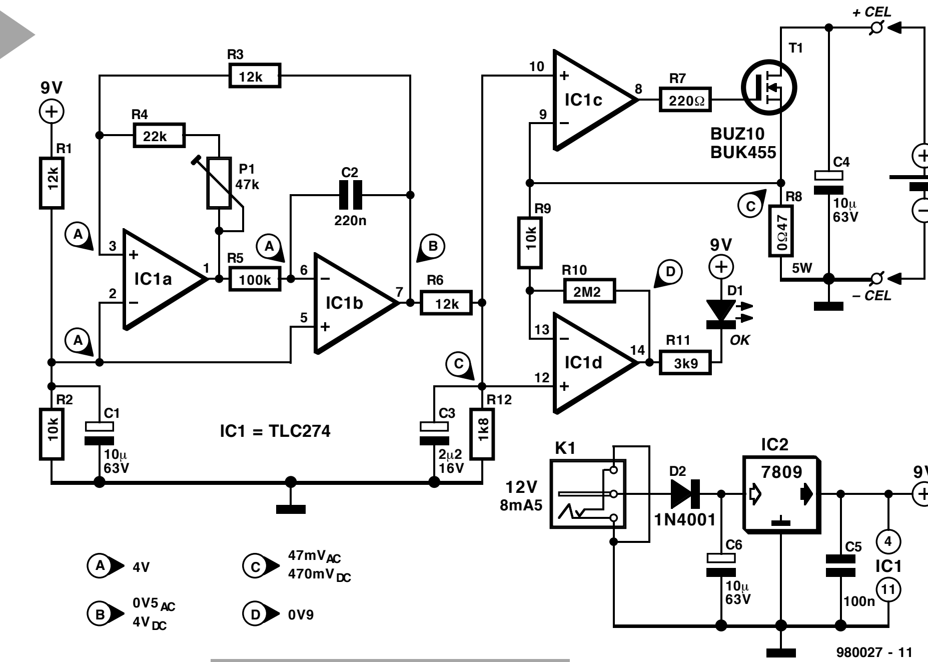


Figure 1. The circuit consists of two main sections: an alternating-voltage generator (IC_{1a} and IC_{1b}) and a current source (IC_{1c} and T_1).

The near-sinusoidal voltage is superimposed on to a direct voltage. This is done by linking the –ve input of IC_{1a} and the + ve input of IC_{1b} to the junction of R_1 and R_2 instead of to earth as is usual. The voltage at the junction is about + 4 V.

Potential divider R_6-R_{12} reduces the generator output to a direct voltage of about 47 mV with superimposed on it an alternating voltage of 47 mV. This complex signal is applied to current source IC_{1c}-T_1. The battery, connected to terminals + bat and –bat, is discharged via the drain-source junction of transistor T_1 and resistor R_8 in the rhythm of the generator signal that drives the gate via op amp IC_{1c}. The potential at the + ve input (pin 10) of IC_{1c} is equal to the voltage across R_8, so that a direct current of 1A and a pulsating one of 100 mA is drawn from the battery. Capacitor C_4 improves the stability of the current source and suppresses any oscillations.

The circuit based on IC_{1d} is a simple indicator network that prevents any measurement errors. Note that diode D_1 lights only when the voltages at pins 13 and 14 of IC_{1d} are equal or very nearly so. At the onset of the measurement, it should be ascertained that this diode lights to prevent a flat battery being confused with one with a low internal resistance. In case of a flat battery, the current is small, so that the potential at pin 13 is low. The output of the op amp is then high, so that the voltages at pins 13 and 14 are not equal and the diode does not light.

Power for the circuit is provided by a standard 12 V mains adaptor connected to K_1. The current drawn from the adaptor remains small: about 8.5 mA. Voltage regulator IC_2 converts the adaptor output into a stable 9 V direct voltage. Diode D_2 prevents any mishaps if the mains adaptor were connected with wrong polarity.

CONSTRUCTION AND CALIBRATION

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

It makes sense to start with building the power supply and checking that the potential across C_5 is 9 V. Next, complete the circuits around IC_{1a} and IC_{1b}, set P_1 to its centre position and verify with a multimeter or oscilloscope that the voltages at various points are in line with those specified on the circuit diagram. Make sure that the meter is set to the correct range (a.c. or d.c.) for each measurement and, if an oscilloscope is used, bear in mind that 470 mV rms has a peak-to-peak value 2.8 times larger.

Build the remainder of the circuit and connect a 1.5 V battery to the bat terminals, whereupon D_1 should light. If it does not, there flows insufficient current through R_8, which means that the entire current source should be inspected thoroughly.

Connect the multimeter, set to the

2

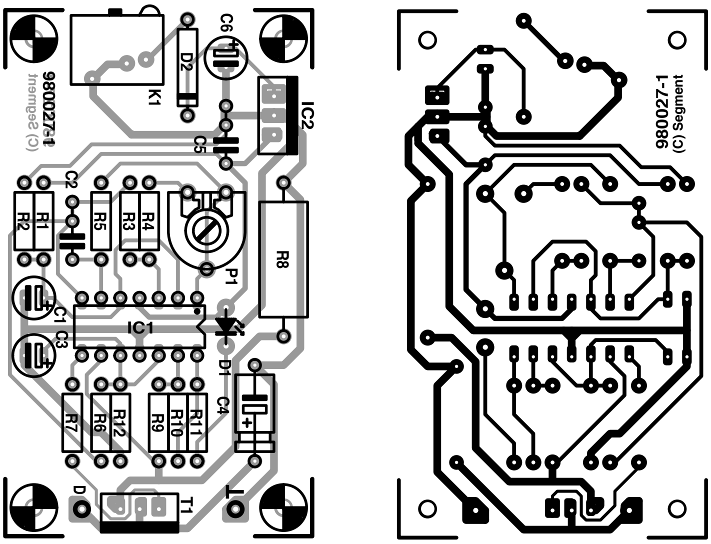


Figure 2. The printed-circuit board guarantees construction without problems.

relevant a.c. range, across R_8 and adjust P_1 for a reading of 47 mV, that is, 1/10 of the resistance value. Set the meter to the relevant d.c. range and check the direct voltage across R_8, which should be about 500 mV. The exact value is not important.

Finally, measure the frequency of the alternating current. If all is well, this should be about 50 Hz, but again, this is not terribly important: 25 Hz or 100 Hz will do as well. Note that the frequency is affected by the position of P_1.

Although the internal resistance of a battery is measured quite quickly, transistor T_1 will not become unduly warm. Nevertheless, it it is advisable to mount it on a small heat sink.

Housing the meter in a suitable enclosure is a matter of personal preference which, in view of the modest dimensions of the board, will not prove too difficult.

Heavy-duty, insulated circuit wire (red for the + ve terminal and black for the –ve one) terminated in suitable clips should be used for connecting the battery to the meter.

A photograph of the completed impedance meter is shown in **Figure 3**.

USAGE

Connect a battery to the bat terminals, check that D_1 lights, and shunt the battery with a digital voltmeter or multimeter set to the appropriate a.c. range. The meter readings are best compared with those obtained with a battery known to be in mint condition. The value of the internal resistance in ohms is the value of the measured alternating voltage in volts divided by 10.

The meter may also be used to determine the contact resistance of battery holders and connecting leads. Contact resistances adversely affect the performance of a battery. First, measure directly on the battery, then on the terminals of the battery holder, and finally at the far end of the connecting wires. This will show quickly where the largest losses occur.

[980027]

Parts list

Resistors:
R_1, R_3, R_6 = 12 kΩ
R_2, R_9 = 10 kΩ
R_4 = 22 kΩ
R_5 = 100 kΩ
R_7 = 220 Ω
R_8 = 0.47 Ω, 5 W
R_{10} = 2.2 MΩ
R_{11} = 3.9 kΩ
R_{12} = 1.8 kΩ
P_1 = 47 kΩ preset potentiometer

Capacitors:
C_1, C_6 = 10 µF, 63 V, radial
C_2 = 0.22 µF
C_3 = 2.2 µF, 16 V, radial
C_4 = 10 µF, 63 V
C_5 = 0.1 µF

Semiconductors:
D_1 = LED, low current
D_2 = 1N4001
T_1 = BUZ10 or BUK455

Integrated circuits:
IC_1 = TLC274
IC_2 = 7809

Miscellaneous:
K_1 = mains adaptor connector
Heat sink for T_1
Connecting cables (see text)

3

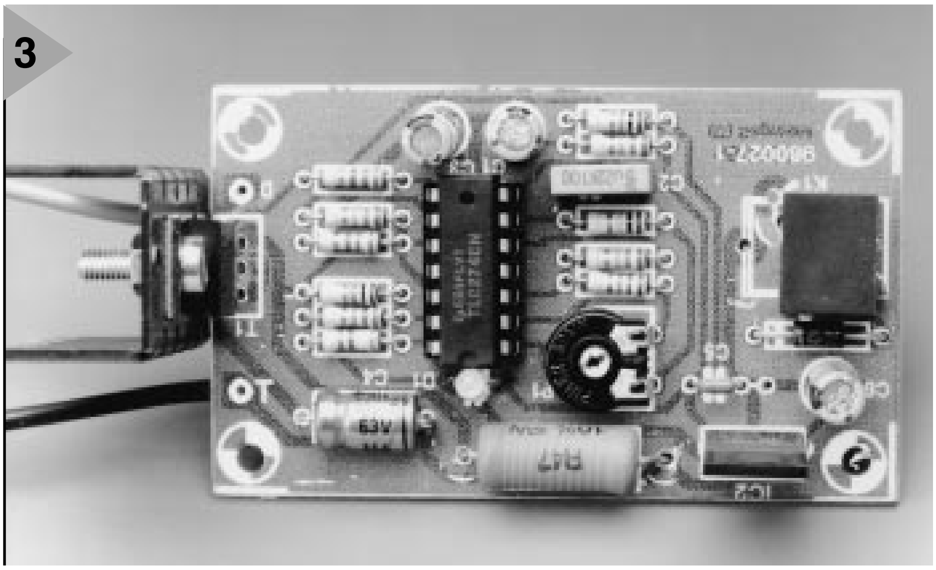


Figure 3. It is advisable to mount T_1 on a heat sink.

Fibre optic data communication

RS232 interface with fibre optic links

When in 1870 John Tyndall, an Irish physicist working in the USA, showed that light can be guided, he could not have foreseen that little over a century later an increasing proportion of the world's communications would be carried by fibre optic cables. Now, fibre optics finds application not only in vast telecommunication systems all over the world, but also in the home (hi-fi system, cable television). The RS232 interface presented in this article enables a computer to be connected to a variety of peripheral equipment via fibre optic cables.

Brief specification

Carrier	*fibre optic cable*
Input levels	*CMOS, TTL or RS232*
Output level	*RS232*
Supply line	*5 V regulated*
Current drain (each interface)	*45 mA*
Maximum data rate	*115,200 symbols*
Interface connectors	*sub-D 25*
Number of fibre optic cables	*2*
Maximum length of cables	*2–3 metres*

Design by T. Giesberts

The serial interface is used to connect a host of peripheral equipment to a computer and enables relatively large distances to be bridged. The RS232 interface described in this article is connected to the serial port of a computer and provides, apart from the well-known advantages, the further benefit of electrical isolation through the use of fibre optic cables.

Depending on the control system in use (no handshaking via hardware signals, but via the X_{ON}/X_{OFF} protocol) serial links enable a duplex connection to be established with only three electrical signals. If use is made of light signals, only two channels are required for data communication, and this is the basis of the present article.

Each of the data channels, TxD and RxD, requires its own dedicated fibre optic cable, which ensures complete electrical isolation between two computers or between a computer and a peripheral unit.

The arrangement entails for all electrical handshake signals (RTS, CTS, DTR,

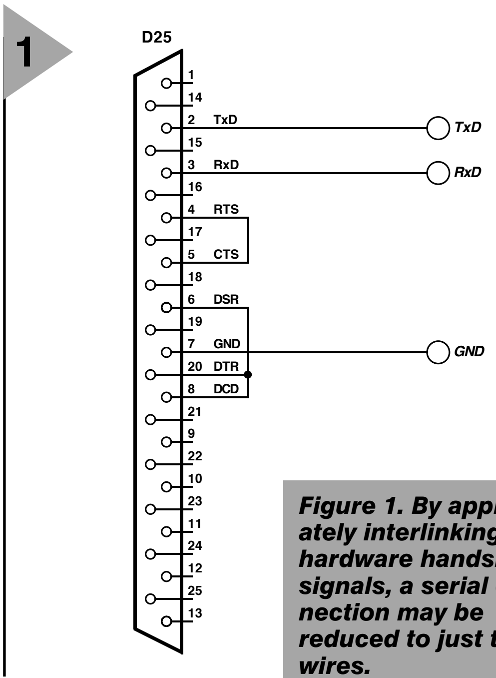


Figure 1. By appropriately interlinking the hardware handshake signals, a serial connection may be reduced to just three wires.

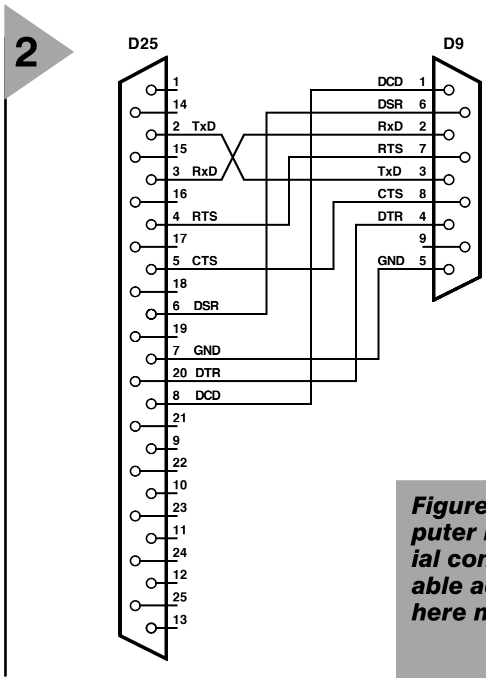


Figure 2. If the computer has a 9-way serial connector, a suitable adaptor as shown here must be used.

DSR and DCD) to be intercepted by the interface, which is effected by links on the connectors. It also requires a suitable software protocol to be chosen.

Figure 1 shows how a practical, serial X_{on}/X_{OFF} communication may be established. If the computer is equipped with a 9-way connector instead of a 25-way one (on which the present circuit is based), a simple adaptor must be used. **Figure 2** shows how a suitable one may be fabricated.

SIMPLICITY IS THE WORD

Not only is the design of the interface straightforward, but the optical parts of the circuit have also been kept fairly simple. This has resulted in a communication system without special coding techniques, which means that each data channel needs its own fibre optic carrier. It would have been possible to use only one fibre optic cable, but this requires a complex method of modulation, which in the present circuit was not felt justified. Also, the additional cost of a suitable modem (modulator/demodulator) would be well in excess of the cost saving on one fibre optic cable.

In spite of its simplicity, the interface may be used with virtually any serial connection. On the basis of relevant manufacturer's specifications, the interface may be used even with the highest current bitrate of 115,200 symbols*.

THE DESIGN

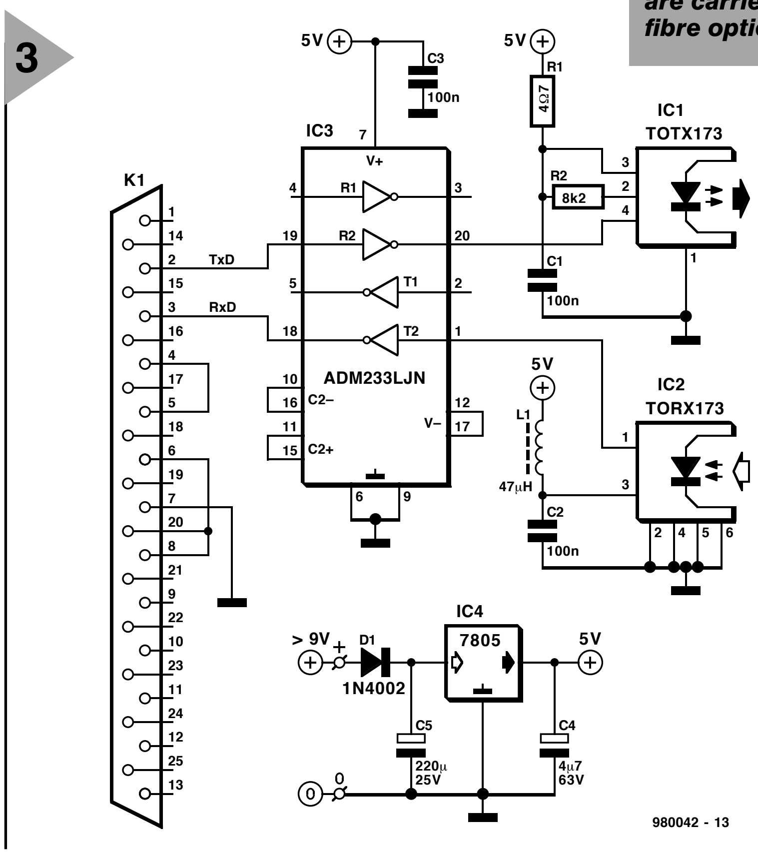
The circuit diagram of the interface is shown in **Figure 3**. Signals RTS and CTS and DTS, DSR, and DCD, are interlinked on connector K_1. This arrangement disables the entire hardware handshaking procedure. All that remains are data signals RxD (pin 3) and TxD (pin 2), and these signals are applied directly to IC_3.

Integrated circuit IC_3 contains two RS232 drivers, two RS232 receivers, and an integral voltage converter. The converter enables the interface to work from a 5 V supply line.

While IC_3 arranges the conversion of RS232 levels to TTL levels, IC_1 and IC_2 arrange the transformation from TTL signals to optical signals and vice versa respectively.

Circuits IC_1 and IC_2 are well known in the audio world, since they are normally used in digital audio equipment fitted with optical connectors. They are coupled to filters that suppress any r.f. signals, which

Figure 3. The design of the interface is straightforward. Serial signals TxD and RxD are carried by separate fibre optic cables.



* *In modern data communications, the symbol is now commonly used to replace the baud as the unit of transmission rate. Like the baud, a symbol may (and frequently does) represent more than one data bit.*

Parts list

Resistors:
R_1 = 4.7 Ω
R_2 = 8.2 kΩ

Capacitors:
C_1–C_3 = 0.1 µF, ceramic
C_4 = 4.7 µF, 63 V, radial
C_5 = 220 µF, 25 V, radial

Inductors:
L_1 = 47 µH

Semiconductors:
D_1 = 1N4002

Integrated circuits:
IC_1 = TOTX713 (Toshiba)
IC_2 = TORX173 (Toshiba)
IC_3 = ADM233LJN (Analog Devices) or MAX233 (Maxim)
IC_4 = 7805

Miscellaneous:
K_1 = 25-way female D-connector, right-angled, for board mounting
PCB Order no. 980042 (see Readers Services towards the end of this issue)

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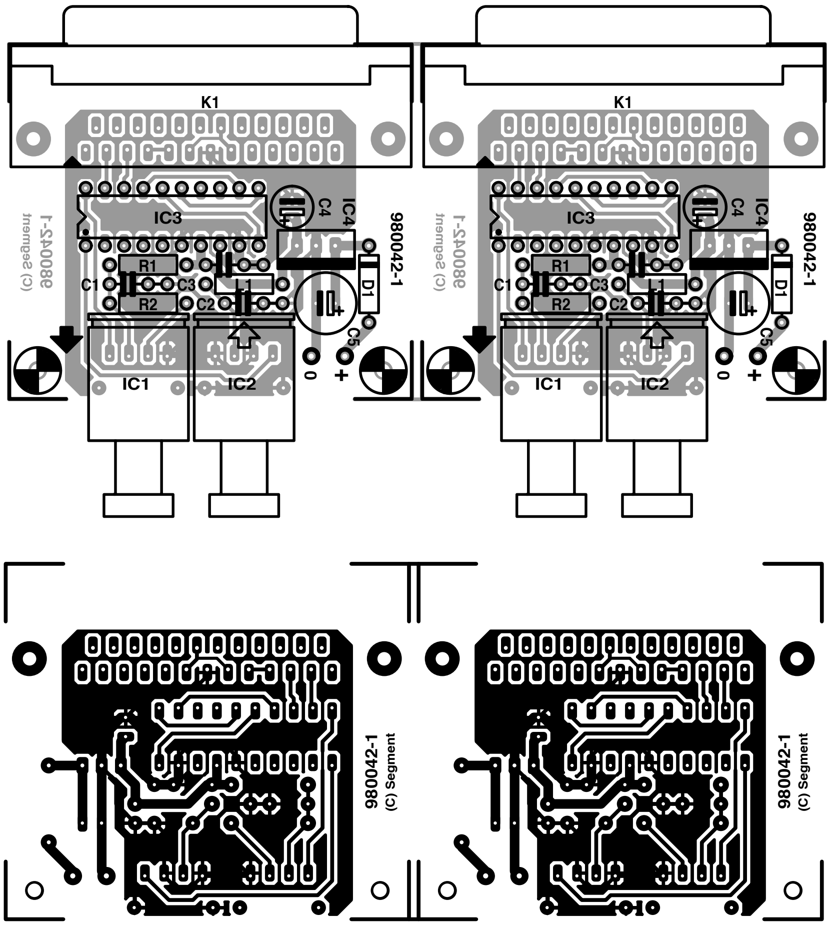
Figure 4. The printed-circuit board for the two interfaces must be cut into two before any work is started.



might mutilate the data.

The optical link and the fibre optic cables to be used are readily available since they are identical to those used in good-quality audio equipment.

Since the interface draws a relatively high current (about 45 mA), it has been provided with a dedicated power supply. This is fed by a 12 V mains adaptor, and consists of capacitors C_4 and C_5, diode D_1, and voltage regulator IC_4. Diode D_1 merely protects the supply against polarity reversal.

CONSTRUCTION

The interface is best built on the printed-circuit board shown in **Figure 4**, but before any construction is started, the board must be cut into two as indicated. The resulting two identical boards enable a complete fibre optic link between two computers or between a computer an a peripheral unit to be established.

Except for IC_3, all components are to be soldered directly on to the relevant board. Mind the polarity of the diode and the electrolytic capacitors. Also, take care not to confuse IC_1 with IC_2 and vice versa. Although these devices look very similar, they are not interchangeable!

Before soldering the pins of K_1, the connector should be fastened on the board with two screws, nuts and washers. This procedure prevents any undue mechanical stresses.

When all soldering has been completed, the interfaces are ready for use. Connect them, together with the fibre optic cables in a serial link and select the correct protocol for both the driver and the receiver (X_{ON}/X_{OFF}).

Note that each interface needs its own power supply, that is, two mains adaptors are needed. Since each interface draws a current of about 45 mA at an input voltage of 9–12 V, it may be possible to derive power from the 12 V supply in the computer.

Switch on the supply to the interfaces. If all is well, the serial link will work as before, but the electrical connection has successfully been replaced by an optical one.

[980042]

Figure 5. Photograph of the completed prototype. The fibre optic cables enable communication at a data transmission rate of 115,200 symbols.

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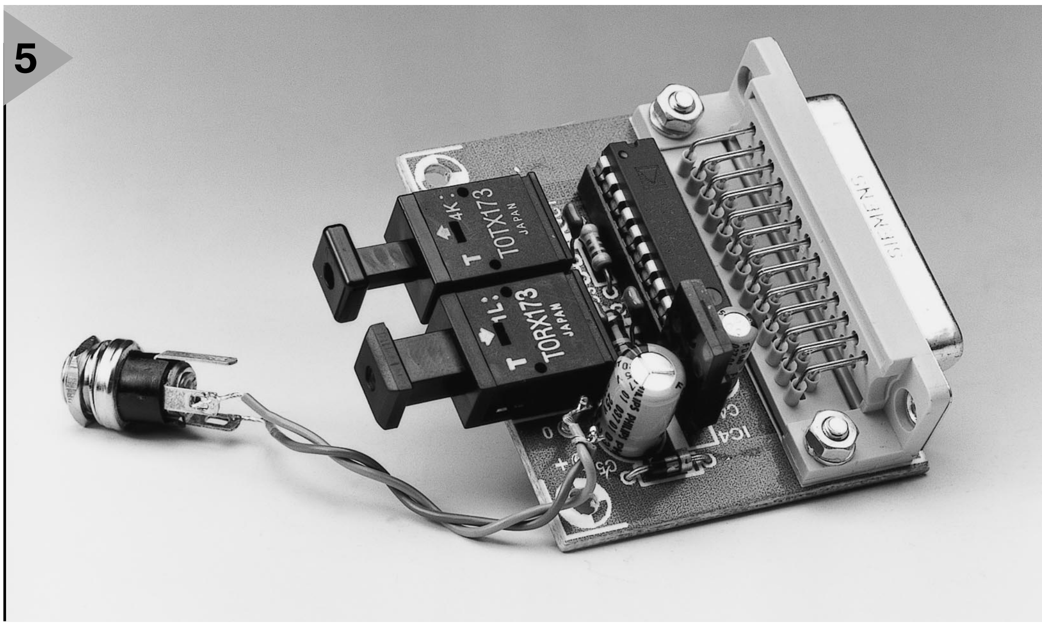


PICXEX

an operating system for PIC16C7x processors

Today most electronic enthusiasts realise that software-based control circuits offer certain advantages over their hard-wired counterparts, but…

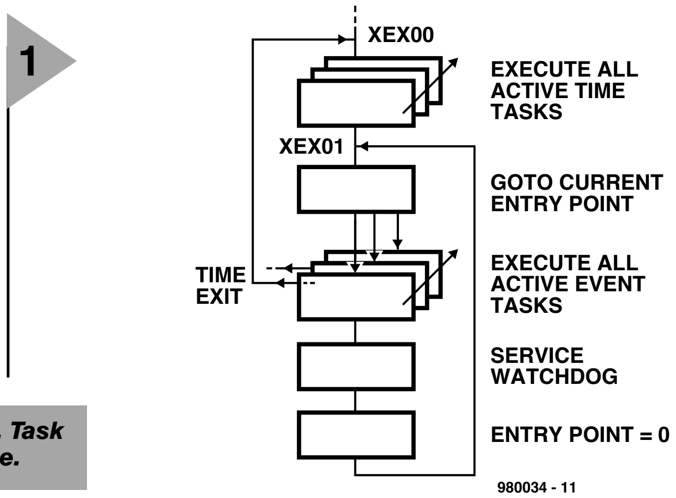


Figure 1. Task Executive.

for me the big question was how to progress from that first piece of software that flashed an LED (my wife could not understand the euphoria) to that 'real' application I always wanted to implement on a microcontroller.

After a lot of code writing, debugging and (re)burning of chips the system was doing more or less what it was intended to do, but I was beginning to have doubts about ease-of-use of software-based systems. Still, the idea of using software appealed to me and it was back to the drawing board.

Why an operating system?

It is a well known fact that one of the most successful methods of system design is to break the problem down into smaller, simpler, tasks. These parts or tasks must now be coded, keeping in mind that to function as a system their execution must be co-ordinated. Some must be executed at predetermined intervals, others at a particular event or state, and the rest at a rate fast enough to give real-time results. In most microcontroller applications, considerable programming effort is spent on the code that controls/regulates the execution of the code that makes up the actual application. Sometimes these two code types are so interlocked that no clear borders exist. This situation complicates debugging in all but the very small software applications. PICXEX is an effort to solve this problem. Despite its simplicity and size it turned out to be an enabling-tool for those 'real' micro controller applications.

With hardware borrowed from a friend and lots of encouragement from the same gentleman, PICXEX was implemented on a PIC16C73 from Microchip using their MPASM assembler and MPSIM simulator. The code uses about 140 program locations, 4 registers and you loose one level of the stack. PICXEX is simplicity itself and the idea can be applied to other microcontrollers with ease. If you have an existing assembly language based application using any of the PIC16C7x range you can probably apply PICXEX to your code without major software surgery.

By L. Legrange

Under the hood of PICXEX

The basic idea is that you have 16 CALL instructions, each associated with a bit (flag). If a flag is set then its CALL instruction is executed, otherwise it is skipped. This provides a mechanism to selectively execute the 16 subroutines referred to as "tasks". The flags of 8 of the tasks, called the Event-Tasks, are set/reset by any of your code. So you can activate and deactivate Event tasks if and when required. The flag bits associated with the other 8 tasks, the Time-Tasks, are set by a scheduler routine at time-intervals you select, and thus we have Time-Tasks that are being executed at regular time intervals.

PICXEX consists of two sections, the Task-Executive and the Time-Task Scheduler.

Task Executive

Figure 1 is a flowchart of the Task Executive. In the first section all Time-Tasks with their flag bits set are executed. If the Scheduler sets the flag for a particular Time-Task every 20 ms. the Task Executive will oblige and execute that task on average every 20 ms.

Event-Tasks are executed in a similar

way. Flags of Event-Tasks are manipulated by any application code, i.e., other tasks, interrupt service routines, etc. by using the macro's XEX_ON_EVENT and XEX_OFF_EVENT.

Time-Task Scheduler

The Scheduler is in the form of a subroutine that must be called at regular intervals from a timer interrupt service routine. Every time this routine (SCHED00) is executed it takes the next entry from a 'circular' lookup table and loads (actually logic ORs) this 'mask' into the register that holds the activation flag bits for the 8 Time-Tasks. See **Figure 2** for a functional diagram of the Scheduler. If we provide for 20 entries in the Scheduler lookup table, and arrange to execute the Scheduler every 10 ms., then every 10 ms another 'mask' will be loaded into the register holding the eight Time-Task flags. So by setting bit 0 in each of the 20 masks Time-Task number 1 will be executed every 10 ms, or if bit 0 is set in every alternative mask, then Time Task number 1 will be executed every 20 ms, etc. With a 20-mask table, and if you call SCHED00 every 10 ms you can select any of the following execution periods for individual Time-Tasks by setting the appropriate bits in the masks:

10, 20, 40, 50, 100, or 200 ms.

A good idea is to 'spread' your bits. If you want to execute more than one task at, say, 40 ms, then do not set their associated flag. bits in the same masks. This way you can even-out your processor load.

Using PICXEX, the basics

As PICXEX is not part of your application code it is straightforward to apply.

Make your application tasks in the form of subroutines. The subroutine names are also the task names.

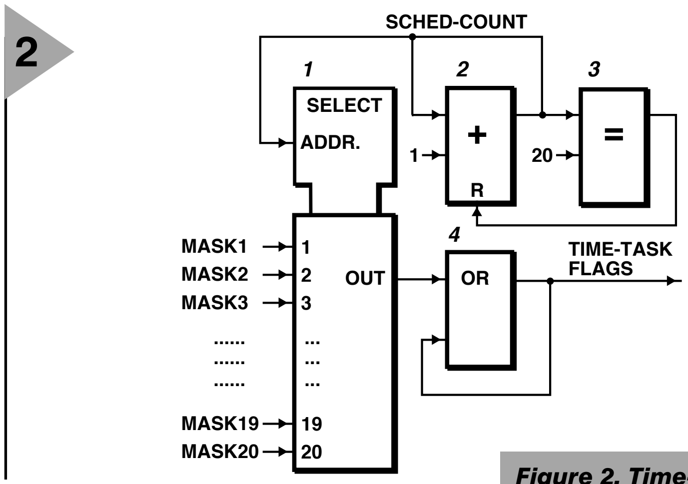


Figure 2. Time-Task Scheduler.

Arrange for a timer interrupt service routine to include a 'call SCHED00' instruction so that the Scheduler subroutine is executed every 10 ms.

Include code after your start-up initialising code to set the active flags of the Event-Tasks you want running at start-up, and to pass control to the Task-Executive of PICXEX. Listing 2 is an example. That final 'goto Main_00' instruction is very important.

PICXEX contains a 'configuration' file where you specify task names, the 4 registers used, timing information for Time-Tasks (in the form of masks) and the number of masks. **Listing 1** is a copy of PICXEX's configuration file as used in the application example discussed later in this article.

Using PICXEX, general guidelines

Divide the application into simpler functions/processors. The time-independent functions will be Event-Tasks, and the ones that require execution at specific intervals the Time-Tasks.

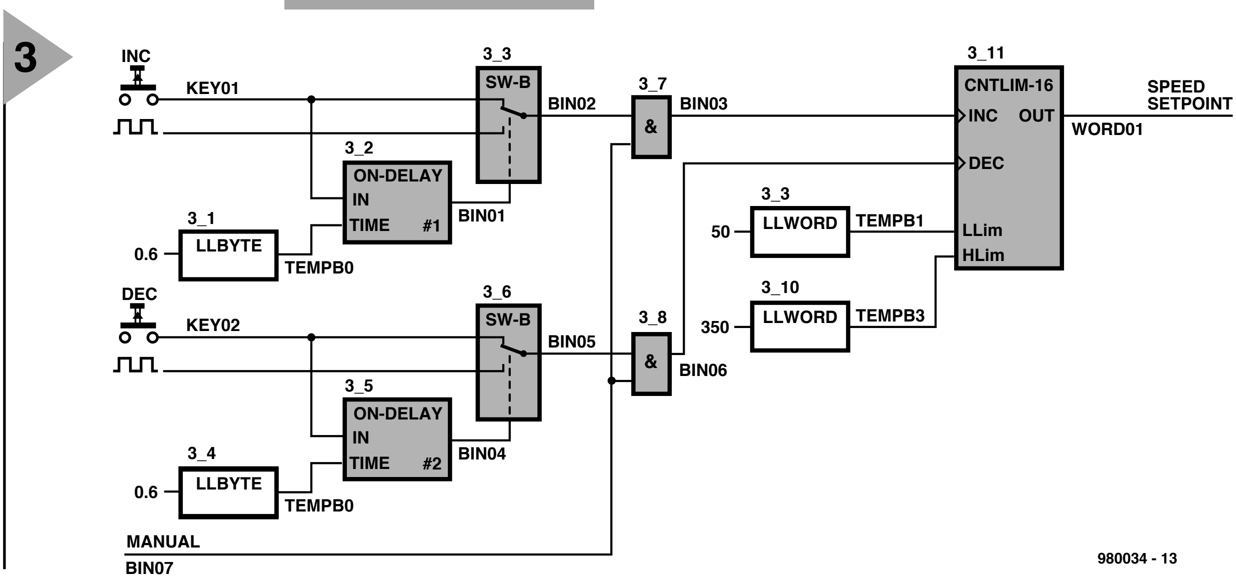
Keep Interrupt Service Routines short. Use interrupts to gather and dispatch data, and to register events. Processing data and events is the responsibility of the tasks. Remember PICXEX is ignorant of any interrupts while it is happily going about its way executing tasks. Interrupt service routines, and all that goes with them, are your responsibility. After all you also are entitled to some of the fun.

The format to use for tasks. Both Event and Time-Tasks must be in the form of subroutines. That is, they start with a unique name and have one or more 'RETURN' instructions. Use the macro XEX_RETURN, which is equivalent to the return instruction, but gives a clear indication in the listing of where you exit a task to return to the Task Executive.

Avoid any but the shortest delay loops inside a task, it will delay other tasks from getting executed. With PICXEX you now have far more elegant ways to implement delays.

The size of a task. Keep Event and Time-Tasks to a size and functionality that will ensure an execution time of about 2 ms. This is enough time to block-write 8 bytes to a serial EEPROM, and if you use an 8-MHz clock, more than enough instructions to do a PID routine using floating point maths.

Figure 3. Setpoint Station (Event-Task 3)



LISTING 1

```
        ; Define start of task code here. For unused tasks
        ; leave as is at 0.
#DEFINE TimeTask1   APP_TIMERS ; service task for timer modules
#DEFINE TimeTask2        0     ; TimeTask2 code label
   ......................
   ......................
#DEFINE TimeTask6        0     ; TimeTask6 code label
#DEFINE TimeTask7        0     ; TimeTask7 code label
#DEFINE TimeTask8        0     ; TimeTask8 code label

#DEFINE EventTask1       0     ; EventTask1 code label
#DEFINE EventTask2       0     ; EventTask2 code label
#DEFINE EventTask3  SETP_STATION  ; setpoint station
   ......................
   ......................
#DEFINE EventTask6       0     ; EventTask2 code label
#DEFINE EventTask7  Debug      ; Debug tool
#DEFINE EventTask8  PERF_PROC  ; Performance Processor

        ; registers in Bank0 used by operating system
; TIME_TASK_STATUS     EQU  0   ;  time-task active flags
; EVENT_TASK_STATUS    EQU  0   ; event-task active flags
; EVENT_TASK_ENTRY     EQU  0   ;  task loop entry point
; SCHED_COUNT          EQU  0   ;  Scheduler counter

        ; definitions for Scheduler look-up masks
#DEFINE Mask1  B'00000001'     ; Mask 1
#DEFINE Mask2  B'00000000'     ; Mask 2
#DEFINE Mask3  B'00000000'     ; Mask3
#DEFINE Mask4  B'00000000'     ; Mask4
#DEFINE Mask5  B'00000000'     ; Mask5
   ......................
#DEFINE MASK10 B'00000001'   ; Mask10
   ......................
#DEFINE Mask17 B'00000000'     ; Mask 17
#DEFINE Mask18 B'00000000'     ; Mask 18
#DEFINE Mask19 B'00000000'     ; Mask 19
#DEFINE Mask20 B'00000000'     ; Mask 20

NR_OF_MASKS        SET  D'20'  ; no. of scheduler masks
```

One last thing, there is a clear-watchdog-timer instruction (clrwdt) at the bottom of the Event-Task section to guard against getting stuck in some task's code. If you follow the guidelines given above for task lengths etc. the nominal time-out period of 18 ms, (with no prescaler) is fine.

USING PICXEX; AN APPLICATION EXAMPLE

The best way to get familiar with PICXEX is to study a working application. The following describes sections of a working system, showing some of the possibilities when using PICXEX with the PIC16C73 microcontroller. The source code for the tasks described, system support utilities, function module macros, and PICSCOPE are supplied on the project disk to allow a working system to be assembled. When running this application on the MPSIM simulator keep in mind that the output from the Performance Processor (see Event-Task 8 description below) is updated every 2 seconds and this could mean a long wait. Task allocation is as follows.

Time-Task 1.
Application Timer Handler to service function module timers, executed every 100 ms. Timing periods available are in the range 0.1 to 6.4 seconds.

Event-Task 3.
Setpoint Station implemented using function module programming. See **Figure 3**. This method of programming is quick to implement and easy to debug. A 16 Bit counter, function module 3_11, is incremented or decremented by two input keys each with an auto-repeat function if the key is operated for longer than 0.65 seconds. The MANUAL state interlocking ensures that the setpoint can only be changed during manual mode. The counter output is limited between 50 and 350. Notice the function code modules are numbered according to task number and execution sequence. These same numbers are used as labels in the source code to mark where the particular function module starts.

Event-Task 7.
Debug Tool. This task is a valuable aid when debugging function module applications. Together with ASYNCH03 (a serial port message handling utility) and PICSCOPE (PC based software) you can monitor and write PIC's registers in bit, byte, word, and floating point format.

Event-Task 8.
Performance Processor. Also implemented with function modules, this task will calculate how many times it is getting executed per second. With PICSCOPE it is now a simple exercise to monitor this value and see how busy your system is. Below 60 you can expect the PIC's internal watchdog to time-out.

FOOD FOR PROGRAMMERS

All programs, source codes files, macros and utilities mentioned in this article, except Microchip's (free) MPASM and MPSIM, are available on a floppy disk, available from the Publishers as order code **986017-1**.

(980034-1)

LISTING 2

```
        ..................................
        .  .  .  .  .  .  .  .  .  .  .  .
   clrf TIME_TASK_STATUS       ; ensure no Time-Tasks active
   clrf EVENT_TASK_STATUS      ; ensure no Event_Tasks active
   clrf EVENT_TASK_ENTRY       ; reset Event-Task loop entry-point
   clrf SCHED_COUNT            ; clear Scheduler mask selector
   XEX_ON_EVENT  3             ; start with Event-Task 3 on
   goto Main_00                ; make it fly!
```

APPLICATION NOTE

Home Automation Modem

The home automation modem Type TDA5051A is an integrated circuit specifically designed for amplitude shift keying (ASK) transmission via the domestic mains supply (US: household AC supply), at a data rate of 600 or 1200 symbols*. It operates from a single 5 V supply.

1

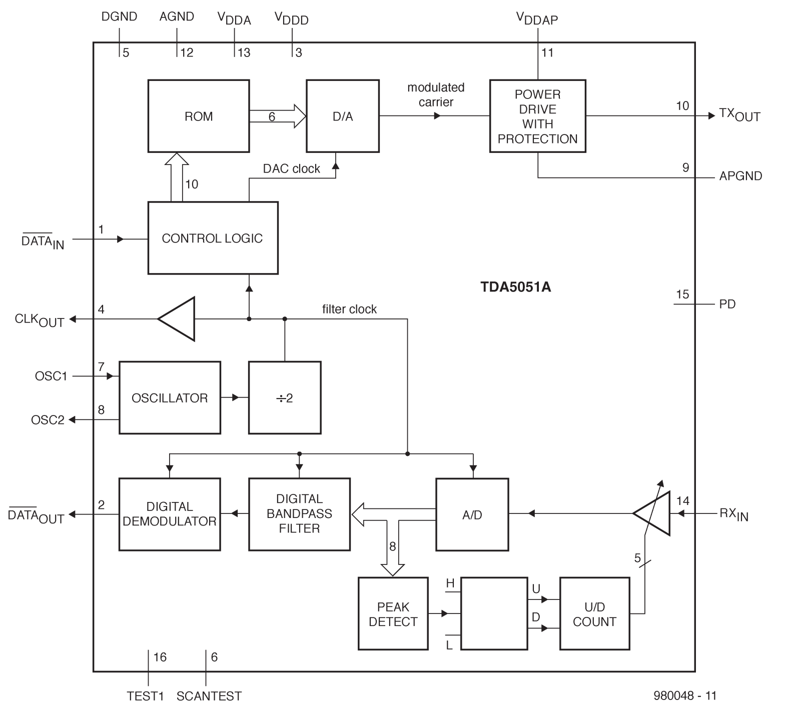


Figure 1. Block diagram of the Type TDA5051A integrated Home Automation Modem.

Main characteristics

- *Full digital carrier generation and shaping*
- *Modulation/demodulation frequency set by adjustment of the internal clock oscillator or an external clock (driven by microcontroller)*
- *Digital-to-analogue converter (DAC) for rejection of aliasing components with high (6-bit) clock rate*
- *Fully integrated output power stage with overload protection*
- *Automatic gain control at receiver input*
- *8-bit analogue-to-digital converter (ADC)*
- *Narrow digital filter*
- *Digital demodulation providing baseband data*
- *Compliance with EN50065-1 through simple interfacing network*
- *Few external components for low-cost applications*
- *SO16 plastic package*

FUNCTIONAL DESCRIPTION

Both transmission and reception stages are controlled by the master clock of a microcontroller or by the the on-chip reference oscillator driven by a crystal. This ensures requisite accuracy of the transmitter carrier and exact trimming of the digital filter, thereby making the performance wholly independent of application disturbances, such as component tolerances, temperature drift, supply voltage drift, and so on.

The interface with the mains supply (US: household AC supply) is via a hybrid *LC* network. The output stage of the modem is capable of applying a 120 dBμV r.m.s. signal to a (typical) 30 Ω load.

To reduce current drain, the modem is disabled by a power-down (PD) input pin (15). When this happens, the on-chip oscillator remains active and the clock continues to be supplied via pin 4 (CLK_{OUT}). For low-power operation in the receive mode, pin 4 may be controlled dynamically by the microcontroller (see Power-down mode later on).

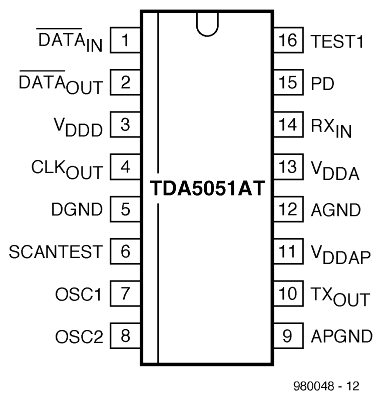
** In modern data communications, the symbol replaces the baud as the unit of transmitted data. Like the baud, a symbol may (and frequently does) represent more than one data bit.*

** For full details, see Data Sheet TDA5051A available from Philips Semiconductors or at http://207.87.1.43/acrobat/datasheets/TDA5051A.pdf*

A Philips Semiconductors Application

Table 1. Pinning

Pin	Symbol	Description
1	$\overline{DATA}_{IN}$	digital data input (active logic low)
2	$\overline{DATA}_{OUT}$	digital data output (active logic low)
3	V_{DDD}	supply voltage for digital circuits
4	CLK_{OUT}	clock output (f_{OSC}/2)
5	DGND	ground (earth) for digital circuits
6	SCANTEST	test input (logic low in application)
7	OSC1	oscillator input
8	OSC2	oscillator output
9	APGND	ground for (analogue) power amplifier
10	TX_{OUT}	analogue signal output
11	V_{DDAP}	supply voltage for (analogue) power amplifier
12	AGND	ground for analogue circuits
13	V_{DDA}	supply voltage for analogue circuits
14	RX_{IN}	analogue signal input
15	PD	power-down input (active logic high)
16	TEST1	test input (logic high in application)



When the modem is controlled by the on-chip oscillator, the requisite crystal is connected between pins 7 and 8. An external clock (microcontroller driven by a crystal) is connected between pins 5 and 7; pin 8 must then be left open.

All logic inputs and outputs are compatible with TTL/CMOS levels, so providing an easy connection to a standard microcontroller I/O port.

The digital part of the modem is fully scan-testable. Pins 6 and 16, SCANTEST and TEST respectively, are used for production tests; these pins must be left open in the functional mode (correct levels are defined internally by pull-up and pull-down resistors).

TRANSMIT MODE

The carrier frequency is generated by the scanning of a read-only memory (ROM) under the control of a microcontroller clock or the reference frequency provided by the on-chip oscillator: both methods provide the accuracy required by environmental conditions.

High-frequency clocking rejects the

2

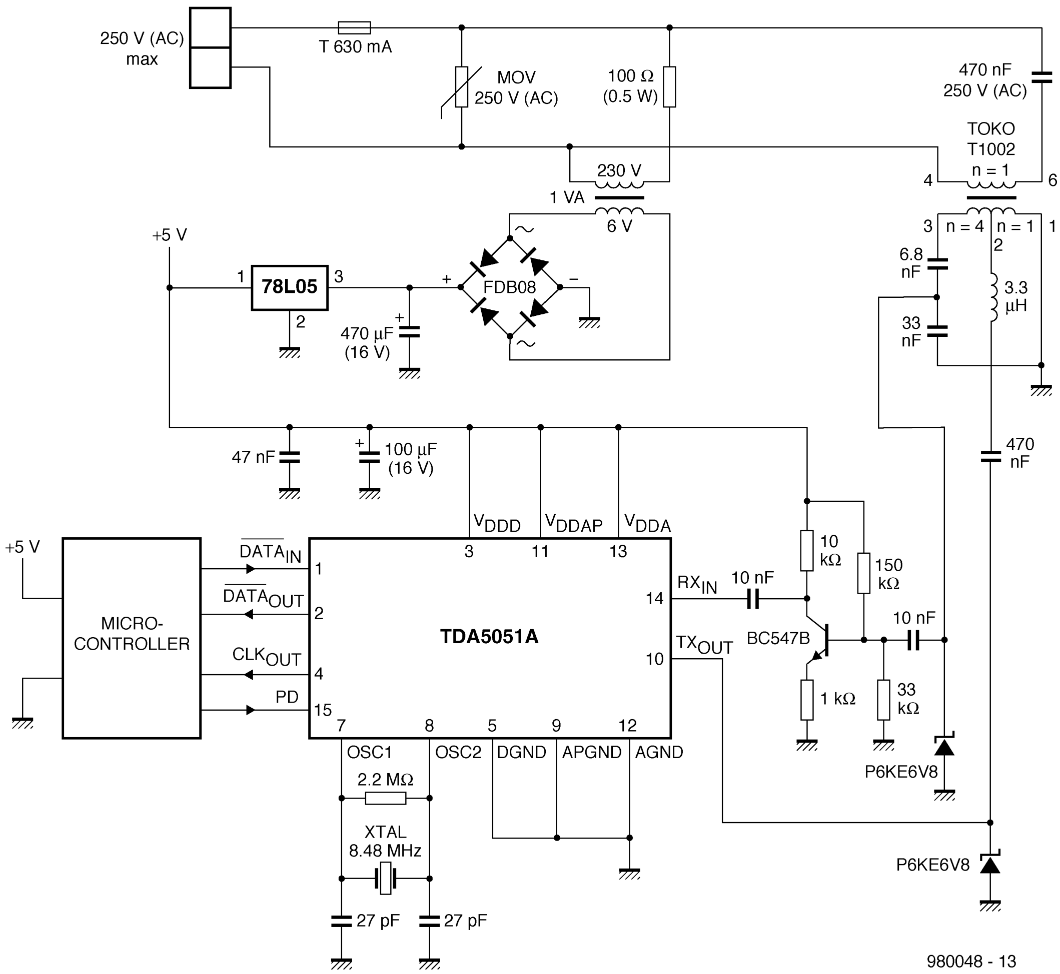


Figure 2. Typical application diagram of the TDA5051A Home Automation Modem with power line isolation and improved sensitivity.

Table 2. Electrical characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
TRANSMIT MODE						
f_{cr}	carrier frequency	f_{osc} = 8.48 MHz	-	132.5	-	kHz
t_{su}	set-up time of the shaped burst	f_{osc} = 8.48 MHz	-	170	-	μs
t_h	hold time of the shaped burst	f_{osc} = 8.48 MHz	-	170	-	μs
$t_{W(DI)(min)}$	minimum pulse width of $DATA_{IN}$ signal	f_{osc} = 8.48 MHz	-	190	-	μs
$t_{W(burst)(min)}$	Minimale Burst-Zeit	f_{osc} = 8.48 MHz	-	360	-	μs
$V_{O(eff)}$	output carrier signal Z_L = CISPR16	$\overline{DATA}_{IN}$ = Low	120	-	122	dBμV
$I_{O(max)}$	power amplifier output current (peak value)	$\overline{DATA}_{IN}$ = Low	-	160	-	mA
Z_O	output impedance of the power amplifier		-	5	-	Ω
V_O	direct voltage output at TX_{OUT}		-	2.5	-	V
RECEIVE MODE						
$V_{i(eff)}$	analogue input (r.m.s.)		66 (82)	-	122	dBμV
V_I	direct voltage at RX_{IN}		-	2.5	-	V
R_{AGC}	automatic gain control range		-	50	-	kΩ
$t_{c(AGC)}$	automatic gain control time constant	f_{osc} = 8.48 MHz	-	36	-	dB
B_{det}	detection bandwidth	f_{osc} = 8.48 MHz	-	3	-	kHz
BER	bit error rate	f_{osc} = 8.48 MHz	-	10^{-4}	-	-

aliasing components to an extent which ensures that when they are filtered by the interfacing *LC* network, they do not cause any significant disturbance.

The data modulation is applied through pin 1 ($\overline{DATA}_{IN}$) and applied smoothly by specific digital circuitry to the carrier (shaping). Harmonic components are limited in this process, thus avoiding unacceptable disturbance of the transmission channel (as laid down in Recommendations CISPR16 and EN50065-1). Total harmonic distortion is attenuated by 55 dB when a typical *LC* interfacing network is used*.

The digital-to-analogue converter (DAC) and the power stage are set to provide a maximum signal level of 122 dBμV r.m.s. at the output (pin 10).

The output of the power stage, pin 10 (TX_{OUT}) must be connected at all times to a decoupling capacitor, since a direct voltage of 500 mV_{DD} exists at this pin, even when the modem is not transmitting. The pin must also be protected against overvoltage and negative transient signals. The direct voltage referred to may be used to bias a unipolar transient suppressor.

Direct connection to the mains supply (US: household AC supply) is via an *LC* network for low-cost applications. However, when power line insulation has to be ensured, a suitable r.f. transformer should be used.

Note that in the transmission mode, the receiving part of the modem is not disabled and the transmitted signal is detected normally. In this mode, the gain chosen before the onset of the transmission is stored and the a.g.c. is set internally to –6 dB as long as $\overline{DATA}_{IN}$ is low. When this is not so, the previous gain setting is restored automatically.

RECEIVE MODE

The input signal received by the modem is applied to a wide-band input amplifier with automatic gain control, AGC, from –6 dB to + 30 dB. This arrangement improves the noise performance and provides a means for signal level adjustment to ensure maximum sensitivity of the 8-bit ADC.

Subsequently, the signal is passed through the ADC and a digital band-pass filter so as to meet the CISPR normalization and to comply with some additional limitations in current applications. After digital demodulation and pulse shaping, the baseband data signal is available at pin 2 ($\overline{DATA}_{OUT}$).

Pin 14 (RX_{IN}) is a high-impedance pin that has to be protected and d.c. decoupled for the same reasons as pin 10 (TX_{OUT}). The high sensitivity at the input (82–122 dBμV) makes the use of a 50 Hz (US: 60 Hz) rejection filter – formed by the *LC* interfacing network –a must. This filter also serves as an anti-aliasing filter for the internal digital processing.

POWER-DOWN MODE

The power-down input, pin 15 (PD) is active high; this means that the current drain is a minimum when the pin is high. When this is so, all functions, apart from the clock oscillator, are then disabled.

DATA FORMAT

Transmit mode

The data input, $\overline{DATA}_{IN}$, is active low, which means that a burst is generated on the line (TX_{OUT}) when pin $\overline{DATA}_{IN}$ is low.

Pin TX_{OUT} is in the high-impedance state as long as the modem is not transmitting. Successive logic 1s are treated in a non-return to zero (NRZ) mode.

Receive mode

The data output, pin $\overline{DATA}_{OUT}$, is active low, which means that the data output is low when a burst is received. The pin remains low as long as a burst is received.

3

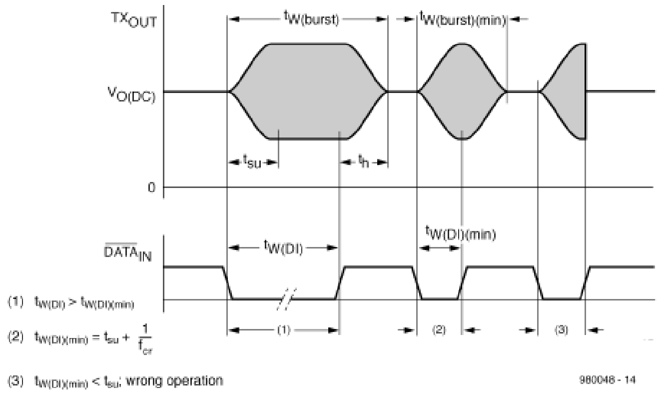


Figure 3. Representative relationship between $DATA_{IN}$ and TX_{OUT}.

ICM7218A

ELEKTOR ELECTRONICS

DATASHEET 5/98

Integrated Circuits
Microprocessor, Interfacing

ICM7218A
8-Digit LED Display Driver

Manufacturer

Maxim Integrated Products Inc., 120 San Gabriel Drive, Sunnyvale, CA 94086, USA. Internet: www.maxim-ic.com.

General Description

The Maxim ICM7218 display driver interfaces microprocessors to an 8-digit, 7-segment, numeric LED display. Included on chip are two types of 7-segment decoders, multiplex scan circuitry, segment and digit drivers, and an 8x8 static memory.
The ICM7218A accepts data in a serial format and drives common-anode displays. Data can be displayed in either hexadecimal or code-B format. The ICM7218A also features a NO Decode mode where each individual segment can be independently controlled. This is particularly useful in driving bar graphs. The Maxim ICM7218 is an alternative for both the Intersil ICM7218 and ICM7228.

Applications

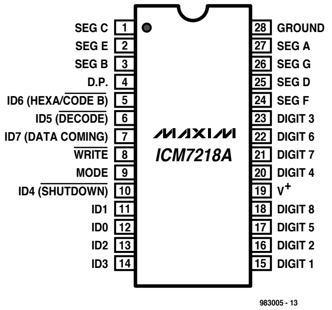
- Instrumentation
- Test Equipment
- Hand Held Instruments
- Bargraph Displays
- Panel Meters

Application Example

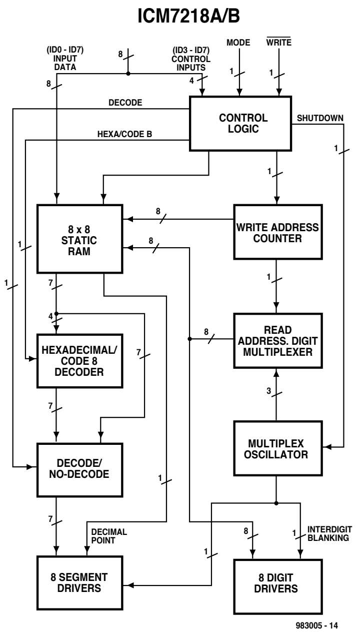
DCF-controlled LED Clock, *Elektor Electronics* May 1998.

Features

- Fast access time: 200ns write pulse width
- Microprocessor compatible
- Hexadecimal and code B decoders
- Individual segment control with 'No Decode' feature
- Digit and segment drivers on chip
- Common-anode (ICM7128A) or common-cathode (ICM7218B) versions
- Low-power CMOS



Pin configuration



ICM7218A/B Block Diagram

T-series Iron Powder Cores

ELEKTOR ELECTRONICS

DATASHEET 5/98

Passive Components
Inductors

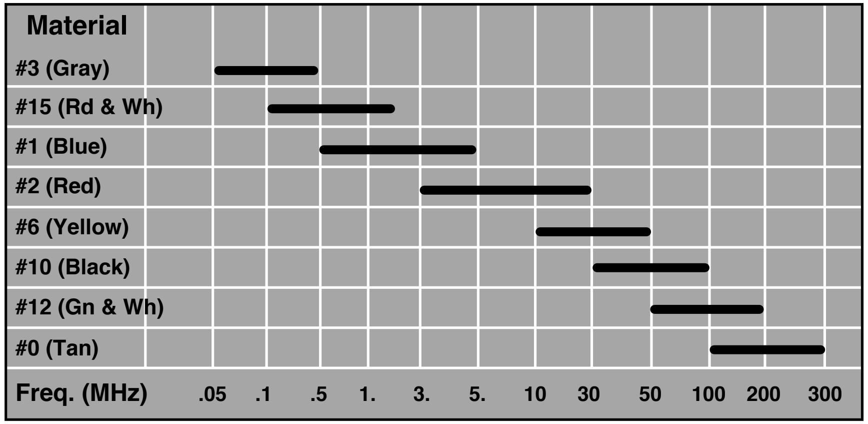
T-series Iron Powder Cores
Amidon Associates

Manufacturer

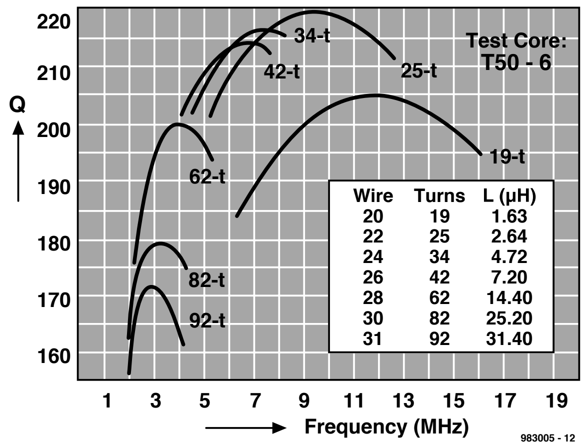
Amidon Associates, 2216 East Gladwick, Dominguez Hills, CA 90220, USA. Internet: *www.amidoncorp.com.*

Application example

Broadband RF preamplifier for VLF, LF and AM BCB, *Elektor Electronics* May 1998.



Iron-powder material vs. frequency range
Higher Q will be obtained in the upper portion of a material's frequency range when smaller cores are used. Likewise, in the lower portion of a material's frequency range, higher Q can be achieved when using the larger cores.



Typical Q curves resulting from various winding on the same core (here; T50-6).

T-series Iron Powder Cores

Passive Components
Inductors

A_L values (μH / 100 turns)		For complete part number, add Mix number to Core Size number.								
Range (MHz) →		to 0.1	.05 - .5	.1 - 2	.5 - 5	1 - 30	3 - 50	5 - 100	20 - 200	50 - 300
Core size	Outer diam. (in.)	26 Mix Yel-Wh μ = 75	3 Mix Grey μ = 35	15 Mix Rd-Wh μ = 25	1 Mix Blue μ = 20	2 Mix Red μ = 10	6 Mix Yellow μ = 8	10 Mix Black μ = 6	17 Mix Grn-Wh μ = 3.5	0 Mix Tan μ = 1
T-12-	.125	na	60	50	8	20	17	12	7.0	3.0
T-16-	.160	na	61	5	44	22	19	13	8.0	3.0
T-20-	.200	na	90	6	52	27	22	16	10.0	3.
T-25-	.250	na	100	100	70	34	27	19	12.0	4.5
T-30-	.307	325	140	93	85	43	36	25	16.0	6.0
T-37-	.375	275	120	90	80	40	30	25	15.0	4.9
T-44-	.440	360	180	160	105	52	42	33	19.0	6.5
T-50-	.500	320	175	135	100	49	40	31	18.0	6.4
T-68-	.690	420	195	180	115	57	47	32	21.0	7.5
T-80-	.795	450	180	170	115	55	45	32	22.0	8.5
T-94-	.942	590	248	200	160	84	70	58	32.0	10.6
T-106-	1.060	900	450	345	325	135	116	na	na	19.0
T-130-	1.30	785	350	250	200	110	96	na	na	15.0
T-157-	1.57	970	420	30	320	140	115	na	na	na
T-184-	1.84	1640	720	na	500	240	na	na	na	na
T-200-	2.00	895	425	na	250	120	100	na	na	na
T-200A-	2.00	1550	na	na	na	218	180	na	na	na
T-225A-	2.25	950	424	na	na	120	100	na	na	na
T-225A-	2.25	1600	na	na	na	215	na	na	na	na
T-300-	3.00	825	na	na	na	115	na	na	na	na
T-300A-	3.00	1600	na	na	na	228	na	na	na	na
T-400-	4.00	1320	na	na	na	185	na	na	na	na
T-400A-	4.00	2600	na	na	na	360	na	na	na	na
T-500-	5.00	1460	na	na	na	207	na	na	na	na

na = not available
μ = permeability

The following equations are useful for calculating the number of turns, inductance, or the A_L value of any iron powder toroidal core. Each core has been assigned an A_L value that may be found in the preceding chart.

$$N = 100\sqrt{\frac{desired\ 'L'(\mu H)}{A_L(\mu H / 100\,\text{turns})}} \qquad L(\mu H) = \frac{A_L \times N^2}{10\,000} \qquad A_L(\mu H / 100\,\text{turns}) = \frac{10\,000 \times 'L'(\mu H)}{N^2}$$

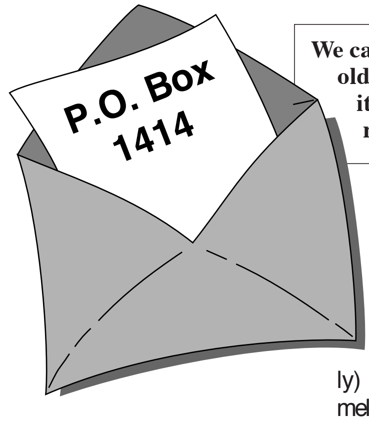
N = number of turns L = inductance (μH) A_L = inductance index (μH/100 turns)

ICM7218A

Integrated Circuits
Microprocessor, Interfacing

Electrical characteristics (V^+ = 5 V ± 10%, T_A = 25 °C)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Supply Voltage	V+	-20°C ≤ T_A ≤ + 85°C	Operating	4		6	V
			Data Retention	2		6	
Shutdown Supply Current	I_Q	ICM7218A, B			5	300	mA
Operating Supply Current	I_{OP}	Decoding all 8's, display open			200	450	μA
		No Decode, display outputs open			200	450	μA
		Display blank, driving display			200	450	μA
		Decoding all 8's and D.Ps, driving display			240		mA
Digit Drive Current	I_{DIG}	Common Anode V_{OUT} = V+ – 2.0V		–200	–300		mA
		Common Cathode V_{OUT} = 1.0 V		50	70		mA
Digit leakage Current	IDLK	Shutdown, V+ - 2.0V					
		Common Anode, V_{OUT} = 0V				–10	μA
		Common Cathode, V_{OUT} = 5V				10	μA
Peak Segment Drive Current	I_{SEG}	Common Anode, V_{OUT} = 1.5V		20	30		mA
		Common Cathode, V_{OUT} = V+ – 2.0V		-10	-20		
Segment Leakage Current	I_{SLK}	Shutdown, V+ = 5V					
		Common Anode, V_{OUT} = 5V			–1	–50	μA
		Common Cathode, V_{OUT} = 0V			1	50	μA
Input Leakage Current	I_{IL}	All inputs					
		V+ = 5V, -20 ≤ T_A ≤ + 85°C					
		V_{IN} = 0V			–0.01	–1	μA
		V_{IN} = 5V			0.01	1	μA
Display Scan Rate	f_{MUX}	V+ = 5V		75	250		Hz
Interdigit Blanking Time	t_{idb}	V+ = 5V		2	10		μs
Input High Voltage	V_{IH}	All inputs, -20°C ≤ T_A ≤ + 85°C		2.0			V
Input Low Voltage	V_{IL}					0.8	V
Write Pulse Width (Low)	t_{wl}			200	100		ns
Write Pulse Width (High)	t_{wh}			1.0			μs
Input Setup Time	t_{ids}	All inputs		250	150		ns
Input Hold Time	t_{idh}	All inputs		0	-20		ns



We can only answer questions or remarks of general interest to our readers, concerning projects not older than two years and published in *Elektor Electronics*. In view of the amount of post received, it is not possible to answer all letters, and we are unable to respond to individual wishes and requests for modifications to, or additional information about, *Elektor Electronics* projects.

Earthing in Variable Power Supply

Dear Editor — I read with interest the Variable Power Supply article in the March 1998 issue of *Elektor Electronics*, and particularly the photograph of the prototype and the circuit diagram.

I would refer you to the earth connection visible on the photograph from the mains input socket to the top of the fixing of the toroidal transformer.

I would suggest that this connection should be routed to metal box/chassis by another path to avoid becoming an effective shorted turn if another piece of earthed equipment touches the external exposed metal box of the power supply. This could lead to a few sparks and mysterious mains fuse failures or the transformer overheating and (potentially more dangerously) the earthing wire insulation melting and possibly burning.

On the subject of (essential) earthing there is no indication in the circuit diagram that the metal box & chassis should be earthed nor is it mentioned in the construction. Also I suggest that the (usual) warnings should have been included in the construction about making sure that:

- The bolt head of the toroidal transformer fixing does not touch the top cover.
- That primary side wiring should have been segregated or sleeved near the secondary winding / circuits to maintain safety insulation since these accessible connections are not earthed.

John H. Joy, C Eng MIEE

We totally agree with your findings in regard of this rather unfortunate arrangement of the earth wiring as shown in the photograph you mention. We advise all readers building this project, or planning to do so, to follow the safety guidelines as set out in Mr. Joy's letter. We also recommend consulting the Safety Guidelines page which is included in the magazine a few times in every year volume.

EPROM Programmer

Dear Editor — Your March 1997 issue contained a fine design for an EPROM programmer, which I'm sure many of your readers had eagerly looked forward to. Having built the circuit I was delighted to note that it worked spot-on, albeit for 27C512 EPROMs only. I did not discover this until after a few months when I had to burn a 27C256 EPROM. That proved to be impossible!

Other EPROMs like the 27C64 and the 27C128 can not be programmed either. The control software then tells me COULD NOT WRITE. If I read out the EPROM, it appears that one or two bytes have been written in spite of this error report. Are you aware of this problem?

R. Becker

Assuming that the programmer handles '512 EPROMs correctly we'd say that the hardware and software are probably okay. Check the following points:

- *In the program, did you select the right EPROM type?*
- *Are you sure the EPROM used is suitable for a programming voltage of 12.5 V (the programmer does not work with 21-V types).*
- *Are you sure the EPROM used is compatible with the 1-ms programming algorithm employed by the programmer (50-ms types are not suitable)?*
- *Is the correct programming voltage being applied to the EPROM? Check the value during programming with the aid of a voltmeter.*

Motorola software utilities pack now by ftp

Dear Editor — Via your P.O. Box 1414 column I would like to advise readers of your magazine that the self-extracting archive file 'ELEKT494'.EXE' mentioned in the article 'RS232 interface for 68HC11' (*Elektor Electronics* March 1998, PC Topics supplement) is also available from the following Internet site:

http://skynet.stack.nl/ftp/68hc11wg/m68hc11

Thought I'd better let you know!

Martin Lemke

Thank you for this useful tip. Actually, some time ago we already received information that this file had made it all the way from Munich down to a Motorola BBS in Australia. We are pleased to see that it has now landed at a site that should be accessible to anyone at the cost of a local phone call.

SWITCHBOARD

Switchboard allows PRIVATE READERS of *Elektor Electronics* one FREE advertisement of up to 106 characters, including spaces, commas, numerals, etc., per month. The advertisement MUST relate to electronics, and it MUST INCLUDE a private telephone number or name and address; post office boxes are NOT acceptable.
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Advertisements will be placed in the order in which they are received. Elektor Electronics (Publishing) reserve the right to refuse advertisements without giving reasons or without returning them.

WANTED A VHF to UHF convertor, or circuits, as I have a display unit with a VHF output, and I wish to connect a T.V. Mr. T. Collins, 215 Arlott Crescent, Oldbrook, Milton Keynes MK6 2QT.

FOR SALE EPROM programmer GP EP8000 £75, Spectron D-586 datascope £185, Intel MDS + ICE with manuals etc. £100. P. Clark (01344) 868985.

FOR SALE Intel Prompt 48 Development System for 8048/8748 Microcontrollers, with manuals £150. D. Fittes, 8 Elisabeth Court, Warwick CV34 6QB. Tel. (01926) 493092.

FOR SALE Due to workshop clearance: 3 multimeters, transistor tester, frequency counter, valve voltmeter. Phone for detailed list. Ken Phillips, phone (01376) 323164 (Essex).