THE ELECTRONICS & COMPUTER MAGAZINE

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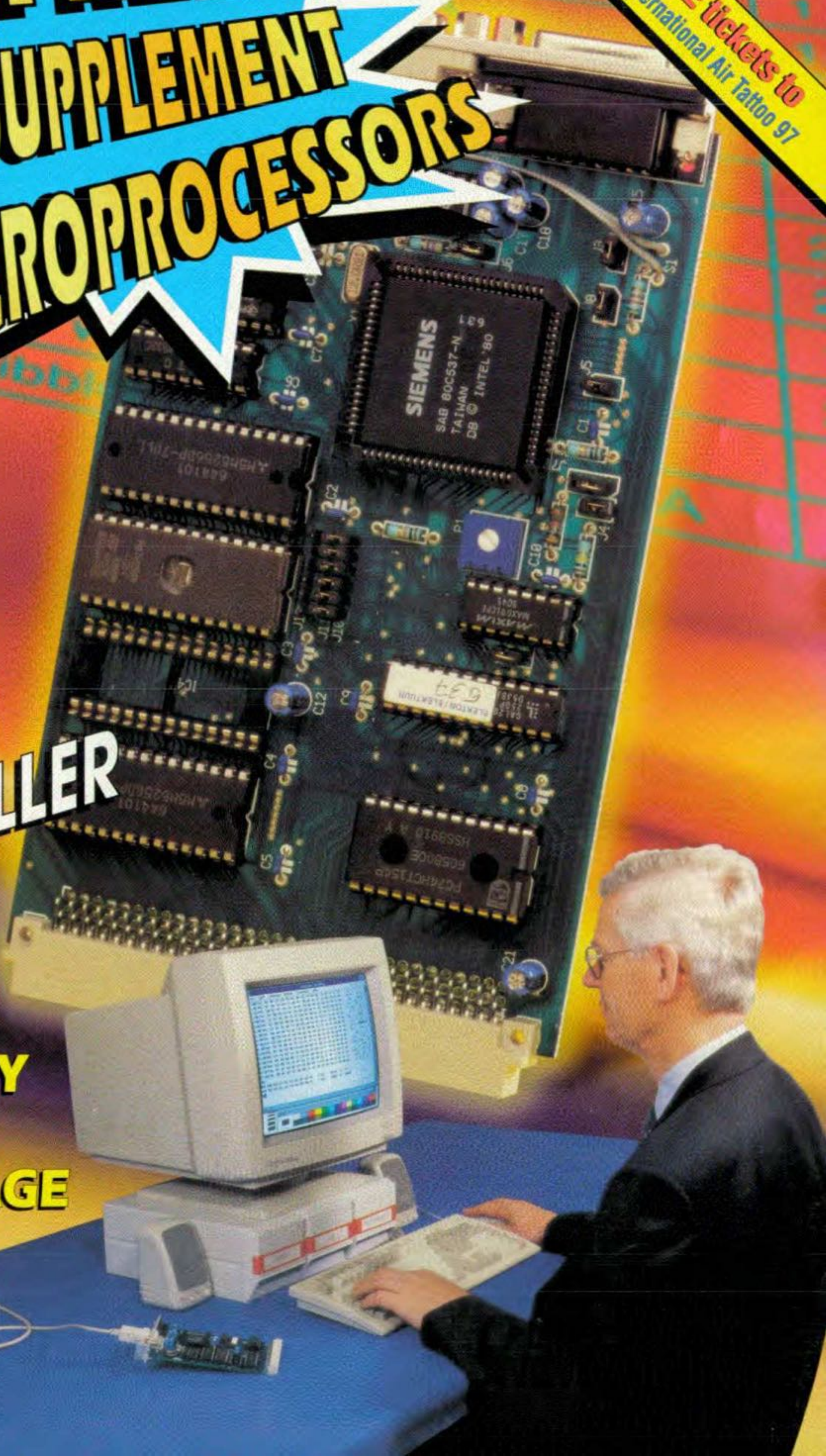

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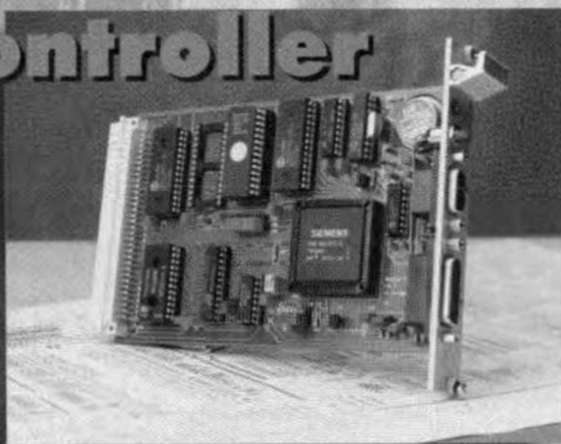

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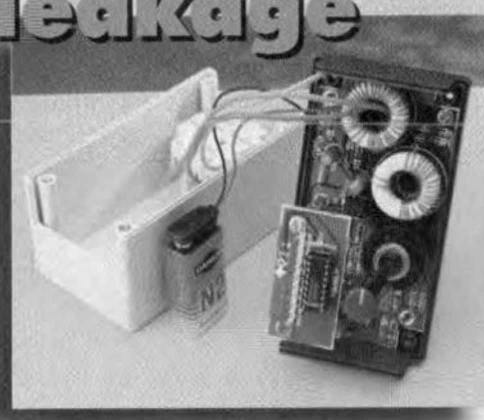

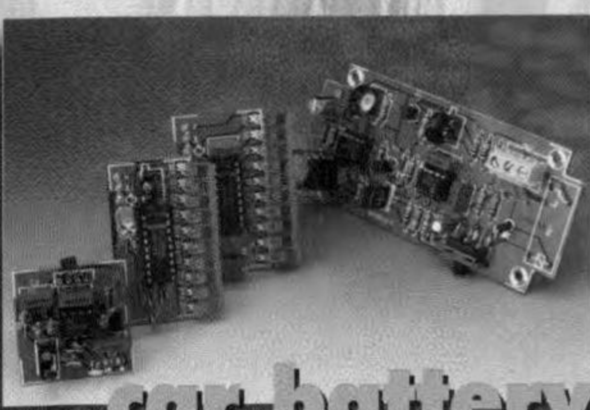

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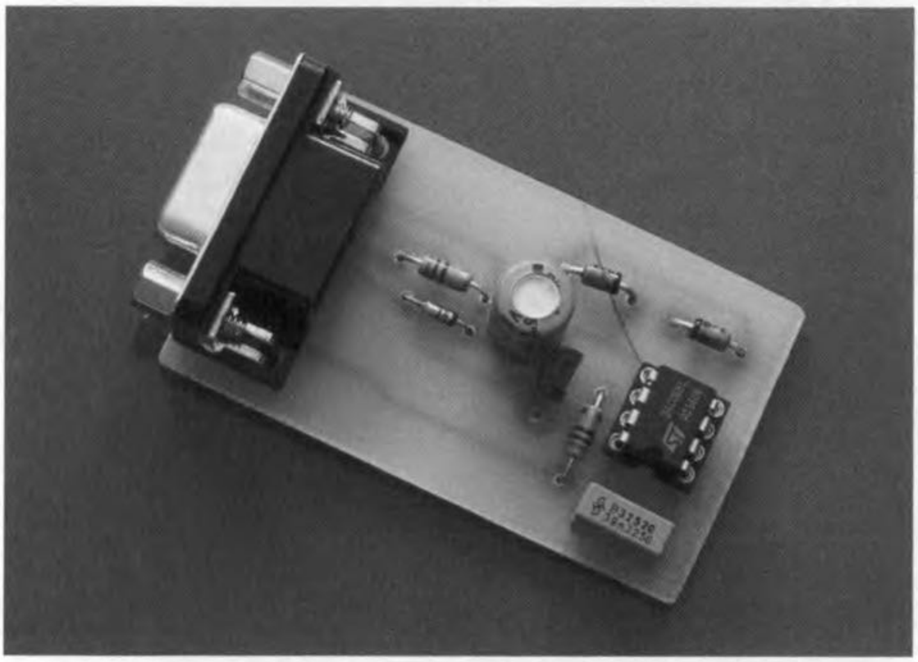
Virtually alongside of the steady increase in the number of applications using serial EEPROM memories, there is a growing need among technicians and hobbyists to read, modify and copy the contents of these inexpensive and widely available parts.

Design by Patrick Gueulle

mini programmer for serial EEPROMs



Family likeness ...

It's no coincidence that the circuit diagram shown in **Figure 1** bears great resemblance to that of the Mini PIC Programmer described elsewhere in this supplement. The reason is that both circuits are controlled by the same software, PIP02, whose 'Select device' menu offers many EEPROM memory devices which are compatible with the I²C bus protocol (notably the 24Cxx devices).
Let's start by noting that the PIP02 software is in a provisional version, and that future releases may offer support for additional memory families. Space has already been reserved for them in the menus!
Like PICs, I²C memories communicate with the programmer via a data line (SDA) and a clock line (SCL), without the need for any voltage greater than 5 volts. Consequently, the strict requirements on the RS232 port as mentioned in the Mini PIC Programmer article do not apply here.
Thanks to the use of a 7805 voltage regulator and two 4.7-V zener diodes, none of the device pins can be drawn to a negative potential, or one exceeding 5 V, even in the presence of an RS232 port employing (as it should) voltage swings of plus and minus 12 V.
To prevent electrostatic discharge (ESD) potentials, it is recommended as well as practical not to insert or remove an EEPROM if the programmer is not connected to the PC. So, always connect the programmer to the PC before launching a program or read operation, and disconnect the hardware after that.

Construction matters

The mini EEPROM programmer is built on a printed circuit board having the same dimensions as the one for the PIC programmer. The track layout is shown in **Figure 2**, the component mounting plan, in **Figure 3**. The present board contains even fewer parts than the that for the PIC programmer. Having identical 9-way sub-D connectors, the two programmer boards are interchangeable.
As on the PIC programmer board, it is recommended to use a turned-pin socket rather than a ZIF socket (few and far between in an 8-pin version, and relatively expensive).

Practical use

No matter if you want to work with PICs or EEPROMs, the PIP02 software is installed and launched in the same way. Simply use the 'Device' option from the 'Select' pull-down menu to pick the PIC or EEPROM you wish to read or program.
Thanks to an initialisation file which is automatically updated every time you launch PIP02, the program always 'remembers' the component it handled on a previous session. It is, therefore, recommended to copy the program into two different subdirectories on the hard disk: one for PICs, and another for EEPROMs. This also eliminates the risk of confusion between two programming files which eventually get the same name (after all, lots of projects these days feature a PIC or an EEPROM).
With reading as well as programming the memory contents are conveyed in the form of an Intel-HEX file. As a matter of course, there's no objection

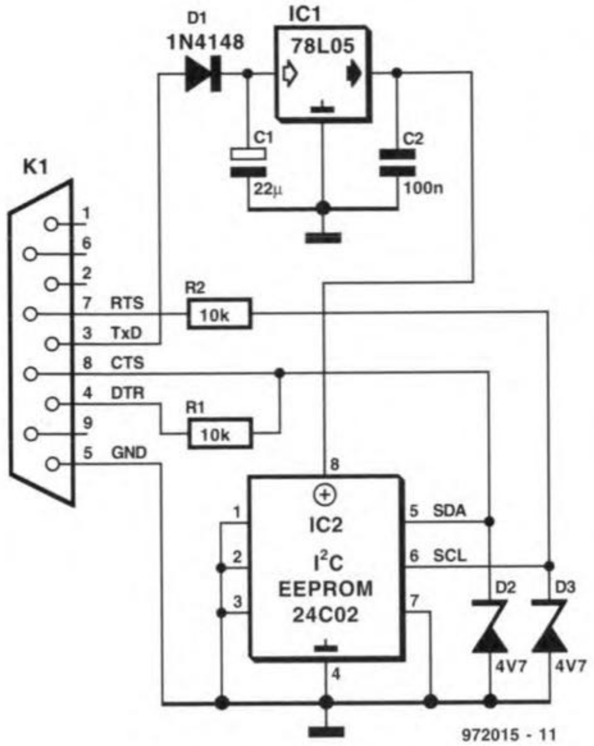
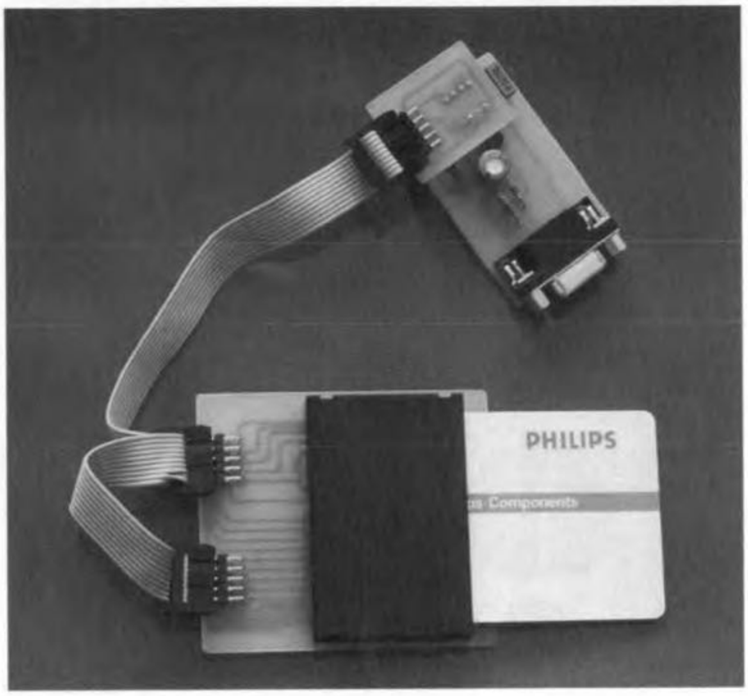


Figure 1. The circuit diagram of the mini serial EEPROM programmer closely resembles that of the mini PIC programmer. It is even simpler, though!



against converting this into or from another format using an appropriate utility.

Interestingly, many 'demo' diskettes for commercial-grade programmers offer file conversion utilities which often work even in the absence of the actual hardware. An example is the demo software supplied by MQP Electronics Ltd. (Park Road Centre, Malmesbury SN16 0BX, phone 01666 825666, fax 825141, email 100447.1124@compuserve.com), which contains a shareware version of the superb file editor 'PDED'. Unlike what applies to PICs, the software is unable to erase EEPROM memories directly in block mode. This shortage, which is due to EEPROMs not being technologically designed for block erasing, may be overcome by preparing (beforehand) a number of HEX files whose contents match those of empty memories. You can either do this by reading a blank EEPROM, or by using a file editor. Erasing an EEPROM is then simply a matter of loading an empty HEX file of the appropriate size.

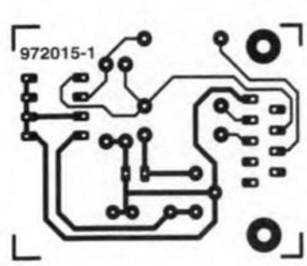


Figure 2. Copper track layout of the PCB designed for the mini serial EEPROM programmer.

Also for chip cards!

Once you know that certain chip cards of the non-intelligent type are nothing but a series of EEPROMs fitted in a special 'case', it will not come as a surprise that the present programmer is capable of reading and writing these 'flexible friends'. As you can see in **Figure 4**, it's all a matter of adapting the pinning. In this way, cards from the D2000 (256 bytes) and D4000 (512 bytes) series manufactured by Philips may be connected to this programmer by means of four wires attached to a standard card reader. The wiring is as follows:

Vss = ISO 5
Vcc = ISO 1
SCL = ISO 3
SDA = ISO 7

In the 'Select device' menu presented by the software, simply declare the D2000 as a 24C02, and the D4000 as a 24C04. It's as simple as that!

(972015)

Note: Readers not having access to the Internet may obtain the PIP02 software from the Publishers under order code ***976007-1****. Price and ordering details are given on the Readers Services page towards the end of this issue.*

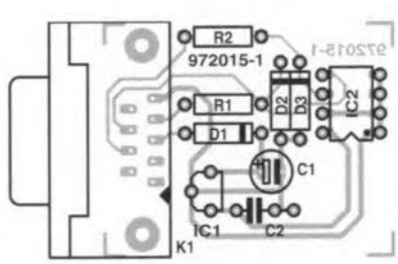


Figure 3. Component mounting plan.

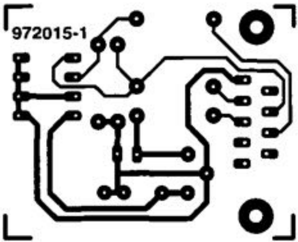
PIP02 problems

I'm having problems with programming a PIC16C84 using the PIP02 program (June 1997 Supplement, *ed.*). My computer is a 166 MHz Pentium system, and I suspect it's too fast. Can you help me, please?

T. Suhonen, Finland

The version of PIP02 we were allowed to distribute by Silicon Studios is not the latest version. We suggest getting in touch with Antti Lukats of Silicon Studios to discuss your problems. Meanwhile, try adding this line to your AUTOEXEC.BAT file:

SET STUDIODIR=C:\PIP02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The universally applicable hardware of this LCD module consists of a compact circuit board (35×80mm), a one-line 16-character LCD (LM16155) and a 68HC11 microcontroller. Depending on the program loaded into the controller, the module acts as a timer, a thermometer or a thermostat. The height of the module is only 25mm.

Design by Roman Mroz

multi-purpose LCD with 68HC11

timer, thermometer or thermostat

As a matter of course, the universal design of the hardware also allows other functions of the module. These functions will only depend on your creativity in writing software for the 68HC11 to run on the module board. The author, for example, hopes to extend the functionality of the LCD module with measuring options for frequency, voltage and capacitance.

In the present application, one of the main advantages of the 68HC11 is the fact that its EEPROM may be reprogrammed up to 10,000times. Programs are downloaded from a PC's serial port (for example, COM2). In most cases, downloading will take only 20 to 40 seconds. The module is conveniently powered by an inexpensive mains adaptor supplying an unregulated direct voltage between 7.5V and 10V. Depending on the application, the current consumption is between 15 and 60mA.

Functions Overview

- **Counter Module I**: Decimal seconds counter
  Display '**000.000.000 SEK**' with Stop and Reset
- **Counter Module II**: Days, Hours, Minutes, 10 seconds
  Display "**0000T 00S 00M 0S**" with Stop and Reset
- **Thermometer/Thermostat I**: −50°C to +98°C
  Display: '**+26°C −02 +45**' (temperature, min. and max.)
  3 switching outputs (relays) for ranges: below min., between min. and max. and exceeding max., acoustic alarm, resolution 2°C.
- **Thermometer/ Thermostat II**: −50°C to +99°C
  Display: '**+26°C −40 +60**' (temperature, min. and max.)
  3 switching outputs (relays) for ranges: below min., between min. and max. and exceeding max., acoustic alarm, resolution 1°C

Circuit description

Figure 1 shows the circuit diagram of the LCD module. IC2 is the microcontroller, a 68HC11E2 from Motorola. It sports 2,048 bytes of EEPROM, an 8×8-bit A-D converter, an 8-bit pulse accumulator, a serial interface and much more. The previously mentioned programs have been realized with the aid of these powerful features. Thanks to the 2-kByte EEPROM, you can do on-board reprogramming as many times as you like.

The controller operates with a 8.000-MHz quartz crystal, Q1, from which it derives an internal 2-MHz clock signal. The 5-V reference voltage for the A-D converter is supplied by D1, an LM366/5.0. This reference voltage enables a resolution of 0.02V to be achieved.

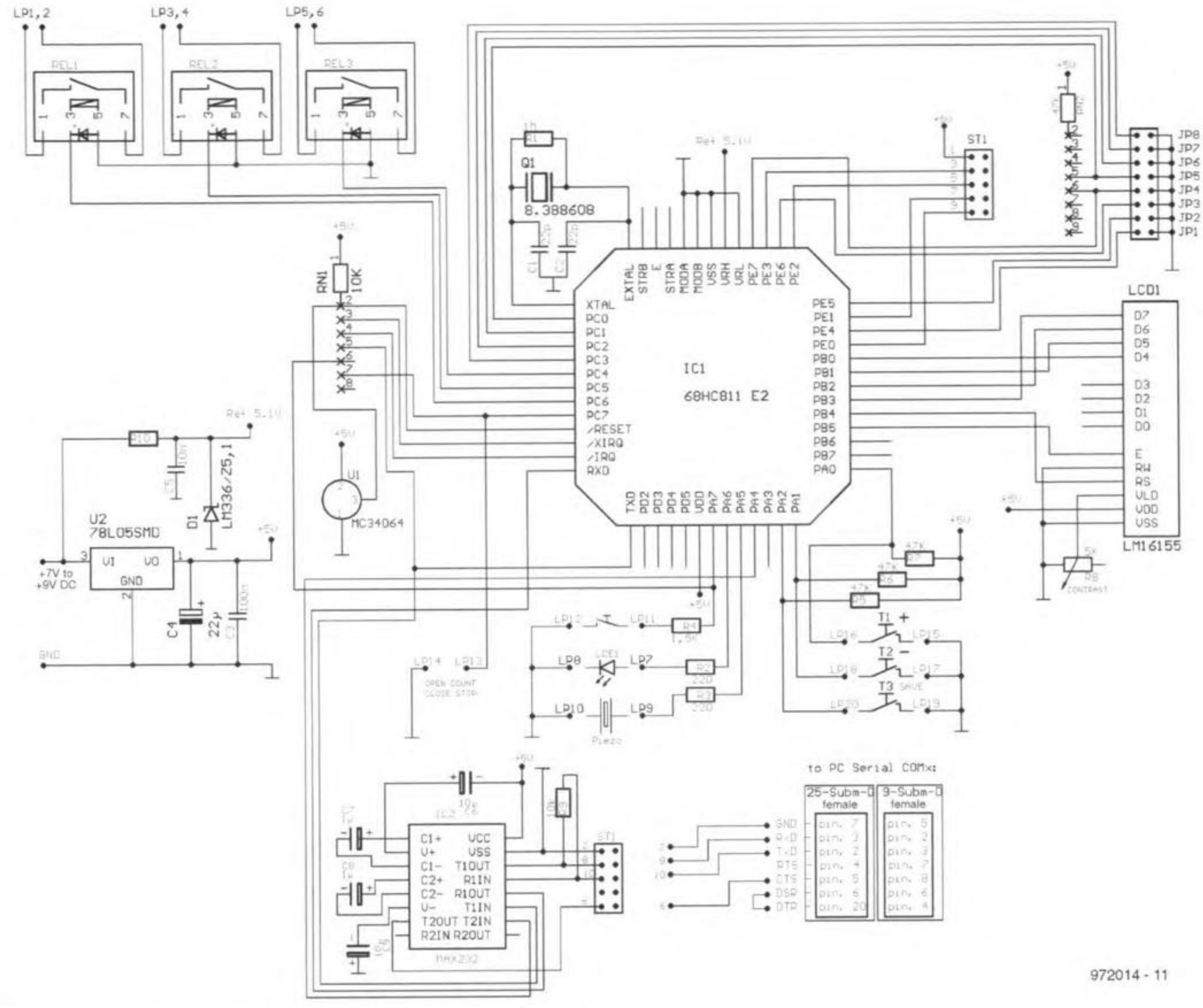


Figure 1. Circuit diagram of the multi-purpose LCD module.

The microcontroller drives the LC display in 4-bit mode. Potentiometer R8 allows the LCD contrast to be adjusted. The three controller port lines set up as switching outputs drive reed relays type SIL05D directly. Each of these compact relays provides one normally-open contact and an internal flyback diode which protects the drive logic against coil switch-off surges.

The reset pulse is generated by U1, an MC34064 supply voltage monitor from Motorola, whose external circuit consists of just one resistor (stolen from array RN1). The MC34064 contains an accurate voltage reference and a Schmitt trigger whose output (on pin 1) swings logic high when the operating voltage (on pin 3) exceeds a value of 4.61 V (typical).

Because the current consumption of the circuit is less than 100 mA, an SMA-style 78L05 happily manages the +5-V supply. The communication between the microcontroller and the serial interface on the PC is arranged by a MAX232 (IC2) level converter, of which the wide-SMA version is used here.

The module is linked to the PC via a four-wire cable which conveys the RxD, TxD, GND and CTS signals. Programming is accomplished with the aid of the COM port and DOS commands MODE and COPY. The different versions of a program are selected by means of eight jumpers, JP1-JP8. More about this further on.

At the solder side of the board you find 10 pairs of large solder eyes which allow the various applications to be realized (see **Table 4**).

Fitting the parts

The copper track layouts of the two board sides are given in **Figures 2a** and **2b**. The mounting of the SMA parts requires accuracy and a low-power soldering iron with a fine tip. To prevent unwelcome surprises, check the polarity of the tantalum capacitors before soldering them in place. The same goes for the orientation of the integrated circuits and relays. The component mounting plans shown in **Figures 3a** and **3b** indicate which parts are fitted at the top and bottom side of the board. The following order is recommended for fitting the parts:

R7, R5, R6, RN1, REL3, REL2, REL1, RN1, IC2, Q1, R10, C5, IC1 (socket), U1, R3, R2, R4, R9, R1, C2, C1, R8, C3, U2, JP1-JP8, ST1, D1, C6, C8, C7, C9 and finally C4.

Once the board is fully populated, IC1 may be inserted in its socket. Next, The LCD module is secured above the board using PCB spacers with a length of about 12 mm (see **Figure 4**). The 14 connecting terminals of the LCD are right above the corresponding 14 terminals on the controller board, and the two sets are connected using short pieces of insulated wire.

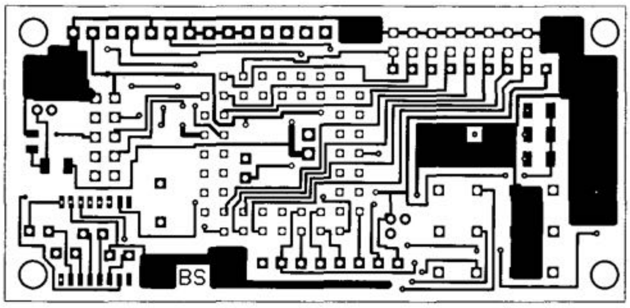
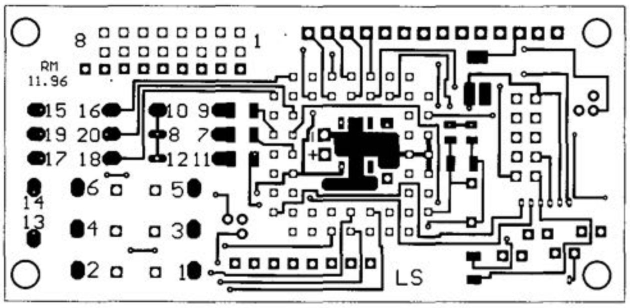


Figure 2. Copper track layouts: (above) component side, (below) solder side.



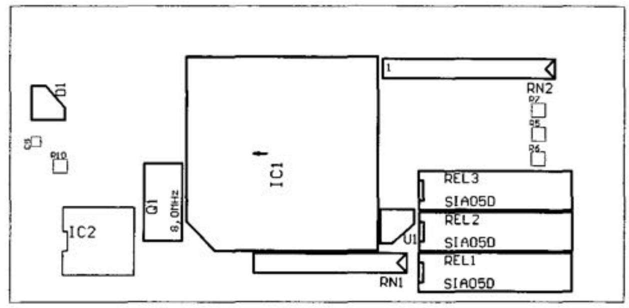
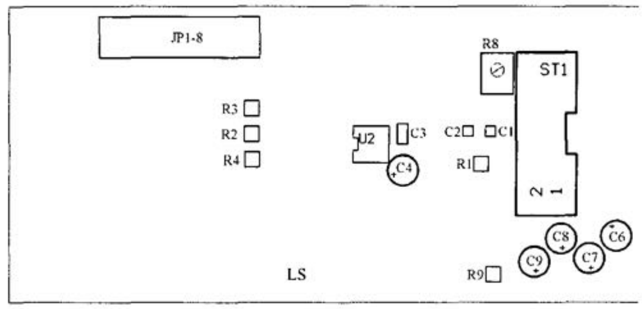


Figure 3. Component mounting plans: (above) component side, (below) solder side.



The PC connection

To be able to program the microcontroller, you have to connect the board to the serial port on your PC via a suitable cable. The connection is shown schematically in **Figure 5**. The connector pinouts are shown in Table 1, which is also useful in case a 9-way sub-D socket is used instead of the larger 25-way version.

Having made and checked the cable you proceed as follows:

1. Select a free COM port on your PC. COM1 is usually occupied by the mouse, which leaves you with COM2, COM3 and COM4 to choose from (if available!).
2. Connect the serial cable to the selected COM port.
3. Start the PC under MS-DOS.
4. Run the program **INSTEE.BAT** which is found on the diskette we sell for this project. The batch file creates a subdirectory called LCD1 on your hard disk (C:) into which all relevant files are copied.
5. Now the program **EE.BAT** may be launched. This batch file allows any of the available application programs to be downloaded to he LCD module. By sending the data the microcontroller is permanently programmed.
6. Perform all further actions suggested by EE.BAT.
7. EE.BAT may be launched again any time from the subdirectory C:\LCD1.

Programming

After switching it on, the LCD module either waits or starts.

A user program is automatically launched if nothing is connected to ST1, or an A-D converter application circuit. If so, the microcontroller transmits a character via TxD (PD1) and the MAX232 (IC2). Because there is no connection to a PC via the MAX232, the character arrives at the RxD pin (PD0) by way of R9 and IC2. This causes the EEPROM-resident program (if available) to be launched.

Table 1 RS232 cable pinning and signals

ST1 Pin	Sub-D 25p.	Sub-D 9p.	68HC11
10	2 (TXD)	3 (TXD)	RXD (PD0)
8	3 (RXD)	2 (RXD)	TXD (PD1)
6	5 (CTS)	8 (CTS)	I/O (PA4)
4 NC			
2	7 (GND)	5 (GND)	GND
	connect 6 to 20	connect 4 to 6	

The system waits when the LCD module is connected to a PC COM port by way of the cable described earlier. When the controller transmits a character, this is not immediately returned to PD0 via R9. The result is that the processor waits, allowing a small program (a *loader*) to be transmitted by the PC. The loader must have a length of 257 bytes, the first byte should be $FF, and it should be transmitted at 1,200 bits/s, 8-N-1. The $FF marker allows the controller to configure its serial port for the bit rate used. The controller automatically launches the loader once 256+1 bytes have been copied.

The function of the loader is to enable a larger (user) program to be received via the serial port, and subsequently

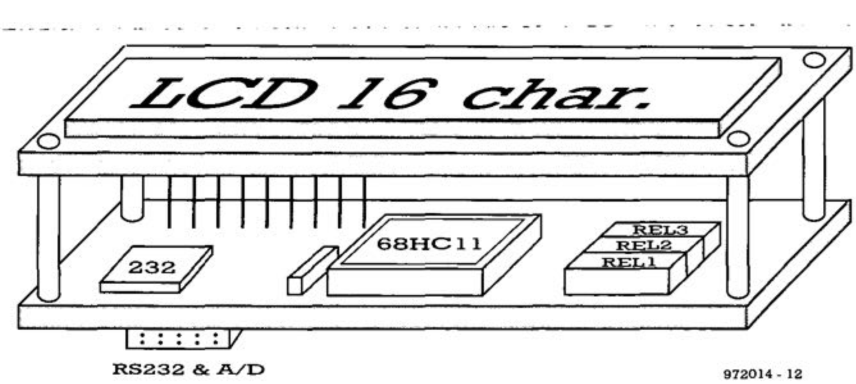


Figure 4. Using PCB pillars the LCD module proper is secured on top of the controller board.

COMPONENTS LIST
ref. Figures 1 and 2

Resistors:
R1 = 1MΩ (SMA)
R2,R3 = 220Ω (SMA)
R4 = 1kΩ5 (SMD)
R5,R6,R7 = 47kΩ (SMD)
R8 = 4kΩ7 (or 5kΩ) preset (SMA)
R9 = 10kΩ (SMA)
R10 = 1kΩ (SMA)
RN1 = SIL resistor array 7x10kΩ
RN2 = SIL resistor array 8x47kΩ

Capacitors:
C1,C2 = 22pF (SMA)
C3 = 100nF (SMA)
C4 = 22μF 10V tantalum
C5 = 10nF SMA
C6,C7,C8,C9 = 1μF5 16V tantalum

Semiconductors:
IC1 = MC68HC11E2FN (Motorola)
IC2 = MAX232 (wide SMA case) (Maxim)
U1 = MC34064 (Motorola)
U2 = 78L05 (SMA, 8-pin)
D1 = LM 336/Z5.0V
LDE1 = LED, red

Miscellaneous:
LCD1 = LCD display 1 line, 16 characters (e.g. Sharp LM 16155)
Q1 = 8.000MHz quartz crystal (miniature)
Rel1,Rel2,Rel3 = SIL05D (5-V reed Relay in SIL case, with diode)
T1,T2,T3 = miniature push-button
Piezo = passive piezo buzzer
ST1 = 10-way boxheader
RS232 connection cable, 4-wire, with 10-way IDC socket and sub-D socket (25 or 9-way)
10-way IDC socket for thermometer
JP1-8 = pinheader double-row, 8-way
6 jumpers
PLCC socket, 52-pin, for IC1
Printed circuit board not available
Software: on diskette, order code 976009-1 (see Readers Services page)

store it into EEPROM. Once this has been done, the user program is started. The program length is limited to 512 bytes on the A1 version of the controller, or 2,048 bytes on the larger E2. During the transmission, the PA4 line is used for synchronization purposes. An LED connected to terminals LP7-LP8 on the board allows you to follow the downloading process. The LED indicates that the programming has been started by remaining off for about 1.5 s and then lighting for about 2 s. This should be taken to mean that the loader has been received, and that it has taken control of the 68HC11. Next, the LED lights at irregular intervals, indicating that the main program is being loaded and stored in EEPROM. The LED does not light if a received byte is already present in EEPROM. If, on the other hand, a received byte is not yet available in EEPROM, the LED lights. In this way, you are able to see how the EEPROM is filled.

Sample application programs

All programs discussed below are available on a diskette with order number **976009-1** which may be ordered through our Readers Services. **Tables 2, 3 and 4** indicate the jumper functions, solder terminal (LP) functions and the pinout of header ST1 on the board. All solder terminals are found at the solder side of the board, and are marked as shown in Table 3. The relay contacts are rated at 15 watts and 200 VDC. For safety's sake however keep the contact voltage below 48 V.

Program PRG-1
(decimal seconds counter)
The module operates as a seconds up-counter. After you switch it on, the display briefly reads 'Programm PRG-1', and then '000.000.000 Sek'. If the counting is not stopped, the highest value of '999.999.999 Sek' will be reached after about 32 years. In this application, the following functions from Tables 2 and 3 may be used:
JP2, JP3, JP4, LP7-8 (LED flashes at a rate of 1 Hz) and LP13-14.

Program PRG-2
(Days, Hours, Minutes counter)
This program causes the LCD module to work as a 10-seconds counter. First the display briefly shows 'Programm PRG-2', then '0000T 00S 00M 0S' (T = days, S = hours, M = minutes, S = seconds). For example, on the change of the first to the second day the display shows '0001T 23S 59M 5S', and after 10 seconds '0002T 00S 00M 0S'.

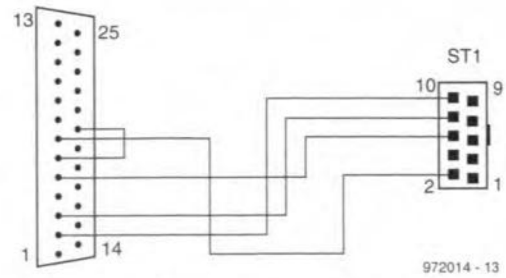


Figure 5. Pinout of the cable which links the PC's RS232 port to the 10-way boxheader on the controller board.

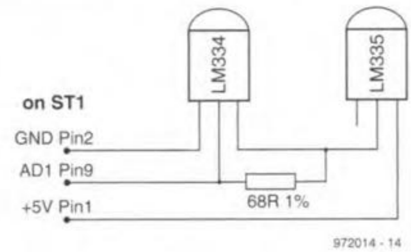


Figure 6. Temperature measurement circuit for use with the thermometer/thermostat program, PRG-3.

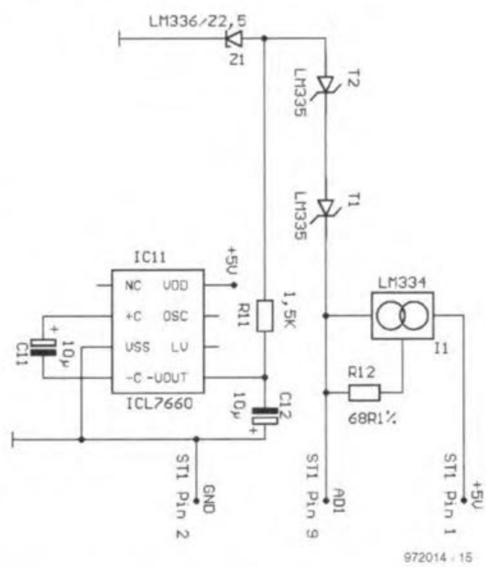


Figure 7. This temperature measurement circuit for use with thermometer/thermostat program PRG-4 offers higher accuracy.

In this application, the following functions are available from Table 2:
JP2, JP3, JP4, LP7-8 (LED flashes at a rate of 0.5 Hz) and LP13-14.

Program PRG-3
(Thermometer/Thermostat)
This program cause the module to operate as a thermometer/thermostat. First, the message 'Programm PRG-3' appears briefly, then 'Minimal -50°C'. Next, you may set the desired lowest value using push-buttons T1 and T2. Press T3 to save the desired value. Next,

Table 2 Jumpers: functions and arrangement		
Jumper	**Function w. jumper set**	**Port**
JP1	Piezo buzzer off	PE4
JP2	Display cleared to 00000000 after a STOP by JP3 or LP13,14. If JP2 is not set, counting continues at the old value after a STOP	PE5
JP3	Hold counter	PE6
JP4	Increase count rate (for testing)	PE7
JP5	+ Offset with thermometer program	PC0
JP6	– Offset with thermometer program	PC1
JP7		PC2
JP8		PC3

Table 3 Function and arrangement of solder pads LP1 - LP20		
Solder pad	**Function**	**Port**
LP 1 - 2	reed relay 1, contact closed	PC6
LP 3 - 4	reed relay 2, contact closed	PC5
LP 5 - 6	reed relay 3, contact closed	PC4
LP 7 - 8	indicator LED	PA6
LP 9 -10	piezo buzzer (Alarm)	PA5
LP11-12	for extension (F meter)	PA7
LP13-14	counter halted when set	PC7
LP15-16	button 1/+	PA0
LP17-18	button 2/–	PA1
LP19-20	button 3/Save	PA2

Table 4 ST1 pinout and function			
Pin No.	**Function**	**Port**	**Use**
10	RxD line from 68HC11 - connected to TxD on PC	PD0	RS232
9	1st 8-bit A/D converter	PE0	A/D-input
8	TxD of 68HC11 - connected to RxD on PC	PD1	RS232
7	2nd 8-bit A/D converter	PE1	A/D-input
6	I/O line, used with CTS for synchronisation by PC	PA4	RS232
5	3rd 8-bit A/D converter	PE2	A/D-input
4	not used		
3	4th 8-bit A/D converter	PE3	A/D-input
2	GND	GND	RS232 and A/D
1	+5V (max. 30mA)	+5 V	A/D

the display shows 'Maximal +50°C'. Use T1 and T2 to set the desired highest temperature, then T3 to save the value. The extreme values are automatically stored in the EEPROM, and the program is started. The min./max. settings are requested every time the unit is switched on with PRG-3 loaded. If there is no need to change previously programmed values, do not press any of the push-buttons and wait for about 8 seconds for the program to start using the values fetched from EEPROM. By pressing T1/– and T2/+ simultaneously, the two values may also be changed while the program is running. Doing so causes the program to jump to routines which allow the min./max. values to be set.

As regards the switching of the relays:

The REL1 contact is closed when the measured temperature is below the programmed minimum.

The REL2 contact is closed when the measured temperature is between the programmed extremes.

The REL3 contact is closed when the measured temperature exceeds the programmed maximum.

Only one relay can be closed at a time.

For the buzzer signal we have:

A low-pitch tone is produced if the REL1 contact is closed, and a high-pitch tone when the REL3 contact is closed.

An intermittent beep is produced. The beeping sound may be mute at any time via jumper JP1.

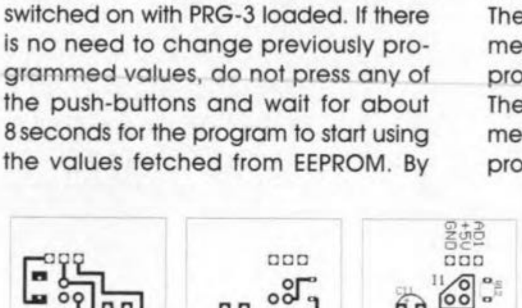


Figure 8. Artwork of the double-sided PCB designed for the temperature measurement circuit of Fig. 7.

The measuring range is –50°C to +98°C at a resolution of about 2°C. If the measured temperature is outside this range, the display indicates 'ERROR –50 +50', although the relays are still correctly driven.

In case temperature measuring errors occur as a result of component tolerances, a correction may be tweaked by means of JP5 or JP6 (see Table 2). For example, if the display reads +26°C while the actual temperature is only +22°C, the display reading may be corrected by briefly closing JP6. The correction is stored as an offset in the system EEPROM, and is automatically recalled each time the program is started.

The temperature offset has a range of –12°C to +12°C in steps of 2°C.

In this application, the following functions from Tables 2 and 3 are available: JP1, JP5, JP6, LP7-8 (LED flashes at a rate of 0.5 Hz), LP9-10, LP1-2, LP3-4, LP5-6, LP15-16, LP16-17 and LP19-20.

The measurement circuit shown in **Figure 6** is connected to ST1 pins 1, 2 and 9. You will need the following parts: an LM334Z current reference, an LM335Z temperature sensor and an 68Ω 1% resistor.

Program PRG-4 (Thermometer/Thermostat)

This program is similar to PRG-3 described above, with the following differences:

- Measurement range –50°C to +99°C at a resolution of 1°C.
- Temperature offset range –6°C to +6°C in 1°C steps. Jumper functions and connections are identical to PRG-3. The circuit shown in **Figure 7** is connected to ST1. This slightly more elaborate measurement circuit is constructed on the printed circuit board shown in **Figure 8**.

(972014)

COMPONENTS LIST ref. Figs. 7 and 8

Resistors:
R11 = 1kΩ5 (SMA)
R12 = 68Ω 1% (SMA)

Capacitors:
C11,12 = 10μF 10V tantalum

Semiconductors:
I1 = LM334Z
T1,2 = LM335Z
Z1 = LM336Z2.5
IC11 = ICL7660 (SMA)

If you have ever been involved in developing code for an embedded 8051 system, you will know how frustrating and time-consuming it can be. With no external code ROM/RAM to hold monitors and other software debugging tools, the developer is forced into using EPROM devices. Unless an EPROM emulator is available, code development is usually hindered by the need to erase the EPROM each time before re-programming with the next code iteration. It's so annoying waiting up to twenty minutes for the device to erase, only to find out that your latest code still doesn't work! FLASH microcontrollers are the answer.

By Patrick Gale, Equinox Technologies

Why you may need to FLASH!

Equinox Technologies Starter System. This contains the Micro-Pro programmer complete with power supply, parallel cable, sample AT89C2051 microcontroller, the PK51-2K IDE including C compiler, assembler, and dScope-51 debugger, together with appropriate software, manuals, CD-ROM and databook.

Whilst few manufacturers have exploited this leading-edge technology in the microcontroller arena, Atmel have introduced a range of 8051 compatible microcontrollers with on board FLASH PROM. The FLASH code memory can be erased electrically in milliseconds with no need for a UV eraser, and such FLASH microcontroller devices can be reliably erased and re-programmed over 1,000 times.

This technology represents an enormous time saving, but its advantages are not just confined to the development environment — it also allows for 'just-in-time' programming in a production environment. If numerous code revisions are the norm before all the bugs are ironed out, FLASH offers the route to overall programming flexibility. The latest code revision can be programmed into a device in seconds whilst it is actually progressing down the production line. With the addition of the appropriate hardware it is even possible to program these devices actually in-circuit without removing the device from the product! If the final product requires frequent code updates, then once again FLASH is the answer — unlike an OTP, the device can simply be re-programmed at no extra component cost to the manufacturer. Better still, the FLASH device is often *cheaper* than the equivalent OTP part!

Atmel supply a wide range of FLASH microcontrollers — brief details of the most popular ones are shown in the table.

When Atmel FLASH microcontrollers are used with the Micro-Pro Programmer and the Keil PK51 Integrated Development Environment (IDE), a very short software development cycle is achieved.

The Micro-Pro programmer can erase, program and verify an Atmel 89C1051 (1K) in under 3 seconds, or an Atmel 89C52 (8K) in less than 10 seconds (timings based on a DX4-100MHz PC). This programmer is a worthy addition to any 8051 developers toolkit, as it is also capable of programming many serial and parallel EEPROM devices, FLASH memories, Configurators such as those offered by Xylinx, Altera and Cypress and even the new Atmel 90S ('AVR') family which is expected to displace the overlauded PIC from its pole position.

	89C51	89C52	89C55	89S8252	89S53	89C2051	89C1051
Flash Code ROM (bytes)	4K	8K	20K	8K	12K	2K	1K
RAM (bytes)	128	256	256	256	256	128	64
EEPROM	-	-	-	2K	-	-	-
In-system reprogrammable	-	-	-	YES	YES	-	-
I/O pins	32	32	32	32	32	15	15
16-bit Timer/Counters	2	3	3	2	3	2	1
Watchdog timer	-	-	-	YES	YES	-	-
Interrupt sources	6	8	8	9	9	6	3
Serial UART (full duplex)	YES	YES	YES	YES	YES	YES	-
SPI interface	-	-	-	YES	YES	-	-
Analogue comparator	-	-	-	-	YES	YES	YES
Data pointers	1	1	1	2	2	1	1
Package pins(DIL)*	40	40	40	40	40	20	20

* LV parts are also available for the 40-pin derivatives.

Why use C?

An increasing number of developers are moving away from using assembly language as their main programming language, and switching to C instead. The reasons for this are twofold; firstly, it is far quicker to write and debug code in C than it is in assembly language and, secondly, the quality of the C compilers available for microcontroller architectures has improved dramatically in recent years.

For 8051 microcontroller applications, the Keil C51 Compiler lets you write programs in C and get very close to the efficiency and speed of assembly language. This compiler is not a modified version of a standard compiler — it was specifically written to generate fast and compact code for the 8051 microprocessor. Target-specific extensions incorporated into the compiler give you full access to all the resources of the 8051. This means that the programmer can refer to the various on-chip peripherals and SFRs (special function registers) by name, rather than by some abstract address.

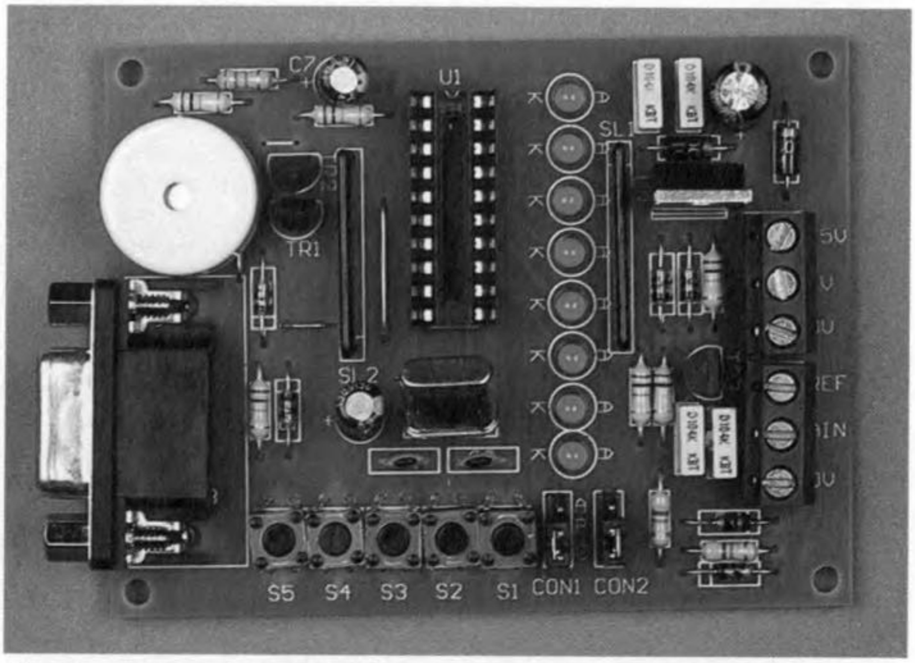
The PK51-2K suite of software tools allows you to author modular programs in C and/or assembly language for many 8051 microcontroller derivatives. It imposes a 2K code limit, which makes it ideal for developing full production projects for the Atmel AT89C2051 & AT89C1051 microcontrollers which feature 2K and 1K of on-chip FLASH PROM respectively.

PK51-2K is also an ideal evaluation tool for many other 8051 derivatives which feature larger code sizes. These include the 8xC51, 8xC52, Siemens 537 and Dallas 320/520 microcontrollers.

In fact, the PK51 environment even allows you to test your code without having a target device available! It includes dScope-51, a software simulator and debugger — this is effectively a PC program which pretends to be your target microcontroller. Using this simulator, a programmer can single-step through the program, watching registers, variables, and peripheral devices, breakpointing at specific statements, and simulating external signals, as if the actual microcontroller was present.

For larger devices, a version limited to 8K code size, and an unrestricted version are available.

Another hurdle often faced by a microcontroller-based system developer is that he may need to make progress with the software development *before* the hardware design has been finalised (or, in some cases, before it has even started!) This is particularly difficult if s/he has little prior experience of using the actual target microcontroller. It is very useful to have some form of 'tried-and-tested' target board on which potential software solutions can be evaluated, whilst at the same time gaining a better understanding of the microcontroller architecture and how to interface to the on-chip peripherals. Such a board - often referred to as an 'evaluation' or 'demo' board - can rapidly reduce the learning curve and therefore the development costs. (972013)

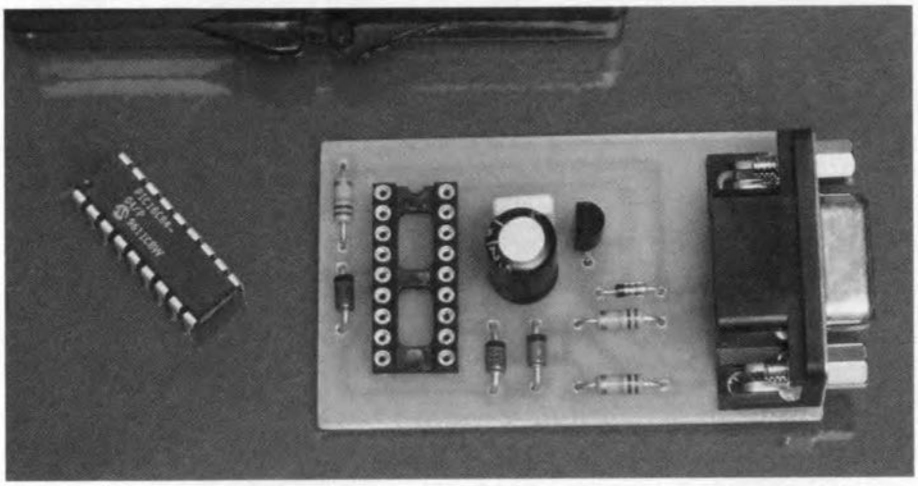


Atmel Flash microcontroller evaluation board complete with push-buttons, LEDs, ADC and piezo sounder.

Even with street prices dropping steadily, good PIC programmers remain relatively costly tools. Provided you exploit the 'serial programming' mode available on recently launched PICs (and, in particular, the 16C84), it is feasible to build a surprisingly simple programmer which is still fully compatible with much of the powerful software now circulating on the Internet.

Design by Patrick Gueulle

mini PIC programmer



Serial-mode programming

Programmable components are increasingly intended to be programmed 'in-circuit'. The process is also *called code downloading*, meaning that the relevant chip is simply connected to a bus consisting of four or five wires.

In this respect, the 'isp' chips from Lattice are the best know examples, although there are new arrivals all the time. Relative newcomers in the field include certain MACH types from AMD, whose appearance on the market has not gone unnoticed.

As you are probably aware, several members of the PIC family offer a similar ability which enables them to be programmed or re-reprogrammed while they remain on the application board, and you do not even have to remove the supply voltage.

These PIC chips are switched to programming mode by pulling their reset pin ($\overline{MCLR}$, pin 4) to a high voltage, usu ally between 12 and 14 volts.

From then on, RB6 (pin 12) acts as a CLOCK input, while RB7 (pin 13) is turned into a DATA input/output line.

The power supply pins of the PIC, Vdd (pin 14) and Vss (pin 5) retain their normal function, that is, they keep the PIC supply voltage at the nominal value of 5 V, although all other pins are effectively disabled.

In this mode, you may program, read and even clear (erase) the PIC simply by communicating with it using a serial format on the DATA line. In fact, this closely resembles the way serial EEPROMs work, as well as some chip cards. The communication protocol used for serial programming is disclosed in a document of some 10 pages called *PIC16C84 EEPROM memory Programming Specification* which is available from Microchip Technology, or, in electronic form, on the CD-ROM published by this manufacturer.

Provided you do accept that the present design can not be labelled as a 'production programmer' the strict rules for programming laid down by Microchip may be relaxed considerably. So, let's agree on calling the present design a 'prototype' or 'development' programmer.

Free programming software

Fortuitously, among the less inspiring things found on the Internet, there's also webbed software for programming PICs. What's more, it's free!

One of these free programs is PIP02. Although still in an early version (1.14), the program is still very satisfactory, and may be found at various Internet sites, including

http://www.sistudio.com/sistudio/download/html

where it is available as a zip file.

Developed by Antti Lukats of Silicon Studio Ltd., PIP02 assumes that the PIC is hooked up to a serial PC port, allowing a trick to be used to 'steal' the necessary supply voltages from the RS232 interface.

A revised circuit diagram

A PIC programmer circuit diagram suggested by Erik Herman has been around on the Internet for a while, while the hardware-software link is due to Rolan Yang.

Far from complying with the rigid Microchip specification, this schematic inspired the author to do some touching up, the results of which are shown in **Figure 1**.

As a matter of course, the wonderful basic idea of extracting the PIC supply voltage from the TxD line on the PC's serial port is fully respected and retained. This approach obviates the need for any kind of external power supply or even a battery, and works very well in practice.

Although a TxD-derived supply voltage does not pose problems for the creation of a 'clean' 5-volt rail using a 78L05 regulator, the availability of at least 12 V for the $\overline{MCLR}$ pin calls for a 'true' RS232 port supplying voltage swings of at least plus and minus 12 V.

The programmer will not work with PCs having a serial port supplying a swing of 5 volt (so watch out for a 'TTL compatible' spec). Unfortunately, such ports are typically implemented on portable and laptop computers whose design often requires recourse to unorthodox solutions as regards energy reduction.

If the serial port on your PC is TTL compatible only, the solution is to add a true RS232 port, for example, one that forms part of a Multi-I/O card.

Once you are aware that signals with a swing of at least 12 volts are present on the RS232 interface lines, you will not be surprised to find a couple of zener diodes in the circuit which reduce these swings to levels which are harmless to the PIC.

Although the relatively high value of the resistors used in the original schematic referred to above is, in principle, sure to prevent destructive current levels, it was considered good practice to eliminate the risk of a negative 12-volt potential being applied to a sensitive and costly part like the PIC controller.

Practical realization

The original Herman schematic has already been the subject of many interpretations, some of which have substantialized into commercially available kits. In some cases, the programmer hardware is even fitted inside the hood of a 25-pin sub-D connector!

As far as the author is concerned, there's no need to fit the present circuit into a case, while it will be more convenient to use a 9-pin sub-D connector. That brings us to the PCB layout shown in **Figure 2**. Even if an ultra-compact component arrangement was never a design goal, the board is still of a modest size. The actual component mounting plan is shown in **Figure 3**. Obviously, it is essential to observe the orientation of all polarized components. Although you should not use zener diodes with a zener voltage below 5.6 V, types with a 6.2 V specification

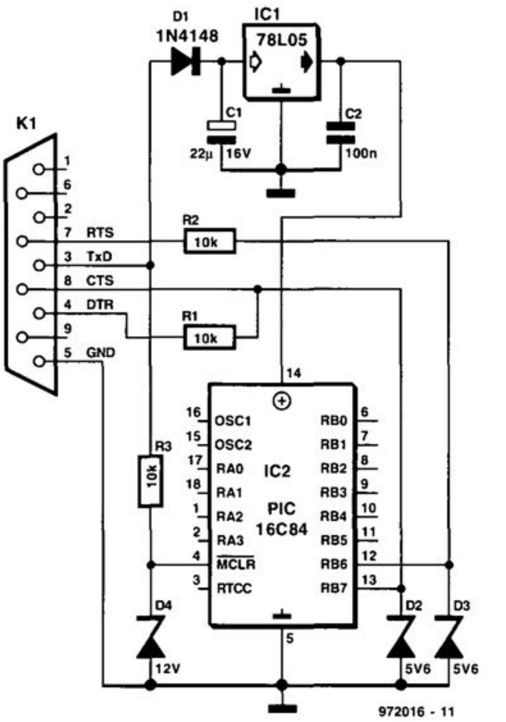


Figure 1. Circuit diagram of the mini PIC programmer. Quick and dirty!

will also be acceptable.

The use of a zero-insertion force (ZIF) socket was not considered essential. Instead, a quality socket with turned pins may be used, provided you also employ a suitable IC insertion and extraction tool and handle it with due care.

The completed board is connected either directly to the PC, or via a 9-way

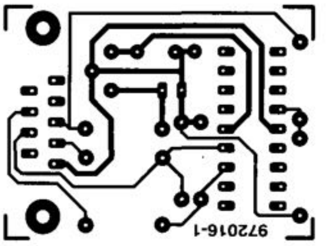


Figure 2. Copper track layout of the miniature board designed for the programmer.

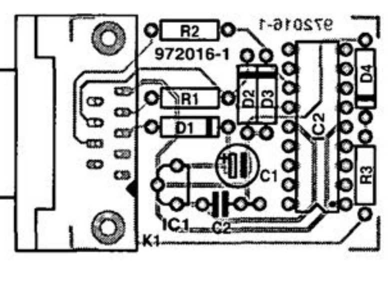


Figure 3. Component mounting plan.

male-female cable which may be picked up from computer stores under the name 'monitor extension cable'. If necessary, you may insert a DB9 to DB25 adaptor, but never a zero-modem cable or one with crossed wires. For the present programmer, you need a cable with a 1-to-1 wire correspondence between the connectors.

Practical use

Before launching the main program, PIP02, it is necessary to install a resident driver (TSR) called COM84 which is included in the PIP02.ZIP file. Use it as follows:

```
COM84 COMn
```

where n is the number of the serial port you wish to use (1 through 4, if available on your PC).

You may want to automate some of the programming drudgery by writing a small batch program (called PIP.BAT for example), which might look like this (assuming COM1: is used)

```
COM84 COM1
PIP02
COM84 REMOVE
```

The last line automatically de-installs and unloads the driver when you quit PIP02, thus avoiding possible conflicts with other software.

Its presentation easily mistaken for that of 'real' utilities from Microchip, PIP02 offers a good level of user-friendliness. Various menus are accessible, and you will get the knack of the program fairly quickly. The thing to remember before launching any operation is to always select the PIC type to be read or programmed. Also, always keep in mind the correct setting of the fuses before you launch the programming operation.

The programming, by the way, requires a file written in INHX8M (Intel hex-8) format. Fortunately, that's convenient because the very same format is generated by the majority of PIC development tools.

To close off, a final, important, detail: if you make an error which causes a total lockup, it is always possible to erase the PIC using the 'Erase' option from the 'Device' menu.

(972016-1)

*Note: Readers not having access to the Internet may obtain the PIP02 software from the Publishers under order code **976007-1**. Price and ordering details are given on the Readers Services page towards the end of this issue.*

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.

In popular demand: Alpha Microelectronics address

I found an interesting article in your July/August 1997 issue about a single chip ac-dc inverter (page 102). It is a small application note numbered 974026 from Alpha. I would be very pleased if you could send me the address of that company, since I have not been able to find it anywhere.

Kari Supponen, Finland (by email)

Actually, the number 974026 is our article production code, Kari, and the full name of the company is Alpha Electronics. Their main product distributor is Unitronic GmbH, P.O. Box 350252, D-404444 Düsseldorf, Germany. Tel. (+49) 211 9511-0, fax (+49) 211 9511-111. We hope this helps you.

PIP02 problems

I'm having problems with programming a PIC16C84 using the PIP02 program (June 1997 Supplement, *ed.*). My computer is a 166 MHz Pentium system, and I suspect it's too fast. Can you help me, please?

T. Suhonen, Finland

The version of PIP02 we were allowed to distribute by Silicon Studios is not the latest version. We suggest getting in touch with Antti Lukats of Silicon Studios to discuss your problems. Meanwhile, try adding this line to your AUTOEXEC.BAT file:
SET STUDIODIR=C:\PIP02

Intel hex-8 format

I refer to the June 1997 Supplement on microprocessors, in particular, the Mini PIC Programmer. Could you please elaborate on what we would use to produce an INHX8M (Intel hex-8) format file, please.

Ian Gill (by email)

We would be surprised to see a PIC code assembler which does not support the Intel hex-8 format. MPASM (free from Microchip) does the job, too. There are also lots of file conversion utilities around which produce INHX8 output.

Thanks Jan,
You were exactly right, MPASM is the program I was looking for (and free too). Unfortunately entry into the world of PICs is difficult for hobbyists faced with numerous businesses trying to sell high priced programmers and software, we don't always get pointed to the simple solutions and free software. Thanks for your help and thank you for running the very timely June edition mini PIC programmer story.

Regards, Ian Gill

HEXFET amplifier oscillation

I have built the amplifier described in the article 'HexFET Amplifier Upgrade' (September 1995). I am very pleased with the performance of the amplifier, both as regards measurement and sonic results. However, during my measurements I discovered short high-frequency oscillation burst which occurs any time the amplifier is switched on or off. Although these bursts are without consequence because of the output relay, I am writing to inform if this problem is known , and if there is a possible remedy.

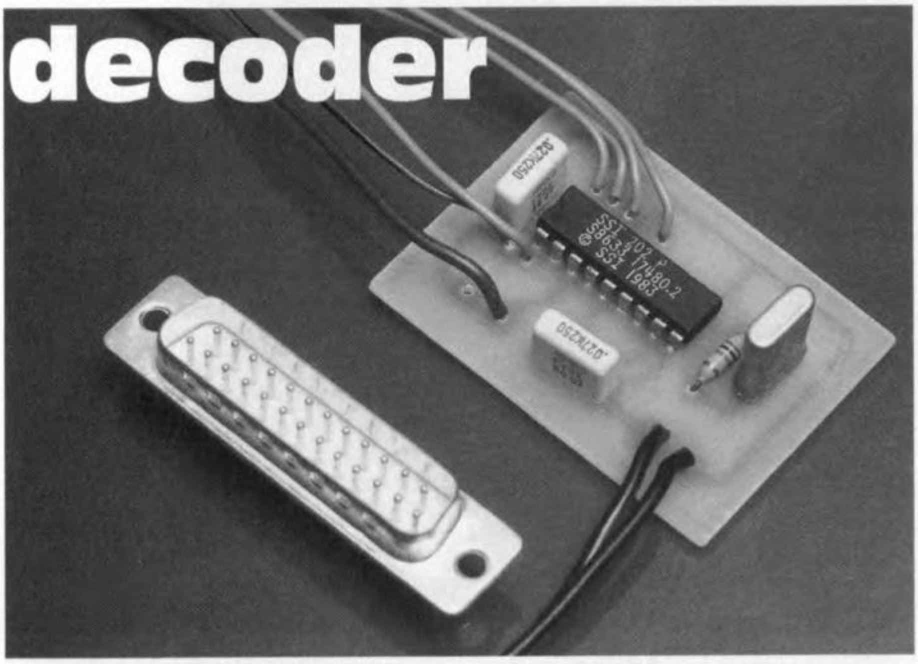
J. Glerum

Yes, we do recognize the phenomenon you mention, it is caused by the IGBT transistors used in the design. Although the oscillation is not harmful, it is not proper! Those of you who want to get rid of it may fit a second Boucherot network in parallel with the one already present (R32-R33-C10). The extra network should consist of a series connection made from a 220-nF (0.22-μF) capacitor and a 6.8-Ω resistor with a power rating of 5 watts. This combination should be connected between point 'A' and ground, which is best done at the solder side of the board. As far as we have been able to ascertain, this modification does not affect the amplifier's performance.

Most of you will be aware that DTMF telephone dialling signals are two-tone combination that may be recorded on any cheap tape recorder, just like speech.
Playing back these tone pairs into a suitable decoder should reproduce the digit originally pressed on the telephone.
The use of a PC as a visualization terminal allows the electronics you need to implement a DTMF decoder to be reduced to its most elementary form.

Design by Patrick Gueulle

PC-controlled DTMF decoder



Recapping

DTMF (dual tone multi frequency) dialling is the immensely successful successor of the older dialling disc associated with pulse-controlled telephone systems. DTMF has many advantages over traditional pulse dialling, including faster access to the called party. In the DTMF system, each digit (and symbol) on the telephone set is associated with two discrete audible frequencies which are transmitted as a pair. The DTMF tone pairs use throughout the world are shown in **Figure 1**. The pairs consist of one four 'low' frequency (697 Hz, 770 Hz, 852 Hz and 941 Hz) and one of four 'high' frequencies (1209 Hz, 1336 Hz, 1477 Hz and 1633 Hz). The total number of possible combinations offered by these tone sets is sixteen, which is actually more than needed for a simple 10-digit dialling pad.
The keys marked # and * have been added to the system, and have found many applications in modern telephone systems. Not available on the most rudimentary of keypads (which do not generate the 1633 Hz signal) are four special codes designated A, B, C and D. So far, these have found little use. As a matter of course, lots of integrated circuits have appeared on the market for generating and decoding DTMF signals.
Among the best known manufacturers of DTMF decoders are Mitel, Teltone and Silicon Systems, whose SSI75T202 is widely available from retail stores, sometimes disguised as SSI202, its older type designation. Compatible chips are also available from second-source suppliers, in particular, RCA/Harris (CD22202).
Having a four-bit databus, the SSI202 employs the conventions shown in **Figure 2** to signal the tone pairs it is able to recognize, provided the chip is set to operate in hexadecimal mode (pin 2 strapped logic high).
The Data Valid (DV) output goes high when a valid DTMF code is detected, and remains high for its entire duration (in principle, 100 ms or longer).

Building the decoder

It will be very hard indeed to beat the simplicity of the circuit shown in **Figure 3**. A common-or-garden 3.579 MHz

HIGH / LOW	1209	1336	1477	1633
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

Figure 1. Correspondence between the DTMF tone pairs and the numbers/signs.

Key	Hexadecimal			
	D8	D4	D2	D1
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0
A	1	1	0	1
B	1	1	1	0
C	1	1	1	1
D	0	0	0	0

Figure 2. SSI202 binary output as a function of received DTMF code.

quartz crystal and its associated resistor are the only two external parts required by the SSI202. We only added a decoupling capacitor on the 5-volt supply rail, and a coupling capacitor at the chip input. The latter is perhaps overkill in view of the capacitor on board the SSI202, but it afford extra protection against direct voltages which may accidentally be applied to the circuit.

Communication with the PC is achieved via five input lines available on all properly designed parallel ports: ACK, BUSY, PAPER END, ERROR and SELECT.

The 5-volt supply may be derived from pin 1 of the 15-way joystick connector. The circuit is best built on the printed circuit board whose copper track layout is shown in **Figure 4**. The relevant component mounting plan appears in **Figure 5**.

Do not make the cable between the PC and the decoder longer than about 50 centimeters. Fortunately, the (screened) signal input cable may be much longer.

Without any kind of preamplifier or attenuator connected at its input, the decoder works properly across a drive range of 30 dB. Consequently, the headphones output of a tape recorder is perfect for driving the decoder if the volume control is set to a normal listening level. None the less, the recorder should be of a reasonable quality, because the accuracy of the DTMF tone frequencies is badly affected by speed variations exceeding 2% or so. The recording conditions also affect the reliability of the decoding process, because the levels of the 'high' and the 'low' tones should not differ by more than 10 dB. If present, treble and bass controls should be set to their neutral (defeat) positions right from the start (recording). Consequently it is preferred to make recordings using a suction-style magnetic coupler, or by electrical coupling. It is not reasonable to expect decent results from microphone recordings , for example, from the sound produced by a loudspeaker in a hands-free phone system, even though the SSI202 will still work reasonably well if voice signals are superimposed on the wanted signals.

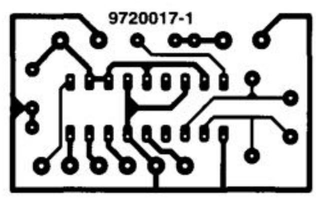


Figure 4. Copper track layout

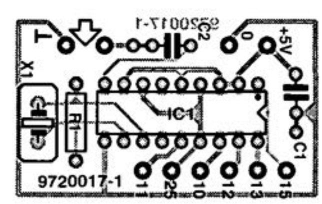


Figure 5. Component mounting plan.

Decoding software

Written in GW-BASIC, the simple program shown in **Figure 6** is intended for a decoder connected to the second parallel port, LPT2:. If you want to use LPT1:, simply replace the port address '279' by '379' in line 30.

The program continuously monitors the state of the decoder's DV output. The character corresponding to the logic state of the four datalines is read and displayed on the rising edge of the DV signal. A reasonably fast PC is thus capable of keeping track of the fastest of automatic dialling systems.

The program returns to line 30 after a delay of five seconds following the last DTMF character. In most cases, this will mean that a complete dialling code has been received.

Experienced programmers should be able to expand the program with routines that enable numbers to be printed on paper, or saved to disk.

In case the decoding is performed in real time, that is, with the decoder directly connected to a telephone line and skipping the recording process, it should even be possible to append date and time information to the received dialling codes. This is easiest done by co-printing the (reserved) BASIC variables DATE$ and TIME$.

(972017)

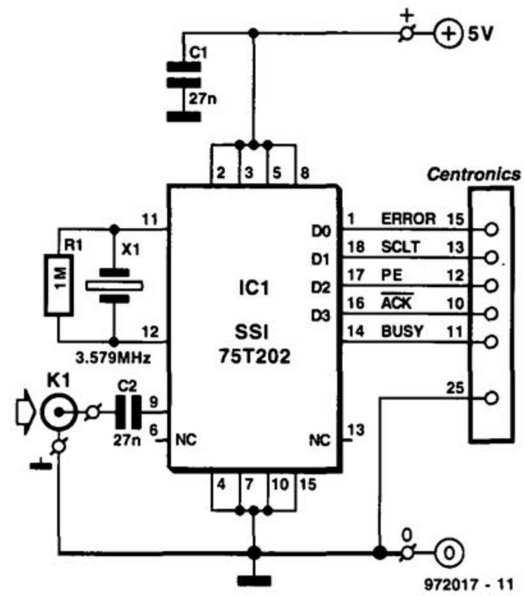


Figure 3. In practice the electronics is limited to the tone decoder clocked by its external quartz crystal.

```
10 REM ----- DECDTMF.BAS -----
20 CLS:KEY OFF
30 I=INP(&H279) ' decoder on LPT2:
40 IF (I AND 128)=128 THEN 30
50 C=0
60 IF (I AND 8)=8 THEN C=C+1
70 IF (I AND 16)=16 THEN C=C+2
80 IF (I AND 32)=32 THEN C=C+4
90 IF (I AND 64)=64 THEN C=C+8
100 IF C=11 THEN PRINT" * ";:GOTO 180
110 IF C=12 THEN PRINT" # ";:GOTO 180
120 IF C=13 THEN PRINT" A ";:GOTO 180
130 IF C=14 THEN PRINT" B ";:GOTO 180
140 IF C=15 THEN PRINT" C ";:GOTO 180
150 IF C=0 THEN PRINT" D ";:GOTO 180
160 IF C=10 THEN PRINT" 0;:GOTO 180
170 PRINT C;
180 I=INP(&H279) ' &H379 for LPT1:
190 IF (I AND 128)=0 THEN 180
200 T=TIMER
210 I=INP(&H279)
220 IF (TIMER-T)>5 THEN PRINT:PRINT:GOTO 30
230 IF (I AND 128) = 128 THEN 210
240 GOTO 50
250 REM (c)1996 Patrick GUEULLE
```

Figure 6. This little GW-BASIC program continuously monitors the DV output of the decoder, and displays the received character.

YOUNG ELECTRONICS DESIGNERS DISPLAY THEIR TALENTS AT YEDA

The quality of the innovations from this year's finalists in the Young Electronics Designers Awards (YEDA) competition was truly inspiring ... from a safety device for irons to a device to detect electric fences in the countryside.

In fact, with such talent and vision on show, the only question is why Britain is not a super-performer in the commercial world. It certainly augurs well for the future.

The man from the UK Patent Office making his first visit to the show was extremely impressed and certainly such is the quality of the devices and designs that there is now a warning to contestant to apply for patent protection before the final.

All the finalists' projects were on display at the Science Museum in London recently and the winners and runners-up in the three categories were presented with their awards at a special presentation dinner by His Royal Highness The Duke of York, the patron of the YEDA Trust which stages this event every year. The names of the prize winners were announced by TV personality Sally Gray.

Emily Collins

Winning the Mercury Communications prize for the best communications-based project was Emily Collins from Ridley High School, Blyth, Northumberland with her sensory alert device for the deaf – a device worn on the wrist which flashes and vibrates as a warning of smoke, intruders, doorbell or a telephone call. Her project was highly commended in the Junior Under-15 Category.

Seventeen-year-old Simon Todd, winner of the Intermediate (15–17 years old) Category and a YEDA trophy, took the £2,500 Texas Instrument prize for the most commercially viable project with his safety device for a domestic iron.

Simon, who shares the award with his school, came on the idea when he discovered that his mum had burnt an iron mark on his favourite shirt while she was ironing and watching TV at the same time.

Simon Todd

He told *Elektor Electronics*: "The device is basically a 5-second timer. When it reaches zero, an alarm is triggered. The timer is activated when the iron is placed in a horizontal position (that is, on top of the ironing board) and is deactivated when the iron is in a vertical position. Every time the iron changes direction, the timer is reset, so that the alarm will be triggered only when the iron is left stationary in a horizontal position for more than five seconds. This should alert the user if the iron is accidentally left on top of the clothing before the material becomes damaged.

Now taking Maths, Physics and Technology, Simon used his project to gain a Grade A in Technology in an internal examination.

Mark Gould, 14, from the Gryphon School, Sherborne, Dorset, won the IEEA Award for the best project from a school entering the YEDA competition for the first time.

Mark Gould

Farmer's son Mark won the £1,000 award for his electric fence detector. Mark said: "I got the idea while trying to listen to my radio which was suffering from interference from a neighbour's electric fence. I therefore realised that radio waves can be used to check whether a fence was live or not. Currently, the only devices on the market are test meters which you have to earth to check the current section by section, whereas with my device you check the fence from two metres away. Already, I have had a lot of interest from farmers in my area, walkers, and horsemen."

Runner-up in the Junior Category (under 15 years old), Mark, along with the other sponsors' award winners and the age category winners, receivers a cordless telephone from Mercury. Every finalist received a Texas Instrument graphics calculator with eight bytes of

James Smith

user memory and a YEDA certificate.

Twenty-two-year-old James Smith, a former student at Brunel University, Egham, Surrey, won the first prize in the Senior Category (18–25 years old) of £1,000 plus a YEDA trophy for his Manta – a communications device for recreational scuba divers.

James, who hit on the idea following a problem caused by lack of communication on his initial dive with a local scuba club, used the project to help him gain a first-class Honours Degree – a B.Sc. in Industrial Design.

Runner-up in the Senior Category was Peter Smith, 23, a former Bangor University student. Now an electronics engineer, Peter received the £500 prize for his integrated, low-cost noise badge dosimeter for people working in noisy environments.

Called BAND (Bangor Noise Dosimetry), the prototype of the system was developed by Peter as his final year project for his degree in Computing Systems Engineering.

"With BAND", said Peter, "workers wear miniature low-cost sound badges on their clothing. These measure the noise doses as a count – the louder the sound and the longer the worker is exposed to it, the greater the count. This is measured at

Peter Smith

the end of a shift by a computer system which also records it on the worker's record, resets the badge and performs a calibration".

"The computer also has the means to test the worker's hearing every few months or when he reaches a certain level of sound dose using its built-in multimedia capabilities. In this way, a worker's hearing can be monitored throughout the years and the first signs of hearing loss identified so that appropriate action can be taken."

Taking third place in the Senior Category and the £250 prize was 21-year-old Leighton Spicer, also from the Bangor University of Wales, with his electronic system to reduce the pressure sores in older and disabled people.

Highly commended in this category were Michael Brown (18) from Bancroft's School, Woodford Green, Essex, for his Gremlinator – a circuit testing aid; and Gwyn Jones (22), another Bangor University student, with his pre-eclampsia monitoring system for measuring the toxemia in pregnancy.

Runner-up in the Intermediate Category was David Marson (16) from St Joseph's College, Trentvale, Stoke-on-Trent, with an electronic hand-held pedestrian crossing sign.

Two pupils from Bishop's Castle Community College, Shropshire, Susannah Baker and Elizabeth Humphreys, took third place in this category with their talking electronic map of the London Underground: 'Braille Rail'.

Among those highly commended in this section were Sumit Rai (17), Dulwich College, London, for his opto-electrical swipe card system, designed for use in public places to monitor entrances and exits; Jonathan Taylor (15), Bryanston School, Blandford, Dorset, for his

David Marson

Coxbox, a device for rowers for recording their stroke rate; Andrew Buckmaster (16), Radley College, Abingdon, for Water Wizard for measuring and displaying the quantity of water used by showers and hose pipes; John Morton (16) and Max Kendall (16), both also from Radley College, for a bath temperature warning device in the form of a toy aptly named the 'Thermo Tug'; and Andrew Early (16), Ravens Wood School, Bromley, Kent, for his model rocket launch controller.

Typical of the problem solving nature of these projects is that of Edward Brocklebank (14) from Radley College, Abingdon, who was helping to improve the lighting system on his grandmother's C5 when he suddenly realized that such a facility is desperately needed for bicycles, indicating as it does when the cycle is in motion, when it is braking, and when it is turning left or right.

Edward, who next year sits his GCSE in Technology, won the Junior Category (under 15) and the prize of £500 and a YEDA trophy with his project "in which Halfords have already expressed an interest."

Third prize in this category went to a quartet of young electronics designers: Rachel Downing (13), Kerri-Anne Devlin (13), Anna Burke (12) and Anne-Marie Gaillaed (12), from St Mary's Junior High School, Lurgan, Northern Ireland, for their education toy to enhance knowledge of the earth and the solar system.

Highly commended in this category were Guy Kewish (13), Philip Redi (13), and Alasdair Lynch (13), from the Merchiston Castle School, Colinton, Edinburgh, for their babies and safety in car seats project, and Stephen Wyber (13), Bancroft's School, Woodford

Edward Brocklebank

Green, Essex, for his electronic kitchen weighing scales for the blind.

Information on this and next year's competition may be obtained from
The YEDA Trust
60, Lower Street
Pulborough
West Sussex RH20 2BW
Telephone (01798) 874767
Fax (01798) 873550
e-mail: yeda@cix.compulink.co.uk

ENHANCE YOUR COMMUNICATION SKILLS

A publication aimed at enhancing the communication skills of engineers and technicians has been produced by The Institution of Electronics and Electrical Incorporated Engineers (IEEIE). *Technically Speaking – Practical communications for engineers and technicians* contains invaluable tips and advice on a variety of topics from self-assessment, writing reports, and using the telephone, to dealing with the media, learning a foreign language, and making presentations.

The publication has won the Clear English Standard 'winning document' logo from the Plain Language Commission, underlining the clarity and straightforward approach to each of the subjects covered.

In publishing *Technically Speaking*, the IEEIE is continuing with its policy of offering sound advice on topical subjects considered necessary for the personal and career development of every practical engineer. The IEEIE is already well known for its commitment to continuing professional development, offering a comprehensive programme of lectures, seminars and courses and, realizing the importance of encouraging and motivating engineers, it has recently piloted a project to promote mentoring as a professional development tool.

Technically Speaking has been distributed free of charge to all members of the IEEIE and is available to new members at no cost. A limited number of copies are available for purchase by non-members for £5. Non-members wishing to purchase a copy should send a cheque, made payable to IEEIE, for £5·00 to The Secretary, IEEIE, Savoy Hill House, Savoy Hill, London WC2R 0BS (for overseas airmail, add £1·00).

EUMATSAT POLAR SYSTEM

In a recent special meeting, the EUMATSAT Council approved a bridging phase for the EUMATSAT Polar System (EPS) to cover essential activities that must start immediately in preparation for the full approval of the programme later this year. The main aim of the bridging phase agreement is to ensure that industrial activities can start on procurement of the MTOP satellites, thus maintaining the present cost and schedule assumptions for a launch of the first satellite in late 2002.

EUMETSAT establishes and maintains operational meteorological satellites for 17 West European states (Austria, Belgium, Denmark, Germany, Finland, France, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. The images and data from EUMETSAT satellites make a significant contribution to weather forecasting and, hence, the safety of all nations in Europe and neighbouring continents.

RECHARGEABLE ALKALINE MANGANESE BATTERIES

In our Focus One article 'Rechargeable-battery systems' (September 1996), we said that although rechargeable (secondary) versions of the alkaline-manganese battery had been available in the USA since the late 1980s, "they have not (yet) caught on in Europe".

This situation is changed by the announcement of Allied Battery Technologies in Stokenchurch, Bucks that mercury-free, rechargeable alkaline manganese batteries are now available in the UK. The company estimates that the use of these new batteries to power toys, cameras, radios, audio equipment, remote control units, torches, and countless other electrical appliances, could the average British family £100 in battery purchases.

Known as RAM™ (Rechargeable Alkaline Manganese) batteries, they are designed and developed in Canada by Battery Technologies Inc. where they are manufactured under licence by the Pure Energy Battery Corporation.

This new concept must not be confused with attempts to recharge conventional alkaline manganese batteries with 'universal' chargers. The RAM batteries are designed to be recharged and the recharge characteristics are such that lifetimes are increased over conventional alkaline batteries by at least 10 and up to 50 times or more. Using the simple charger, which fits neatly into a 13 A wall socket, is like holding a battery store in the home. The batteries have a shelf life of five years.

The RAM batteries have proved to be very successful in Canada and the USA where they have captured 53% of the NiCd battery market. Initially, AA size cells, which represent 62% of the UK market, will be available and the smaller AAA cells later this year.

Entirely 'green', RAM cells are an environmentally responsible alternative to NiCd batteries because they contain no toxic chemicals such as mercury or cadmium, In addition, because the batteries last so much longer than conventional batteries, fewer are thrown away.

The RM technology represents the first rechargeable product that can easily and economically replace single-use batteries world-wide. Pure Energy's RAM batteries are complete interchangeable with conventional, non-rechargeable alkaline batteries and they are also suitable in many cases as a cost-effective and environmentally friendly alternative to rechargeable NiCd batteries. In addition, they can be used in equipment labelled 'unsuitable for rechargeable Nickel Cadmium batteries'. This is because RAM batteries do not deliver the 'overcurrent' that is potentially damaging to consumer electronic equipment.

Another advantage is that there is no 'memory effect' such as occurs with NiCd batteries. Conversely, the RAM battery performs best when it is 'topped up' in the charger when it is not in use. Also, the RAM cell has an e.m.f. of 1.5 V as opposed to the 1.2 V of the NiCd cells and is, therefore, more cost-effective for 3 V and 6 V applications.

Allied Battery Technologies (ABT) Ltd; 14, Bates Industrial Estate, Wycombe Road, Stokenchurch, Buckinghamshire HP14 3RJ. Telephone (01494) 484050; Fax (01494) 482161.

ELECTRONICS WORKBENCH

Robinson Marshall (Europe) PLC have announced the Electronics Workbench EDA and the Electronics Workbench Professional. The differences between the two are that there are more devices and more analysis available to EDA users. The User Interface, however, is exactly the same, so private users may well opt for the Professional version as this costs £199 and the EDA version just below £800.

A description of both versions is given in 'Software for Electronics' elsewhere in this issue.

MULTI-STANDARD MODULATOR/PLL

Siemens has added to its product line of r.f. ICs for video and TV applications a new multi-standard modulator, the Type TDA 6060XS. This new product is compatible with all world standard, including PAL, NTSC, and SECAM. In a technological first, this one chip combines the functions of a digitally programmable phase-locked loop (PLL) with a multi-standard video modulator and a programmable sound FM and AM modulator. With its diverse functions, the new IC is suitable for all modulator boxes, such as those for video recorders, games, satellites receivers, cable headends an d set-top boxes.

The PLL permits the frequency of the modulator oscillator to be set precisely from 30 MHz to 950 MHz in steps of 250 kHz. The tuning process is controlled by a microprocessor via an I^2C bus. The internal reference frequency is 62.5 kHz. The modulator block includes a gain-adjustable video amplifier, a double balanced mixer working as an AM video modulator, a frequency and amplitude-stable balanced oscillator for the VHF, hyperband and UHF ranges, a sound modulator for FM and AM modulation, a programmable sound carrier oscillator and a voltage reference source. The sound carriers are generated by an oscillator which is digitally programmable on chip; the four possible frequencies are 4.5 MHz, 5.5 MHz and 6.0 MHz (for FM only) and 6.5 MHz (for FM and AM).

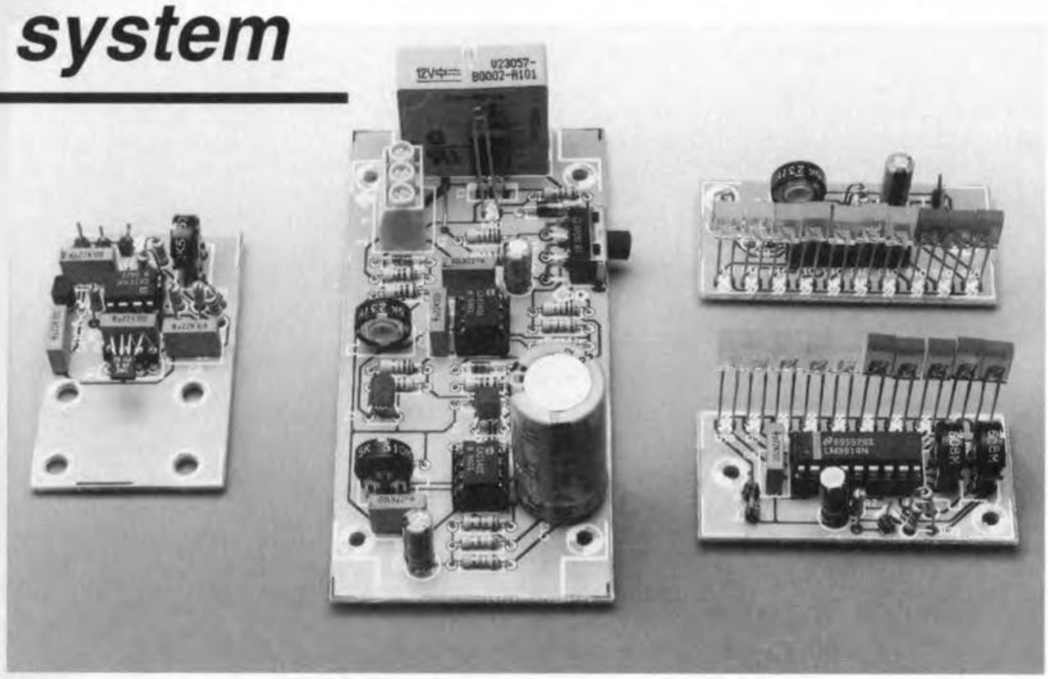
The new chip is another member in the family of highly integrated r.f. ICs. It enables easy connection of Siemens' single-chip solutions for TV, video recorder and satellite tuners, and of the Siemens I/Q demodulator for digital satellite reception to almost any TV set in the world.

Siemens AG, UK B HL, D-81617, Munich, Germany.

car battery monitor

four-module control system

The ignition warning light in a car indicates whether the battery is being charged or not (and indeed whether it is connected properly to the electrical system). It does not tell the driver, however, the state of the battery*. This information is of particular interest to mobile home and caravan owners, since these have to take into account additional appliances and a second battery. The modular monitor described indicates the level and the direction of the battery current, in other words whether it is being charged or discharged. It does so without the need for any leads to be interrupted.



* There are, of course, cars that have a dashboard ammeter which indicates whether the battery is being charged or discharged.

Design by K. Bachun

INTRODUCTION

Battery maintenance in a car with caravan added or in a mobile home is more complex than one would expect. This is particularly so since most of us do not pay all that much attention to our car's battery – until it starts giving problems. A caravan or mobile home has many more electrical appliances (such as a fridge, interior lighting, drinking water tank), than a car, and all these need to be operated by the battery. There is normally also a second battery to be looked after.

There is a plethora of commercial control and display units on the market, from a simple isolating relay to a microprocessor-controlled charging system. Most of these do not justify their price, however.

This article proposes a unit comprising four modules that measure the current and voltage of the electrical system, indicate the level of these, and, should the current be too high or the voltage too low, operate a relay to isolate one or more loads from the system. The modules, which may be used independently of one another, are electronically as well as mechanically straightforward, and, since they use mainly standard components, fairly inexpensive.

CURRENT DETECTOR

Circuit A in **Figure 1** measures the current and prepares the input signal for further processing. The input is obtained from an external magneto-resistive sensor linked to input connector K_1. The internal circuit of this device is described in the box. The sensor is arranged as a metering bridge, so that the output is not referred to earth, but applied as a differential signal to the inputs of op amp IC_2, which is arranged as an instrumentation amplifier. In this way, the amplifier can determine not only the level but also the direction of the current (charging or discharging). The amplification of the op amp is determined by the ratio R_4:R_1, and is with values as specified about ×25. The amplified differential signal is superimposed on to a direct voltage of about half the supply voltage (2.5 V), which is derived from variable potential divider R_5-R_6-P_1. Since the values of R_3 and R_4 are equal or nearly so, the quiescent currents into the two inputs are equal.

To enable the current detector to operate correctly, any brief bursts of interference are nullified by C_2 and C_1.

The supply lines to the op amp are smoothed by C_3 and C_4 and stabilized by IC_1.

VOLTAGE DISPLAY

The designs of the current display and the voltage display are virtually identical—see **Figure 1C**. The input of the voltage display IC_4 is derived directly from the battery voltage via potential divider R_{11}-R_{12}-P_2. This variable input is about 3 V for a battery potential of

Some parameters

- Load-current measurement without interrupting the circuit
- 10-position LED display of charging and discharge currents
- Measurement of battery voltage
- 10-position LED display of battery voltage
- Resettable overload and short-circuit current cut-out
- Undervoltage cut-out

12 V. The display range depends on the internal voltage reference and resistors R_8–R_{10}.

The reference output (REFOUT), which here is also the upper display level, is always 1.25 V higher than the level at REFADJ, so that the current from REFOUT to earth is about 1 mA with component values as specified. The potential difference (pd) caused by this current across R_9 (0.95 V) and across R_{10} (1.8 V) determines the lower display level. The current flowing from REFADJ to earth is so small that it may be ignored.

The lowest LED lights when the input voltage is 1.8 V, whereas the uppermost LED lights when the voltage exceeds 4 V. Since the input signal is divided by 4, the display ranges should be multiplied by this figure. Therefore, the actual display range is 7–16 V, that is, 1 V per LED. The two lowest LEDs are red to indicate 'battery low', the next six LEDs are green to indicate 'all is well', and the two uppermost LEDs are yellow to indicate an 'overvoltage' state.

CURRENT DISPLAY

The operation of the current display—see **Figure 1B**—is very similar to that of the voltage display. Here, the input signal is derived from the sensor amplifier (Figure 1A) and applied to the SIG input pin via R_7. The upper and lower display ranges are variable under the control of presets P_5 and P_6. This arrangement is necessary because the sensitivity of the sensor amplifier depends strongly on the coupling between the magneto-resistive sensor and the current-carrying cable. Tests on the prototype gave a sensitivity of 8 mV A^{-1} at battery currents of up to 30 A and with the relevant cable held against the sensor.

EMERGENCY CUT-OUT

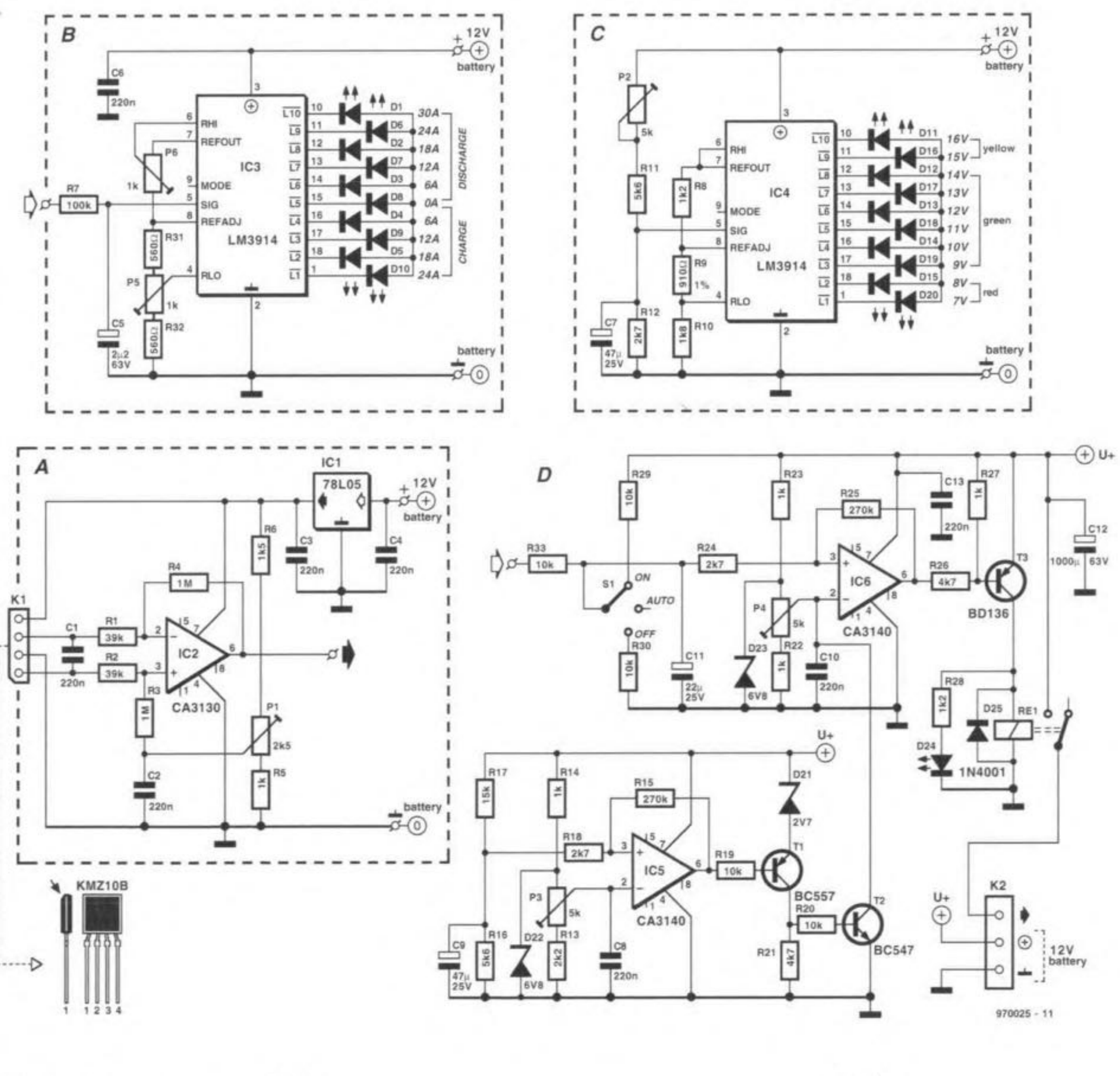
The emergency cut-out circuit in **Figure 1D** may be used as an alternative to, or in conjunction with, the current display. The output signal of the sensor amplifier is applied between R_{33} and earth, smoothed by C_{11}, and applied to the non-inverting input of comparator IC_6.

The reference voltage at the inverting input of the comparator may be set between 1.1 V and 6.8 V with P_4. This wide range ensures correct operation even when the coupling between cable and sensor is weak

The comparator changes state when the reference voltage is exceeded by the output signal of the sensor amplifier or by switch S_1 being set to ON. Resistor R_{25} provides some hysteresis to prevent the relay from

Figure 1. Circuit diagram of the four modules comprising the car-battery monitor.

1



2

Figure 2. The battery current is measured with the aid of a magneto-resistive sensor; there is no need of interrupting any circuits.

clattering.

When the comparator has changed state, driver T_3 is cut off, whereupon the relay is deactuated, so that its contact disconnects the relevant load from the battery.

The state of the relay is indicated by D_{24}, while diode D_{25} is the usual free-wheeling device.

The overload circuit can be switched off by with S_1.

As an alternative, the comparator may be made to change state at a low input by voltage monitor IC_5. This op amp, which also functions as a comparator, likens the part of the battery voltage at the junction of potential divider R_{16}-R_{17} with a voltage level set with P_3. Operation is then as described earlier for IC_6. The emitter of the output transistor is at a level 2.7 V below the battery voltage to ensure that the op amp can switch off T_1 at all times when required.

When the battery voltage becomes low, transistor T_2 pulls the inverting input of IC_6 to earth, whereupon the load is disconnected from the battery.

CONSTRUCTION AND CALIBRATION

Nothing much needs to be said about completing the printed-circuit board shown in **Figure 3**, which is self-evident from the drawing.

The only aspect of the construction that needs careful consideration is the coupling of the current-carrying battery cable to the sensor—see **Figure 2**.

For the calibration of the monitor, a variable power supply, a car battery, a digital multimeter (DMM) and four 55 W car bulbs are needed.

Set presets $P1_1$ and P_2 to the centre of their travel, P_3, P_4 and P_6 for maximum voltage at their wipers, and P_5 for minimum voltage at its wiper.

Connect the voltage display to the power supply and set the output of this to 12 V. Adjust P_1 until D_{13} lights.

To calibrate the sensor amplifier, adjust P_1 until the output level is roughly half the supply voltage, that is, 2.5 V.

Next, connect the current display to the sensor amplifier. Pass a heavy-duty cable through the fixing hole of the PCB and arrange the sensor to its most suitable position – the metering bridge is situated in the top half of the sensor.

During the calibration of the current display, it is not easy to generate a defined high enough current. Ideal is, of course, the use of a variable power supply with current limiting to provide such a high current.

As an alternative, use a (partly charged) car battery, an ammeter (20 A

magneto-resistive sensor

A current-carrying conductor is surrounded by a concentric magnetic field whose strength, H, is directly proportional to the value of the current and inversely proportional to the distance from the conductor.

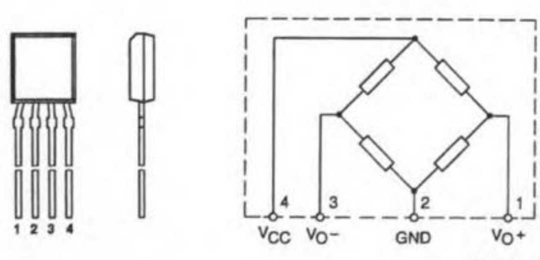
The monitor uses a sensor that consists of four Hall-effect devices arranged in a bridge configuration. When a Hall-effect device is placed in a magnetic field, a voltage is produced across it which varies almost linearly with the magnetic flux density. So, the voltage developed across a Hall bridge is a measure of the magnetic flux density, which itself is directly proportional to the current causing it. This means that the sensor can measure current in a conductor without interrupting that conductor. Also, it facilitates the measurement of small voltages with respect to earth that would otherwise make special demands on the input voltage range of the sensor amplifier.

*The internal circuit in **Figure A** shows the four elements and the terminals for the supply voltage, V_{CC} and GND, and the signal voltage output, V_O- and V_O+.*

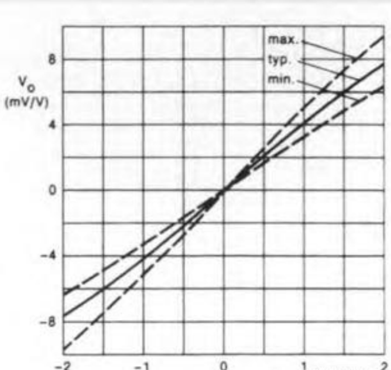
*The sensor has a virtually straight output characteristic—see **Figure B**. Its sensitivity is typically 4 mV V^{-1} kA^{-1} m^{-1}. When a current of 30 A flows through a cable of 16 mm^2 dia. (so that the sensor is about 3 mm from the centre of the cable), H is about 10 kA m^{-1}. With the sensitivity of the sensor as specified, this would result in a sensor output voltage of 4 × 10 = 40 mV.*

Assuming a current through the conductor (battery cable) varying from −24 A (battery being discharged) to +30 A (battery being charged), the output voltage range of the sensor is 72 mV. This will be raised by the sensor amplifier in the monitor (amplification factor ×25) to 1.85 V.

A



B



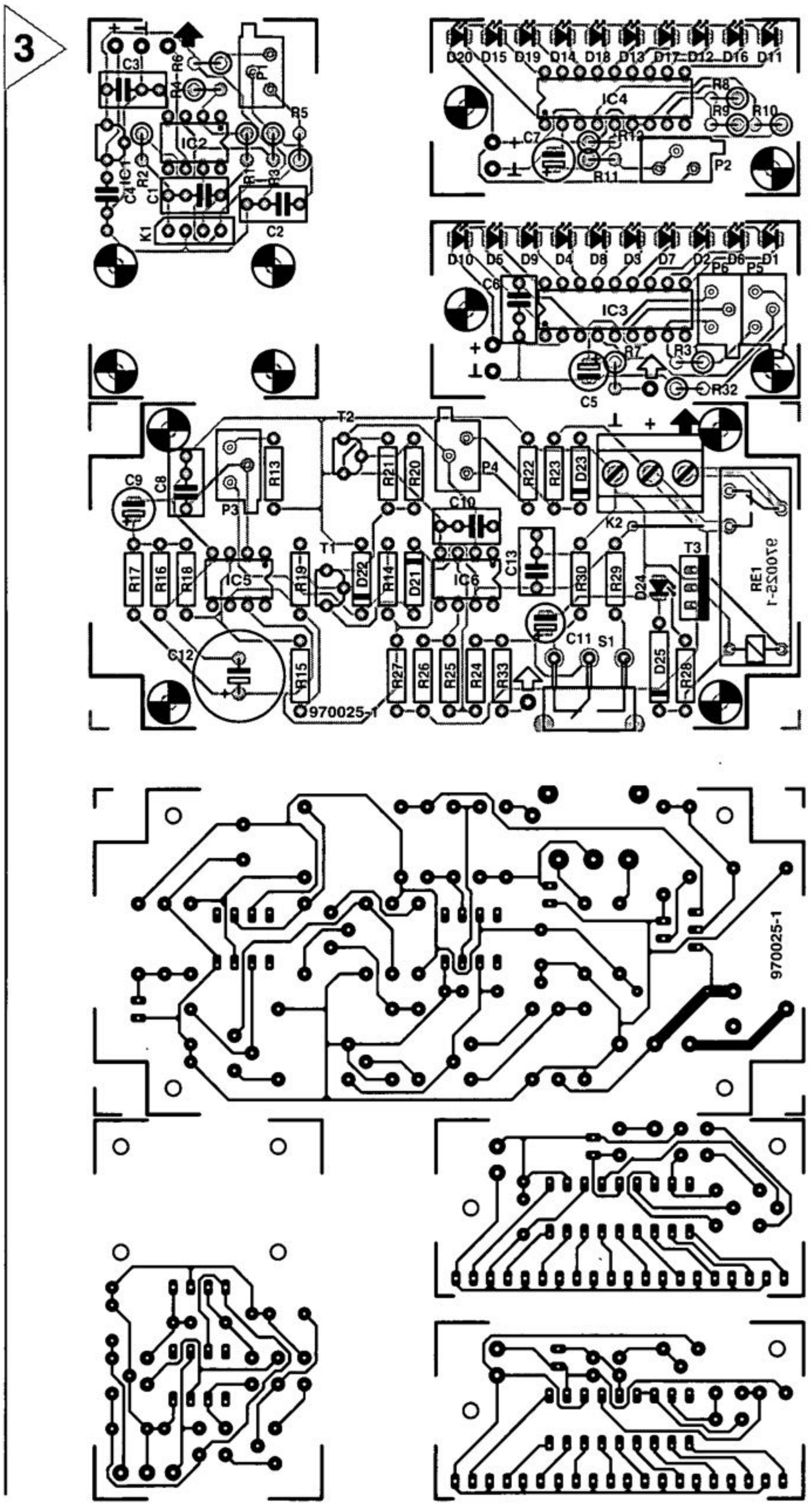


Figure 3. The printed-circuit board for the car-battery monitor.

d.c.) and four parallel-connected 55 W car bulbs (which provide a 220 W load that draws a current of 19 A). To start with, short-circuit the ammeter in the circuit with a heavy-duty cable, because it may not survive the very high current at power-on.

All connections in this circuit must be suitable for high currents: use 16 mm^2 cable with appropriate car-type connectors and heavy-duty battery terminal clamps.

Arrange for a charging current to flow into the battery and adjust P_5 until the LED corresponding to the value shown by the DMM lights.

Next, arrange for a discharge current to flow from the battery and adjust P_6 until the LED corresponding to the value shown by the DMM lights.

When the circuit is interrupted, the LED corresponding to 0 A should light.

Note the voltages at the output of

Parts list

Resistors:
R_1, R_2 = 39 kΩ
R_3, R_4 = 1 MΩ
R_5, R_{14}, R_{22}, R_{23}, R_{27} = 1 kΩ
R_6 = 1.5 kΩ
R_7 = 100 kΩ
R_8, R_{28} = 1.2 kΩ
R_9 = 910 Ω, 1%
R_{10} = 1.8 kΩ
R_{11}, R_{16} = 5.6 kΩ
R_{12}, R_{18}, R_{24} = 2.7 kΩ
R_{13} = 2.2 kΩ
R_{15}, R_{25} = 270 kΩ
R_{17} = 15 kΩ
R_{19}, R_{20}, R_{29}, R_{30}, R_{33} = 10 kΩ
R_{21}, R_{26} = 4.7 kΩ
R_{31}, R_{32} = 560 Ω
P_1 = 2.5 kΩ multiturn preset, radial
P_2, P_3, P_4 = 5 kΩ multiturn preset, radial
P_5, P_6 = 1 kΩ multiturn preset, radial

Capacitors:
C_1–C_4, C_6, C_8, C_{10}, C_{13} = 0.22 μF
C_5 = 2.2 μF, 63 V, radial
C_7, C_9 = 47 μF, 25 V, radial
C_{11} = 10 μF, 25 V, radial
C_{12} = 1000 μF, 63 V, radial

Semiconductors:
D_1, D_2, D_3, D_6, D_7, D_{15}, D_{19}, D_{20} = LED, square, red
D_8, D_{11}, D_{16} = LED, square, yellow
D_4, D_5, D_9, D_{10}, D_{11}, D_{12}, D_{14}, D_{17}, D_{18} = LED, square, green
D_{21} = zener, 2.7 V, 400 mW
D_{22}, D_{23} = zener, 6.8 V, 400 mW
D_{25} = 1N4001
T_1 = BC557
T_2 = BC547
T_3 = BD136

Integrated circuits:
IC1 = 78L05
IC_2 = CA3130E
IC_3, IC_4 = LM3914
IC_5, IC_6 = CA3140E

Miscellaneous:
K_1 = 4-way board terminal
K_2 = 3-way board terminal
S_1 = 1-pole, 3-position board mounting slide switch
Re_1 = 12 V car type relay
Magneto-resistive sensor Philips Type KMZ10B

IC_2 when the charging and discharge currents are maximum. Since the output characteristic of the sensor is fairly linear, the output level of IC_2 may be calculated for higher currents. This, of course, enables smaller currents to be used for the calibration.

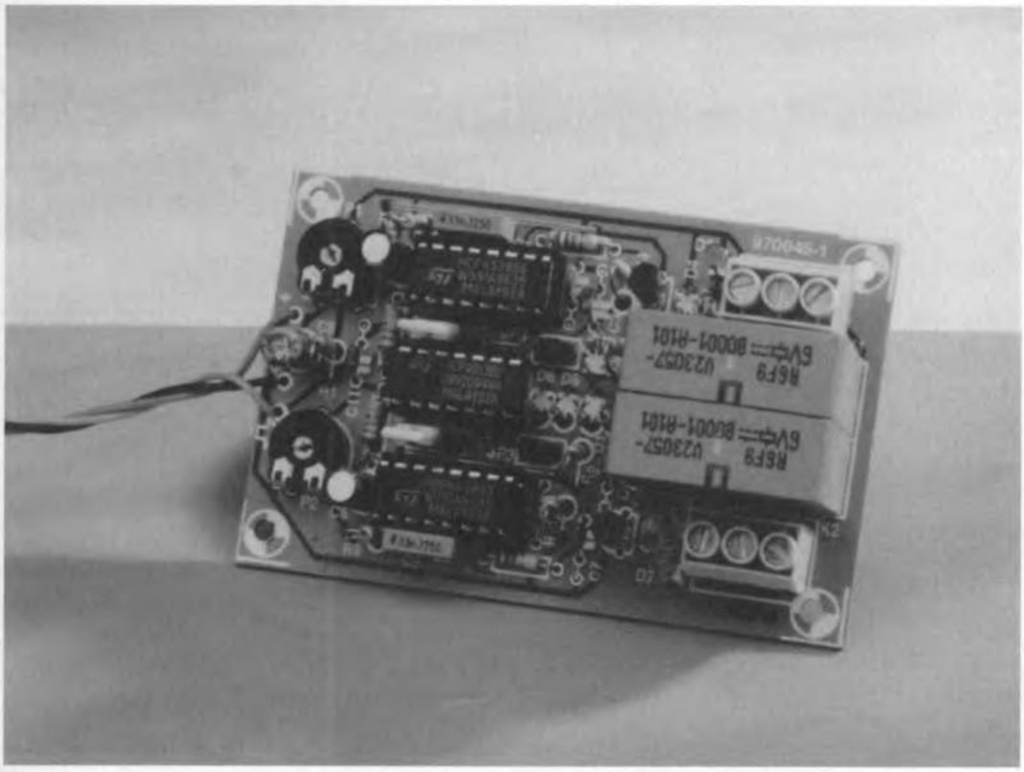
To calibrate the emergency cut-out (or overload) module, apply a voltage to the input of the module that results in a discharge current of, say, 40 A. Adjust P_4 until the relay just releases.

Remove the input voltage and set the output of the variable power supply to 10.4 V (which corresponds to the terminal voltage of a discharged battery). Adjust P_3 until the relay just releases.

[970025]

RC biswitch

dual switch function for model craft



The *RC* switch is a well-known and very popular adjunct in the world of model craft. It makes it possible to use the joystick for operating a given on-board function such as a search light, siren or winch at the same time as it is controlling the speed of the craft. The switch described in this article is a dual model provided with a memory. This duality and the memory offer the keen modeller a number of interesting applications.

Design by M. Decroubele

INTRODUCTION

The circuit is generally fairly standard. Received control pulses are demodulated at the input, while a relay at the output enables an external device to be switched or selected. One of the benefits of the memory is that when the joystick is moved past a certain position the relay is energized (as it is in any standard *RC* switch) and remains so (which it does not in a standard *RC* switch) when the joystick is returned to neutral. The relay is deactuated only when the joystick is once again moved past the same given position. The circuit may be used as a standard switch when the memory is disabled with the aid of a jumper.

There is also provision for connecting a microswitch that functions as a dead stop; this is a useful aspect when a winch or windlass is being operated.

The duality of the switch makes it possible to control two completely independent relays over a single *RC* channel.

CIRCUIT DESCRIPTION

The circuit diagram of the switch is given in **Figure 1**. As is to be expected, it consists of two identical halves, only the top one of which will be discussed.

As is known, control of model craft is carried out with a pulsewidth-modulated signal. In this, the high-frequency carrier wave is modulated with pulses at regular intervals (20 ms). The width of the pulses can be varied with the joystick between 1 ms and 2 ms. In the on-board receiver the (command) pulses are demodulated and, after amplification and processing, used to drive servo motors which attain a position corresponding to their width.

In the diagram in Figure 1, the pulses arriving at pin PC_2 are applied directly to the T(rigger) input (pin 12) of IC_{1b}. This monostable multivibrator (MMV) functioning as a reference generator is triggered by the leading edge of the pulses. The mono time of the MMV is determined by time constant P_1-R_2-C_1; the preset allows it to be set

1

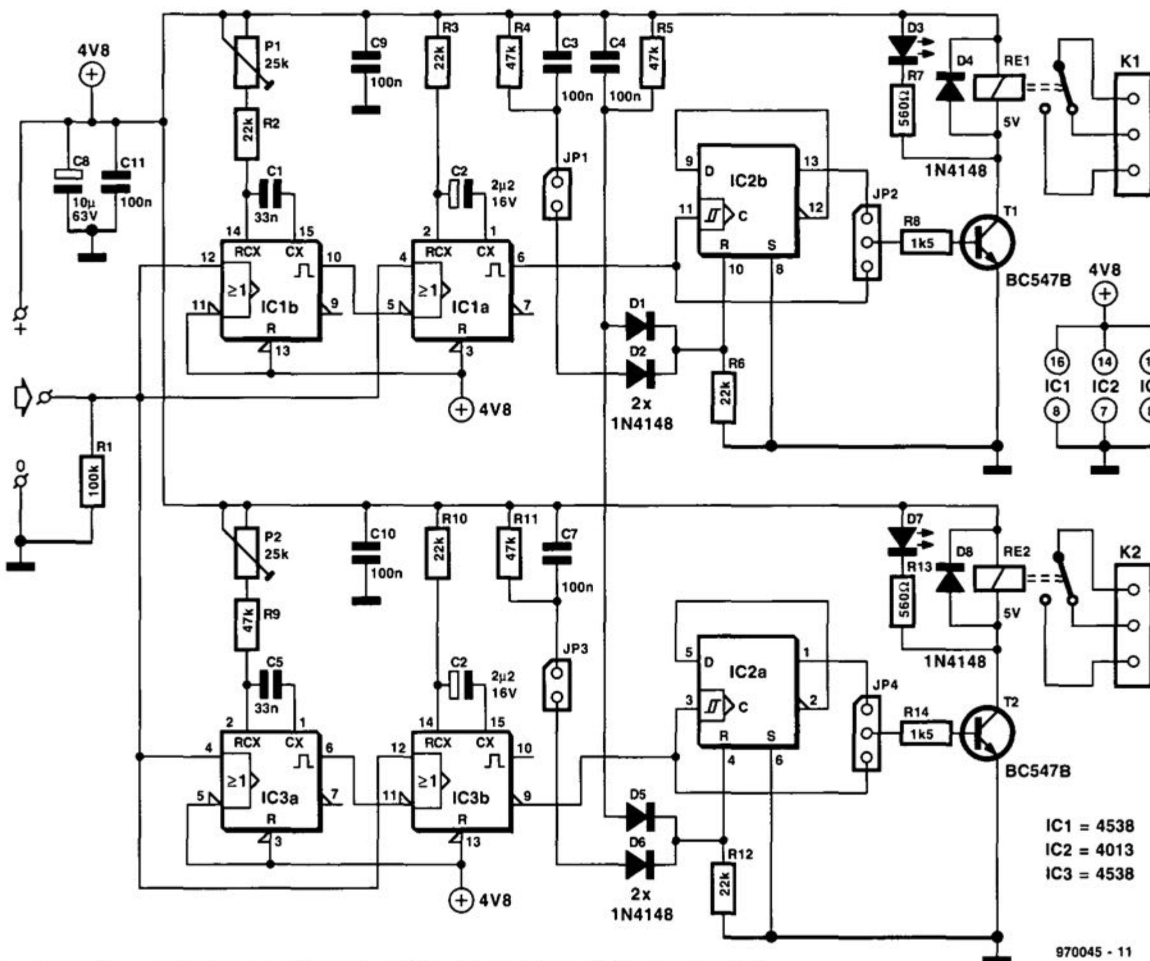


Figure 1. The dual RC switch is provided with a memory formed by a D-bistable (IC_{2a} or IC_{2b}) which may be used or not with the aid of jumper JP_2 or JP_4.

2

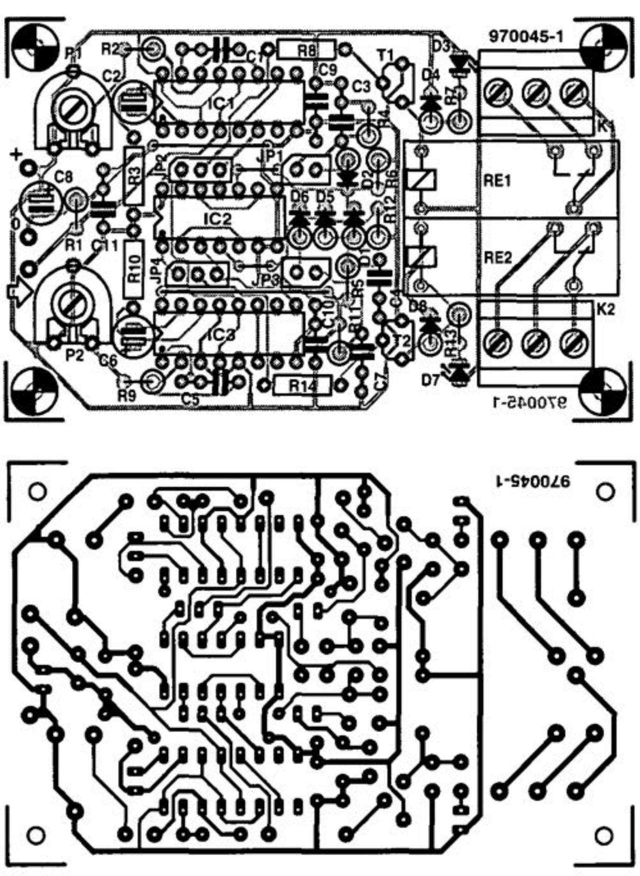


Figure 2. The small printed-circuit board has space for all components, including the relays.

Parts list

Resistors:
R_1 = 100 kΩ
R_2, R_3, R_6, R_{10}, R_{12} = 22 kΩ
R_4, R_5, R_9, R_{11} = 47 kΩ
R_7, R_{13} = 560 Ω
R_8, R_{14} = 1.5 kΩ
P_1, P_2 = 25 kΩ preset

Capacitors:
C_1, C_5 = 33 nF
C_2, C_6 = 2.2 µF, 16 V, radial
C_3, C_4, C_7, C_9–C_{11} = 110 nF
C_8 = 10 µF, 63 V, radial

Semiconductors:
D_1, D_2, D_4, D_5, D_6, D_8 = 1N4148
D_3, D_7 = LED
T_1, T_2 = BC547B

Integrated circuits:
IC_1, IC_3 = 4538
IC_2 = 4013

Miscellaneous:
JP_1, JP_3 = 2-pin jumper
JP_2, JP_4 = 3-pin jumper
Re_1, Re_2 = miniature relay, 5 V or 6 V, 1 change-over contact for PCB mounting.
K_1, K_2 = 3-way screw terminal for board mounting
PC_1, PC_2, PC_3 = board terminal pin

between 0.75 ms and 1.5 ms.

The reference pulses generated by the MMV are applied to a second MMV, IC_{1a}, together with the input pulses. The mono time of IC_{1a} is determined by time constant R_3-C_2, which is longer than the pulse repetition time of 20 ms. However, IC_{1a} will be triggered only if the input pulse is longer than the reference pulse. If that is so, a debounced high logic level appears at the Q-output (pin 6) of IC_{1a}. If the input pulse is shorter than the reference pulse, the output of IC_{1a} is logic low.

The output of IC_{1a} is applied either directly or via the memory circuit to the base of T_1. This transistor drives the relay as well as signal-indication diode D_3. The choice of whether the memory is used or not is made with jumper JP_2.

The memory is formed by D-bistable IC_{2b}, which is arranged as a binary scaler. The bistable is given a power-on reset, generated by R_5-C_4, via D_1. The identical reset network R_4-C_3 may be actuated externally via JP_1. So, if a microswitch is connected across the JP_1 pins, it may function as a dead stop for a winch or windlass.

The lower half of the diagram is identical to the upper half, but the mono time of IC_{3a} may be set between 1.5 ms and 2.3 ms so that the other half of the joystick movement can be used. This results in another difference, namely that the $\overline{Q}$-output of IC_{3b} is used rather than the Q-output: since this is high when the input pulse is longer than the reference pulse.

CONSTRUCTION

The switch is best built on the printed-circuit board shown in **Figure 2**. This board contains all the components, including the relays, for the dual switch. In view of the density of population, some dexterity is required in the construction, but with a little patience and careful attention to Figure 2 it will prove not to be too tedious after all.

Mind the polarity of the diodes and electrolytic capacitors. Mount the upright diodes with the cathode on top. The servo cable from the receiver must be connected to the pins marked with an arrow. Use an insulating sleeve and provide some strain relief: this may be done by winding the cable around the solder pin a couple of times.

The switch is best housed in a plastic case. In view of the small dimensions of the board, finding a suitable case should not prove difficult.

Power is derived from the 4.8-V battery supplying the receiver. The current drawn by the switch is largely that required by the relays: the ICs need only a few milliamperes.

[970045]

CONSTRUCTION GUIDELINES

Elektor Electronics (Publishing) does not provide **parts and components other than** PCBS, fornt panel foils and software on diskette or IC (not necessarily for all projects). Components are usually available form a number of retailers – see the adverts in the magazine.

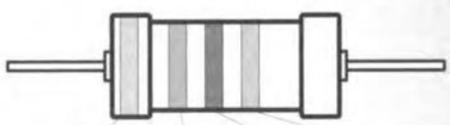
Large and small values of components are indicated by means of one of the following prefixes :

E (exa) = 10^{18}	a (atto) = 10^{-18}
P (peta) = 10^{15}	f (femto) = 10^{-15}
T (tera) = 10^{12}	p (pico) = 10^{-12}
G (giga) = 10^{9}	n (nano) = 10^{-9}
M (mega) = 10^{6}	μ (micro) = 10^{-6}
k (kilo) = 10^{3}	m (milli) = 10^{-3}
h (hecto) = 10^{2}	c (centi) = 10^{-2}
da (deca) = 10^{1}	d (deci) = 10^{-1}

In some circuit diagrams, to avoid confusion, but contrary to IEC and BS recommandations, the value of components is given by substituting the relevant prefix for the decimal point. For example,
3k9 = 3.9 kΩ   4μ7 = 4.7 μF

Unless otherwise indicated, the tolerance of resistors is ±5% and their rating is ⅓–½ watt. The working voltage of capacitors is ≥ 50 V.

The value of a resistor is indicated by a **colour code** as follows.



color	1st digit	2nd digit	mult. factor	tolerance
black	–	0	–	–
brown	1	1	$\times 10^{1}$	±1%
red	2	2	$\times 10^{2}$	±2%
orange	3	3	$\times 10^{3}$	–
yellow	4	4	$\times 10^{4}$	–
green	5	5	$\times 10^{5}$	±0.5%
blue	6	6	$\times 10^{6}$	–
violet	7	7	–	–
grey	8	8	–	–
white	9	9	–	–
gold	–	–	$\times 10^{-1}$	±5%
silver	–	–	$\times 10^{-2}$	±10%
none	–	–	–	±20%

Examples:
brown-red-brown-gold = 120 Ω, 5%
yellow-violet-orange-gold = 47 kΩ, 5%

In **populating a** PCB, always start with the smallest passive components, that is, wire bridges, resistors and small capacitors; and then IC sockets, relays, electrolytic and other large capacitors, and connectors. Vulnerable semiconductors and ICS should be done last.

Soldering. Use a 15–30 W soldering iron with a fine tip and tin with a resin core (60/40) Insert the terminals of components in the board, bend them slightly, cut them short, and solder: wait 1–2 seconds for the tin to flow smoothly and remove the iron. Do not overheat, particularly when soldering ICS and semiconductors. Unsoldering is best done with a suction iron or special unsoldering braid.

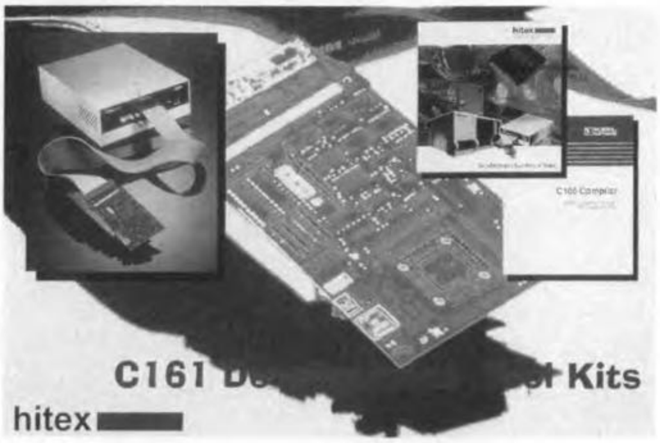
Faultfinding. If the circuit does not work, carefully compare the populated board with the published component layout and parts list. Are all the components in the correct position? Has correct polarity been observed? Have the powerlines been reversed? Are all solder joints sound? Have any wire bridges been forgotten?

If voltage levels have been given on the circuit diagram, do those measured on the board match them – note that deviations up to ±10% from the specified values are acceptable.

Possible corrections to published projects are published from time to time in this magazine. Also, the readers letters column often contains useful comments/additions to the published projects.

First in-circuit emulator for Siemens C161

The new C161 microcontroller brings 16-bit processing power down to the price of a mainstream 8-bit microcontroller giving a 15-40 times performance increase over a 12MHz 8032.



In keeping with the low cost, high performance standards set, Hitex has teamed up with Keil and Phytec to produce two complete low-cost 16-bit development kits specifically for the C161.

The **KiTCON161** starter/evaluation kit is based on a new Phytec C161 microcomputer card and features FLASH EPROM, RAM and a complete I/O and bus interface. It uses the 16MHz C161V which can be programmed and debugged with the inclusive Keil C166C compiler and **HiTOP161**/WIN monitor. A CD-ROM holds extensive support material, including user manuals and application notes.

For real project work, the PDP161-T kit includes a 161-specific version of the existing Hitex ROMless in-circuit emulator plus the C166-derived C161C compiler and so contains all the main elements required to develop real C161 applications.

AX16I is a full emulator with multi-channel triggering, real time trace, full peripheral support and the same HiTOP161/WIN debugger that is bundled with the KiTCON161 evaluation kit. For later projects on other C16x variants, the AX161 can be upgraded to use the bond-out emulation chip, as used on the AX166B and the T32/KKiT16x emulators. The C161C compiler is adapted from the Keil C166 compiler but has been limited to supporting only the C161. It has all the features of the C164 and C165. The kit starts at £3995, a very similar price to a typical 8032-bit development system, and somewhat less than other 16-bit systems.

As part of a complete service to C16x users, a two day introductory course is available at Hitex's offices on the University Of Warwick Science Park to provide a thorough grounding in C161 programming and application.

Hitex (UK) Ltd., University of Warwick Science Park, Coventry, CV4 7EZ. Tel. (01203) 692066, fax (01203) 692131.

(977081)

Powerline battery isolators

The new range of Powerline Battery Isolators from the Merlin Equipment allows simple yet effective charging of multiple battery banks from a single alternator or DC power source.

Ideal for use on vehicles or charging systems who require separate batteries for engine starting and ancillary equipment use.

Powerline battery isolators automatically split the available charge between the multiple battery banks according to their own individual requirements. Therefore Powerline Isolators eliminate the need for relay systems that wear out or '1, 2, both & off' charging selector switches which are regularly forgotten about, often resulting in situations where engine(s) cannot be started. Powerline isolators will not allow overcharging, they are a charge splitters not charge boosters which are often associated with gassing batteries.

New CE approved Powerline isolators use new 'LO-LOSS™' technology which includes highly efficient Schottky diodes, minimising voltage drop usually associated with other types of splitting diodes/battery isolators. The high quality components are sealed within a rugged aluminium heat sink making these units totally waterproof.

Unlike some other multiple battery charging methods, Powerline Isolators are very easy to install. The unit simply mounts on a bulkhead in the engine room, the charging cable from the alternator is attached to the centre bolt on the isolator. Cables are then run from the remaining bolts on the isolator to the respective positive battery posts on the multiple battery banks. In most instances, installation takes just 20-30 minutes.

The Powerline range of Battery Isolators from Merlin Equipment is available for all electrical installations, with single or twin alternators up to 190 amps with twin, triple or quadruple battery bank configurations.

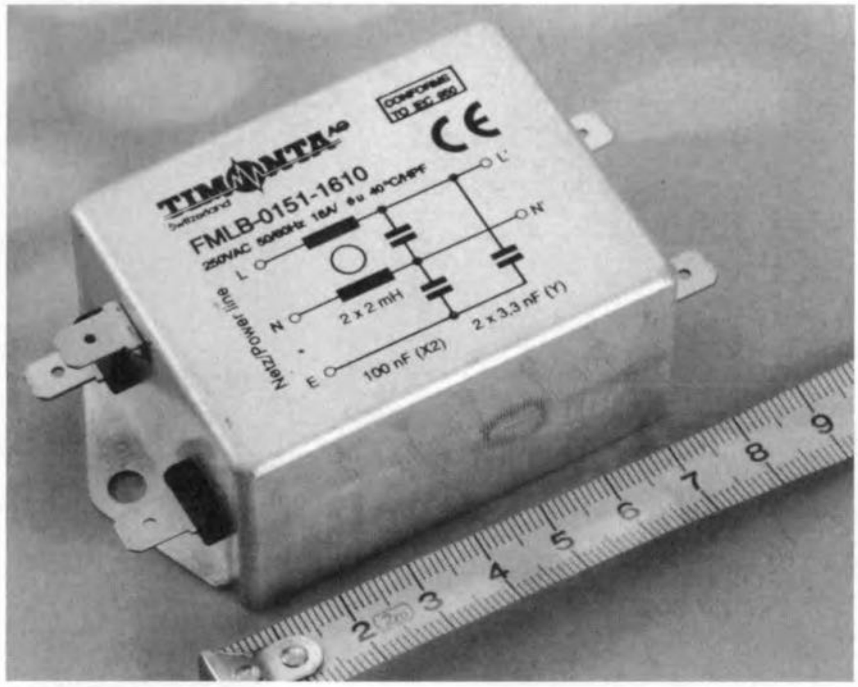
Prices of Powerline battery isolators start at just £30 ex VAT & Carriage.

Merlin Equipment, Unit 1, Hithercroft Court, Lupton Rd, Wallingford, Oxfordshire, OX10 9BT. Tel. (01491) 824333, fax (01491) 824466.

(977084)

focus on: mains-noise suppression

Design and function of mains filters



When the loudspeaker of your audio installation crackles or your computer gives problems, the cause may lie in disturbances on the mains supply. These may be suppressed by special mains filters, which also prevent any noise from your installation getting on to the mains.

By our editorial staff

INTRODUCTION

In spite of EEC legislation restricting the electro-magnetic interference exported by electrical and electronic appliances and setting a standard of imported interference with which such appliances must be able to cope, mains filters proliferate as the number of electrical appliances in the average household increases. It is not that such equipment is of poor quality, but rather because of the complexity of much of it, such as computer adjuncts, which are in use all day long.

A further source of interference arises from the use of the mains supply network for mains signalling – MS. This superimposes signals on the mains in the frequency band from

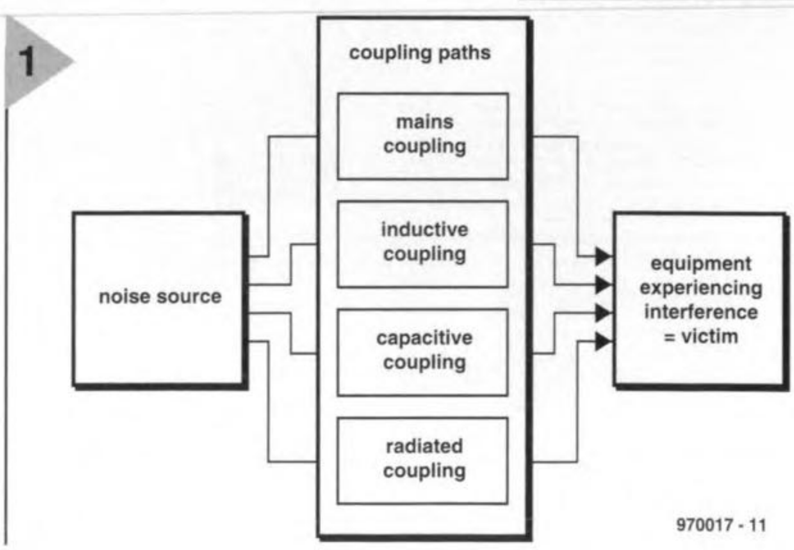


Figure 1. Various coupling paths.

3 kHz to 150 kHz. Unfortunately, this is also the frequency band in which, for instance, switch-mode power supplies, variable speed motor drives, induction heaters, and fluorescent lamp inverters operate.

Mains filters are therefore indispensable in many circumstances. Irrespective of whether such filters are intended to suppress exported or imported noise, they are called mains filters.

NOISE COUPLING AND TYPES OF NOISE

There are various paths via which noise can be coupled from a source to a victim (= electrical appliance) and these are shown in **Figure 1**.

Mains coupling means of course the coupling of noise via the mains supply lines. The mains filters described in this article are suitable for combating this type of interference.

The suppression of radiated noise requires different means, such as screened cables and shielded enclosures.

Noise sources within an appliance or circuit cause interference by capacitive and inductive coupling (together also called common impedance coupling). Examples are the coupling capacitance of a mains transformer and the inductive coupling resulting from parallel wires or tracks on a circuit board. Noise resulting from such couplings may, however, easily be prevented from entering the mains supply by a suitable filter at the point where the mains cable is connected to the appliance.

Typical disturbances on the mains electricity supply are:

- *Voltage fluctuations.* These are fluctuations with small amplitudes against which filters are virtually ineffective; the only remedy lies in the use of (magnetic) regulators and uninterruptible power supplies.
- *Voltage variations.* The mains network has a finite source impedance and varying loads affect the terminal voltage. Not including voltage drops within the customer's premises, the nominal mains voltage in the UK is 230 V with a tolerance of +10%, –6%. From 1 January 2003, the nominal voltage will be 230 V with a tolerance of ±10%.
- *Voltage interruptions.* Faults on the mains supply may cause drops of almost 100%, but these are cleared quickly and automatically by protection devices.
- *Waveform distortion.* At source, the a.c. mains is generated as a pure sine wave, but the reactive impedance of the mains network together with the harmonic currents drawn by non-linear loads causes voltage distortion.
- *Transients and surges.* Switching operations generate transients of a few hundred volts as a result of current interruption in an inductive circuit. These transients normally occur in bursts and have risetimes of no more than a few nano-seconds.
- *Superimposed r.f. signals.* Radio frequency signals and their harmonics at frequencies up to 1 GHz superimposed through radiated coupling.

All these sources of disturbance can cause malfunction in systems and equipment that do not have adequate protection.

It is important to appreciate the dif-

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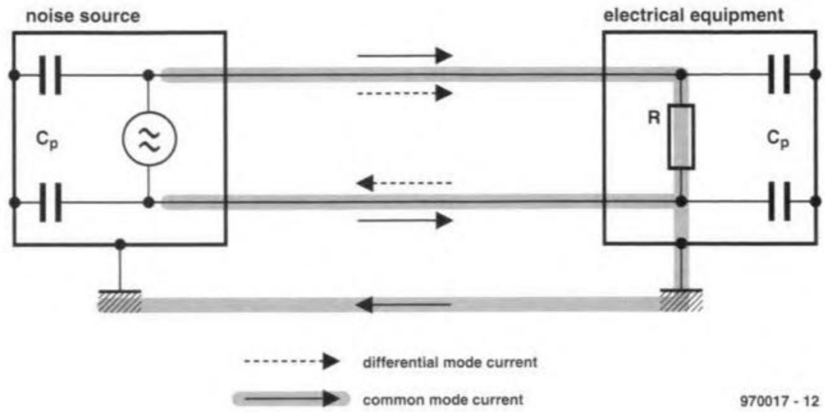

Figure 2. Common mode currents flow through the mains lines as well as the earth line; differential mode currents do not.

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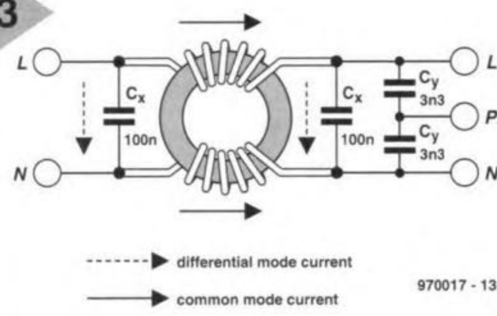

Figure 3. The current-compensated choke is an important component in mains filters.

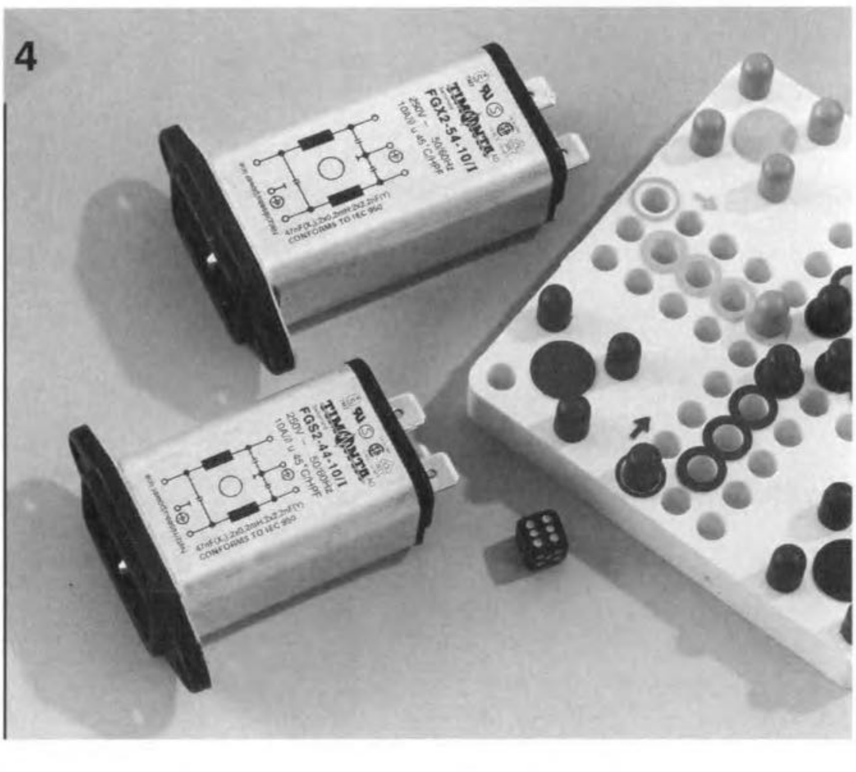

Figure 4. Suppression filters may be integrated with a mains outlet.

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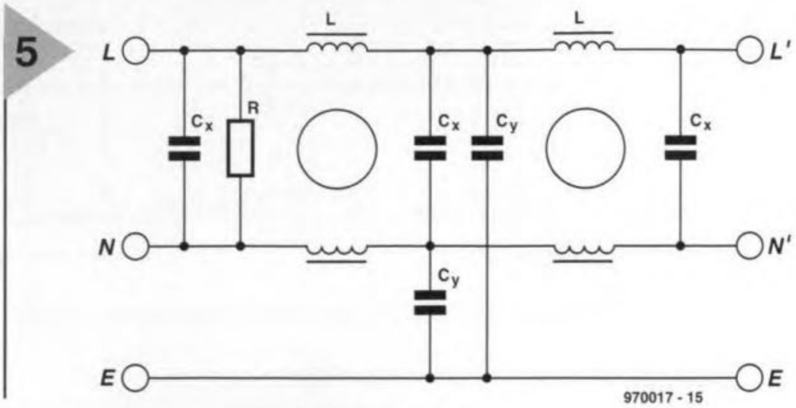

Figure 5. This 2-stage filter with two current-compensated chokes is specially designed for common mode noise suppression.

Figure 6. Standard chokes in the mains lines increase the suppression of differential mode noise.

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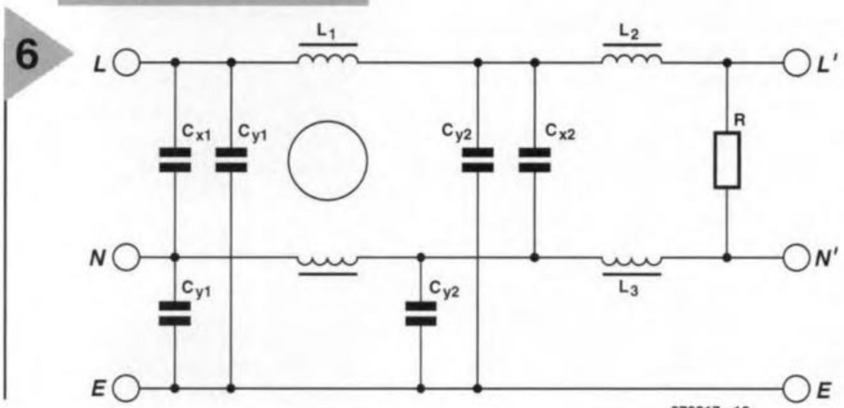

ference between common mode and differential mode noise currents. Differential mode current – see **Figure 2** – is the current that flows in one direction along one cable conductor and in the reverse direction along another.

Common mode current flows equally in the same direction along all conductors in the cable.

Disturbances below about 500 kHz are generally of the differential mode type, whereas those above about 500 kHz are normally common mode.

FILTERING

It is not possible to completely eliminate noise exported or imported along connecting leads. All that filtering can do is to attenuate exported noise to a level at which it meets a given specification, or imported noise to a level at which it does not result in system malfunction. The design of mains filters is distinguished from conventional filter design in that the filter elements are purely reactive, because in the stop band the filter should be as lossy as possible.

FILTER ELEMENTS

The most frequently used element in mains filters is the current-compensated choke, which consists of two identical windings on a high permeability toroidal core—see **Figure 3**. As in a transformer with two windings that are wound in opposition, differential currents (line to neutral) cancel each other. This means that only the leakage inductance will attenuate differential mode noise. Since therefore the risk of saturation caused by the mains supply current, even with a high permeability core, is small, high currents with relatively small-dimension chokes are possible.

With common mode interference, however, the currents in the windings flow in the same direction, so that the induced flux in the core is the sum of the fluxes induced by each separate winding. This means that the full inductance of each winding is available to attenuate common mode currents with respect to earth. The value of the capacitors between the phase and neutral lines and the earth line can therefore be kept low.

The X and Y in the subscripts (inferiors) of the capacitors indicate that they are manufactured to BS 6201 Part 3 (IEC384-14). Class X and Y capacitors are sub-divided into categories X1–X3 and Y1–Y3, where category 1 has the most demanding specification, particularly as regards the ability to cope with pulses (X1: 4 kV and Y1: 8 kV) and life expectancy.

FILTER CIRCUITS

The simple network in Figure 3 is the most popular mains filter for use in single-phase systems. It is also used integrated in a mains outlet (**Figure 4**).

Capacitors C_Y attenuate common mode interference and, if C_X is large, have no significant effect on differential mode noise. Capacitors C_X attenuate differential mode noise only and may have fairly high values. This type of filter is, therefore, suitable for the suppression of common mode noise at frequencies ≥ 500 kHz.

Capacitors C_Y cannot have very high values because of the limits of the permissible continuous current that may flow in the earth line, owing to the mains operating voltage existing across C_Y. Class X capacitors are not so

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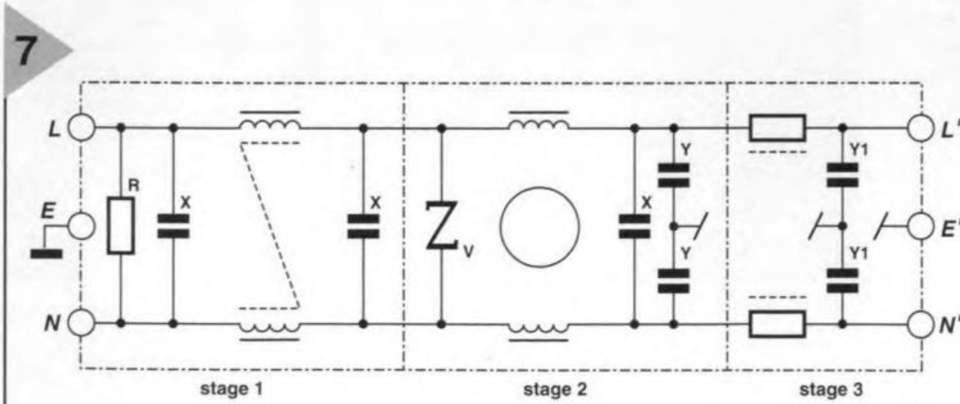

Figure 7. Three-stage filter for suppressing common mode as well as differential mode noise over the frequency range of 10 kHz to 300 MHz.

8 *Asymm. = common mode*
Symm. = differential mode

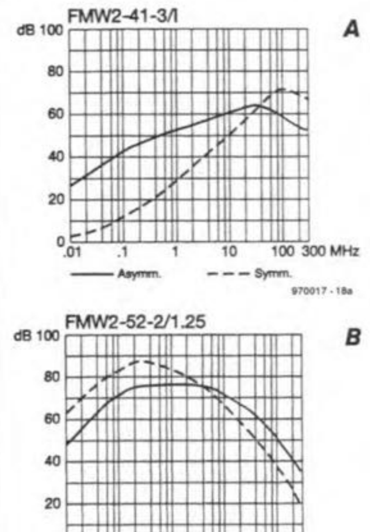

Figure 8. Suppression vs frequency characteristics of various filters.
A: standard mains filter as in Figure 3.
B: 2-stage filter (Figure 5) with better specification than that in Figure 3.
C: 2-stage filter with improved differential mode suppression compared with that in Figure 5.
D: 3-stage filter for meeting stringent requirements (similar to that in Figure 7).

limited, but may be used only where their failure does not lead to a potential shock hazard.

The filter action may be improved by the use of a choke in the earth line. However, only special IEC approved types may be used there because of their importance to the overall safety of the filter. These chokes are invariably wound on small toroidal cores. Since the normal current through them is small (actually the current through the Y-capacitors) toroids with very high permeability may be used.

If the relative high-value X-type capacitors are not discharged quickly enough by the appliance after the mains has been disconnected, they should be shunted by a resistor of 0.5–1.0 MΩ. The voltage rating of the resistor should be commensurate with the capacitor potential.

Such a shunt resistor is used in the filter in **Figure 5**. This is a 2-stage network that meets stringent requirement for the suppression of common mode noise. It is especially suitable for use in switch-mode power supplies.

If differential mode noise needs to be suppressed, the 2-stage filter in **Figure 6** should be used. Note that in contrast to the network in Figure 5, the choke in the second section is not current-compensated.

If the current-compensated choke in the first stage is a high-inductance (10–15 mH) type, the filter may be used for the suppression of both common mode and differential mode noise. The (not current-compensated) choke in the second section should have a value of 0.2–1.0 mH. Chokes that are not current-compensated must have an air gap to prevent the core becoming saturated when high currents flow through the winding.

A filter that meets the most stringent requirements is shown in **Figure 7**. This is a 3-stage network that suppresses common mode and differential mode noise as well as r.f. interference.

Stage 1 is a differential mode filter that uses a standard 0.1–0.5 mH choke, whereas stage 2 is a common mode filter that employs a current-compensated choke of 4–20 mH. Overvoltage protection is provided by a varistor: the first stage supplies the d*i*/d*t* limit for this.

Stage 3 has separate r.f. chokes of about 3 μH in each of the mains lines. This section provides common mode as well as differential mode noise suppression at frequencies up to 300 MHz.

Figure 8 gives the suppression vs frequency characteristics of various types of filter. They are obtained with commercial (Timonta) filters operating with nominal currents of 2–4 A.

Depending on the application, a wide variety of filters may be designed on the same basis as the few introduced in this article. Note that the current rating will depend on that of the choke used.

In principle, filters for three-phase mains supplies are constructed in the same way as those for single-phase systems—see **Figure 9**. Of course, the number of chokes and capacitors is increased in proportion to the number of lines. The chokes are always in series with the mains lines, X-type capacitors are connected between the L(ive) (phase) and N(eutral) lines, and Y-type capacitors between the L(ive) (phase) or N(eutral) line and the E(arth) line.

Multiple current-compensated chokes are available for use in three or four lines. [970017]

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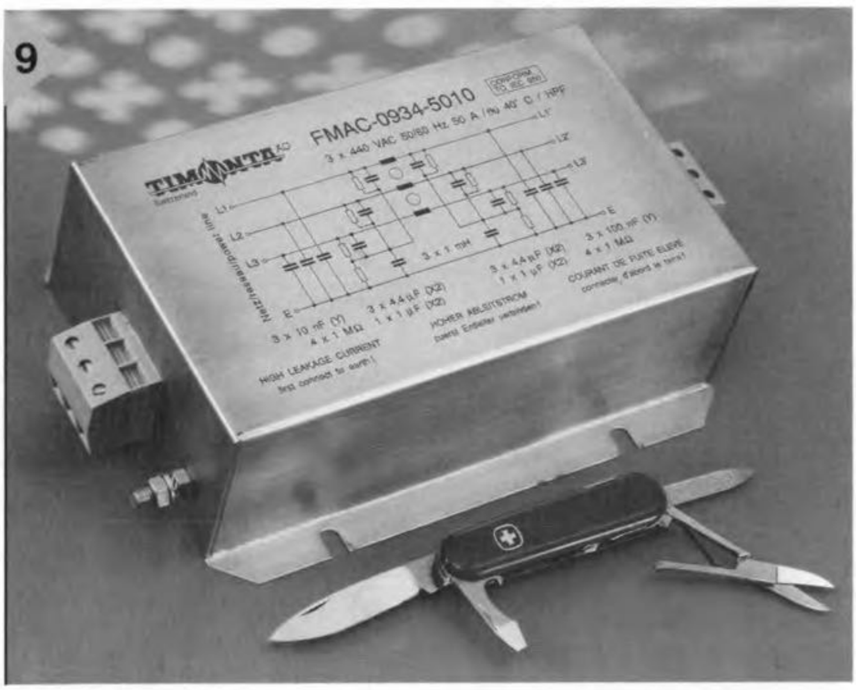
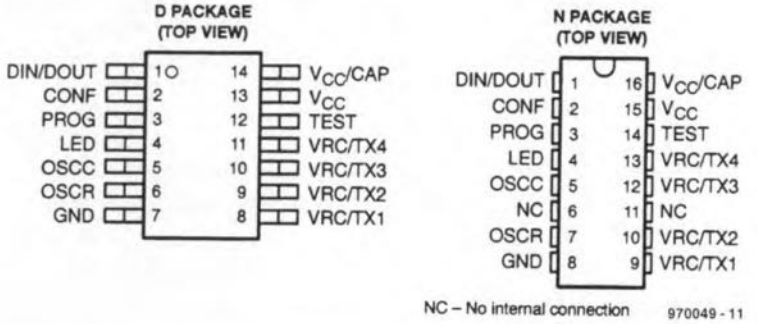


Figure 9. High-current suppression filter for use in 3-phase mains systems.

APPLICATION NOTE

Remote control encoder/decoders TRC1300 & TRC1315

The TRC1300 and TRC1315 are remote control serial-data encoders and decoders, and are members of the MARCSTAR™ (Multi-channel Advanced Remote Control Signalling Transmitter and Receiver) family of remote control serial-data devices. Each can be configured to perform as either the transmitter (encoder) or the receiver (decoder) in a remote control system.



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GENERAL DESCRIPTION

The TRC1300 and TRC 1315 are low-power devices well suited to battery operation with a supply voltage of 2.7–6 V for the TRC1300 and 2.7–15 V for the TRC1315.

Four functions allow control of 16 devices. Forty bits of stored code provide high security, more than 2^{40} possible combinations, so that the same code will never be used twice by a MARCSTAR™ device over several lifetimes of a typical system. The MARCSTAR™ devices are self-programming with internal charge-pump programming circuitry. A decoder design learns up to four different encoders, all in a high-security hopping-code format.

MARCSTAR devices include several on-chip functions that normally require additional circuitry in a system design. These include an amplifier/comparator for detection and shaping of input signals as low as a few millivolts (typically when an r.f. link is used) and a variable-frequency internal oscillator to clock the transmitted or received security code.

PRINCIPLES OF OPERATION

Operation of the MARCSTAR devices is shown in **Figure 2**. The devices have two primary modes of operation: transmitter (encoder) mode and receiver (decoder) mode. Additional modes and functions include programming and learning mode, self-testing mode, code generation, and clock generation.

Each of the devices can be pin-selected for operation either as an encoder on the transmitter end of a remote control system, or as a decoder on the receiver end. The intervening medium can be a wired, r.f., IR, or any other type of link with sufficient bandwidth to pass the signal.

A MARCSTAR device operating as an encoder can send four different function codes either individually or in any combination to actuate up to 16 different functions at the receiver.

Once a receiver (decoder) learns a security code from a transmitter, it responds to that particular encoder only. A MARCSTAR device operating as a decoder can learn and respond to as many as four different transmitters and provides four independent function outputs. These outputs can be further decoded (externally) to provide a 1-of-16 function output.

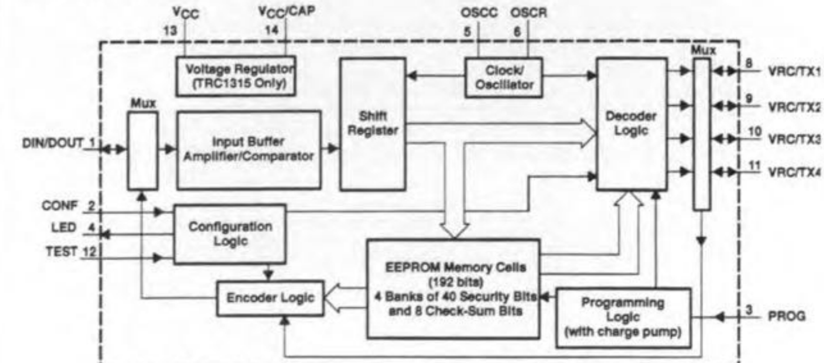
Hopping code

MARCSTAR devices use a hopping-code algorithm to significantly increase the security level of the system. The security code transmitted *and* the security code accepted as valid by the receiver change after each transmission. This is done inde-

Figure 1. Functional block diagram.

1

functional block diagram



NOTE A: Terminal numbers are for the D package.

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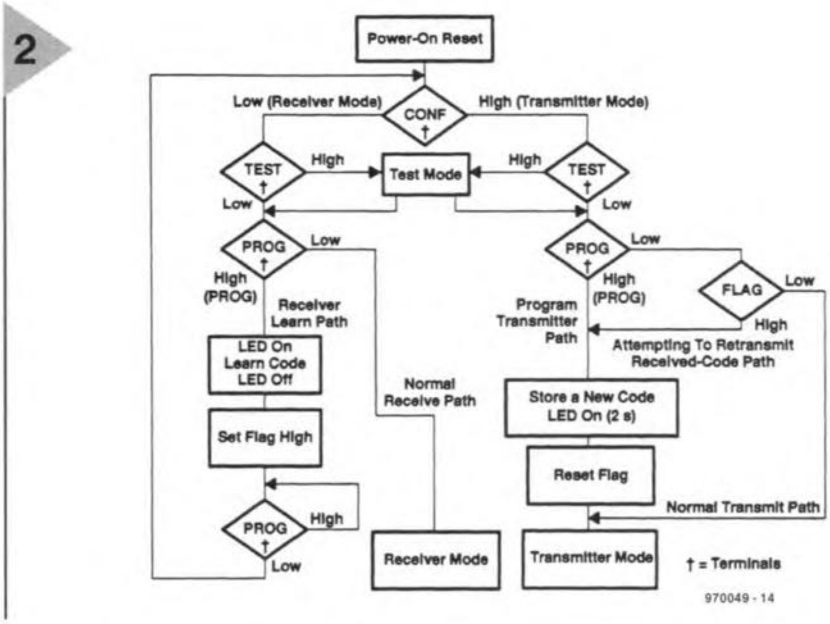
A Texas Instruments Application

Figure 2. Top level operational flow.



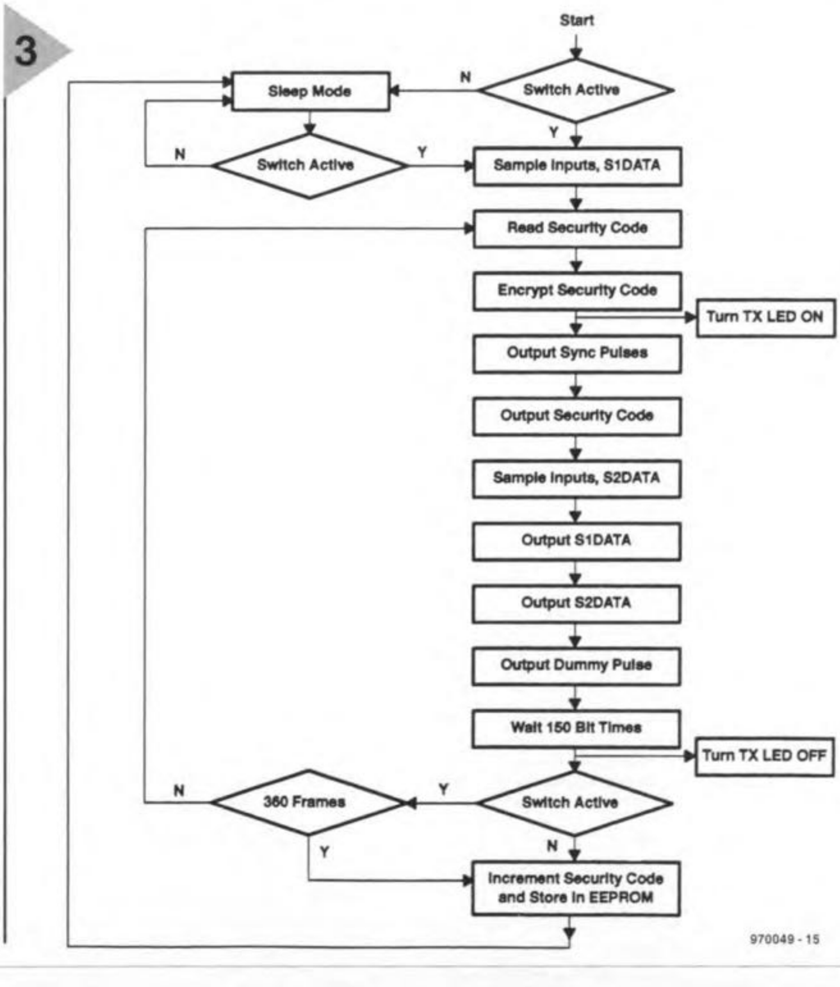
pendently for each of the four learned transmitter codes in the receiver (decoder).

As a transmitter, the MARCSTAR device is provided in the factory with a unique 40-bit security code stored in an on-board EEPROM. Since each device has a unique code, it is ready for immediate use and requires no programming. Each time the transmitter button is pressed for any of the four functions, the 40-bit security code is fetched from the EEPROM and encrypted. Next, the encoder assembles the data frame to be transmitted and sends it out. The data frame consists of the synchronizing bits, the encrypted security bits, the function data bits, a dummy bit, and the blank-time bits. After the transmission ends, the encoder increases the 40-bit security code by applying the hopping-code algorithm to it and then stores the results in the EEPROM for the next transmission. So, each time a transmission is initiated, the 40-bit security code that is sent is different from the security code in the previous transmission. With more than 2^{40} possible combinations, the same code is never repeated over the lifetime of a system.

As a receiver, a MARCSTAR initially learns the 40-bit security code stored in a particular encoder by receiving it and storing it in an on-board EEPROM. Each time a valid security code is received from a learned transmitter, the device decrypts the received 40-bit security code and compares it with the *next* security code expected from that transmitter. The next expected security code is calculated by applying the same hopping-code algorithm used in the transmitter to the 40-bit code stored in the receiver memory. If the received security code matches the next security code expected from the encoder, it is declared valid and the attached function code is decoded. If the function code is valid, the appropriate function output or outputs are asserted. The just-received 40-bit security code is then increased according to the algorithm, becoming the next security code expected from the transmitter, and stored in the EEPROM for next time. If the received security code does not match the next expected code from the matching encoder, the received function data and security code are ignored.

Because the receiver only actuates function outputs when the next expected code in the hopping-code

Figure 3. Encoder mode operational flow.



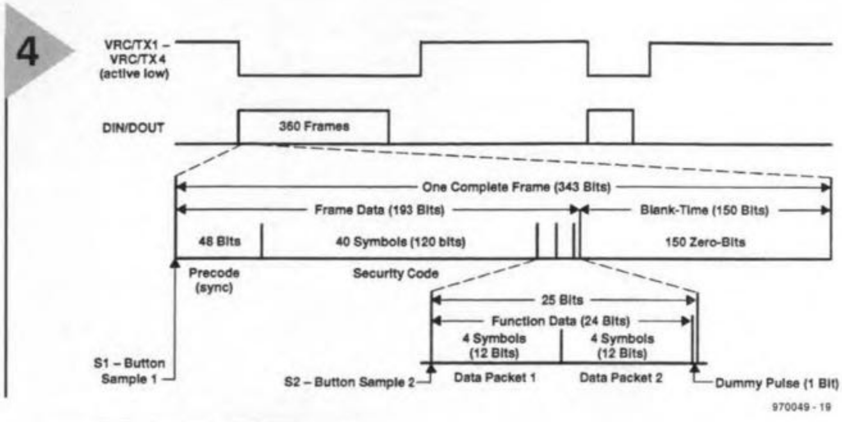


Figure 4. Transmitter data format.

sequence is received, interception and subsequent retransmission of the same code does not actuate the receiver.

Hopping-code provides extremely high security for the transmitter/receiver pair and prevents unauthorized access to the receiver by means of signal interception and retransmission of the intercepted signal.

Transmitter (encoder) mode

The encoder mode operational flow chart is shown in **Figure 3**. When a button on the transmitter is pressed, the device sends a maximum of 360 frames of data. Function data is sent in two 12-bit packets. The first function-data packet is derived from the first sample of the buttons (S_2) immediately after the 40-bit security code (see **Figure 4**). When valid function data has been received in the first packet, but the second packet in a frame contains different function data (caused by a second button being down at sample 2 time), both data packets are discarded and the receiver function outputs remain in their previous state.

The rate of the transmitted data is variable from 500 Hz to 5 kHz (adjustable using an external resistor and optional capacitor) so that the time to send one frame of data (193 bits) varies from 386 ms to 38.6 ms. When 360 frames have been sent, the device stops. This is to prevent indefinite code transmission (and battery depletion) when a transmit button is held down continuously, and increases the opportunity for the receiver to detect the transmitted code. The receiver actuates a function output on the first valid received code. The data portions of the transmitted frames are separated by one 'dummy pulse' and 150 data clock cycles. This gives a lower effective frame duty factor, so that the average power output of an interfaced r.f. oscillator is reduced, and higher peak power can be used for increased range.

Decoder mode

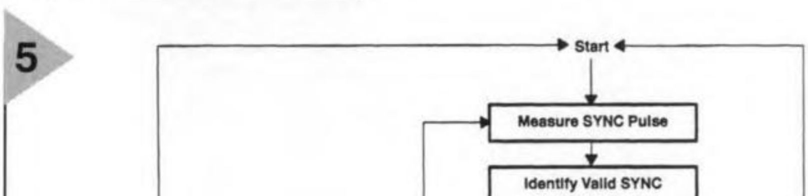
The MARCSTAR decoder mode operational flow is shown in **Figure 5**.

In the receiver (decoder) mode, the device receives serial data from input terminal DIN/DOUT. The input data signal is first passed through the internal amplifier/comparator for signal conditioning before being decoded and compared with the four 40-bit security codes stored in the EEPROM. When a match is found with *one* or *more frames*, the appropriate function output terminals are enabled. The receiver actuates a function output only when two identical function data packets are received in the same frame. The function output remains active for a minimum period of 768 data clock cycles, which can range from 154 ms to 1.54 s, depending on the clock frequency used. At a 1 kHz data clock rate, for example, a function output is asserted for a minimum of 768 ms. The receiver keeps the appropriate output terminals active as long as it receives a valid code, and through the blank time between frames, which is 150 clock cycles. The function outputs go inactive when invalid function data code is received.

Configured as a decoder, the device samples the incoming serial data at 10 times the expected transmitted data rate. As each symbol is sampled, an integrator determines if it represents a 1 or a 0 by the total number of high and low samples. A high symbol (110) has a high level for about two-thirds of the symbol period, while a low symbol (100) is high for only one-third of the symbol period. Therefore, if five or more out of eight of the samples are high, the symbol is decoded as a 1, and if three or fewer of the samples are high, the symbol is decoder as a 0. The symbol format also improves synchronization of the decoder with the incoming serial data. A transition from low to high always signifies the beginning of a symbol.

The method of synchronization employed by MARCSTAR devices uses a precode sync pattern that precedes the security and function data portions of each frame sent by the

Figure 5. Decoder mode operational flow.



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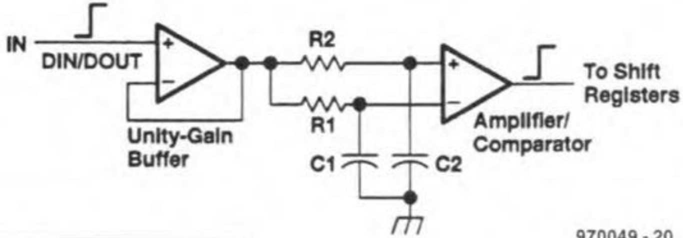


Figure 6. Amplifier/comparator equivalent schematic.

transmitter. The precode consists of 24 pulses with a duty factor of 0.5, each being high or low for one period of the data clock. This equates to a total of 48 bit times.

Amplifier/comparator

A representation of the amplifier/comparator section of the MARCSTAR devices is shown in **Figure 6**. This circuit is used to amplify and wave-shape low-level input signals to logic levels for input to the shift registers. Internal components R_1 and C_1 form a reference-setting (autobias) network, whose time constant is about three symbols, or 12 bits of code.

Components R_2 and C_2 form a low-pass network with a time constant equal to about one tenth of one DCLK (data clock) period, so that high-frequency transients are attenuated before reaching the comparator.

The amplifier/comparator is implemented wit advanced switched-capacitor technology. This is done for two reasons. First, since the TRC1300 and TRC1315 are variable frequency, the values of R_1, R_2, C_1 and C_2 must change depending on the received data rate. Since they are switched-capacitor design, the filter characteristics scale depends on the oscillator in the receiver device, which must match the transmitter oscillator frequency. With this arrangement, the amplifier/comparator functions at all received code data rates. The second reason is the increased accuracy and precise filter response that ensue.

EEPROM stored-code format

The EEPROM contains four banks that are used for 40 bits of security code for each of the four channels, and 32 additional bits (8 bits per channel) for error detection. The total memory is 192 bits. When the device is configured as a decoder, the EEPROM banks store up to four learned 40-bit security codes; when the device is configured as a transmitter, only the first bank of 40 bits is used for the security code.

Oscillator

An internal variable-rate clock runs at the SCLK (sample clock) frequency, and is adjustable from 5 kHz to 50 kHz. The DCLK (data clock) is derived from the SCLK so that both clocks are synchronous. The DCLK runs at one-tenth the speed of the SCLK and clocks the transmitted data at a rate varying between 500 Hz and 5 kHz. The SCLK is used to sample the received data at 10 times the received data rate. The high sampling rate in the receiver combined with the symbol code format and the internal signal-conditioning amplifier circuitry provide accurate correlation of the received signal. The SCLK frequency is set by an external *RC* network.

Test mode

The TRS1300 and TRC1315 devices are equipped with a self-test function that checks the RAM, ROM and EEPROM.

[970049]

earth-leakage meter

with peak indicator

The earth-leakage meter is suitable for use where direct earthing is impracticable and where the protective multiple earthing (PME) system* is not in use. Since this system is normally used in all domestic premises in the United Kingdom, the meter is mainly of benefit in locations such as garages, workshops, and outhouses, where damp conditions are likely and portable appliances may be used.

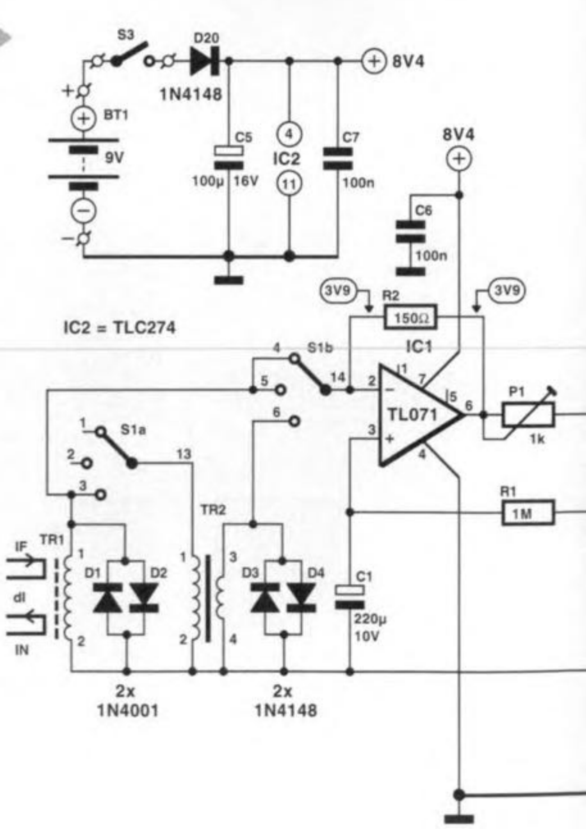
*see box 2

Brief specification

Meter ranges	*1–10 mA*
	10–100 mA
	100–1000 mA
Tolerance	*5%*
Current drain	*15 mA*
Peak indicator	*Integral*
Indication	*10 LEDs*
Power supply	*9-V battery*

Design by H. Bonekamp

1



INTRODUCTION

An electrical appliance is connected to the domestic mains supply to obtain electrical energy for the operation of an inbuilt motor, compressor, heating element, lamp, or electrical circuit. Since the neutral point of most low-voltage mains systems (in the United Kingdom) is earthed (so that a voltage exists between earth and the other pole or poles), it is necessary for non-current-carrying metalwork of wiring systems and exposed metalwork of electrical appliances to be earthed (IEE Regulations 13-8), except in certain circumstances (IEE Regulations 471-26), such as in the case of a double-insulated appliance.

Where direct earthing is impracticable, and where the PME system is not in use, it is advisable to check the electrical soundness of an appliance with the earth-leakage meter. (In the UK, also make sure that the IEE Regulations are not contravened).

CIRCUIT DESCRIPTION

The circuit diagram of the earth-leakage meter is shown in **Figure 1**. In essence, it is based on the measurement of any imbalance between the phase (live) and neutral currents. For this purpose, the phase and neutral conductors act as two separate windings of a toroidal transformer core (Tr_1); the secondary winding is connected as shown in the diagram. Normally, the currents in the phase and neutral windings are equal and opposite, so that no flux will be induced in the core and no current flows in the secondary winding. When an earth fault occurs in an installation where direct earthing or the PME system is not used, the leakage current returns direct to the substation without passing through the neutral winding†. The currents in the phase and neutral lines therefore become unbalanced by an amount equal to the leakage current and this results in a secondary current in Tr_1. Since the secondary winding consists of 40 turns (each of the primaries only one), the current in the secondary winding is $\frac{1}{40}$ of any detected leakage current. This attenuation is, of course, taken into account in the meter circuits. When switch S_1 is in position 1 or 2, the measurand (that is, secondary current) is raised to the correct level by op amps IC_{1a} and IC_{1b}.

In position 3, an additional transformer, Tr_2, is used. The primary winding of this transformer has 2 turns and a secondary winding of 20 turns. This means that any leakage current is further reduced by a factor 10. Diodes D_1–D_4 serve a double function: (a) they limit the secondary voltage to a safe value should IC_1 fail and (b) they are free-wheeling devices when S_1 is changed over. When that happens, voltage peaks are caused by the energy stored in the transformer core.

Operational amplifier IC_{1a} is arranged as a current-to-voltage converter. It ensures that the secondary voltage is always 0 V.

Op amp IC_{2a} functions as an active rectifier. It is designed to provide a voltage amplification of ×2.35 or ×23.5, depending on the position of S_1. Preset P_1 makes possible a setting range of ±25%. In conjunction with the op amp, diodes D_5–D_8 provide full-wave rectification of the amplified measurand.

Op amps IC_{2b} and IC_{2c} form a buffered differential amplifier which measures the potential across R_5 or R_4.

The output voltage of IC_{2b} exists across C_2. When switch S_2 is open, this capacitor functions as an analogue peak detector. Resistor R_{10} prevents the detector responding to small signals. With values as specified, the detector is operating at the correct level within 5 ms, i.e., a quarter of the period of the mains voltage. When S_2 is closed, the hold function ceases since C_2 is then discharged via R_{11}.

The LED display is driven by IC_3, which is a ready-made display driver controlled by the output signal of the preceding circuit via its SIG pin. An internal reference source, V_{REF}, provides a calibrated LED drive. The reference voltage, available at REFOUT, is also used to provide an auxiliary voltage of 3.9 V. This is done with the aid of IC_{2d} which is arranged as a d.c. amplifier with an amplification of about ×3. This auxiliary voltage makes

† If direct earthing or the PME system is used, the relevant fuse or circuit breaker would instantly blow or cut out, as the case may be.

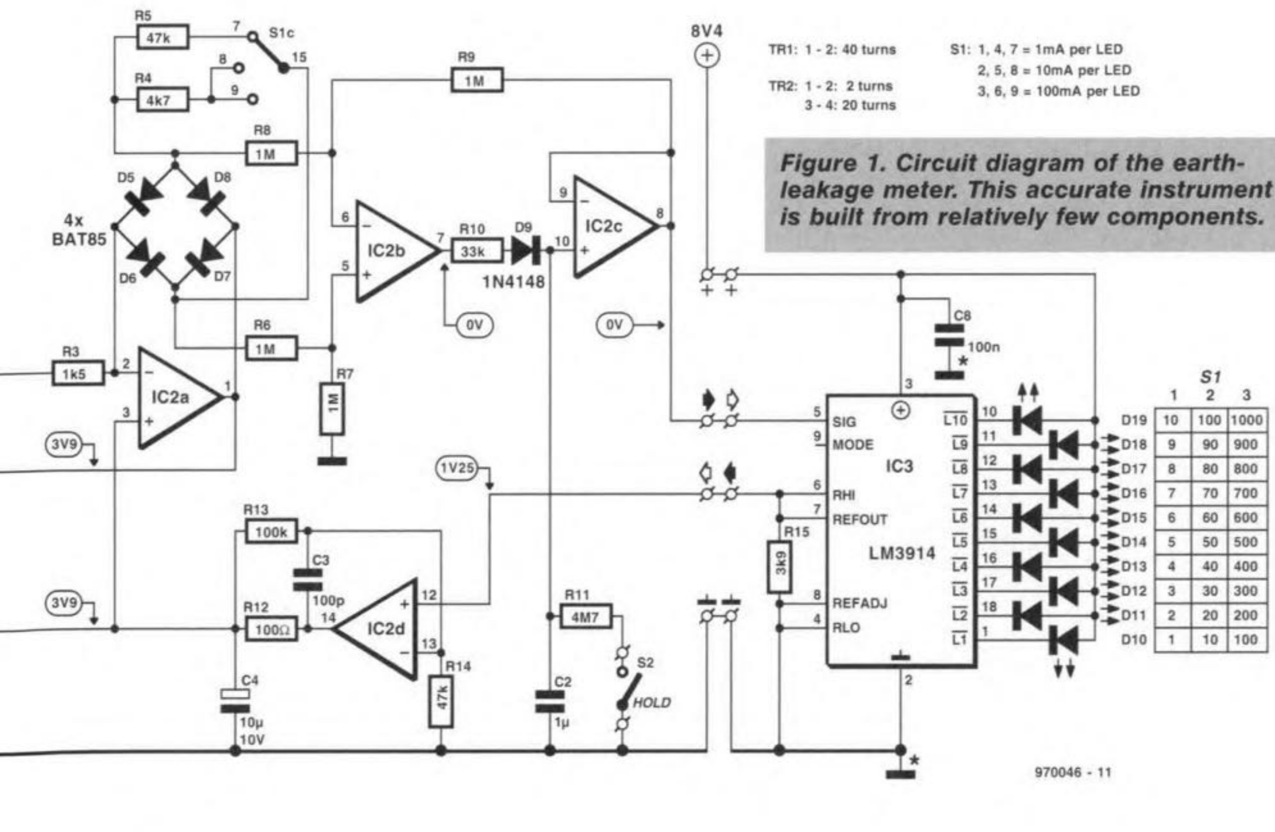


Figure 1. Circuit diagram of the earth-leakage meter. This accurate instrument is built from relatively few components.

possible a dual supply from only one 9-V battery.

Diode D_{20} provides protection against incorrect polarity.

CONSTRUCTION

The prototype meter was built on the two-section PCB shown in **Figure 2** and housed in a suitable PSU case with integral mains plug and a mains socket added on a trailing cable. This enables the meter to be inserted between the suspect equipment and a mains outlet.

Separate the display section from the combined board and cut away the corners from the mother board.

Wind the transformers on the specified toroidal cores and note from the mother board where the turns of Tr_2 will be located. In the case of Tr_1, the turns of the secondary winding are evenly divided across the core. It may prove useful to secure the windings in place with araldite or superglue after the transformers have been soldered into place.

The current to be measured flows through the phase and neutral wires that come in via the integral plug and are looped over the core of Tr_1 and returned to the trailing socket. The holes necessary for looping the wires in this way have already been drilled in the board. Note that the earth wire should be continous from entry plug to trailing socket. The completed prototype is shown in **Figure 3.**

Mount the display about 40 mm above the mother board with the aid of spacers. The most useful kind of spacer is that with a screw-thread at both ends or at one end and a tapped hole at the other end.

Mount the LEDs about 20 mm above the display board, but check before soldering them into place that they are slightly higher than the top cover. If so, they will fit nicely into the holes that are to be drilled into the front panel at a later stage.

2

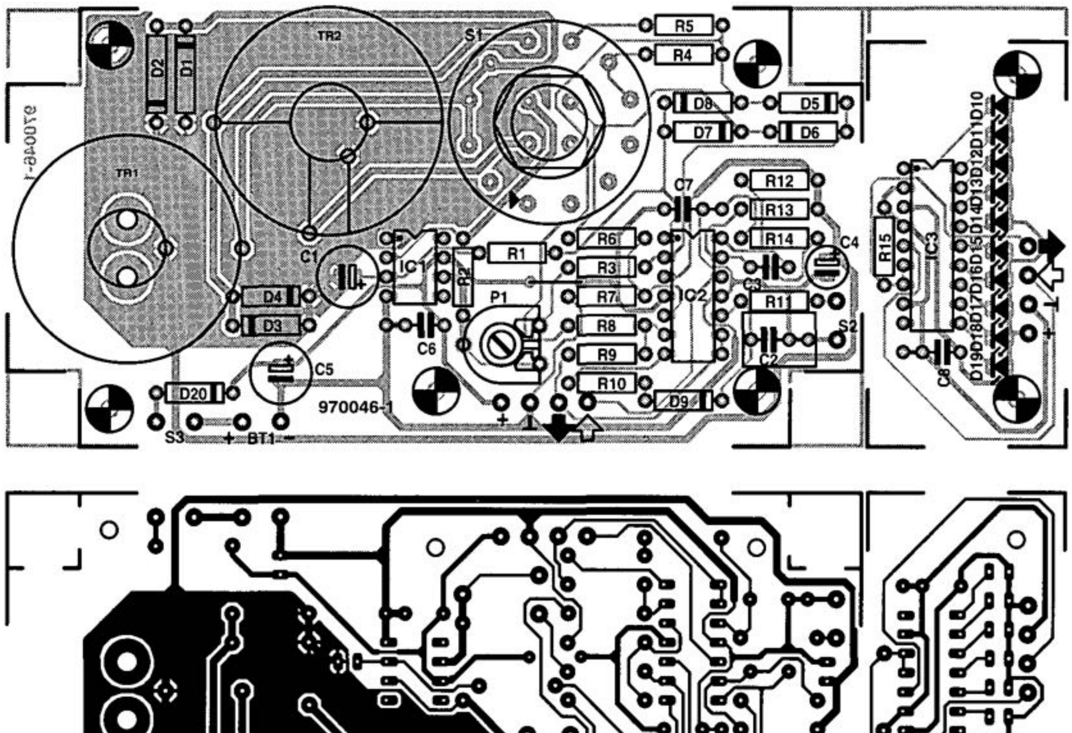


Figure 2. Printed-circuit board for the earth-leakage meter. Before any work is done, the display section must be separated from the mother board.

Parts list

Resistors:

R_1, R_6–R_9 = 1 MΩ
R_2 = 150 Ω
R_3 = 1.5 kΩ
R_4 = 4.7 kΩ
R_5, R_{14} = 47 kΩ
R_{10} = 33 kΩ
R_{11} = 4.7 MΩ
R_{12} = 100 Ω
R_{13} = 100 kΩ
RF_{15} = 3.9 kΩ
P_1 = 1 kΩ preset

Capacitors:

C_1 = 220 μF, 10 V, radial
C_2 = 1 μF metallized polyester
C_3 = 100 pF, ceramic
C_4 = 10 μF, 10 V, radial
C_5 = 100 μF, 16 V, radial
C_6–C_8 = 100 nF, high stability

Semiconductors:

D_1, D_2 = 1N4001
D_3, D_4, D_9, D_{20} = 1N4148
D_5–D_8 = BAT85
D_{10}–D_{19} = LED, red, high efficiency

Integrated circuits:

IC_1 = TL071CP
IC_2 = TLC274CN
IC_3 = LM3914N

Miscellaneous:

Tr_1 = secondary 40 turns of 0.8 mm dia enamelled copper wire on toroidal core, Philips Type 4330.030.3753 (A1 = 10 μH) – for primary, see text
Tr_2 = primary 2 turns of 0.8 mm dia enamelled copper wire; secondary 20 turns of 0.8 mm dia enamelled copper wire on toroidal core, Philips Type 4330.030.3753 (A1 = 10 μH)
S_1 = rotary switch, 3-position, 4-pole
S_2, S_3 = mini toggle switch, 1 make contact
Bt_1 = 9-V alkaline battery
PSU box with integral plug (120×65×66 mm). Suitables cases to UK, US and European standards are available from Bopla [in UK represented by Phoenix Mecano Ltd, 6–7 Faraday Road,Aylesbury HP19 3RY, England, Telephone +44 (0)1296 398 855]
PCB Order no. 970046.

Figure 3. Photograph of the completed prototype. Note that the earth wire should be continuous from entry plug to trailing socket.

The two boards are interlinked by a short length of 4-way flatcable.

Next, drill suitable holes in the top lid of the enclosure for the rotary switch, the ten LEDs, and the hold switch. The illustration in **Figure 4** is a good guide for this work. The on/off switch is fitted at one of the short sides of the enclosure (see also Figure 4).

Screw the boards tightly into the enclosure. Secure the 9-V battery with nylon cord to the spacers on which the display board is mounted.

ELEKTOR		☐
230 V ~	50Hz	
No. 970046		
I = max. 16A		

CALIBRATION

A 9-V a.c. source such as a bell transformer and a 1 kΩ resistor are required for the calibration. Connect the resistor in series with one of the the primary windings of Tr_1 and apply the 9-V a.c. voltage across this winding so that a current of 9 mA flows through it. Switch on the circuit with S_3, disable the hold function with S_2 and set S_1 fully anti-clockwise (meter range 1–10 mA). Adjust P_1 until D_{18}, the penultimate LED, just begins to light. That's all!

Remove the a.c. source and 1 kΩ resistor, reconnect the mains leads as required, and screw the lid on the enclosure. [970046]

mains supply earthing in the United Kingdom

In the United Kingdom, the consumer's main earthing terminal is connected by the electricity board to the neutral conductor at the meter position on the consumer's premises. This means that a phase to earth fault becomes a phase to neutral fault. With protective multiple earthing (PME), as normally applied in the UK, the wiring on the premises to lighting points, socket outlets, and so on, is normal, that is, the earth and neutral lines are kept separate for all wiring on the consumer's side of the consumer unit. All exposed metalwork on the premises must be bonded to the main earthing terminal. This is vital so as to prevent any difference in voltage between the metalwork of electrical appliances and any other extranelus metalwork should a break in the neutral occur outside the premises.

The neutral line is usually connected by the electricity board to earth electrodes at a number of points along the route: this ensures that the neutral is earthed even if a break occurs along the route.

The great advantage of PME is that a metallic path of very low impedance is provided back to the transformer neutral points, and this means that the consumer's overload protective devices will normally operate when a phase to earth fault occurs. Another big advantage is that this path is continuously monitored since a break in the neutral will be immediately noticed.

In each consumer's installation, the protective conductors are brought back to an earthing terminal in the usual way, but the earthing lead (which must be insulated) is connected to the neutral-supply terminal by the electricity board. No fusible cut-out, automatic circuit breaker, removable link or single-pole switch must be included in the neutral conductor (or any conductor which is connected to the neutral conductor) on the consumer's side of the supply terminals. This applies, of course, to all systems, whether PME or not.

Earth-leakage circuit-breakers (ECLBs) are used where direct earthing is impracticable and where the PME system is not in use. They are also often used to provide extra protection in locations such as garages, workshops, and out-houses, where damp conditions are likely and portable appliances may be used. They are available as separate units or combined with socket-outlets.

Figure 4. Suggested front panel for the earth-leakage meter.

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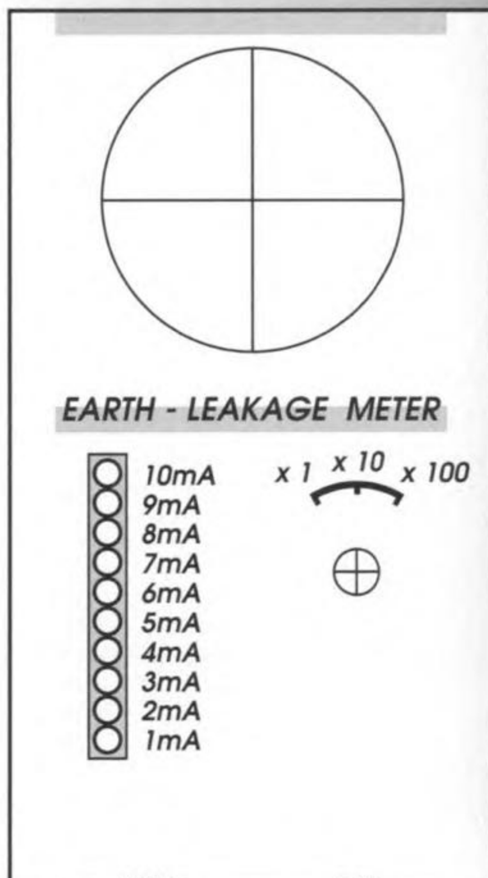


970046-F

CORRECTIONS & UPDATES

68HC11 Emulator
February 1997 - 970008

If the reset does not work properly it is recommended to fit a 100-nF capacitor near C5, between pins 1 (REF) and 4 (ground).
In case there is insufficient room for C10 (located inside the socket), then this part (preferably SMA) may be fitted at the underside of the board.

Earth Leakage Meter
June 1997 - 970046

The article states incorrect type numbers for the inductor cores. Although this does not affect the operation of the circuit, problems may arise when the circuit is built into the specified case. The correct core type is: TN26/15/10-3C11, $A_l=5\mu H$ (Philips Components)

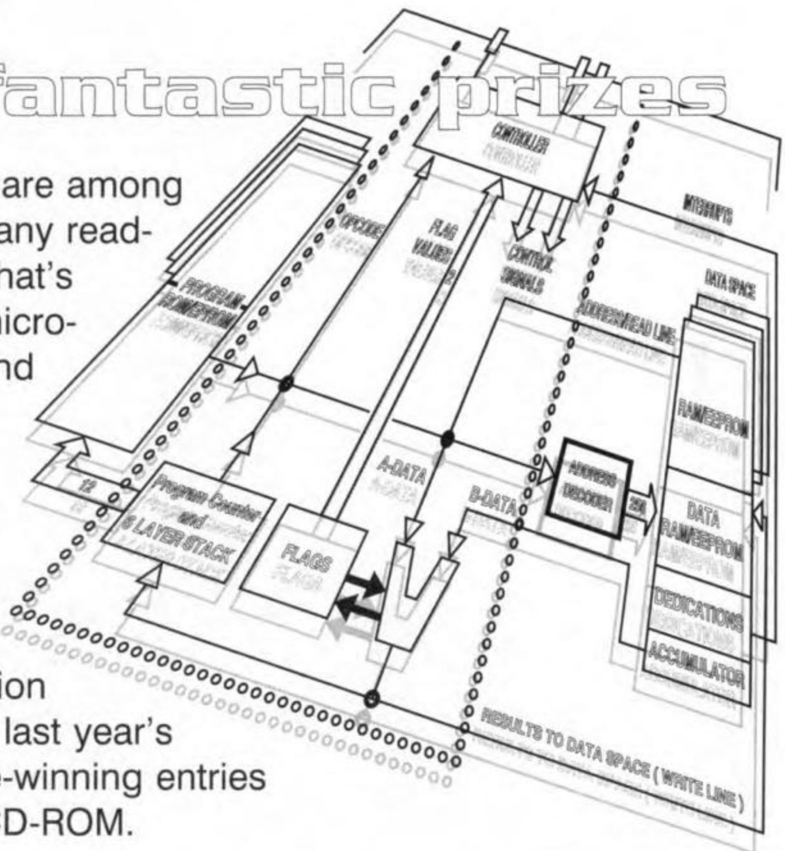
Advanced LCR Meter
April, May, June 1997 - 970028

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

Next month:

International Microprocessor Contest

with lots of fantastic prizes



Microprocessors and microcontrollers are among the most popular subjects as far as many readers of this magazine are concerned. That's why we invite everyone dealing with microprocessors and microcontrollers to send us his/her software and/or hardware, and so participate in the Contest to be officially launched in next month's issue. Our interest is fairly wide. Software in the form of a debugger, assembler or simulator is just as welcome as a practical hardware application of a popular processor board. As with last year's highly successful competition, all prize-winning entries will be collected and published on a CD-ROM.

Circuits based on µPs and µCs are not only popular items in *Elektor Electronics* magazine — lots of hardware and software is also offered by our advertisers and other manufacturers. A multitude of ready-made boards is currently available based on the BASIC Stamp, PIC, 87C513, 68HC11, Z180 and TMS370 to mention but a few beasts. Such boards are not only used for educational purposes or experiments — they are, of course, intended for use as a central control element in a certain application system. *Elektor Electronics*, too, has added its penn'orth of processor controlled circuits and boards (8032/52, 80C552, 80C535, PIC, PLC, 68HC11 and 80C537), backed by a number of programming courses. It is our firm belief that a vast amount of useful, interesting or plain amusing software and hardware has been designed in which a microcontroller plays a crucial part. If you have anything in this field which you feel may be of interest to other readers, let us know, and participate in the Contest. You may win a great prize!

What are we looking for?

This Contest is all about that microcontroller or microprocessor for which you have developed software and/or hardware. The emphasis is on originality and practical realization. There are no special requirements as far as the hardware is concerned. You may either use an existing board, a home-made system or an *Elektor Electronics* design. As regards software, we are not just interested in the control program executed by the processor, but also in the associated PC software, if used. A few examples: a stand-alone microprocessor board controlling the domestic heating system; an emulation program which 'replaces' a certain processor on a board; a PC simulation program mimicking the operation of a complete processor board; an assembler or a debugger (in the last three cases, no hardware is used). When hardware is included, the components should be generally available (no esoteric types, please). Computer programs should work on a PC running DOS or Windows.

All Contest entries will be judged by a jury consisting of members of the international editorial and design staff, who look forward to being inundated with your submissions.

Do not miss the July/August 1997 issue of *Elektor Electronics*, which will contain the official conditions for participating in the 1997 Microprocessor Contest , as well as an overview of the prizes to be won. (975070)

80C537 microcontroller board

versatile experimenting with a powerful CPU

The 80C537 from Siemens is a powerful version of the industry standard 8051 processor. The project described here contains all software and hardware required to set up a complete control system based on the 80C537 CPU. Despite its powerful specifications, the computer still fits on a single Eurocard.

MCS-51, of which the 8051 is the generic member, is without doubt the most popular and widely familiar microcontroller family currently on the market. Aiming to fulfil specific needs of different application areas, a number of manufacturers have expanded the 8051 CPU core originally designed by Intel. Today, there are versions of the 8051 which have extra features like more I/O capacity, an on-chip I^2C interface, extra memory, an A-D converter or a D-A converter. Not forgetting, of course, the CMOS variants with reduced power consumption, and the miniature derivatives in compact 20-pin or 24-pin cases. So, there's a perfect version available for almost any application.

Design by Prof. Dr. Ing. B. vom Berg and Dipl. Ing. P. Groppe

The heart of the present circuit is a Siemens SAB80C537 microcontroller, which is the ROM-less counterpart of the SAB80C517. The '537 runs all existing 8051 software without problems. Existing libraries containing elementary routines may be used, too, on this processor.

Extra functionality

As a matter of course, the 80C517/80C537 offers more functionality than the generic 8051. Compared with the original 8-bit 8051 design the additions are, among others, a 32/16-bit MDU (multiplication/division unit), an enhanced (four-level) interrupt structure, and the number of data pointers has been increased to no fewer than eight 16-bit units. Moreover, three 8-bit I/O ports have been added to the design, as well as 12 universally applicable inputs. One of the serial channels implemented on the '537 is compatible with the 8051-style UART, and uses a programmable baud rate generator. Digital signal processing is possible with the aid of an on-chip 8-bit A-D converter which uses an adjustable voltage reference. The operation of this converter is helped by a powerful compare/capture unit employing two 16-bit timers.

Apart from the current-saving CMOS technology, further power reduction features are available, including idle, power-down and slow-down modes. In the block diagram shown in **Figure 1**, the shaded boxes represent the extra modules with respect to the 'bare' 8051.

The processor handles instructions in one, two or four machine cycles, where an instruction has a maximum with of three bytes. One machine cycle lasts 12 clock cycles. Based on a clock

Technical Specifications

Processor:	SAB80C537
Memory: in monitor mode:	32 Kbytes (less 256 bytes) RAM for user code
	32 Kbytes (less 512 bytes) RAM for user data
in stand-alone mode:	64 Kbytes program memory
	64 Kbytes (less 512 bytes) data memory
Interfaces	2 serial channels
	96-pin expansion bus
	real-time clock
	watchdog timer
	decoder with 16 CS outputs
Programming	Programs are written on the PC and then downloaded via the serial channel (in monitor mode).
Power Supply	5 V/100 mA, backup for data and RTC
Monitor program	up/downloading of data
	up/downloading of machine code

frequency of 12 MHz, instructions are therefore completed in 1, 2 or 4 microseconds. No fewer than five modes are available to address the memory. The internal ROM memory of the 80C517 has a capacity of 8 kBytes (the 80C537 has no internal ROM), while up to 64 kBytes of data memory and an identical amount of program memory may be connected. The internal RAM memory has a capacity of 256 bytes of which the lower eight bytes (bank 0) are used by the CPU for its eight registers. If necessary, the user may put another three banks of eight registers at the CPU's disposal. The rest of the memory (above the banks used for register storage) is freely available. Memory locations 32 through 48 are also addressable at bit level, while locations 0 through 128 may be addressed directly or by way of a register. Locations 128 through 255 may only be addressed via a register. Alongside the latter addresses is an internal memory for the special function registers (SFRs).

The distinction between program memory addressing and data memory addressing is realised with the aid of a number of special instructions from the instruction set. As an addition to the original 8051 architecture, the 80C537/517 makes use of eight data pointers which speed up access to the external data memory.

Expansion in all directions

The external bus interface of the 80C517 consists of an 8-bit databus (Port 0), a 16-bit address bus (Port 0 and Port 2) and four control lines. The address latch enable signal (ALE) is used to dissect the multiplexed data and address information on Port 0. As soon as the processor requests access to the external program memory, the $\overline{\text{PSEN}}$ control line is actuated. The $\overline{\text{RD}}$ (read) and $\overline{\text{WR}}$ (write) lines are used to give access to the external data memory.

All of the processor's facilities (I/O ports, serial ports, timers, compare/capture registers, the interrupt controller and the A-D converter) are handled by means of the special function registers. This flexible approach is also used in the original 8051 design, albeit with fewer options. Finally, a number of SFRs such as the accumulator, the B-register, the programs status word (PSW), the stack pointer (SP) and the data pointer (DPTR) are used by the processor to co-ordinate the execution of a program.

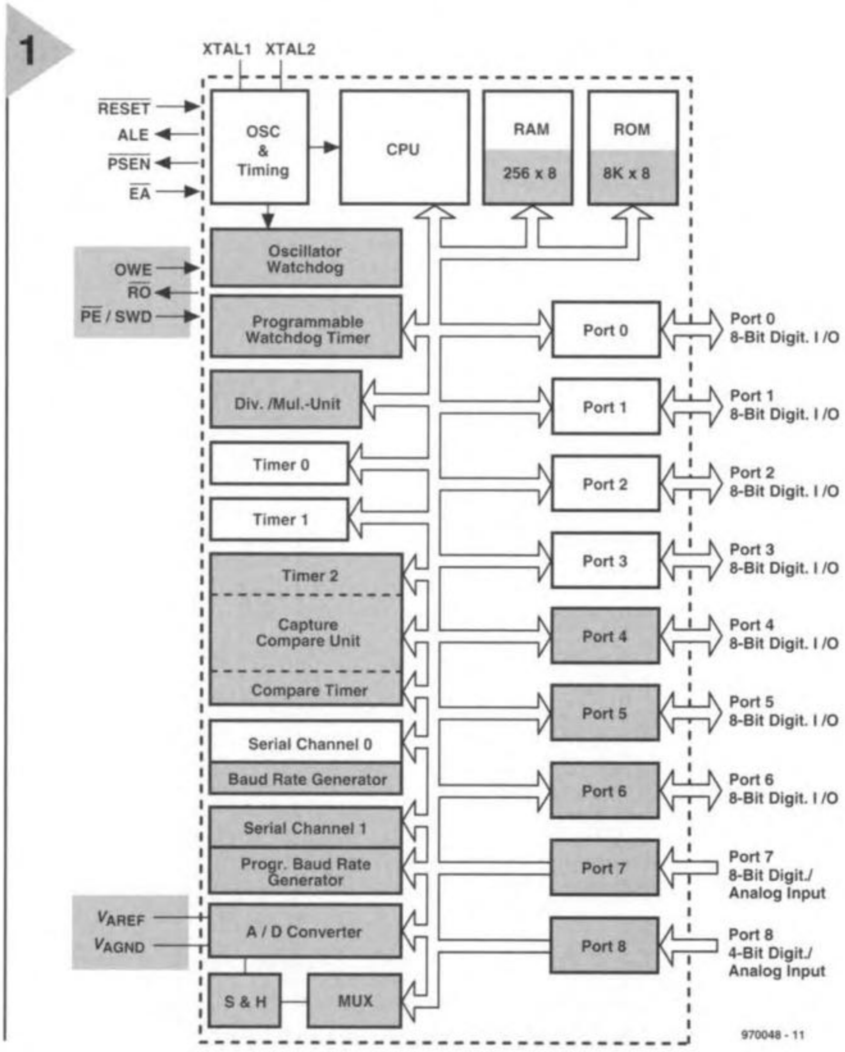


Figure 1. The 80C537 architecture. All shaded blocks are extensions to the original Intel 8051 design.

Towards practical matters

The block diagram of the 80C537 single-board computer is shown in **Figure 2**. Besides the processor and the memory, a number of functions have been added, including a real-time clock, a reset circuit/supply guard and an RS232 serial interface. A Lithium battery ensures that all data stored on the board is retained after the supply voltage is switched off.

The address decoder is built around a bit of programmable logic in the form of a GAL type 20V8. Both the EPROM and the RAM bank have a

2

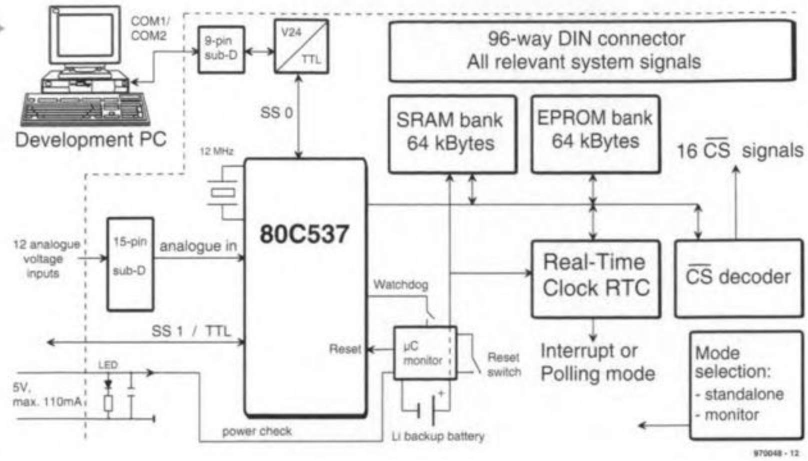
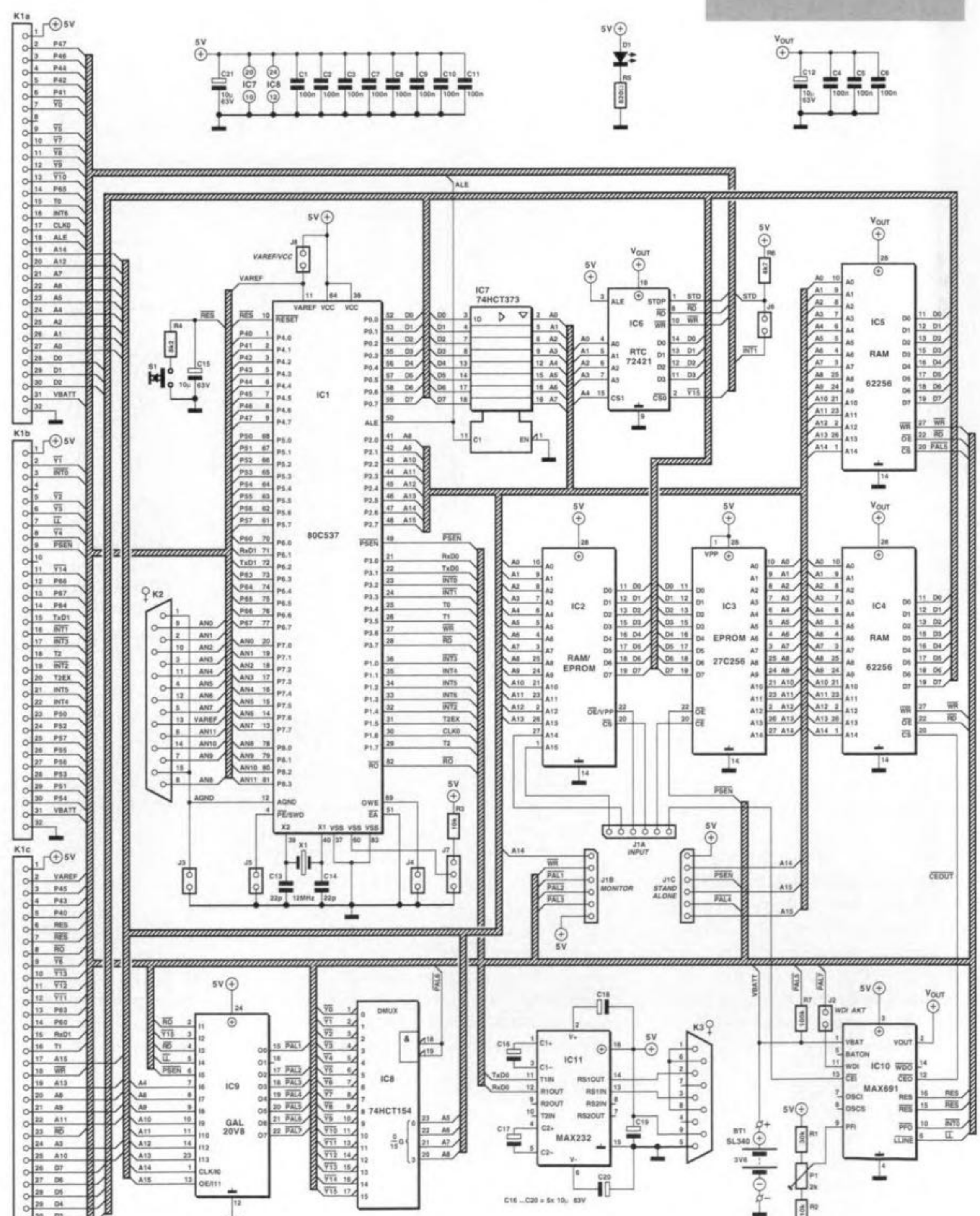


Figure 2. Block diagram of the 80C537 SBC. All important functions are accommodated on a compact Eurocard sized board.

Figure 3. Circuit diagram of the single-board computer. Despite the apparent complexity, the general structure is easily seen.

3



size of 64 kBytes, which is ample for most ordinary applications. Thanks to the use of static memories, the battery is capable of keeping information (i.e., program code as well as data) stored quasi-permanently in memory. The 80C537 is equipped with two serial ports. Of these, serial port 0 uses RS232 signal levels and is intended for communication with a PC, while the other port uses TTL levels only.

In keeping with this magazine's tradition, the step from theory to practice is a small one. The proof is **Figure 3** which shows the complete circuit diagram of the 80C537 single-board computer. Although we must admit that more compact microcontroller systems were published in previous issues of *Elektor Electronics*, the discerning eye will have few problems unravelling the basic structure of the present circuit.

The heart of the SBC is the SAB80C537, an integrated circuit with a whopping 84 pins. The system memory is formed by IC2, IC3, IC4 and IC5.

The memory division is determined by a GAL, IC9. The actual configuration depends on whether the system works in 'stand-alone' or 'monitor' mode. In stand-alone mode, the entire 64-kByte program memory is available, while the data memory is available with the exception of the upper 512 bytes. So, only addresses 0000H through FDFFH are allowed for use as data memory. Exceeding the top address may have unpredictable results.

Construction

As always with digital circuits, the construction poses few problems if you stick to the usual set of rules. The component mounting plan and the copper track layouts of the double-sided, through-plated Eurocard are shown in

System monitor in EPROM

The system monitor stored in EPROM (order code 976510-1) is described briefly here. An extensive manual describing all monitor functions may be found on the project diskette, order code 976008-1.

The main features of the system monitor are:

- *Display memory contents, registers and SFRs in hexadecimal and ASCII format.*
- *Edit memory contents, registers and SFRs interactively.*
- *Disassembler and simple in-line assembler.*
- *Up/downloading of programs in Intel-hex format.*
- *10 break-points.*
- *Program execution in real time using break-points.*
- *Single-stepping, with option to have subroutines executed faster.*
- *A Help menu.*

On the PC you should have a simple terminal program, for example, HyperTerminal which is included with the Windows 95 operating system. Choose the following settings in HyperTerminal:

New Connection → enter the name and optionally select one of the icons → OK → In the phone number window, under Connect using, select Direct to Com1 (or another Com port) → OK → In the Port Settings window for Com1 (or another Com port), select 9600 baud, 8 bits, no parity, 1 stop bit. Set Flow control to 'None'. Click on OK.
Now do File → Properties → Settings → (use Auto detect) → ASCII Setup → tick 'Send line ends with line feeds' → OK.
Reset the SBC. The following welcome prompt should appear in HyperTerminal:

```
TFH-80C537er-Monitor V1.00a
(C) TFH/PHYTEC 1996
MONITOR MODE
```

The available commands are listed below, they may also be viewed on the screen by using 'Help'. The general syntax is
command space address enter
There are also commands with a start and an end address, the syntax is then
command space start address space end address enter
Commands like 'A' may be aborted by pressing Ctrl-C (control-C). Addresses should be entered in hexadecimal format.

Edit program memory:

DC	start address	end address		display code
EC	start address			edit code
U	start address	end address		disassemble
A	start address			assemble
FILLC	start address	end address	value	fill range with value

Edit internal data memory

DD	start address	end address		display data
ED	start address			edit data
FILLD	start address	end address	value	fill range with value

Edit internal indirectly addressable data memory:

DI	start address	end address		display data
EI	start address			edit data
FILLI	start address	end address	value	fill range with value

Edit external data memory:

DX	start address	end address		display data
EX	start address			edit data
FILLX	start address	end address	value	fill range with value

Edit registers:

X	display contents of all registers
X register name	edit register contents

Edit bit-addressable memories:

DB	start address	end address		display bits
EB	start address			edit bits
FILLB	start address	end address	value	fill range with value

Edit external data memory page-wise (1 page = 256 bytes)

DP	start address	end address		display data
EP	start address			edit data
FILLP	start address	end address	value	fill range with value

Breakpoints:

BS	set breakpoint
BK	kill breakpoint
BL	list breakpoint
BE	enable breakpoint
BD	disable breakpoint

Test program:

G	address [break address]	start real-time execution of the program
T	number	single-step inclusive of subroutines
P	number	single-step exclusive of subroutines

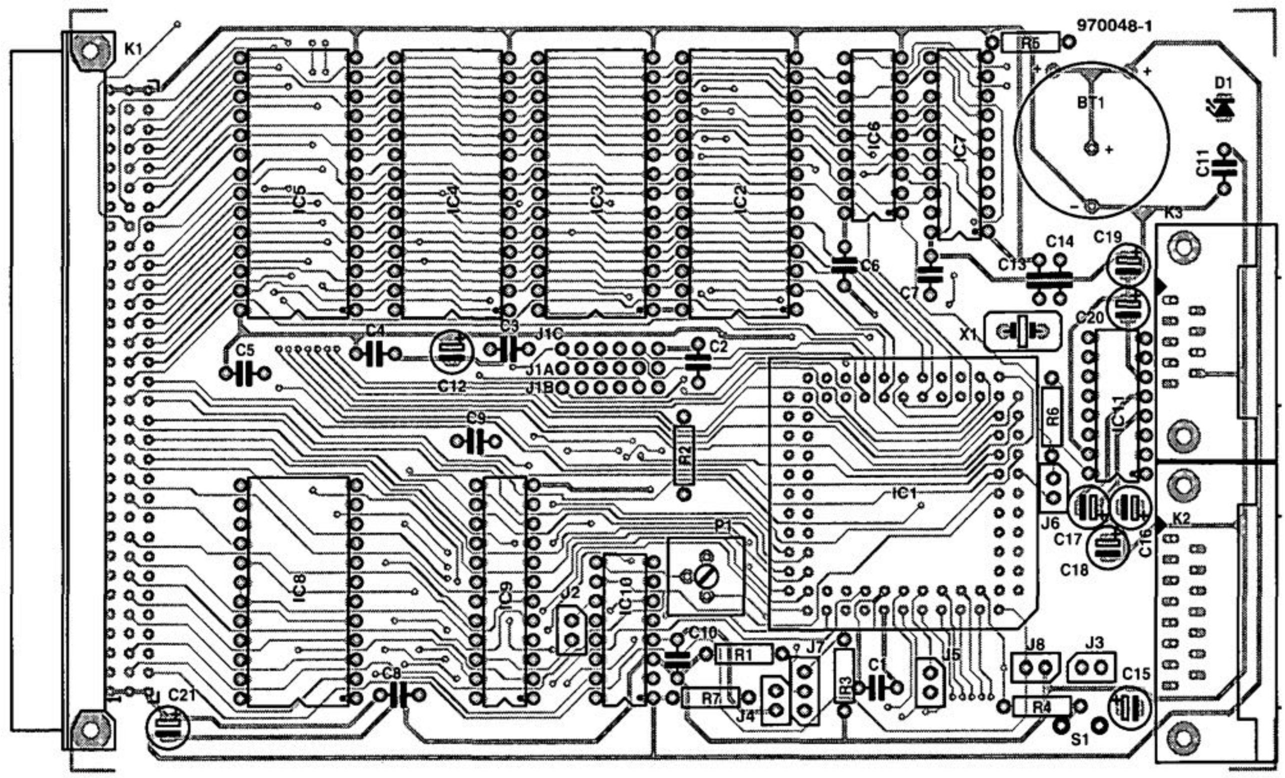
Writing and reading of programs:

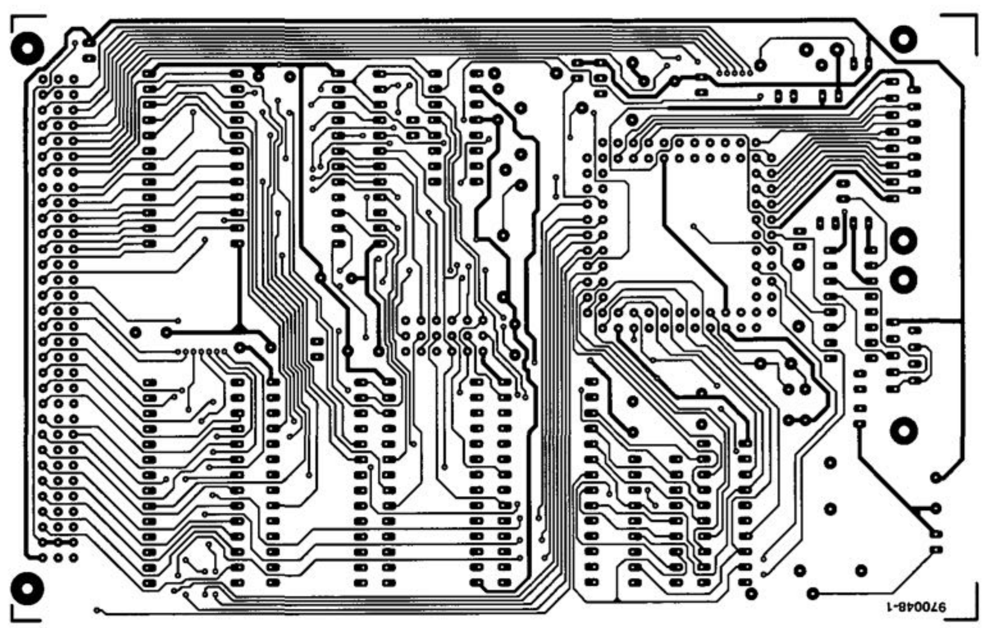
S start address end address read from processor in Intel-hex code
Upload Intel-hex file by sending it without a previous command (ASCII with ***no*** *protocol, using Transfer → Send Text File)*

General:

F1	Back to DOS
F2	Start program download
F3	Also write screen data to file
HELP	Help menu
;	Start comment
Ctrl+C	End command

4





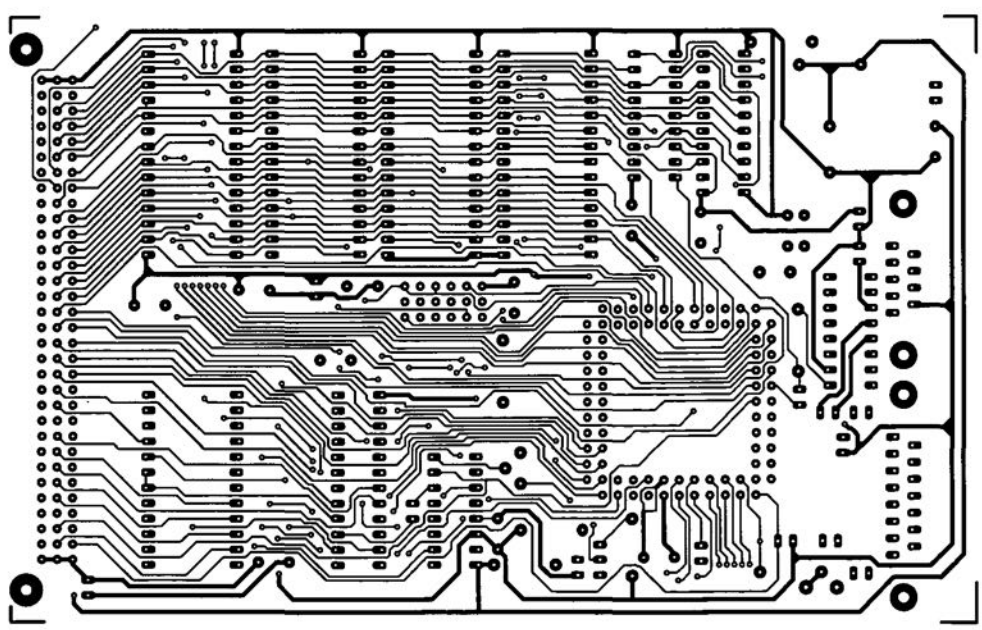


Figure 4. Track layout (80% of actual size) and component mounting plan of the circuit board used to build the computer (double-sided, through-plated board, available ready-made).

Figure 4. Start by fitting the sockets for the 11 ICs, paying attention to their orientation. Next, fit the pinheaders for the jumpers, the 96-pin system expansion connector and the two sub-D connectors. The underside of the battery receives an isolating washer to prevent short-circuits with the copper tracks running underneath. Finish the construction by fitting the resistors, decoupling capacitors, the preset and the quartz crystal. The circuit is then ready for use.

The 5-volt supply voltage arrives via the expansion connector. The supply voltage of 5 V should be connected to pins 1a, 1b and 1c, while ground goes to pins 32a, 32b and 32c. The current consumption is about 100 mA.

ABOUT THE JUMPERS

Before the circuit may be tested, you have to decide on the jumper settings. The table below shows the options for **jumper J1**. The connections between A and B are made if the optional monitor program is used, while the links between B and C are associated with the system's stand-alone mode.

	B (monitor)	A (input)	C (stand-alone)
1	A14	IC2(1)	V_{CC}
2	$\overline{WR}$	IC2(27)	A14
3	$\overline{PAL1}$	IC2(22)	$\overline{PSEN}$

COMPONENTS LIST

Resistors:
R1 = 30kΩ
R2,R3 = 10kΩ
R4 = 8kΩ2
R5 = 820Ω
R7 = 100kΩ
R6 = 4kΩ7
P1 = 2kΩ multiturn preset, vertical

Capacitors:
C1-C11 = 100 n
C12,C15-C21 = 10µF 63V radial
C13,C14 = 22pF

Semiconductors:
D1 = LED
IC1 = 80C537-N (Siemens)
IC2 = RAM/EPROM (see text)
IC3 = 27C256 (monitor EPROM, order code 976510-1)
IC4,IC5 = 62256
IC6 = RTC72421 (Seiko)
IC7 = 74HCT373
IC8 = 74HCT154
IC9 = GAL 20V8 (order code 976511-1)
IC10 = MAX691
IC11 = MAX232

Miscellaneous:
Bt1 = 3.6V Lithium battery, Sonnenschein type SL340P
J1A,J1B,J1C = 6-way SIL pinheader
J2-J6,J8 = 2-way SIL pinheader
J7 = 3-pin SIL pinheader
K1 = 96-way plug, angled pins, a, b and c row, to DIN41612
K2 = 15-way sub-D socket, angled pins
K3 = 9-way sub-D socket, angled pins
S1 = push-button with make contact
X1 = 12MHz quartz crystal
84-pin PLCC socket
PCB, programmed GAL and programmed monitor EPROM, set, order code 970048-C (see Readers Services page).
Monitor EPROM only: order code 976510-1.
GAL only: order code 976511-1.
Monitor program description on floppy disk, order code 976008-1.

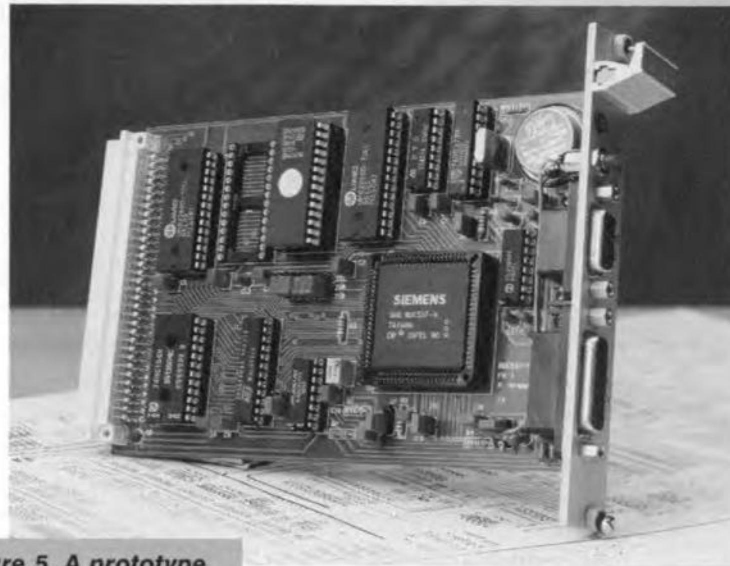


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Figure 5. A prototype of the SBC.

4	$\overline{PAL2}$	IC2(20)	A15
5	$\overline{PAL3}$	IC3(20)	$\overline{PAL4}$
6	V_{CC}	IC10(13)	A15

With connections between A and B, the system is prepared for the use of the monitor program. RAM memory IC2 (a type 62256) may then be loaded with a user program, using address range 0000H-7EFFH and the serial link with the PC. The user program has a maximum and minimum size of 32 kBytes less 256 bytes. The monitor program requires 256 bytes in the address range 7F00H-7FFFH. The other RAM, IC5, is employed as a data memory occupying the address range 8000H-FDFFH. The memory area above the latter address is reserved for peripheral devices. In this configuration, IC4 is omitted. So, when producing program code, be sure not to store it above 7EFFH, while addresses 8000H-FDFFH only are available in IC5 for variables. IC3 is an EPROM type 27256 containing the monitor program which is slotted into the memory range between 8000H and FFFFH.

If you select the setting with A and C linked, then IC2 (a type 27256 EPROM) forms the program memory between 0000H and 7FFFH. If necessary, this may be extended with IC3 (another 27256) which also acts as program memory but then between 8000H and FFFFH. IC4 is a RAM type 62256 for data within the address range between 0000H and 7FFFH, and, if necessary, IC5, another RAM as data memory, but then addressed between 8000H and FDFFH.

Although the most important system settings are covered by jumper block J1, seven other jumpers are available on the board whose setting needs to be looked at carefully.

Jumper J2 enables/disables the actuation of an external watchdog type MAX691. No jumper means that the MAX691 is not used. With the jumper installed, the system expects an external watchdog, mapped between FFE0H and FFEFH and using the Watchdog Timeout Period of 1.6 s. *Default setting:* J2 not fitted.

Jumper J3 allows the analogue and digital ground paths on the board to be connected. Without the jumper, these paths are separated. *Default setting:* J3 fitted.

Jumper J4 enables the oscillator watchdog inside the 80C537. If the jumper is not fitted, the internal watchdog (MAX691) is actuated. Fitting the jumper disables this device. *Default setting:* jumper not fitted.

Jumper J5 enables software control of the power-saving mode (J5 fitted), or enabling of the internal watchdog (J5 not fitted). *Default setting:* jumper fitted.

Jumper J6 determines whether or not the external real-time clock is allowed to generate interrupts. If the jumper is not fitted, the clock is unable to generate $\overline{INT1}$ signals. Fitting J6 enables the clock to trigger $\overline{INT1}$. *Default setting:* jumper fitted.

Jumper J7 has two settings: either it connects pins 1 and 2, or pins 2 and 3. The setting is determined by the processor used in the circuit. The 'A' type requires pins 2 and 3 to be connected. Pin 60 of the CPU is then wired to the supply voltage. In all other cases, the connection between 1 and 2 has to be made, causing pin 60 to be connected to ground. *Default setting:* jumper fitted between pins 1 and 2.

Jumper J8, finally, determines whether the analogue reference voltage is connected to V_{cc}. *Default setting:* jumper fitted.

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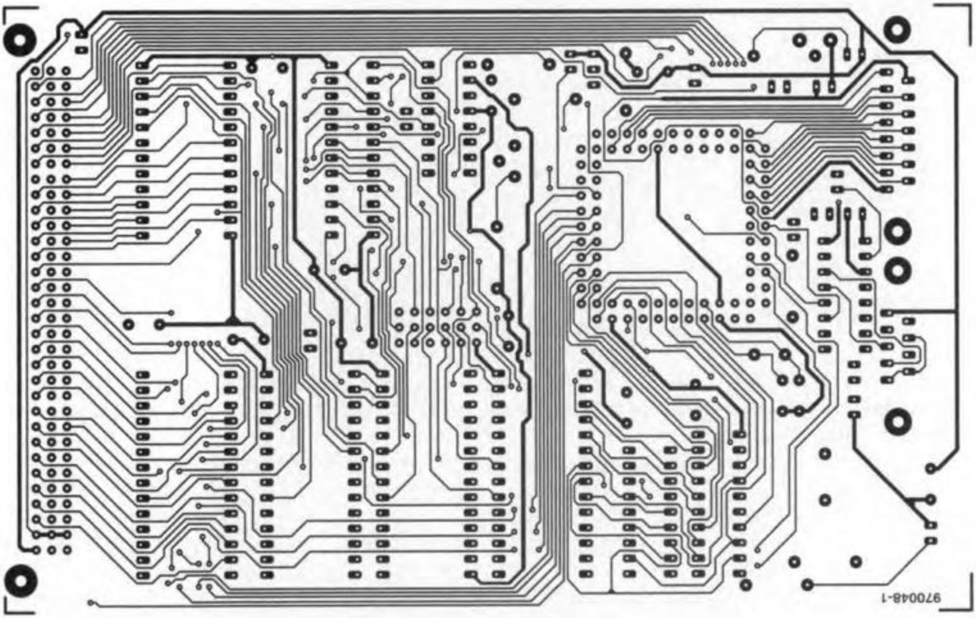
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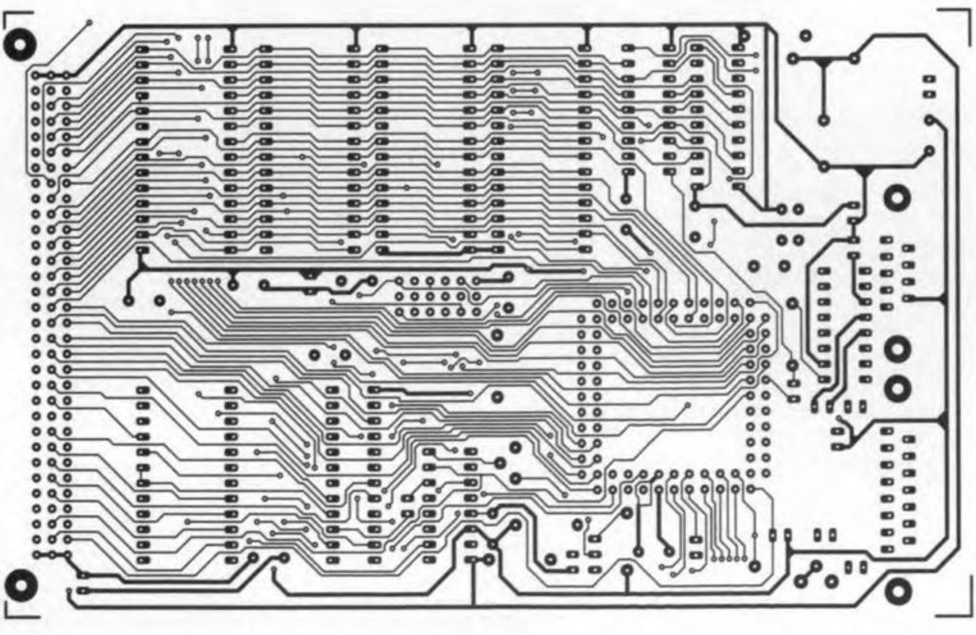


CORRECTIONS & UPDATES

80C537 Microcontroller Board
June 1997 - 970048-1

The pin assignment of the 9-way RS232 socket requires some attention because it is different from the normal configuration. Pin 9 supplies +5 V to enable an exetrnal interface (if used) to be powered. Normally, the presence of a supply voltage does not pose problems, because pin 9 is not used for the RS232 connection. At least one case has been reported to us, however, of serious problems caused on a laptop computer. For safety's sake, cut the +5 V connection to pin 9, and do not restore it until you actually need the +5 V line to power an external device or interface.

Also note that pins 1, 6 and 8 are linked on the 9-way socket. This arrangement may not function on some PCs, causing (delayed) error reports to the effect that a communication error has occurred. If that happens, it is recommended to change the pinout to reflect the standard zero-modem layout. This is achieved by interconnecting, either in the cable or at the socket, pins 1, 4 and 6, and (separately) 7 and 8.

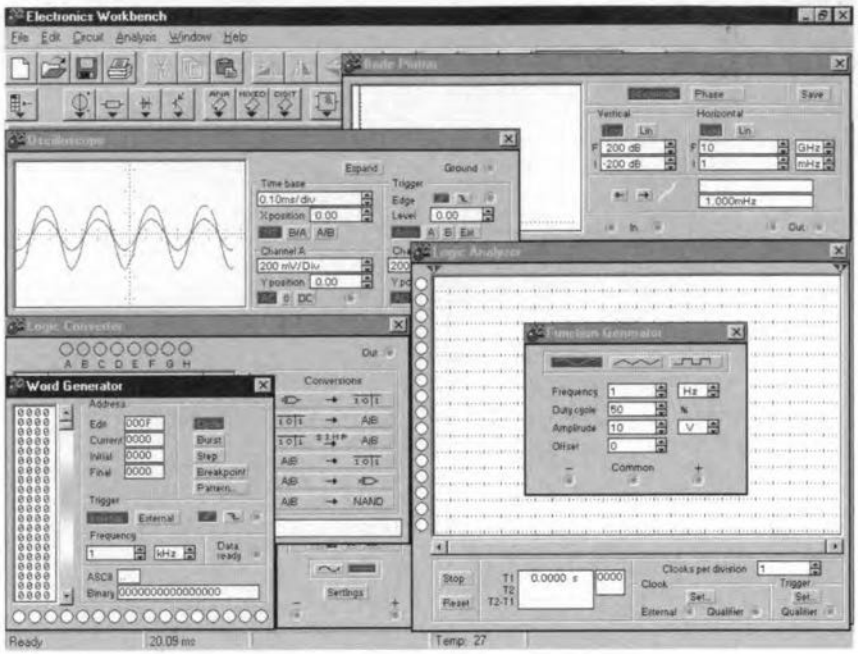
Alternatively, disable the handshaking in the communication program.

Chipcard Reader/Programmer
September 1997 - 970050-1

*The correct order code of the RS Components (ElectroMail) card reader module used in this project is **453-791**. An alternative is the CCM01 2N032 (9320) from ITT-Cannon.*

Electronics Workbench v. 5

With the launch of version 5, the mixed-mode electronic simulation program *Electronics Workbench* has become even more versatile and professional. The program now supports six analysis modes and offers about 4000 component models, including diodes, transistors analogue and digital ICs.



Programs are short-lived in today's software business. Most software houses release new, more extensive, better and faster releases of their programs at very short intervals. Interactive Image Technologies Ltd. are no exception, producing frequent updates of their simulation program, albeit not at the rate kept up by Corel (yes, the makers of Corel Draw, and also a Canadian company). Fortunately, the improvements made by Interactive are invariably useful, so that a new version means a really worthwhile step forward to the electronic design engineer.

Electronics Workbench is a program which allows you to simulate analogue, digital and mixed-mode circuits. The most remarkable feature of Electronics Workbench is the fact that the makers have always tried to mimic the (small) electronics laboratory as faithfully as possible on a computer. For this purpose, the program offers a number of generators and test instruments which may be connected to a virtual circuit to check its electrical behaviour. Initially, EWB was used mainly in schools, probably because of its extremely user friendly interface.

Over the past few years, and a couple of versions later, Electronics Workbench has grown into a full-blown simulator which is no longer confined to educational use. These days EWB is also used by professionals by virtue of its simple user interface and utterly clear structure.

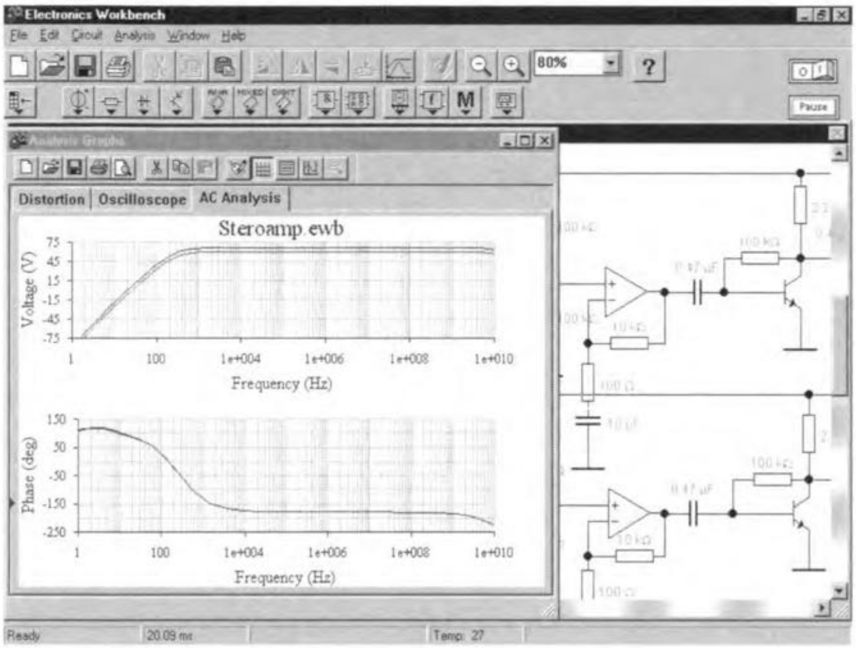
With the release of version 5, Interactive Technologies have successfully raised Electronics Workbench to the level of a comprehensive simulation package which is ready to compete with existing professional products. In a sense, EWB represents the best of both worlds. On the one hand, inexperienced users can easily draw circuits on the screen, connect test virtual test equipment, and start analyzing the behaviour of a particular design. The professional user, on the other hand, may enter complex schematics with lots of bells and whistles, and subject these circuits to many types of simulation.

The new release is not only extended with respect to version 4, it is also marked by improvements in some areas. A less important, but still very convenient detail is the improved schematic capture (circuit drawing) program. The autorouting algorithms applied by earlier versions of EWB used to cause connection lines to run crisscross on the screen. This has been considerably enhanced. Although the improved line routeing operation will make no difference for the operation of the program, your circuit will look much neater for it. A substantial improvement is the simulation speed: 10 times faster than earlier versions, the makers claim. We would say the simulation speed now matches that of other, much more expensive, programs. A Spice 3F5 engine is now used for analogue circuit simulations. Furthermore, the number of analysis options has been extended to six: dc operating point, ac frequency (Bode plot), transient response, Fourier analysis, noise behaviour and distortion analysis.

Whereas the student or hobbyists is likely to employ test equipment which may be directly connected to junctions in the circuit, professional users will require more extensive analysis options, an aspect which was neglected to some extent by previous versions of EWB. Fortunately, version 5 provides abundant recompense. Besides the usual test instruments from the older versions you now have an Analysis Graphs window which shows a neatly arranged overview of all analysis data for all junctions in the circuit. Grids and scales may be defined and adjusted to personal requirements. In the new version, you will look in vain for the parts window which used to appear beside the schematics window. Instead, a button bar has been added which appears above the schematic. Here, the components are ordered in groups, which makes it much easier to find them. Moreover, you may sweep and hide frequently used parts under a 'favourites' button. Electronics Workbench v. 5 contains a standard library of about 4000 models, which covers all widely used electronic parts, and sets a standard for the competition, including much more expensive programs.

Just as with earlier versions, the user may select between the DIN and ANSI standards for displaying component symbols. Very useful for European users!

Schematics may be exported in various formats, for example, for processing by a PCB layout program. Alternatively, a circuit diagram may be saved in Spice format, while it is also possible to import a Spice netlist.



Our only, minor, criticism on the new release concerns the appearance (with some analysis options) of messages telling you that functions are only available in the more expensive EDA version of the program. As far as we are concerned, Interactive Technologies should have left out these messages altogether, which would have made things a lot clearer.

Electronics Workbench runs under Windows 3.1, 95 and NT. The absolute minimum to get going with the program is a 486 processor and 8 Mbytes RAM. We recommend a 133 MHz or faster Pentium and 16 Mbytes of RAM if the program is used intensively. EWB version 5 is priced at £199 exclusive of VAT and P&P.

For professional users, there is Electronics Workbench EDA, offering even more simulation options, including transfer function and Monte-Carlo analysis. This version, priced below £800 in the UK, also comes with 4000 extra component models.

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Electronics Workbench is available from Robinson Marshall (Europe) Plc, Nadella Building, Progress Close, Leofric Business Park, Coventry CV3 2TF. Tel. (01203) 233216, fax (01203) 233210, email sales@rme.co.uk.

CALL FOR PAPERS

Starting with this issue, *Elektor Electronics* brings you a free monthly **Supplement** (except with the July/August magazine) full of interesting articles on a particular subject. In the autumn/winter 1997 magazines we plan to cover **audio technology, PC upgrading, test & measurement technology** and **hi-fi loudspeakers**. Authors are now invited to contribute to these Supplements with existing (but as yet unpublished) material, or new articles written with the advice of the editorial staff. In particular, authors with broad experience in PC upgrading (including software and hardware tips to make PCs faster, motherboard and CPU replacement, and extension cards), are now invited to contact the *Elektor Electronics* editorial staff.

We call for stories covering interesting topical subjects in the field of electronics and computers, as well as for reviews and construction projects with an extensive explanatory text. Some experience in writing is appreciated, but not essential (who knows, you could be a natural talent).

If you have recently finished an interesting construction project, write a text with it and send us the article. Preferably, the text and illustrations should be supplied on floppy disk. The same applies to reviews and topical stories. Send your manuscript to

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If you would like to offer your free-lance writing services for assigned subjects, inform us (in writing) about your specialism or favourite interest, and any proposals you may already have. Even if your specialism is not mentioned above, we would still like to hear from you in view of other subjects to be covered next year.

Every article is judged by the editorial staff on the basis of its publication value. You will receive our verdict as soon as possible. If your article is of interest, you will also receive our conditions for publication.

This call is also addressed to companies having press releases and other interesting background information available on the subjects mentioned above.

advanced *LCR* meter

Part 3: Calibration and usage

The design and construction of the *LCR* meter have been described in the April and May issues of this magazine.This 3rd and final part deals with the calibration and manner of use and also contains a comparison with a commercial *LCR* meter.

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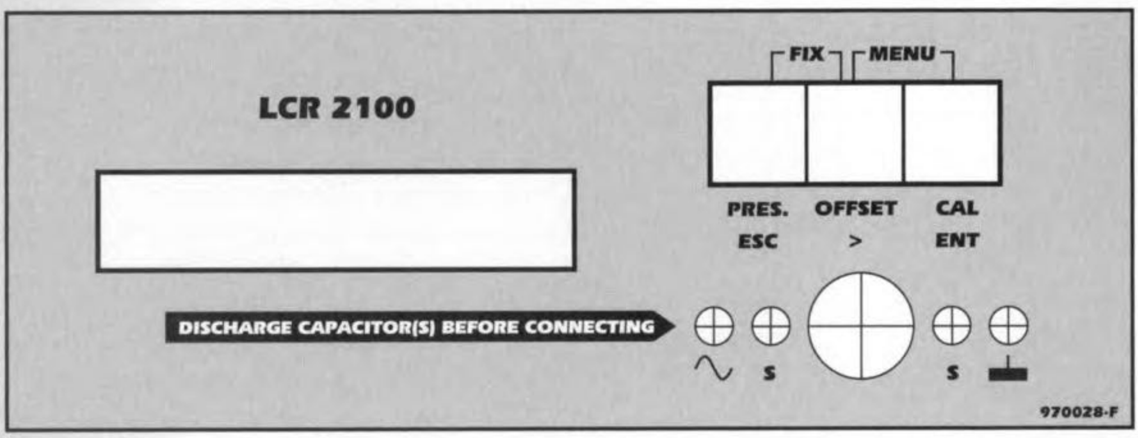


Figure 11. The front panel foil gives the meter a professional appearance.

Design by H. Bonekamp

INTRODUCTION

In this final part of the article it is assumed that the construction is complete and that the meter is fitted in a suitable enclosure. To enhance the appearance of the meter, a front panel foil (see **Figure 10**) may be obtained through our Readers' Services (towards the end of this issue).

CALIBRATION

The calibration embraces three steps.

The first step concerns the setting of the oscillator frequency of the CODEC. To do this, connect a frequency meter between the PCB pin to the left of IC_1 and earth. Adjust C_2 for a reading of 12.288 MHz on the meter.

The second step refers to the zero and infinity calibration, in which the user is guided automatically to the required actions by the software contained in the meter. For the zero calibration, short-circuit the test terminals with a 1 mm thick strip of aluminium. Drill a suitable hole in the centre of this strip to make space for the screw at that position in the test adaptor. When this process is completed, store the settings in MEM 0. This is facilitated by actuating the MENU (by pressing switches S_2 and S_3) and entering them by pressing ENT(er) switch S_3. Then, press three times on ">", whereupon the digit "0" appears on the display. Again, store the settings by pressing ENT.

The third, and most important, step concerns the so-called pole calibration. In this, three poles at defined positions must be set to zero. The procedure for this is actuated by pressing S_1 and S_3 for five seconds. The necessary instructions are then shown on the display. During this process, the adaptor for a four-wire test must be used (see box on page 38 of the May 1997 issue). Use of a test lead is not recommended. Also, use low-inductance resistors (whose accuracy does not matter).

When the process has been completed, check that the dissipation factor, *D*, is infinity (∞) using the same resistors as used for calibrating each of the poles. If it is not, the calibrations must be repeated.

impedance

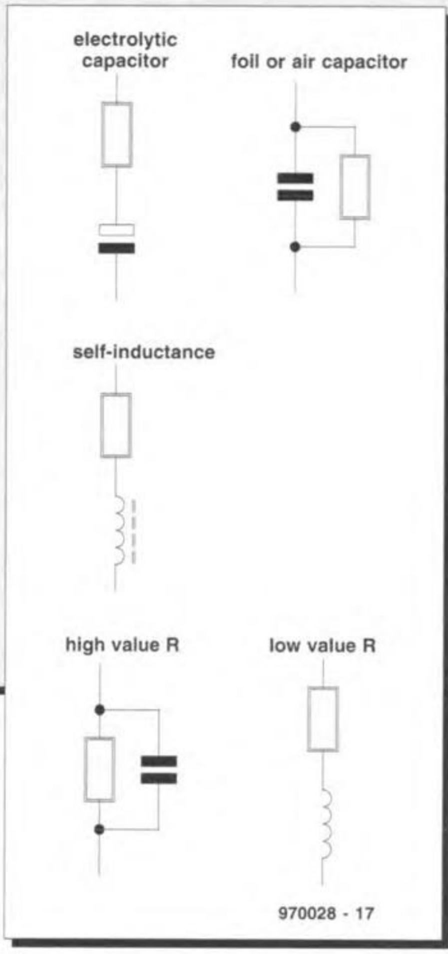
Designers of passive components such as capacitors, resistors and inductors aim to make them perfect components. It depends to a large extent on the application whether their efforts are successful or not.

For instance, if a resistor is used in a current source, only its tolerance (and perhaps its temperature coefficient) will affect the performance of the source. If the same resistor is used in an r.f. circuit, or as emitter resistor in an amplifier, or in a frequency-compensated attenuator, its parasitic part may have a considerable effect on the performance. In such situations, the impedance (that is, the vector sum of the reactance and resistance) rather than just the resistance of the component is the important factor.

When a capacitor is used as a time-determining element, its parasitic resistance will have a substantial influence on the performance.

In the same way, the parasitic series resistance of an inductor greatly affects the Q(uality) factor of the component.

The illustrations show what kind of practical component a given resistor, capacitor or inductor really is.



The LCR meter can display the impedance in one of four different ways as shown below. For this purpose, it is important to know that a series impedance can be converted into a parallel (or shunt) impedance and vice versa. The instrument itself determines whether the Q(uality) factor or the D(issipation) factor will be displayed. The Q-factor is used when it is ≥ 1 (inductor or capacitor with small resistance; the prime component is reactive). The D-factor is used when Q<1 (resistor with low inductance and capacitance; the prime component is resistive). The data pages in this issue (towards the end) give the equations with which the various impedances may be converted.

1. *serial prime + secondary*
2. *parallel prime + secondary*
3. *serial prime + Q-factor or D-factor*
4. *parallel prime + Q-factor or D-factor*

FINALLY ...

When the calibration has been completed, the *LCR* meter can be taken into use. Note that when components with a reactance or resistance lower than 1 kΩ are tested, the four-wire test (see page 32 of the April 1997 issue) must be employed.

Best results are obtained if the special test adaptor is used. This adjunct automatically arranges the correct links between the device on test and terminals PC_1–PC_4. If a test lead is used, connect this to K_1. Note that all test leads should be screened types. In the prototype, use was made of the thin screened lead contained in a SCART cable. Four such leads fit without any problems into a mini DIN plug. Note that when test leads are used, it is imperative for good results that the zero and infinity calibration is repeated. If such leads are used regularly, the calibration settings should be stored in one of the available memories (MEM1–MEM3).

When reactances or resistances ≥ 1 MΩ are to be measured, it is advisable to repeat the calibration just prior to the measurement. This may sound tedious, but it enables any drift in the parasitic impedance to be compensated.

Not only linear but also non-linear components may be tested, but when this is done, attention must be paid to the setting of the meter. Use option FIX by pressing S_1 and S_2 to select a constant test voltage of 0.1 V_p. Unfortunately, this makes determination of the secondary component rather less accurate. Whether FIX is enabled is indicated by the letter "u" between

12

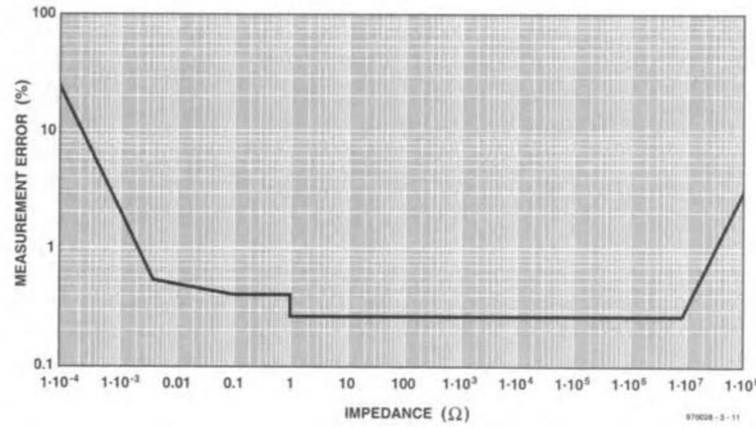


Figure 12. The measurement error as a function of the absolute value of the device on test. This characteristic shows the excellent performance of the meter, which is not attainable by a number of commercial instruments.

13

Figure 13. The meter is compared in the text with this Hewlett-Packard LCR meter, which is, however, not affordable by the average amateur.

two arrows at the last position on the second line of the display. This option should also be used when the device on test is shunted by a semiconductor. Owing to the low voltage, the semiconductor remains blocked and does not affect the measurement.

Key-switch S_2 enables a positive or negative offset to be actuated. This makes it possible for electrolytic capacitors to be tested in the correct circumstances. This option is also useful for testing components that contain a semiconductor. The setting of an offset is indicated by a "+" or "–" at the last position of the first line of the display.

This completes the information that can be given for using the *LCR* meter correctly. However, practice makes perfect and it is, therefore, only by using the instrument that you learn what effect the various settings have on a diversity of tests.

HOW GOOD IS THE METER?

Most constructors like to know what they are getting for their money and efforts, and this can be shown in two ways.

The first is a characteristic that shows the worst-case accuracy and this is shown in **Figure 12**. In this, the *x*-axis shows the absolute value of the tested component, while the *y*-axis shows the measurement error in the value of that component.

The second way is a comparison between the present meter and a commercial *LCR* meter. For this, the Hewlett-Packard Type HP4263B *LCR* meter was chosen. This instrument, depending on the number of optional extras, costs between £2000 and £2500 and has a basic accuracy of 0.1%. In contrast to the present meter, it uses five different test frequencies: 100 Hz, 120 Hz, 1 kHz, 10 kHz and 100 kHz. Its measurement ranges are rather wider as shown below.

Quantity	Range
|Z|, R, X	1 mΩ – 100 MΩ
|Y|, G, B	10 ns – 1000 s
C	1 pF – 1 F
L	10 nH – 100 kH
D	0.0001 – 9.9999
Q	0.1 – 9999.9
	–180° – +180°
	-999.99 – 999.99%

From this, it is clear that the differences between the present meter and the HP instrument are not that large. It is true that matters of vital importance to professional designers, such as guaranteed accuracy, long-term stability, reliability, and others, are not being considered, but these are not so important to amateur designers or in small workshops. And in all this, it must, of course, be borne in mind that the present meter is considerably less expensive than a commercial one. [970028-3]

operating controls

All functions of the LCR meter are actuated by the three operating push-button key switches on the front panel. The list below gives a brief overview of how the controls should be used. The various functions are marked on the front panel.

Control	Function
S_1	*PRES/ESC*
display:	*1. serial prime + secondary (press once)*
	2. parallel prime + secondary (press twice)
	3. serial prime + Q-factor or D-factor (press three times)
	4. parallel prime + Q-factor or D-factor (press four times)
escape:	*discontinue selected function*
S_2	*OFFS/>*
	OFFSET: setting the offset of the measurand 0, –, +
	(the component value, together with a + or –, is shown on the first line of the display)
	>:
	next item
S_3	*CAL/ENT*
	Calibration of zero and ∞ (items may be ignored with EX)
	Enter: confirmation of chosen selection
$S1+S_2$	*FIX*
	Sets the test voltage to 0.1 V (pressing the key actuates or deac tuates the function; if it is actuated, the last character on the dis play reads → u ←
S_1+S_3 (>5 s)	*Pole calibration*
	1 pole RM_1, R = 100 kΩ
	2 pole PGA_{10}, R = 1 kΩ
	3 pole PGA_{100}, R = 1 Ω
	4 store (0) calibration (this calibration point may be ignored with "ESC"
S_2+S_3	*Menu memory functions*
	Store MEM 1, 2, 3, 0
	Recall MEM 1, 2, 3, 0
	(select item with ">", confirm with "ENT", and prematurely dis continue with "ESC")
$S_1+S_2+S_3$	*Resetting the hardware*
	All settings are retrieved from memory MEM 0.

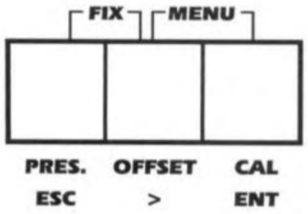
Advanced LCR Meter

Quick Reference Card

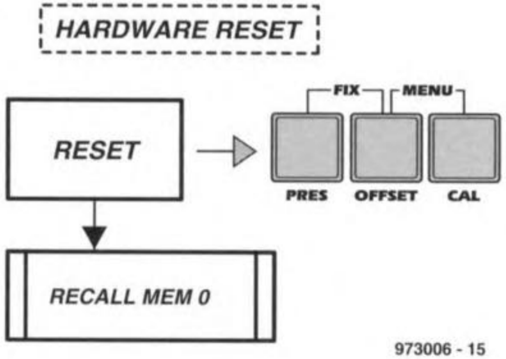
ELEKTOR ELECTRONICS

DATASHEET 06/97

Push-buttons on front panel



Instrument reset



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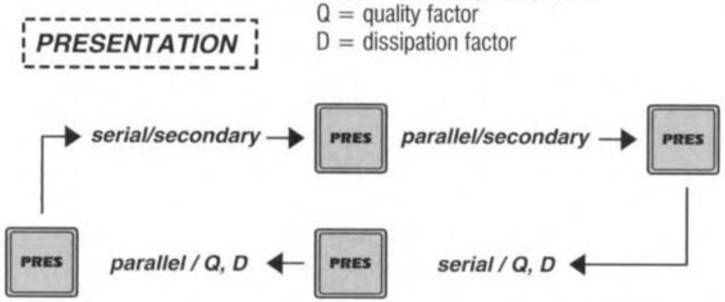
Presentation of component value on display (4 options)

secondary = stray component

Q = quality factor

D = dissipation factor



973006 - 16

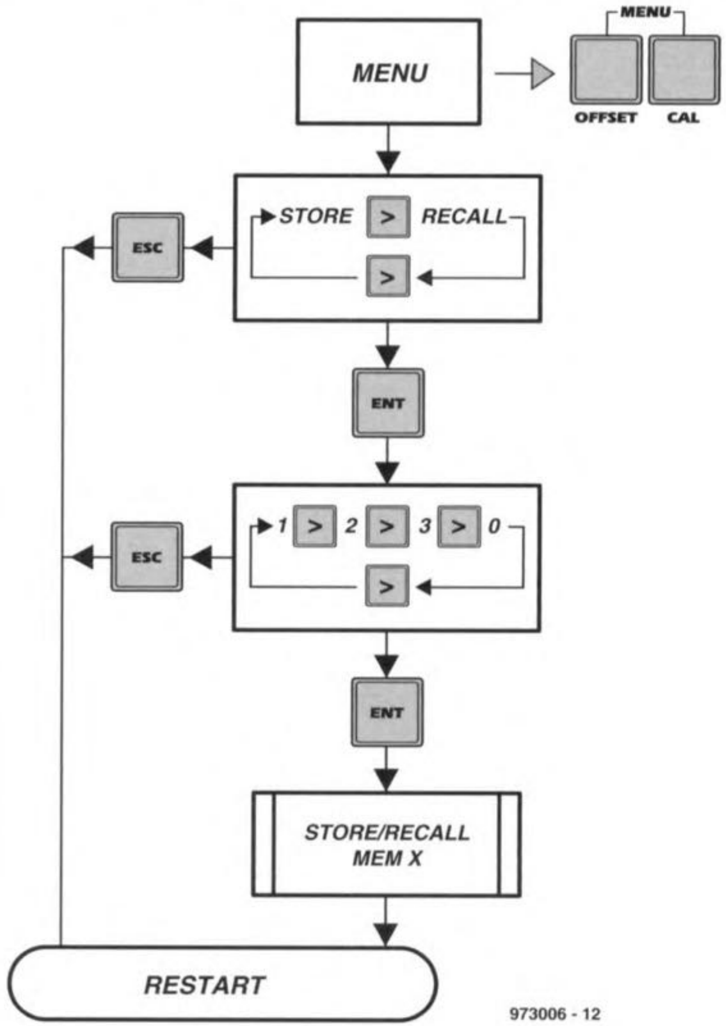
Advanced LCR Meter

Quick Reference Card

ELEKTOR ELECTRONICS

DATASHEET 06/97

Menu used for storing and recalling instrument settings



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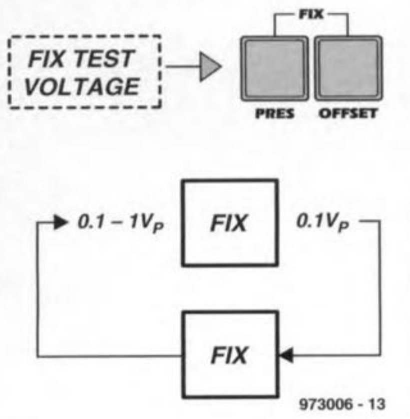
Advanced LCR Meter

Quick Reference Card

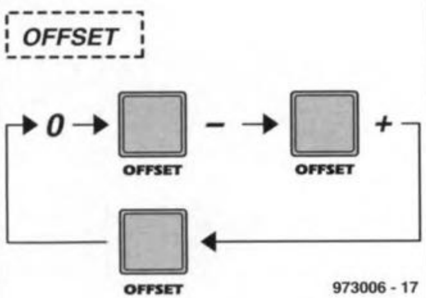
ELEKTOR ELECTRONICS

DATASHEET 06/97

Test voltage applied to device on test



Offset setting for device on test



Equations for Serial-to-Parallel and Parallel-to-Series conversion

$$R_p = R_s \cdot \left(1 + Q^2\right) \qquad R_p = R_s \cdot \left(1 + \frac{1}{D^2}\right)$$

$$L_p = L_s \cdot \left(1 + \frac{1}{Q^2}\right) \qquad L_p = L_s \cdot \left(1 + D^2\right)$$

$$C_s = C_p \cdot \left(1 + \frac{1}{Q^2}\right) \qquad C_s = C_p \cdot \left(1 + D^2\right)$$

$$Q = \frac{X_s}{R_s} = \frac{R_p}{X_p} \qquad D = \frac{R_s}{X_s} = \frac{X_p}{R_p}$$

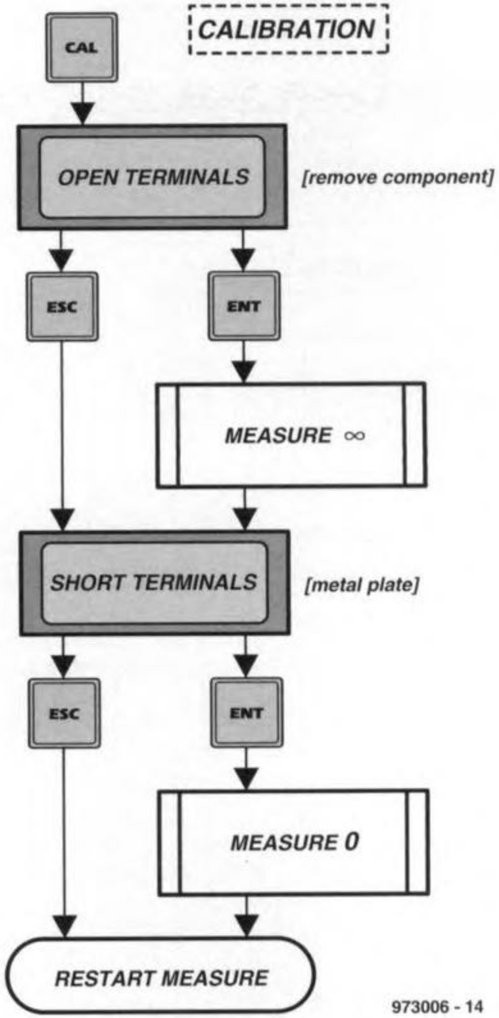
Advanced LCR Meter

Quick Reference Card

ELEKTOR ELECTRONICS

DATASHEET 06/97

Calibration procedure for infinite and zero-ohm settings



Remote control by telephone

Telephone-controlled switching on a budget

In this article we describe a system which enables you to control and check the status of electrical appliances by means of commands sent over the public switched telephone network (PSTN). That's right, no boxes crammed with hardware, and no problems with BT type approval: all you need are a PC and a Hayes-compatible modem at both sides of the link. Mind you, this equipment need not be state-of-the art: with some restrictions, even old 286-ATs and 2400-baud modems can be dusted off to do the job.

By David & Peter Hildenhagen

This project is based on three ingredients: (1) a program written in QuickBASIC (QBASIC) v.4.5, (2) the parallel port on your PC and (3) any type-approved Hayes-compatible modem, internal or external. With an abundance of old PCs around these days, modem prices dropping every day, and software supplied on disk by the Publishers, we think that sourcing these ingredients should not be a problem. In any case, the total effort in obtaining them will be worth your while as compared to building a dedicated DTMF-controlled receiver unit with lots of bells and whistles.

The program has been kept as simple as possible, and is open to experimentation and extension to personal requirements. Indeed, this article is aimed at those of you who like to experiment and have older computer

Table 1. Main Hayes AT Commands

AT Command	Description
A	*Answer call*
D	*Dial*
P	*Use pulse dialling*
T	*Use tone dialling*
,	*Pause*
W	*Wait for dial tone*
L0-3	*Loudspeaker volume, 0 (off), 1, 2 or 3 (max.)*
+++	*Switch to On-Line Command mode*
H	*Hang up*
X1	*Disable dial and busy tone detection (often useful for extensions)*
Sn?	*Request value in S-Register n*
Sn=x	*Load S-Register with value n*

Example: AT X1 DT 0,0123 45678
Possible application in a system using a telephone exchange, where a 0 has to be dialled, followed by a pause, to get an outside line.

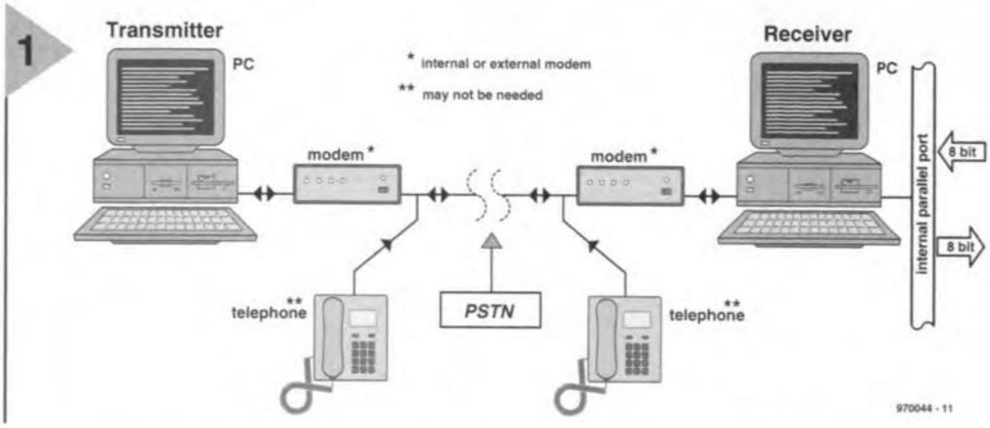


Figure 1. The hardware needed to implement remote control by telephone. The modems may be internal or external types, as long as they are Hayes compatible.

equipment available for this purpose. First, however, let's have a look at the arrangement of the components that form the system.

THE BIG IDEA

Simple, as you can see from the drawing in **Figure 1**. Most of the units shown will be familiar to those of you who own, or have access to, an IBM-compatible PC. The fact that ready-made, type-approved, modems are used (say, inexpensive 14K4 internal or external types), allows the system to exchange commands over the PSTN without problems. Commands for what? Well, what about switching on your coffee machine, or lowering the (electrically operated) sun blinds at home, or monitoring the alarm system in your holiday home, from any location where a PC and a modem are installed (dare we say it... your office, may be?).

The operation of the system is illustrated by the flow chart shown in **Figure 2**. Note that the receiving stations returns an acknowledge signal to confirm correct reception of a command. This is done to give you certainty that any command you just sent has been received properly. The system as described is experimental, and allows up to eight devices to be controlled, and another eight to be monitored.

ABOUT THOSE MODEMS

Most, if not all, modems used for PC communications by telephone are compatible with (a part of) the *Hayes Modem Command Set*. This set is often referred to as the *AT Command Set* because all commands start with the letter combination AT (for ATtention). An overview of all AT commands supported by your modems should be printed in the user manuals. An overview of the main AT commands used by the present software is shown in **Table 1** .

Modems generally work in one of three modes: Command Mode, Data Mode or On-Line Command Mode. The Command Mode is used to send AT commands to the modem, initialize it, and establish communication. Once the link to another modem has been established (i.e., after the baud-rate negotiation phase) the modem is switched to Data Mode which is used for the data exchange proper. In this mode it is not possible for the modem to execute AT commands. Once the data exchange is finished, the modem switches to On-Line Command Mode, which is used to go off-line again. In this mode, it is possible to process AT commands again.

Returning to the modem commands, a special function is reserved for the so-called S-Registers which serve to program and store basic settings of the modem. The main S-Register is S0 which enables/disables auto-answering. Note that some older modems require the S28 register to be loaded with the value 5 to enable a connection at 9,600 baud to be established.

THE PARALLEL PORT ISSUE

Digital output data (bits) which serves to control external electrical appliances at the receiver side is available on the 8 data lines, D0-D7, of the parallel printer port (pins 2 through 9). Digital input information is read by the same port via the Status Register (pin 10 through 13, 15) and the Control Register (pin 1, 14 and 16). All pin numbers refer to the 25-way sub-D socket of the PC's parallel port. The associated signal names and 36-way Centronics plug pin numbers may be found in **Table 2**. In this way, eight bits may be input and output in parallel fashion, all under the control of the QBASIC program. Note that the level of the BUSY bit is inverted in the status register, while the $\overline{\text{STROBE}}$ and $\overline{\text{AUTOFEED}}$ lines are active-low. All three lines may therefore have to be inverted if you want to modify the software and/or hardware as shown here.

The (usual) addresses of the parallel port are shown in **Table 3**, along with those of the data, status and control registers. You will need this information later if you want to adapt the QBASIC program for use with, say,

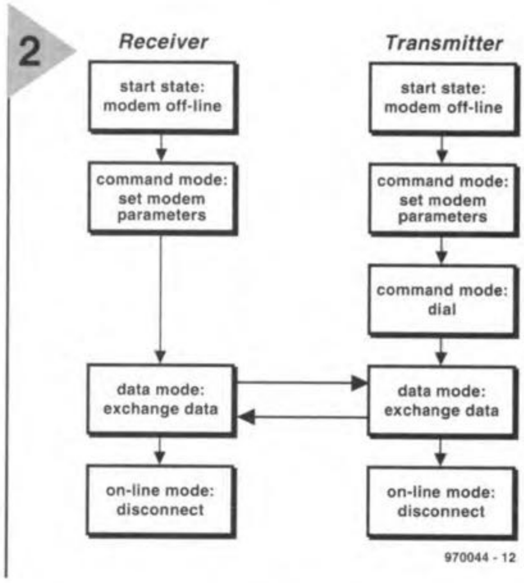


Figure 2. Flow charts of the programs running on the transmitting and receiving PC.

Table 2. Parallel port/cable pin functions

Signal	Pin no. on 25-pin Sub-D	Pin no. on 36-way Centronics
$\overline{\text{STROBE}}$	1	1
Data 0-7	2-9	2-9
$\overline{\text{Acknowledge}}$	10	10
BUSY	11	11
Paper Empty	12	12
Select	13	13
$\overline{\text{Auto Linefeed}}$	14	14
$\overline{\text{Error}}$	15	32
$\overline{\text{Reset}}$	16	31
$\overline{\text{Select Input}}$	17	36
Ground (0V)	18-25	19-30,33
Signal Ground		16
Chassis Ground		17
+5V		18
Not used		34,35

Table 3. Parallel Port Address Selection

Port	Data register	Status Register	Control Register
LPT1	3BCh	3BDh	3Beh
LPT2	378h	379h	37Ah
LPT3	278h	279h	27Ah
LPT4	2BCh	2BDh	2Beh

LPT2. When in doubt about LPT addresses and availability in your system, run the BIOS setup on your PC, or use MSD (Microsoft Diagnostics).

THE PROGRAMS

The program **TX.BAS** is used at the transmitter side, the program **RX.BAS**, at the receiver side. Both programs are found on a disk which you may order through our Readers services as number **976005-1.** To set up a communication, you have to start RX.BAS before TX.BAS, in other words, the receiving machine has to be on stand-by all the time.

Both programs start with routines that set the parameters of the serial interface (to which the modem is connected). QBASIC unfortunately limits the maximum baud rate to 9,600 bits/s. The good news is that most modems of the 14K4 and 28K8 class are capable of stepping down to 9K6 or even lower without the slightest problem. Next, an AT command sequence is sent to the modem to set various parameters and to initiate the dialling process. When the communication with the remote modem is established, the modem at the transmitter side is switched to on-line mode. You may then enter numbers between 1 and 8 to set the corresponding bits D0 through D7 in the printer data register of the PC at the receiver side. The received number is echoed back to the transmitter to assure you that the command has been received, and passed to the subroutine SUB OUTPUT.

The bits in the data register and the input signals applied to the parallel port (status and control registers) may now be interrogated by pressing the 'S' key. To be able to understand and process the numbers returned by the receiving PC, you need to convert them to binary values. An example:

output status: 173

means that the following bits are set:

$$173 = 2^7+2^5+2^3+2^2+2^0 = \text{binary } 1\,0\,1\,0\,1\,1\,0\,1$$

So, the output configuration on the data lines is:

Pin:	2	3	4	5	6	7	8	9
Level:	H	L	H	L	H	H	L	H

The levels applied to the input lines are decoded in a similar way (but note the staggered order):

Pin:	1	10	11	12	13	14	15	16
Value:	2^0	2^6	2^7	2^5	2^4	2^1	2^3	2^2

The routine called SUB OUTPUT in the receive program arranges the outputting of data on the parallel port. A trick is used for this purpose: the individual pins are addressed using an XOR combination, that is, only the bit to be set is changed – all others retaining their earlier levels.

The SUB STATUS routine in the receive program does an XOR with the first five bits of the status register and the first three bits of the control register. The program may be ended by pressing the Esc (escape) key. This breaks the connection with the remote station, and both modems will go off-line.

PORT INTERFACE ELECTRONICS

Each of the data lines of the parallel port on the receiving computer may be fitted with a one-transistor LED output driver as shown in **Figure 3**. The input electronics is likewise simple, consisting of just two resistors on each control or status line, see **Figure 4**. The push-button may, of course, be any normally-open contact, such as that of an actuator relay which forms part of a domestic alarm system. For the interface power supply we suggest a 7805 three-pin voltage regulator.

(970044)

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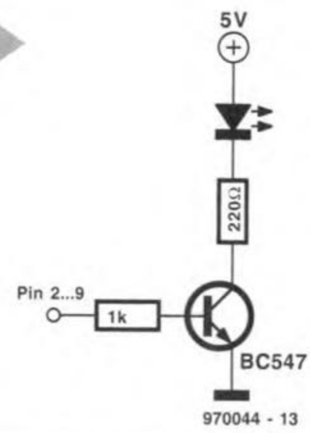


Figure 3. Output interface (one of eight).

4

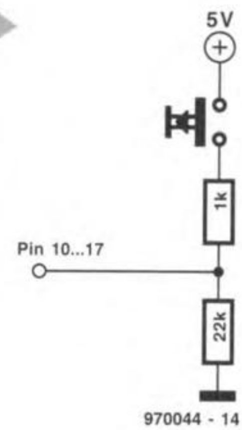


Figure 4. Input interface (one of eight).

Figure 5. Extract of the transmitter program, TX.BAS. Here, the part that handles the modem initialization is shown.

5

```
'****************************************************************
'*                  Remote Control by Telephone                 *
'*                       Transmit Program                       *
'*           Peter Hildenhagen          David Hildenhagen       *
'*      Copyright 1997 Segment BV, Beek, The Netherlands        *
'****************************************************************
DECLARE SUB DELAY (pause&)
DEFINT A-Z
'Note: QBasic does not support COM3 & COM4!!
OPEN "COM2:2400,N,8,1" FOR RANDOM AS #1 LEN = 256  'Ser. interface
                                                   'Modem setup
                                                   'Max. 9600 Baud
TelNr$ = "12345"                                   'phone number

PRINT "AT DT" + TelNr$                             'echo setting
PRINT #1, "AT DT" + TelNr$                         'initialise modem
                                                   'change if necessary!
DO                                                 'main loop
  KeyIn$ = UCASE$(INKEY$)                          'scan keyboard and change
                                                   'input to upper case
  IF KeyIn$ = CHR$(27) THEN
    EXIT DO                                        'Exit? (Esc pressed)
   ELSEIF ((KeyIn$ > "0") AND (KeyIn$ << "9")) OR (KeyIn$ = "S") THEN
     PRINT #1, CHR$(13) + "Command " + KeyIn$ + CHR$(13);
  END IF
```

temperature-voltage converter for DMMs

cheap and useful

Temperature measurement circuits have been described on several occasions in this magazine. Although pretty accurate, these circuits were generally extensive and relatively costly to build. By contrast, the thermometer adapter described in this article is inexpensive and simple to build. None the less, the converter is sufficiently accurate and reliable for most applications.

Design by F. Hueber

Electronic engineers and designers have a special interest in the operating temperature of components, sub-circuits and even complete electronic and electrical apparatus. Stand-alone temperature meters as well as add-on units for use with DMMs (digital multimeters) are commercially available for this purpose. Most of these units offer a large temperature range of 200ºC or more, and are fairly expensive. With occasional use in mind, however, the investment in a such a costly electronic thermometer is hard to recover. In most cases, a temperature range of –30ºC to +120ºC will be perfectly adequate. Moreover, that is easily realized using common-or-garden components.

Measuring bridge based on p-n junction

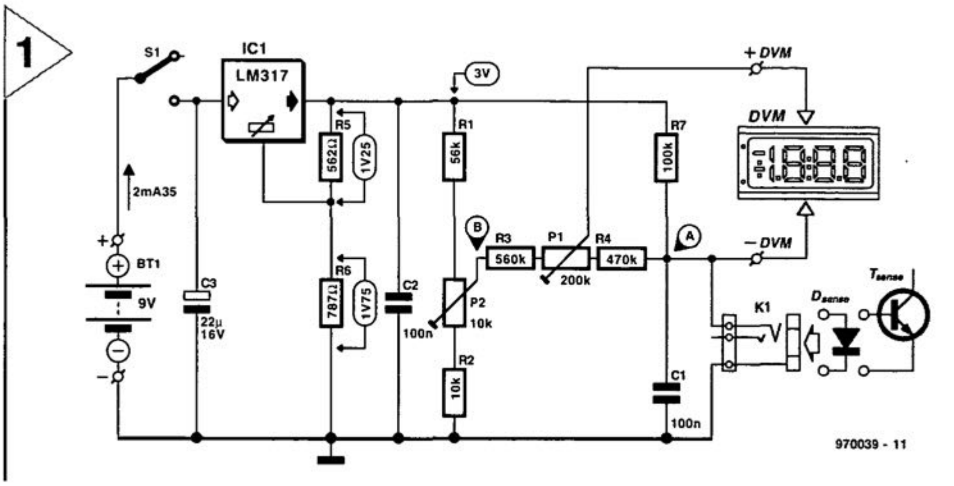
As you can easily see from the circuit diagram shown in **Figure 1**, the essential part of the T/V converter is a resistor bridge. Resistor R7 provides a constant current through the sensor, which is either formed by a transistor p-n junction or a silicon diode. An adjustable voltage divider, R1-P2-R2, is responsible for the constant reference voltage at junction B. The voltage between junctions A and B, also called the measuring gradient, is proportional to temperature change. Provided it is properly scaled to give a meaningful readout, the measured voltage is easily indicated by a high-impedance voltmeter. For this purpose, the circuit has a second preset potentiometer, P1, which is incorporated in the measuring bridge. The adjustment of P1 will be discussed further on in this article.

To prevent the sensor from heating up as a result of its internal current flow, the bridge section is operated at a low voltage and current level. Adjustable voltage regulator IC1, an LM317, provides a bridge supply voltage of only 3 V. To ensure that this value remains stable, close-tolerance (1%) resistors are used in positions R5 and R6. Because the current consumption is below 2.5 mA, and the battery is allowed to go as 'flat' as 5 V, the 9-V PP3 battery will last a number of years in this circuit.

A home-made sensor

The sensor may be a silicon diode (for example the ubiquitous 1N4148) or a silicon transistor. The ultimate part for this application is a miniature transistor type BC146 (from Philips or Temic/Telefunken) or the BC121, BC122 or BC123 from Siemens. Unfortunately, these devices are no longer manufactured, although with some luck they may still be found in the electronic surplus trade. The good news is that modern transistors like the BSX20 (having a metal case for good thermal contact), BC546B (plastic case) or the SMA-style BC848B (more difficult to use) may also be employed here. The thermal capacity of the transistor case determines the converter's reaction speed to temperature changes. A small metal case

Figure 1. The converter consists of a measuring bridge and a power supply.



ensures fast measurements, while large plastic cases exhibit a sluggish response to temperature variations. Whichever you use, the sensor is connected to the converter by means of a sufficiently long, screened, cable. The wire connections to the emitter and base terminals of the transistor are properly isolated, while the collector remains open. The actual construction of the temperature probe depends on your application and requirements. For example, the transistor may be fitted in a pen holder whose tip is drilled to size, allowing the transistor body to be secured with two-component glue. A 3.5-mm jack plug may be fitted at the free wire end.

Construction and calibration

Populating the printed circuit board shown in **Figure 2** should take only a few minutes. All resistors should be metal film types which guarantee long-term stability of the circuit. Cermet multiturn presets are used for the same reason.

To calibrate the circuit you need a small amount of distilled water which is put in a freezer to make ice cubes. Put the ice cubes into a glass, and add water until they just start to float. Stir frequently, and allow the cubes to thaw about half-way. The temperature of the water/ice mixture is then very close to 0 ºC.

Put the (electrically isolated) temperature sensor in the water/ice mixture. Set the DMM to the 200-mV range. Next, adjust P2 until the meter reads 00.0. If necessary, repeat this procedure several times, not forgetting to gently stir the water/ice mixture between measurements.

Preset P1 has virtually no effect on this calibration, and should be left at a mid-travel setting.

Next, heat the water to the boiling temperature, and immerse the probe again. Wait until the readout is stable, then adjust P1 for a meter reading of 100 (mV).

To enable the circuit to be accurately adjusted, the cermet presets have a relatively small range. If a particular range is not large enough, it is perfectly possible to change the value of one the fixed resistors in the bridge.

The boiling temperature of water depends on the relative air pressure. Fortunately, unless you are at the top of a really high mountain, or smack in the eye of a hurricane, the deviation caused by low or high air pressure is insignificant with respect to the normal measurement error of ±1.5 ºC.

(970039)

p-n junction as temperature sensor

The p-n junction of a silicon semiconductor is employed as a temperature sensor in the converter described here. Basically, it is irrelevant whether a diode is used, or a diode junction (base-emitter junction) of a bipolar transistor (whose collector is not connected).

A silicon p-n junction is marked by a negative temperature coefficient. The voltage dropped by the junction under forward biasing conditions decreases by about 2 mV with a temperature rise of 1 K. Although the exact value depends on doping level of the semiconductor material, and the manufacturing technology, it remains virtually constant over the entire temperature range we are interested in, provided, of course, the bias current remains constant.

The absolute voltage drop across the junction is between 380 mV and 430 mV with a low-power diode (at 25 °C and 25 µA), and between 520 and 550 mV with a low-power transistor. Cooling to 0 °C causes the voltage drop to rise by about 50 mV, or 110 mV at – 30 °C. Heating the semiconductor to 100 °C causes the 25 °C specification to decrease by about 150 mV. At 120 °C, the decrease is 190 mV. Incidentally, two-component glue and the pen holder plastic will start to soften at this temperature, hence this upper limit for the present circuit. The total variation of the sensor voltage is, therefore, some 300 mV.

COMPONENTS LIST

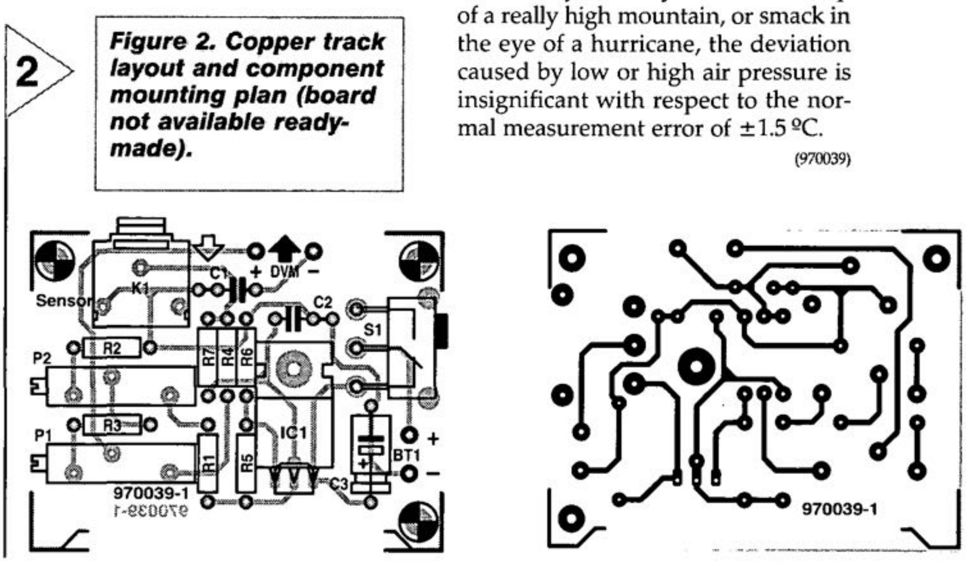
Resistors:
R1 = 56kΩ
R2 = 10kΩ
R3 = 560kΩ
R4 = 470kΩ
R5 = 562Ω 1%
R6 = 787Ω 1%
R7 = 100kΩ
P2 = 10kΩ multiturn preset
P1 = 200kΩ multiturn preset

Capacitors:
C1,C2 = 100nF
C3 = 22µF 16V

Semiconductors:
IC1 = LM317, LM317L (TO92) or LM317T (TO220)
Sensor = BC546B, BSX20 or 1N4148 (see text)

Miscellaneous:
Bt1 = 9V PP3 battery with clip
S1 = slide switch, toggle, PCB mount
K1 = stereo jack socket, 3.5mm, PCB mount
2 solder pins

Figure 2. Copper track layout and component mounting plan (board not available ready-made).



yes Cinderella, you *can* have a programmer that's both universal and low cost

The TUP-500 Universal programmer from Computer Solutions sets a new standard for low-cost universal programmers. The TUP-500's pins are individually conditioned and software controlled, so pin rerouting modules are not required for each different family of devices as is the case with other low cost programmers. The £475 TUP-500 comes as standard with a 40-pin DIP socket and supports nearly all devices with 8 to 40 pins, right out of the box.

The TUP-500 can program nearly all the devices you can think of including EPROM, EEPROM, FLASH, serial PROM, PLD, CPLD, FPGA, microcontrollers (8751, Dallas, Microchip, Motorola, NEC, Hitachi, Toshiba, WSI, ...), DSP, BPROM, etc.

Support doesn't stop at 40 pins – Comsol provides adapters and converters for nearly every type of IC package and every pin count from 8 pins to over 300 pins. Adapters for programming PC cards (PCMCIA) and for testing SIP as well as 30-pin and 72-pin SIMM modules are available also.

The TUP-500 has programmable Vcc and Vih levels to fully support the latest low voltage devices and it uses algorithms approved by leading IC manufacturers including AMD, Atmel, ICT, Macronix, national Semiconductor, Winbond, WSI, and others.

The TUP-500 connects to the PC via the parallel port so it can be used with a desktop or laptop PC and can be easily transported.

The TUP-500's software interface is among the easiest to use in the industry. Press 'B' to blank check, 'P' to program and verify, 'R' to read a master device, or 'A' to automatically blank check, program, and verify a device. An external 'YES' key on the TUP-500 can be used to initiate programming operations so that the PC keyboard does not have to be used once the programmer is set up. Simple batch files can be used to set up the programmer for production jobs. All popular file formats are supported for file loading (bin, Intel-hex, Motorola S-Record, JED, Altera POF, etc.). Both Dos and Windows 3.1/95 are supported.

Computers Solutions Ltd., 1a New Haw Road, Addlestone, Surrey KT15 2BZ. Tel./fax (01932) 829460. Email: comsol:@forthinc.demon.co.uk.

(977107)

C-programmable controller in a box

The PK2300 is Z-World's new versatile controller that contains a set of user configurable flexible I/O lines, providing up to 16 protected digital inputs and 8 high current outputs.

The PK2300's 19 I/O lines are initially set as 11 protected inputs and 8 high-current outputs. However, 5 of the outputs and 6 of the inputs are user configurable. The PK2300's I/O flexibility provides you with between 11 and 16 protected inputs and up to 8 outputs to assign as needed. Possible configurations include combinations of level sensitive interrupts and protected inputs. Configurations can also include an analogue-resistive input and an RS485 port. Screw terminals facilitate quick wiring. The rugged enclosure easily mounts to either a flat surface or any of the 3 DIN rail standards.

You program the PK2300 using Z-World's multitasking Dynamic C™, a version of the industry-standard C programming language optimized for real-time control. Dynamic C is a software-development system that is an integrated editor, compiler, and interactive debugger. The compiler, running on your host PC, compiles directly into the flash memory of the PK2300 for in-target software development. This approach virtually eliminates expensive test equipment such as ROM or in-circuit emulators.

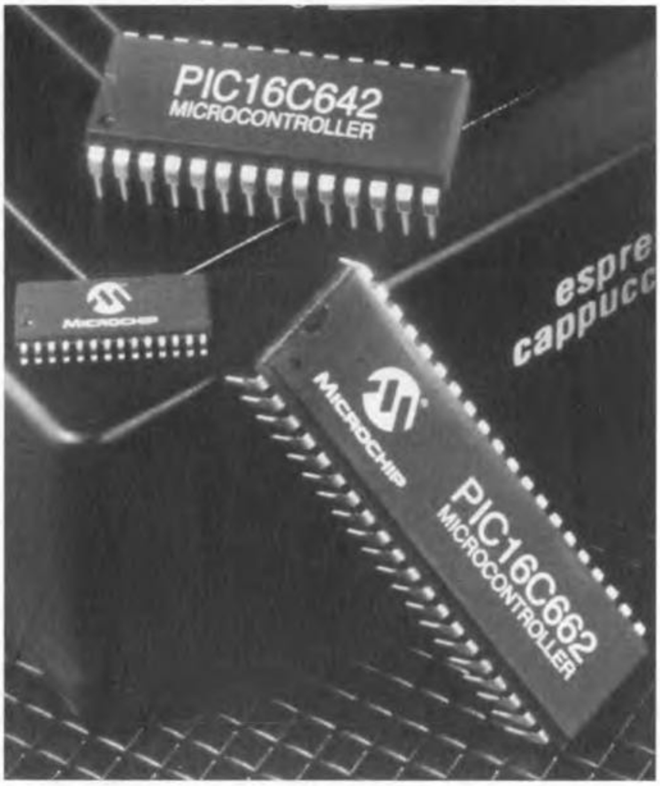
The PK2300 Developer's Kit includes items necessary for software and hardware development using the PK2300, and is a one-time purchase. The kit includes a reference manual, a wall power supply, schematics and cables and a demo board with 4 switches, 4 LEDs, jumpers, a buzzer and field-wiring terminals. For additional information, or for a free Dynamic C demo disk, contact

Z-World, 1724 Picasso Ave, Davis, CA 95616, USA. Tel. (916) 757-3737, fax (916) 753-5141.
Email: zworld@zworld.com.
Internet: www.zworld.com.

(977110)

low cost PIC OTPs go analogue

Microchip's new 8-bit microcontroller families provide low-cost advanced analogue features for automotive and appliance industry applications.



The PIC16C642 and PIC16C662, the first members of the PIC16C64X and PIC16C66X families, provide an industry leading 4.0-volt brown-out protection, two high precision voltage comparators and a voltage reference module. These features improve system integration, increase reliability, lower manufacturing costs and reduce board space and component count.

The new devices provide 4096 words (4K×14) of on-chip EPROM program memory and 176bytes of RAM for maximum design flexibility. They are also pin-for-pin compatible with Microchip's popular PIC16C63 and PIC16C84 microcontrollers.

The one-time programmable capabilities offered by the PIC16C642/662 allow engineers to react faster to code changes and reduce the time to fix bugs. OTP also reduces the design verification cycle, which can be as long as 16 weeks with competing ROM-based devices.

The PIC16C642 and PIC16C662 are supported by the PICMASTER-16P Universal Development System, the industry's most complete, fully integrated programming development and emulation system, and the low-cost PICSTART Plus development system. Other support and development tools include the MP-Driveway™ Automatic Application Code Generator, MPLAB™-C compiler, fuzzy logic tools and programming support.

Available in 28-pin and 40-pin packages, the PIC16C64X and PIC16C66X family members are claimed to cost significantly less than comparable mid-range 8-bit microcontrollers.

Arizona Microchip Technology Ltd., Unit 6 The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks SL8 5AJ. Tel. (01628) 851077, fax (01628) 850259.

(977108)

new 166 microcontroller designer's guide

As a long-time fan of the '166 microcontroller architecture, Mike Beach of Hitex has independently produced a comprehensive design ideas source book for new and prospective '166 family users. As the title of 'The Insider's Guide To Planning 166 Microcontroller Designs' implies, it covers all the tricky hardware design questions that crop up when such a powerful and flexible CPU is used for the first time. Most of the material has been produced in response to questions put by UK users over the last couple of years, and so is very relevant. While there are other similar publications, they are all in German, which makes them of limited use to UK and USA engineers.

The Guide is intended to fill the gaps left by Siemens and ST user manuals, providing new users with the accumulated wisdom that normally is only gained after completing a major project. It is ironic that at the beginning of a project when designers needs the most experience to make the best choice of pin allocation, bus mode, etc., they in fact have the least experience to go on! To help, there are sections on which I/O pins are best for what sort of application, with examples.

Information is also included on how CPU performance is related to bus mode and how power consumption is influenced by clock speed. The best way to calculate memory access times and how to most effectively use the chip-selects are covered in detail. Useful hints and tips on oscillator design pull-down resistor selection and CAN interfaces further expand important aspects of 166 hardware design.

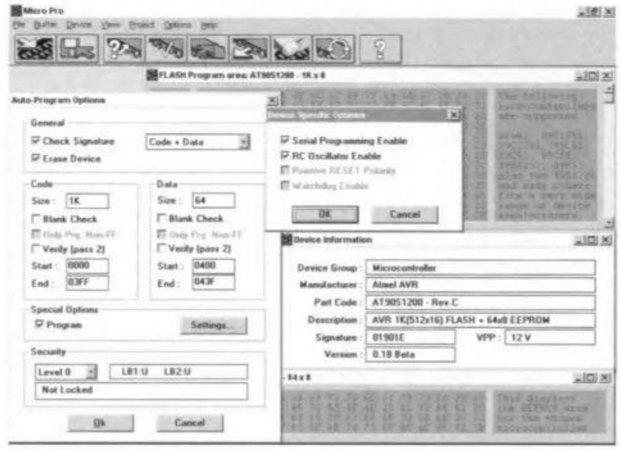
The Guide is available as a traditional printed booklet or electronically as a .PDF file for use with the Acrobat Reader. Printed versions of the Guide will be mailed to the first 100 fax or email enquirers, free of charge. Engineers are invited to send their requests to 100646.1526@compuserve.com or fax (01203) 692131.

Further information from Mike Beach, c/o Hitex (UK) Ltd., University of Warwick Science Park, Coventry CV4 7EZ.

(977124)

Windows software for Micro-Pro Programmer

Equinox Technologies are pleased to announce that their world-renowned Micro-Pro Parallel Programmer now comes complete with Windows software.



As well as being much easier to use, Micro-Pro for Windows also supports many more devices than the existing DOS software, which has been frozen at version 2.60.

The new software permits programming of all of the Atmel 89C and 89S families of microcontrollers, and is ahead of the competition in offering support for the promising new AT90S1200 ('AVR') device.

Existing customers may download this new software free of charge from the Equinox Technologies WWW site (http://www.equinox-tech.com).

With the addition of appropriate libraries (purchased separately), Micro-Pro for Windows transforms the Micro-Pro Programmer into an even more useful tool, capable of programming a wide range of FLASH memory, EEPROM, and Configurator devices.

So, don't clutter up your workbench with a different programmer for each type of device – just use the one pioneered and developed by Equinox Technologies, who claim to be 'The Embedded Solutions Company'.

Equinox Technologies, 229 Greenmount Lane, Bolton BL1 5JB. Tel. (01204) 492010, fax (01204) 494883. Email: sales@equinox-tech.com. Internet: www.equinox-tech.com.

(977105)

8-bit PIC OTP controller with 10-bit ADC

Microchip's PIC17C756 is the first device in their new PIC17C75X family of high-performance 8-bit one-time programmable (OTP) microcontrollers with a 10-bit analogue-to digital converter (ADC) in 64- and 68-pin packages. The PIC17C756's industry-leading performance of 8.25 MIPS CPU at 33 MHz and single-cycle (120 ns) 8×8 hardware multiply provides engineers with a higher performance solution than Motorola's MC68HC11 and Hitachi's H8 products.

The PIC17C756 includes two 8.25 Mbit/s USARTs, up to 16K×16 of OTP on-chip program memory and up to 902×8 bytes of user RAM. The high-precision 10-bit 12-channel ADC offers a high speed conversion rate and can convert while in sleep mode. Other peripheral features include up to 50 I/O pins with individual direction control, 4 pins configurable as capture input (120 ns resolution), 3 pins configurable as PWM output(1-10 bits resolution with 130 kHz at 8 bits and 32 kHz at 10 bits), local communications capability for peripheral expansion (I^2C/SPI compatible) and 4 timers (two 8-bit and two 16-bit). In addition, the large program and data memory and affordable OTP make the PIC17C756 ideal for demanding real-time embedded control applications such as set-top boxes, motion process control, instrumentation, UPS, printer, plotter copier, ABS, air bag controllers, security, network switches, modems and data encryption.

Arizona Microchip Technology Ltd., Unit 6 The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks SL8 5AJ. Tel. (01628) 851077, fax (01628) 850259.

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