80C535 Hardware & Assembler Course

ELEKTOR ELECTRONICS

THE INTERNATIONAL ELECTRONICS MAGAZINE

PIC PROGRAMMER

for PIC16C and PIC17C controllers

100 watt AF power amplifier

AF signal tracer

Direct conversion receivers

Building electronic circuits

ELEKTOR Electronics

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- Headphone amplifier
- Mains transmission equipment
- Stroboscope light
- Direct conversion receivers – Part 2
- Halogen light dimmer
- A lower frequency receiving system
- Figuring it out – Part 15: Sine waves and others
- and others for your continued interest

Front cover
The PIC (Programmable Integrated Controller) is a (fairly) new RISC-based (Reduced Instruction Set Coding) microcontroller manufactured by Microchip Technology Inc. The article on page 26 describes a programmer that enables a large number of PIC16Cx and PIC17Cx devices to be loaded with your own application programs. Software development for these controllers will be the subject of a short course starting in this magazine later this year.

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A B C
AUDIT BUREAU OF CIRCULATIONS
CONSUMER PRESS

AF signal tracer – p. 5

100 W AF power amplifier - p. 15
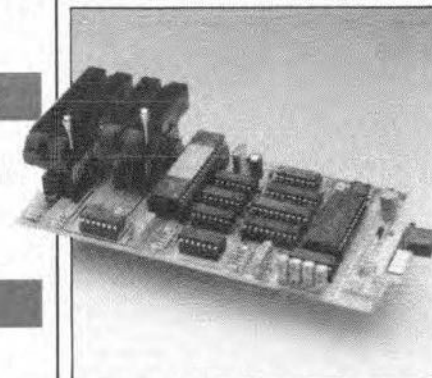
PIC programmer – p. 26

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AF SIGNAL TRACER

Design by K. Feigl

In the design, fault-finding and repairing of audio equipment several pieces of test instrument are either required or just downright useful. One of these is a signal tracer as described in this article. It consists of a signal generator and a processor with which the injected signal can be detected (and made audible) at a number of locations in the equipment on test.

The tracer is based on the assumption that all that is required is knowing whether the signal passes through the equipment or, if not, where it fails.

Rectangular or sinusoidal

The unit provides either a rectangular or a sinusoidal signal. The former is generated by IC_2 and the latter by T_1-T_2. Selection between the two is with S_{2b}, while S_{2a} selects an appropriate indicator LED. The output level of the generator is set with P_5. Transistor T_3 provides a low output impedance. The test lead of the generator is connected to K_2.

The tracer/detector section is formed by IC_3, whose input is via K_3 and whose level is adjusted by P_6. It is a straightforward, standard application of an LM386. The test signal is made audible via a small loudspeaker, LS_1.

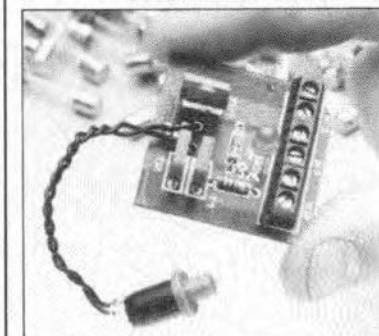Power is derived from a 9-V mains adaptor or battery. The supply line is stabilized by regulator IC_1.

The sine wave generator consists of transistors T_1 and T_2, which switch one another on and off in turn. Emitter resistors R_4 and R_8 ensure that this switching is not abrupt and that the transistors do not become saturated. The result is that the edges of the signal are not steep and that the tops of the signal are not chopped off: in other words, a waveform that is very close to a sine wave.

The operating point of the generator is set with P_1. The lower the output level, the better the waveshape. A good compromise is an output level of about 30 mV (measured with a multimeter in position a.c.). The distortion is then fairly modest.
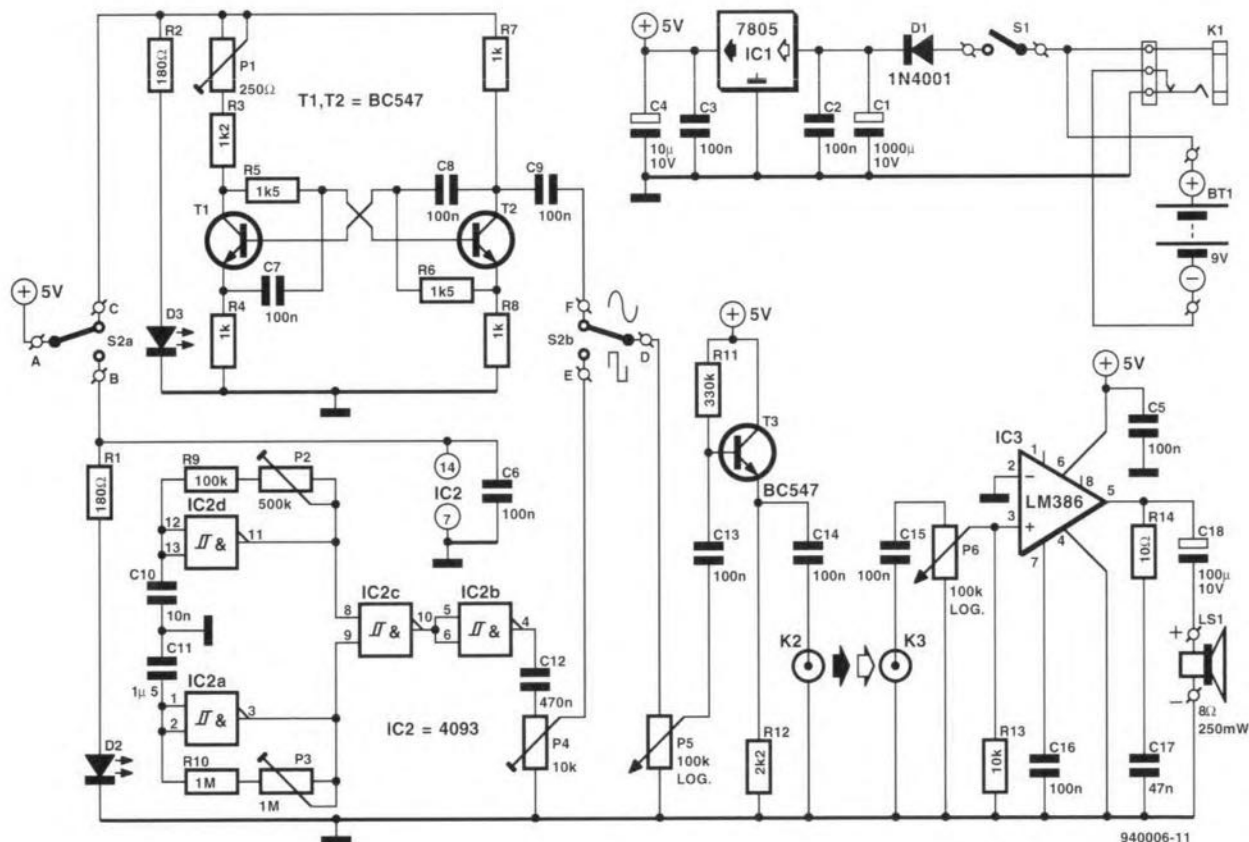
The frequency of the generator, deter-

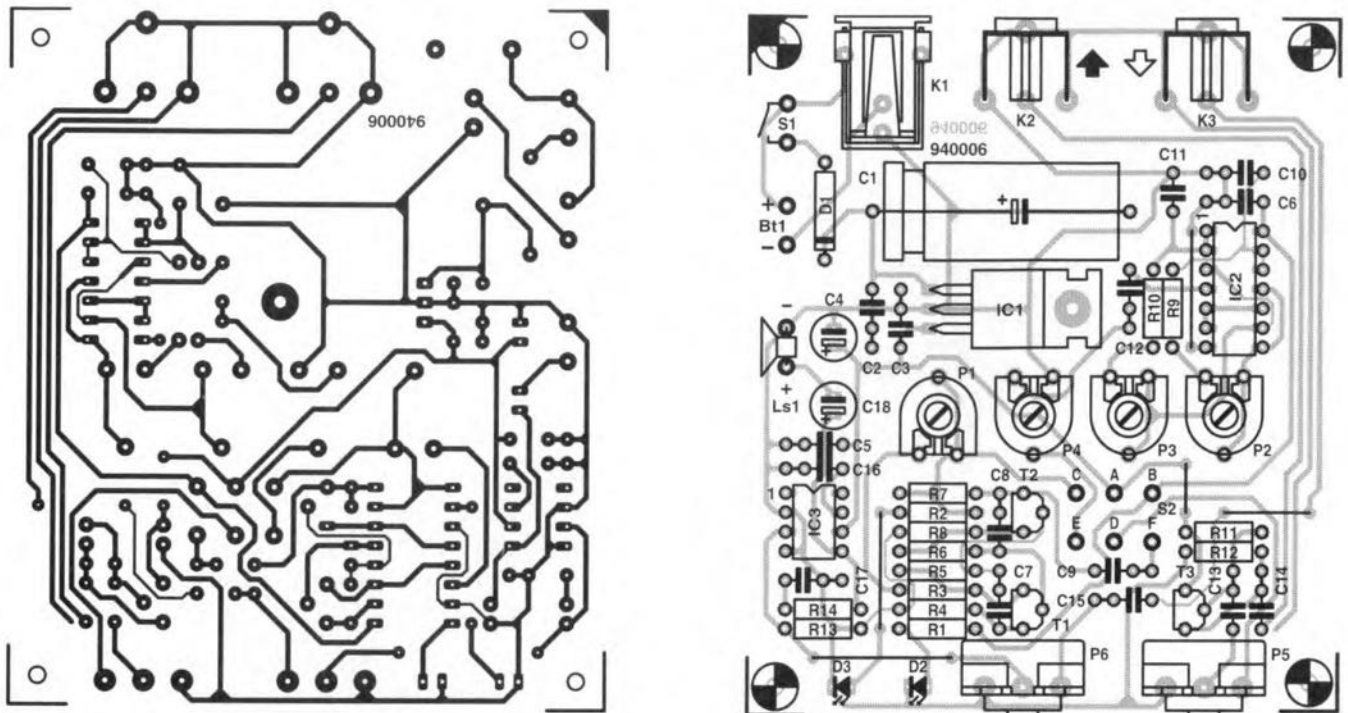Fig. 1. Circuit diagram of the a.f. signal tracer.

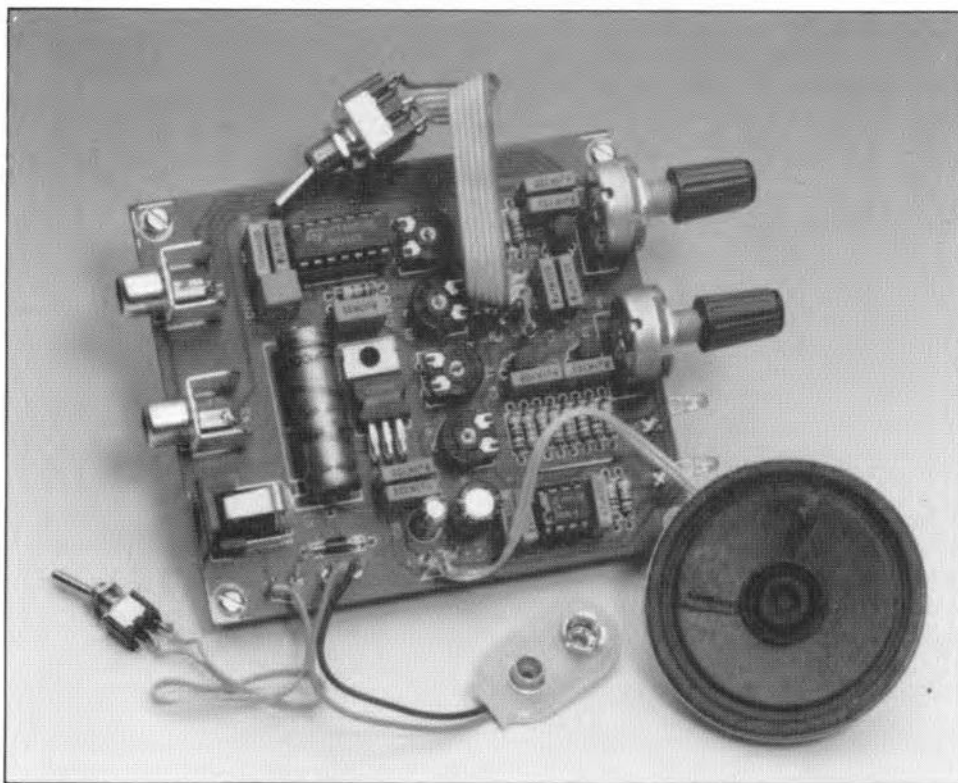Fig. 2. Printed circuit board for the a.f. signal tracer.

Fig. 3. Completed printed circuit board.

cuit board in **Fig. 2**. Populating of the board with reference to **Fig. 2** and the parts list is straightforward. **Figure 3** shows a correctly completed board.

This type of instrument is, of course, best housed in an easily held small enclosure. Suggested front and rear panel foils are shown in **Fig. 6**.

Two test leads are needed, and each of these may be made from two lengths (about 30 cm = 12 in) of flexible, insulated circuit wire, terminated at one end into test pins and at the other into a phono plug.

For most purposes, a battery supply is fine. The unit draws a current of 30–60 mA, provided that the volume control is not set permanently to maximum (when the current exceeds 100 mA).

Calibration

Preset P_1 is intended for setting the level/distortion of the sine wave generator. This is done as follows: connect a multimeter (a.c. mV range) to K_2, turn P_5 to maximum and set S_2 to position sine wave. Adjust P_1 till the meter reads 30 mV. If an oscilloscope is available, adjust P_1 for minimum distortion at a usable output voltage (25–35 mV).

Interconnect K_2 and K_3; switch S_2 between sine wave and rectangular wave and turn P_4 until the two signals sound equally loud. The tone and length of the burst may be set to individual taste with P_2 and P_3 respectively.

mined by the values of R_5, R_6, C_7 and C_8, is roughly 1 kHz.

The rectangular-signal generator comprises four Schmitt trigger/inverter stages and also produces a frequency of 1 kHz. The signal consists of short bursts about 1 s lopng with a mark:space ratio of about 50%. IC_{2d} is the generator proper, while IC_{2a} sets the length of the signal bursts. Fine adjustment of the frequency is provided by P_2 and P_3. The outputs of IC_{2a} and IC_{2d} are combined by IC_{2c} and in-

verted by IC_{2b}. Preset P_4 sets the level of the rectangular signal to about that of the sine wave, so that overdriving at switchover is obviated. When S_2 has been set as appropriate, the output level of the unit can be set as required with P_5. The signal is then available at K_2 via emitter follower T_3.

Construction

The tracer is best built on the printed cir-

Parts list

Resistors:
R_1, R_2 = 180 Ω
R_3 = 1.2 kΩ
R_4, R_7, R_8 = 1 kΩ

R_5, R_6 = 1.5 kΩ
R_9 = 100 kΩ
R_{10} = 1 MΩ
R_{11} = 330 kΩ
R_{12} = 2.2 kΩ
R_{13} = 10 kΩ
R_{14} = 10 Ω

Potentiometers:
P_1 = 250 Ω preset
P_2 = 500 kΩ preset
P_3 = 1 MΩ preset
P_4 = 10 kΩ preset
P_5, P_6 = 100 kΩ log (16 mm dia)

Capacitors:
C_1 = 1000 µF, 10 V (if mains adaptor is used, rating must be 25 V)
C_2, C_3, C_5–C_9, C_{13}–C_{16} = 100 nF
C_4 = 10 µF, 10 V, radial
C_{10} = 10 nF
C_{11} = 1.5 µF, MKT (polytheraphtalate)
C_{12} = 470 nF
C_{17} = 47 nF
C_{18} = 100 µF, 10 V, radial

Semiconductors:
D_1 = 1N4001
D_2 = LED, 3 mm, yellow
D_3 = LED, 3 mm, green
T_1, T_2, T_3 = BC547

Integrated circuits:
IC_1 = 4805 (7805 if mains adaptor is used)
IC_2 = 4093
IC_3 = LM386

Miscellaneous:
Mains adaptor socket for board mounting or (9-V) battery holder and clip
K_2, K_3 = phono socket for board mounting
S_1 = SPST switch
S_2 = double-pole change-over switch
LS_1 = loudspeaker, miniature, 8 Ω, 0.25 W
Enclosure, ESM 14/3 (available from Maplin Electronics)
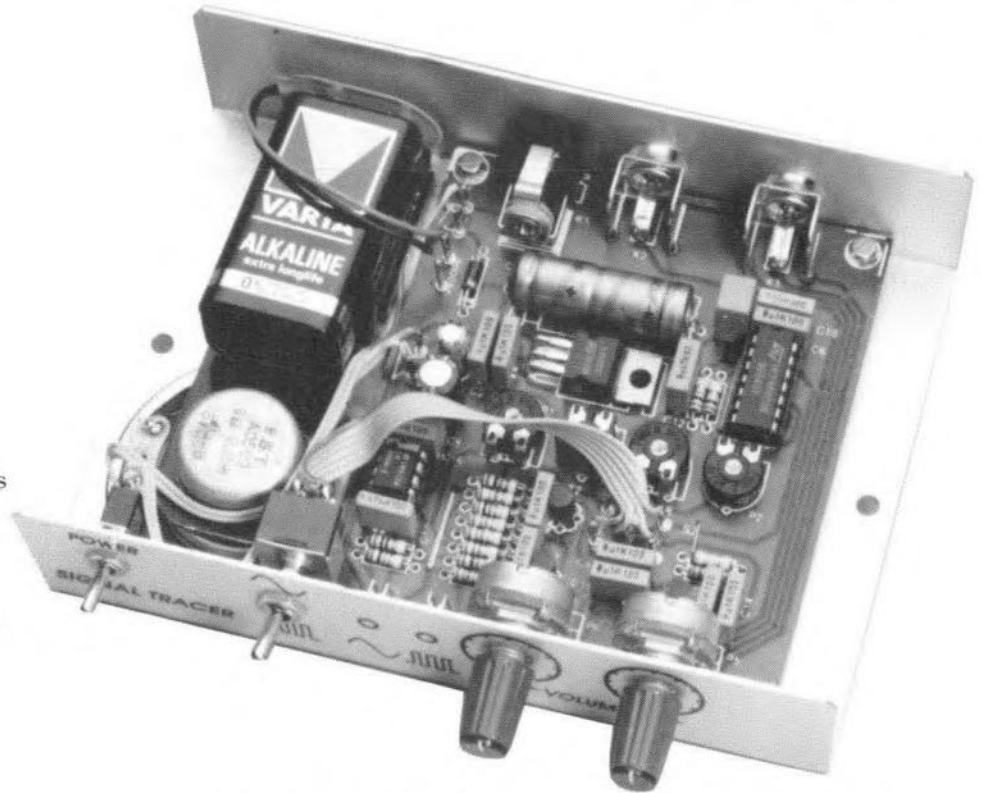
Fig. 4. General view of the a.f. signal tracer with top panel removed.

Faultfinding

Always start tracing a fault with an inspection of the outside of the equipment. Often, the fault lies in the mains cable or in the mains fuse.

On the inside of the unit, look for visible damage: burnt wiring, blackened resistors and leaking electrolytic capacitors quickly point to a likely source of the failure. If nothing untoward is visible, check for short or open circuits, starting with the power supply. With the aid of a multimeter, look for defect fuses, or a possible short circuit of the collector-emitter junction of power transistors.

If these checks do not point to a likely fault, a signal trace should be carried out. Switch on the equipment (it is assumed that the power supply is OK) and inject a signal from the tracer into one of the equipment inputs. Next, using the tracer, try to follow the signal from input to output. Where the signal fails to be detected is the source of the defect. If, for example, the signal is present at the input of an operational amplifier or transistor and not at its output, the device is almost certainly the culprit. It may still take some time (and cause a few headaches) before the ultimate reason for the defect is found.
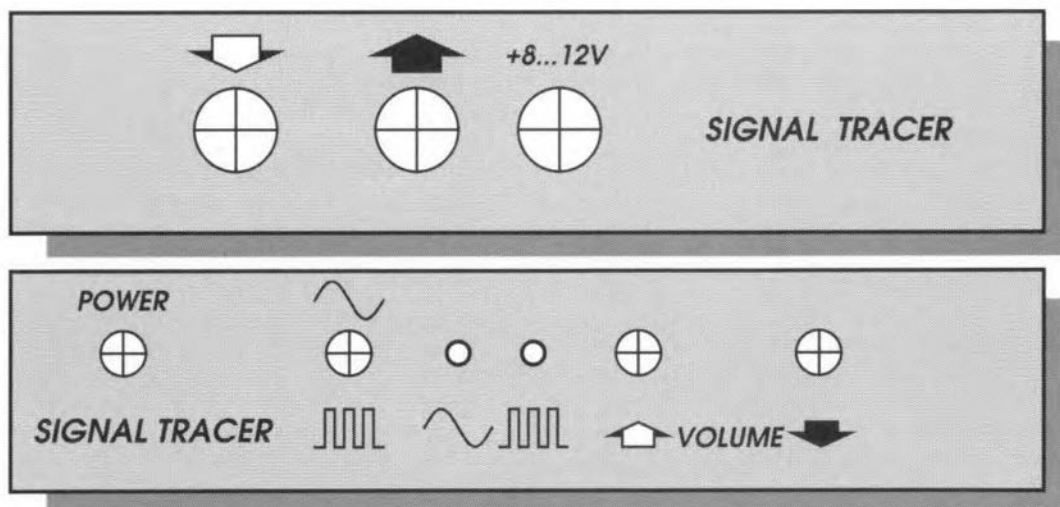
940006-F

Fig. 6. Suggested front and rear panel layouts for the a.f. signal tracer.

940006

S1
Bt1
+
−
D1
C1
K1
940006
K2
K3
C11
C10
C6
IC1
C4
C2 C3
IC2
R10 R9
C12
−
+
Ls1
C18
C5
C16
P1
P4
C
E
A
D
B
F
S2
P3
P2
IC3
1
C17
R7
R2
R8
R6
R5
R3
R4
R1
C8
T2
C7
C9
C15
R11
R12
T3
C13
C14
R14
R13
D3
D2
T1
P6
P5
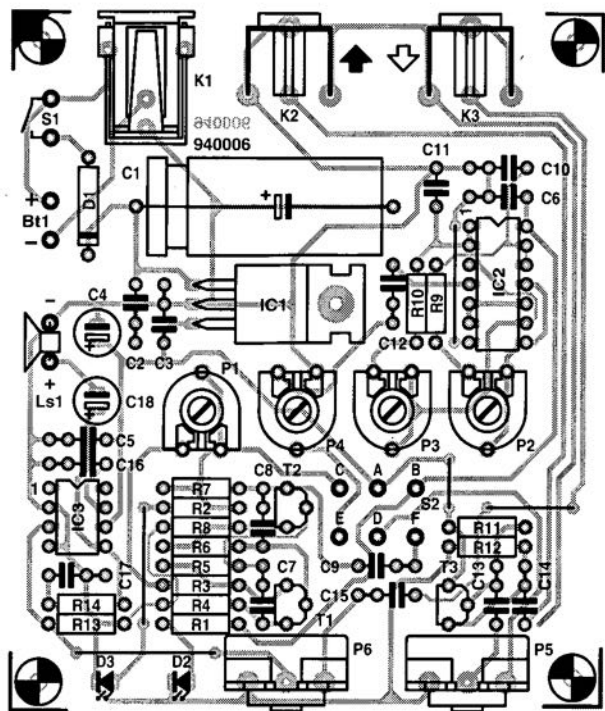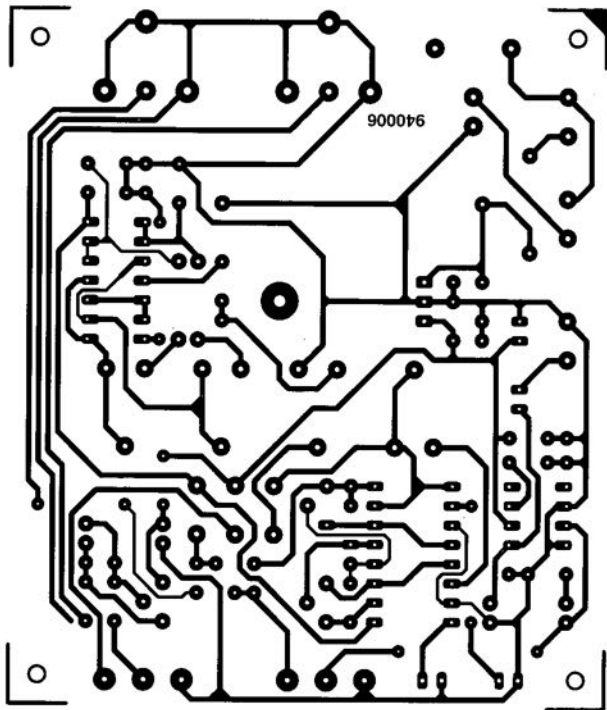
80C535 HARDWARE/ASSEMBLER COURSE

PART 1: INTRODUCTION AND FIRST PROGRAMMING EXAMPLES

Welcome to the first instalment of a four-part course on programming the 80C535 microcontroller. The present 'short' course is a sequel to the eight-part 8051/8032 assembler course featured about two years ago in this magazine. Hardware and software peculiar to the 80C535 processor will be discussed in an educational/didactic way, based on examples: an assembler and a communication program are available as 'courseware' on a diskette. The hardware you need to follow this course is the 80C535 single-board computer featured in last month's magazine.

Software by Dr. M. Ohsmann

THE present course has an 'easy' entry level for those of you who have followed the 8051/8032 assembler course (Ref. 1), because both the monitor EPROM (EMON51) and the assembler (EASM51) can be used straight away on the 80C535 single-board computer described last month (Ref. 2). None the less, a new, extended monitor program and assembler were developed to take full advantage of the extra features offered by the 80C535 compared with the 8051. These extra features are summarized in **Table 1**. The new monitor and assembler are

called EMON52 and EASM52 respectively, and may be found on the courseware disk, order code 1811 (see Readers Services page). Note in particular that the new software supports the Intel Hex file download option, which is a big asset if you have an EPROM programmer which is compatible with that file format.

The way ahead: 80C535

The 80C535 is an Intel MCS-51 compatible derivative of the 'generic' 8051. The SAB80C535 is manufactured by

Siemens, and has a number of extra features over the 8051. To start with, the C535 has two additional bidirectional ports, P4 and P5. It also offers an analogue input port sporting eight inputs and a common 8-bit analogue-to-digital converter (ADC). Remarkably, this port may also be used as a digital input port.

Furthermore, there is a powerful timer and compare/capture unit. The available interrupt options have been considerably extended, and a new baudrate generator has been added. The polarity of the RESET signal has been changed from positive on the 8051 to negative on the 80C535 (pin 10).

The new features are introduced in the following sections, using example programs where appropriate.

Some of you may wonder why we keep referring to the 80C535 processor, when it is a derivative from the 'original' 80515 or 80535. Unfortunately, the NMOS 80535 and the CMOS SAB80C535 are **not pin-compatible**. Pin 4 ($\overline{PE}$) and pin 37 (Vcc) have different functions on the 80535. For all other functions, the C535 and the 535 are, however, virtually identical, with the exception of the POWER-DOWN and IDLE modes. In this course we restrict ourselves to the 80C535.

SFRs, power-save and PCON

As with other 'upgrade' versions of the 8051, the new hardware options of the 80C535 are realized by special functions registers (SFRs). The SFRs contained in the 80C535 are listed in **Table 2**. Note that some of the SFRs familiar from the 8052 have been renamed, although the 'old' name is also given.

The CMOS 80C535 processor offers two ways of reducing power consumption, which are of particular interest if the controller is used in battery-operated equipment. To actuate the power-save modes, certain bits must be set in the PCON special function register. The meaning of these bits is illustrated in **Fig. 1**.

The IDLE mode allows the CPU proper to be actually halted, while the peripherals, like timers, counters and interrupt circuits remain active. The

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- ▶ Improved assembler (EASM52), offering
    - Intel-Hex file download option;
    - DW command to generate 16-bit address constants;
    - DI command to generate 16-bit integer constants;
    - EQU command capable of processing bit operations.
- ▶ A new system monitor (EMON52) offering
    - 80C535 and 80C537 interrupt chaining;
    - Intel-Hex file downloading.
- ▶ A new PC communication program (V25COM) source code, offering
    - an Intel-Hex file download option.
- ▶ EPROMEMU, a program to support the *Elektor Electronics* EPROM Emulator II.
- ▶ A new MENU program for fast object code development and downloading.
- ▶ Assembly code (.A51) files of all example programs discussed during the course.
- ▶ Complete source code files (Turbo Pascal or MCS-51 assembler) of all utility programs.

Table 1. Overview of new features on the 80C535 course disk.

SFR PCON (87H)

SMOD	PDS	IDLS	–	GF1	GF0	PDE	IDLE	87H
7	6	5	4	3	2	1	0	

Symbol	Position	Function
SMOD	PCON.7	When set, the baud rate of the serial channel in mode 1, 2, 3 is doubled.
PDS	PCON.6	Power-down start bit. The instruction that sets the PDS flag bit is the last instruction before entering the power-down mode.
IDLS	PCON.5	Idle start bit. The instruction that sets the IDLS flag bit is the last instruction before entering the idle mode.
–	PCON.4	Reserved
GF1	PCON.3	General purpose flag
GF0	PCON.2	General purpose flag
PDE	PCON.1	Power-down enable bit. When set, starting of the power-down mode is enabled.
IDLE	PCON.0	Idle mode enable bit. When set, starting of the idle mode is enabled.

920152-11

Fig. 1. Functions of the bits contained in the PCON register.

watchdog timer is, however, stopped. The CPU is taken out of the IDLE mode with the aid of an interrupt, which is 'serviced' by an appropriate software routine. After the RETI (return from interrupt) instruction at the end of that routine, the CPU continues with the instruction that follows the one that caused it to go into IDLE mode. The IDLE mode is controlled by bits 0 (IDLE) and 5 (IDLS) in the PCON register. First, the IDLE preparation bit, IDLE, must be set, then the IDLE-SET bit, IDLS. A sequence of two instructions is used rather than just one instruction to prevent the IDLE mode being selected by accident. Since the PCON register is not bit-addressable,

the IDLE and IDLS bits are normally set with the aid of an ORL instruction.

The POWER-DOWN mode is selected by first setting the PDE bit, and then the PDS bit. In POWER-DOWN mode, the processor is totally 'inert', and can be actuated again by a reset only. The data contained in the SFR and the on-board RAM remain intact. Both the IDLE and the POWER-DOWN mode can only be actuated if the $\overline{PE}$ input of the 80C535 (pin 4) is held low. If not, these modes are disabled. The hardware disable option of the power-down modes is provided to eliminate any risk of them being selected by accident as a result of a crashing program. This is, obviously, essential in no-break systems,

where all hardware would stop functioning if the POWER-DOWN mode were selected, and there is no way of restarting the CPU except by switching the supply off and on again.

Testing the power-down modes

To be able to use the example programs discussed during this course, follow this procedure:

Hardware

Connect the 80C535 single-board computer to a 5-V power supply and the COM1: serial port on your PC as shown in **Fig. 2**. All jumpers must be fitted on the board. The EPROM socket on the SBC board should contain the EMON52 EPROM (order code 6221). Switch on the PC and the SBC.

Software

Copy all files contained on the course diskette, order code 1811, to the hard disk, into a suitably named subdirectory, for instance, C:\80C535 or C:\COURSE. Next, load the ASCII file MENU.PAR into your word processor, and change the first line so that it contains the name of your favourite word processor ('editor'), complete with the associated path. The author used the editor contained in Turbo Pascal. Save the changed file under its old name, i.e., MENU.PAR.

Next, go to the course subdirectory, and start MENU by typing
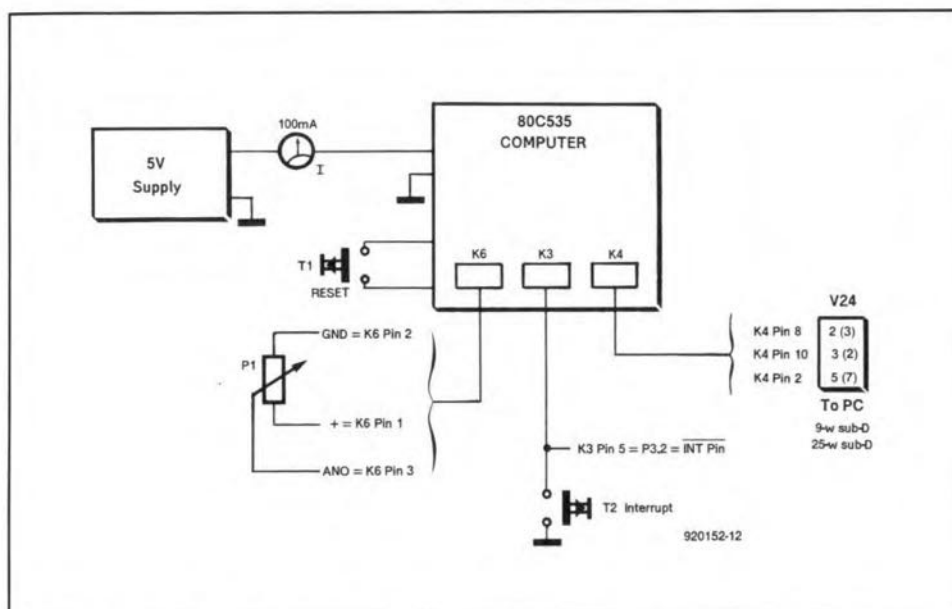
Fig. 2. Schematic showing the interconnections between the hardware needed to follow the course.

MENU 535XMP01 (return)

The menu should appear in the right-hand top corner of the screen. First, select 'Assemble', with the aid of the vertical arrow keys, and press return. The first example program is assembled, and the files 535XMP01.OBJ and 535XMP01.LST are written. Return to the main manu, and select the V24 (download) option. Press the RESET key connected to the SBC, whereupon the 80C535 should report with

-- EMON52 -- version 0.1 (2.7.1992)
RAMTOP=44

Next, start the actual download operation by typing CONTROL-D. Start the program by entering command X 4100. Watch the ammeter on your power supply. After a couple of reports reading 'ACTIVE', the 80C535 is switched to low-power mode, indicated by the text 'IDLE', and the current consumption dropping to about 20 mA. Generate an external interrupt-0 by pressing switch T_2. This should cause the processor to wake up, and the current consumption to rise to about 40 mA. Shortly afterwards, the CPU returns to IDLE mode.

The IDLE mode is initiated by the instructions contained in lines 25 and 26 of the assembly code file 535XMP01.A51. Two lines marked by the label PDOWN could cause the POWER DOWN mode to be actuated. Check what happens if jumper JP2 is omitted, and the above experiment is repeated. Or: the interrupt is enabled in line 24, and disabled again in line 27. What happens if you leave out line 27? Press the interrupt key several times while the program runs. Imagine, the main program has just called monitor subroutine STXT, is interrupted, while the interrupt routine itself calls STXT.

Baudrate generator and system clock

All programmers who used the 8051 (or 8032) with a 12-MHz quartz crystal were unable to have the serial interface running at exactly 4,800 baud, because the bit clock was derived from the system clock (12 MHz/12 = 1 MHz). This problem is solved by a special baudrate generator contained in the 80C535. Consequently, one timer is freed for other purposes. The baudrate generator is switched on with bit 7 in the ADCON special function register. A simple bit set command may be used for this purpose since ADCON is bit-addressable. As with the baud rate generator based on Timer 1, bit 7 in the PCON register is used to

P0	80H	*	Port 0
SP	81H		Stack pointer
DPL	82H		Data pointer low
DPH	83H		Data pointer high
PCON	87H	+	Power control register
TCON	88H	*	Timer control register
TMOD	89H		Timer mode register
TL0	8AH		Timer 0 low byte
TL1	8BH		Timer 1 low byte
TH0	8CH		Timer 0 high byte
TH1	8DH		Timer 1 high byte
P1	90H	*	Port 1
SCON	98H		Serial control register
SBUF	99H	*	Serial buffer
P2	A0H	*	Port 2
IEN0	A8H	* +	Interrupt enable register 0 (IE)
IP0	A9H	+	Interrupt priority register 0
P3	B0H	*	Port 3
IEN1	B8H	* +	Interrupt enable register 1 (IP)
IP1	B9H	+	Interrupt priority register 1
IRCON	C0H	* +	Interrupt request control register
CCEN	C1H	+	Compare/capture enable register
CCL1	C2H	+	Compare/capture register 1 low byte
CCH1	C3H	+	Compare/capture register 1 high byte
CCL2	C4H	+	Compare/capture register 2 low byte
CCH2	C5H	+	Compare/capture register 2 high byte
CCL3	C6H	+	Compare/capture register 3 low byte
CCH3	C7H	+	Compare/capture register 3 high byte
T2CON	C8H	* +	Timer 2 control register
CRCL	CAH	+	Compare/reload/capture register low byte (RCAP2L)
CRCH	CBH	+	Compare/reload/capture register high byte (RCAP2H)
TL2	CCH	+	Timer 2 low byte
TH2	CDH	+	Timer 2 high byte
PSW	D0H	*	Program status word
ADCON	D8H	* +	A-D converter control register
ADDAT	D9H	+	A-D converter data register
DAPR	DAH	+	D-A converter program register
P6	DBH	+	Port 6
ACC	E0H	*	Accumulator
P4	E8H	* +	Port 4
B	F0H	*	B register
P5	F8H		Port 5

Table 2. List of 80C535 special function registers. The SFRs marked with an asterisk (*) are bit-addressable. Where appropriate, the corresponding 8051 SFR denotation is given in brackets. SFRs marked with a plus sign (+) are new, or have been assigned new functions.

```
;
ADCON    EQU   0D8H
PCON     EQU   087H
;
B4800    ANL   PCON,#01111111B   ;clear bit 7 in PCON
         SETB  ADCON.7           ;baudrate generator on at 4800 bd
         RET
;
B9600    ORL   PCON,#10000000B   ;set bit 7 in PCON
         SETB  ADCON.7           ;baudrate generator on at 9600 bd
         RET
```

Fig. 3. EASM52 listing of baudrate generator test program.

```
****** EASM52 ASSEMBLER LISTING (535XMP01) ******
LINE LOC  OBJ         T       SOURCE
   1 0000                     ; 535XMP01.A51 ; Testing 80C535 POWERDOWN Modes
   2 0000                     ;
   3 0000             IE       EQU   0A8H
   4 0000             ACC      EQU   0E0H
   5 0000             PCON     EQU   087H
   6 0000             P3       EQU   0B0H
   7 0000                     ;
   8 0000                     ;------------------------------------------------------------
   9 0000                     ;
  10 0000                     ORG   4100H
  11 4100 90 41 38 [2] START   MOV   DPTR,#INT0       ; Chain interrupt routine
  12 4103 74 01    [1]         MOV   A,#1
  13 4105 75 30 40 [2]         MOV   COMMAND,#ccLINK
  14 4108 12 02 00 [2]         LCALL MON
  15 410B 79 06    [1] LP2     MOV   R1,#6            ; Send text 6 times
  16 410D 90 41 49 [2] LP1     MOV   DPTR,#TXT1       ; Text ACTIVE
  17 4110 12 41 64 [2]         LCALL STXT             ; Send
  18 4113 90 01 F4 [2]         MOV   DPTR,#500        ; 0.5 sec
  19 4116 75 30 21 [2]         MOV   COMMAND,#ccLTIME ; Wait
  20 4119 12 02 00 [2]         LCALL MON
  21 411C D9 EF    [2]         DJNZ  R1,LP1           ; Continue loop
  22 411E 90 41 3F [2]         MOV   DPTR,#TXT0       ; Send text IDLE
  23 4121 12 41 64 [2]         LCALL STXT
  24 4124 75 A8 81 [2]         MOV   IE,#10000001B    ; Switch on interrupts EA,IE0
  25 4127 43 87 01 [2]         ORL   PCON,#00000001B  ; Prepare for IDLE mode
  26 412A 43 87 20 [2]         ORL   PCON,#00100000B  ; and actuate
  27 412D 75 A8 00 [2]         MOV   IE,#0            ; Switch off interrupts
  28 4130 80 D9    [2]         SJMP  LP2
  29 4132                     ;
  30 4132 43 87 02 [2] PDOWN   ORL   PCON,#00000010B  ; Start power down mode
  31 4135 43 87 40 [2]         ORL   PCON,#01000000B
  32 4138                     ;
  33 4138 90 41 53 [2] INT0    MOV   DPTR,#TXT2       ; Interrupt routine
  34 413B 12 41 64 [2]         LCALL STXT             ; Send text
  35 413E 32       [2]         RETI                   ; Finish interrupt
  36 413F                     ;
  37 413F 0D 0A 49           TXT0 DB 13,10,'IDLE...',0 ;
       44 4C 45
       2E 2E 2E
       00
  38 4149 20 41 43           TXT1 DB ' ACTIVE ',0 ;
       54 49 56
       45 20 20
       00
  39 4153 0D 0A 49           TXT2 DB 13,10,'INTERRUPT E0',13,10,0 ;
       4E 54 45
       52 52 55
       50 54 20
       45 30 0D
       0A 00
  40 4164                     ;
  41 4164                     ;                       MONITOR INTERFACE
  42 4164             COMMAND EQU  030H  ; MONITOR: command location
  43 4164             MON     EQU  0200H ; MONITOR: jump address
  44 4164             ccSTXT  EQU  002H  ; Send text
  45 4164             ccLINK  EQU  040H  ; Interrupt chaining
  46 4164             ccLTIME EQU  021H  ; DPTR delay in milliseconds
  47 4164                     ;
  48 4164 75 30 02 [2] STXT MOV  COMMAND,#ccSTXT
  49 4167 02 02 00 [2]       LJMP MON
  50 416A                     END
******** SYMBOL TABLE (18 symbols) **********
      IE :00A8        ACC :00E0      PCON :0087      P3 :00B0
   START :4100        LP2 :410B       LP1 :410D   PDOWN :4132
    INT0 :4138       TXT0 :413F      TXT1 :4149    TXT2 :4153
 COMMAND :0030        MON :0200    ccSTXT :0002  ccLINK :0040
 ccLTIME :0021       STXT :4164
```
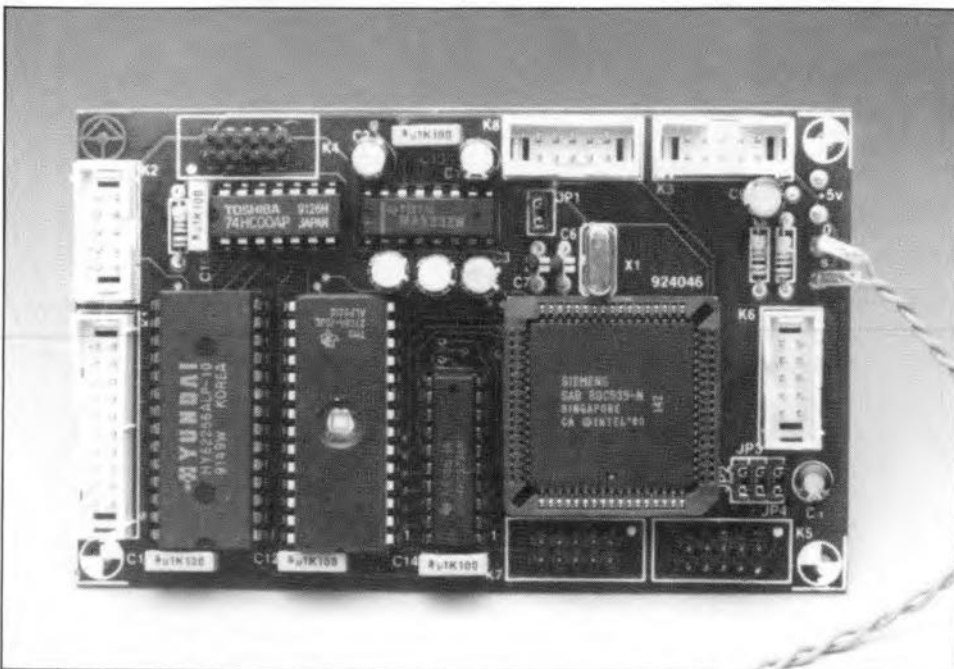
Fig. 4. Assembler code listing of 535XMP01 found on your course disk. This program is used to demonstrate the operation of the two power-down modes of the 80C535 microcontroller.

Fig. 5. 80C535 single board computer described in Ref. 2. The board should be fitted with the EMON52 system EPROM, no. 6221.

select between 4,800 (bit=0) and 9,600 baud (bit=1). The listing in Fig. 3 shows how to program the baud rate on the serial interface.

Note that this program takes into account that PCON is not bit-addressable: to prevent the 'other' bits in the register from being affected, masking instructions ANL and ORL are used.

The course diskette contains a program called 535XMP02.A51 which, when assembled, downloaded and run on the 535 SBC, transmits texts alternately at 4,800 and 9,600 baud. If you start the download program V24 (or the new version, V25) with the corresponding speed parameter (see .DOC file), one of the texts will be legible. The baud rate may be defined either by changing the appropriate parameter in MENU.PAR, or by calling V24COM (or V25COM), followed by the appropriate parameter, directly from the DOS prompt.

In some cases, peripheral ICs require the system clock (quartz clock divided by 12). To have the 80C535 supply the system clock at pin 30 (P1.6), set bit 6 in the ADCON register, and write a 1 to P1.6. The latter is necessary to enable the output function of the port line, which is controlled via an internal logic-AND combination. Thus, write

```
SETB    ADCON.6
SETB    P1.6
```

and take the system clock from the P1.6 line.

To be continued.

References:

1. 8051/8032 Assembler course. *Elektor Electronics* February through November 1992.
2. 80C535 Single-board computer. *Elektor Electronics* February 1994.

100 WATT HIGH-END POWER AMPLIFIER

Design by T. Giesberts

The simplified circuit diagram in **Fig. 1** clearly shows the symmetrical design of the amplifier. The input stage is formed by differential amplifiers T_1, T_3, whose gain is limited to about 40 dB (×100). The stage is coupled to differential amplifiers T_2, T_4, whose gain is around 10 dB (×3). These amplifiers are linked via optoisolators to drivers T_{12}, T_{13}, which form the link between the input and output stages. The zener symbol between the drivers indicates a variable zener transistor, which enables the accurate setting of the quiescent current through the output transistors. The output stage consists of transistors T_{16} and T_{17}, each of which drives two parallel-connected power transistors: T_{18}, T_{19} and T_{20}, T_{21} respectively.

The optoisolators provide suppression of the on/off switching clicks, which, owing to the absence of an output relay, is essential. The POWER ON DELAY (which is part of a protection circuit on a separate PCB) ensures that the LEDs in the optoisolators light up only gradually after switch-on. Consequently, the optotransistors in the collector circuits of T_{12} and T_{13} come into conduction slowly, resulting in the power supply to the output transistors building up gradually. This arrangement effectively prevents annoying clicks at switch-on. When the mains is switched off, the LEDs go out rapidly, resulting in an abrupt removal of power from the output transistors. Consequently, the output stage gets no time to produce irritating switch-off phenomena.

The protection circuit uses no relay and relies on the current through the emitter resistors of the output transistors and the output voltage for correct operation. If, for whatever reason, the current rises unduly or a direct voltage appears at the output, two actions take place: the optoisolators are cut off, so that the power to the output stages is removed instantly, and the supply lines are shorted to earth with the aid of triacs, A somewhat drastic, but very effective and reliable means of safeguarding the amplifier from compression and distortion at large drive voltages.

Not shown in **Fig. 1** is a thermal protection circuit, which, again via the optoisolators, removes the power from the output transistors if the temperature of these devices rises unduly.

Amplifier circuit

The circuit diagram of the amplifier (single channel) in **Fig. 3** is, in large parts, similar to that of the 'Output amplifier for ribbon loudspeakers' [2]. The differences lie

This article describes a completely updated and higher-power version of the 'Medium power a.f. amplifier' published in this magazine just over three years ago [1]. At the suggestion of many readers, the new amplifier also incorporates a number of features of the 'Output amplifier for ribbon loudspeakers' published two years later [2]. It provides 100 W into 8 Ω and does not use an output relay.
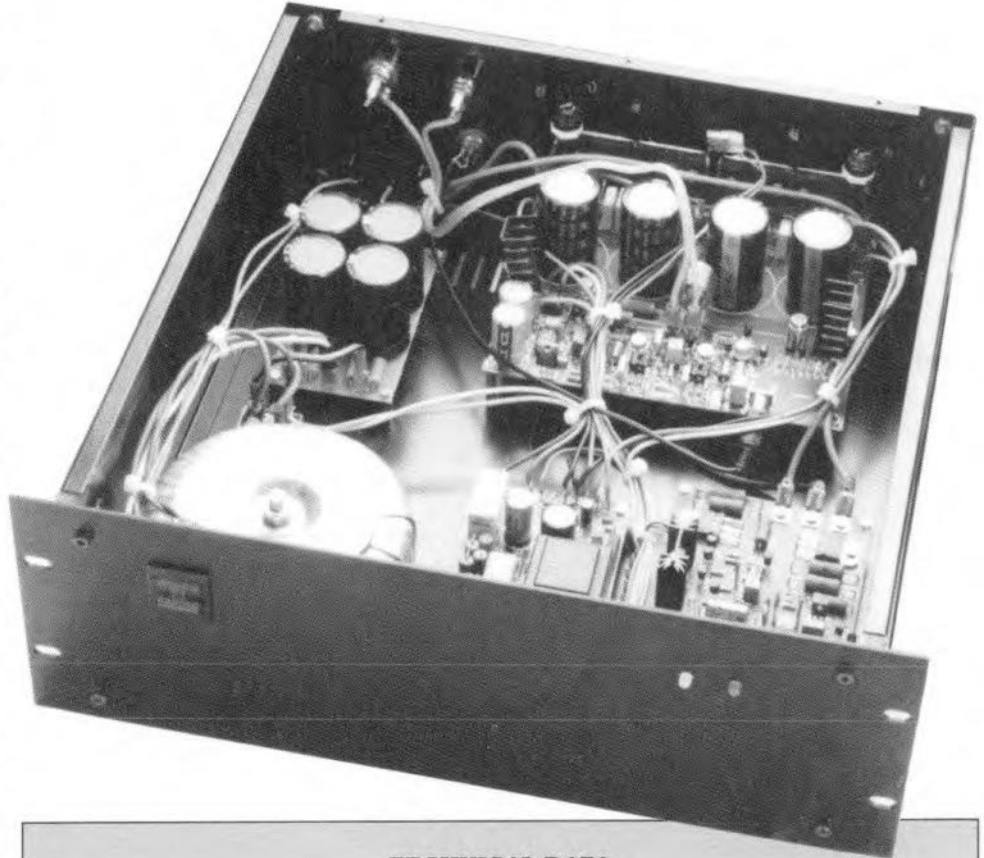
TECHNICAL DATA

Input sensitivity	1 V r.m.s.
Input impedance	46.5 kΩ
Output power (0.1% THD)	100 W into 8 Ω
	175 W into 4 Ω
Music power (500 Hz burst: 5 periods on.	105 W into 8 Ω
5 periods off)	185 W into 4 Ω
Power bandwidth (50 W into 8 Ω)	1.5 Hz – 220 kHz
Slew rate	>50 V µs⁻¹
Signal-to-noise ratio (1 W into 8 Ω)	>102 dB (A weighted)
Harmonic distortion (B = 10 Hz – 80 kHz)	
at 1 W into 8 Ω	<0.0025% (1 kHz)
at 90 W into 8 Ω	<0.0015% (1 kHz)
	<0.015% (20 Hz – 20 kHz)
Intermodulation distortion	<0.002% (1 W in to 8 Ω)
(50 Hz : 7 kHz; 4 : 1)	<0.003% (50 W into 8 Ω)
Dynamic IM distortion (block 3.15 kHz	<0.0025% (1 W into 8 Ω)
with 15 kHz sine wave)	<0.0015% (100 W into 8 Ω)
Damping factor (8 Ω output)	>1000 (1 kHz)
	>290 (20 kHz)

Fig. 1. Simplified circuit diagram of the amplifier (one channel).

Fig. 2. The protection circuit does not use relays.

mainly in the much higher supply voltage (2×42 V instead of 2×15 V) and the much lower peak output current. Other, smaller, differences are a number of altered component values, new types of transistor in various positions, lower value fuses, fewer parallel-connected emitter resistors for the output transistors and an additional capacitor, C_{fb}, in the feedback loop. Also, the separate sense lines to the loudspeaker(s) are no longer there, and the connections between IC_3 and the supply lines have been broken (D_9 and D_{10} are omitted), because the supply voltage for the DC correction is now provided by an auxiliary supply.

At the input, there is a combination of a high-pass section, C_1-R_1, and a low-pass section, C_2-R_2. The first filter prevents any direct voltage entering the amplifier, while the second restricts the upper limit of the input bandwidth to about 300 kHz.

The signal is applied to differential amplifiers T_1 and T_3. Since the maximum permissible supply voltage of the excellent dual transistors MAT02 and MAT03 is too low, these types had to be replaced by a 2N2914 and a BFX36 respectively. Frequency compensation of the input stage is provided by networks R_5-C_3 and R_{10}-C_4. The open-loop bandwidth of the amplifier is around 14 kHz. The gain of the amplifiers is determined by the ratio of their collector and emitter resistors.

Current sources T_5 and T_6 guarantee stable operation of T_1 and T_3. This is augmented by the arrangement of holding the current through reference LEDs D_1 and D_2 stable with the aid of a third current source: T_9.

The next stage consists of dual transistors T_2 and T_4, which are controlled by current sources T_7 and T_8. Again, the current through LEDs D_3 and D_4 is held stable by current sources T_{10} and T_{11}.

Diodes D_1–D_4 must be of the same type with a forward voltage of 1.55–1.65 V to ensure that the operating points of the various transistors remain unchanged.

The optoisolators for the power-on delay are inserted in the collector leads of T_{2b} and T_{4b}. Their LEDs are controlled by the external protection circuit via B1 and B2.

The collectors of predrivers T_{12} and T_{13} are connected via T_{14} and T_{15}. The latter transistors form a zener transistor, the voltage across which, and thus the quiescent current through the output transistors, is set as appropriate with P_1.

Each of the two halves of the output stage, a super emitter follower, consists of a driver, T_{16} and T_{17}, and two power transistors, T_{18}, T_{19} and T_{20}, T_{21} respectively. The power transistor pairs are connected in parallel, but have their own emitter resistors. Transistor T_{22} monitors the voltage drop across the emitter resistors via potential divider R_{44}-R_{45}. If the total peak output current exceeds 18 A, T_{22} switches on, which causes the external protection circuit to be actuated.

A 6.3 A fuse has been incorporated in the collector line of each of the power transistors. The + and – taps in these lines are connected to the triacs (+ and –) in the protection circuit—see **Fig. 2**. If the fuses blow, D_5 and D_6 light to indicate this. In practice this will happen hardly ever, because the primary fuse will almost certainly blow first.

Boucherot network R_{47}-C_{12} ensures that the amplifier remains loaded adequately at high frequencies.

Output power is supplied to the loudspeaker(s) via inductor L_1, which limits the rise time of the signal when the load
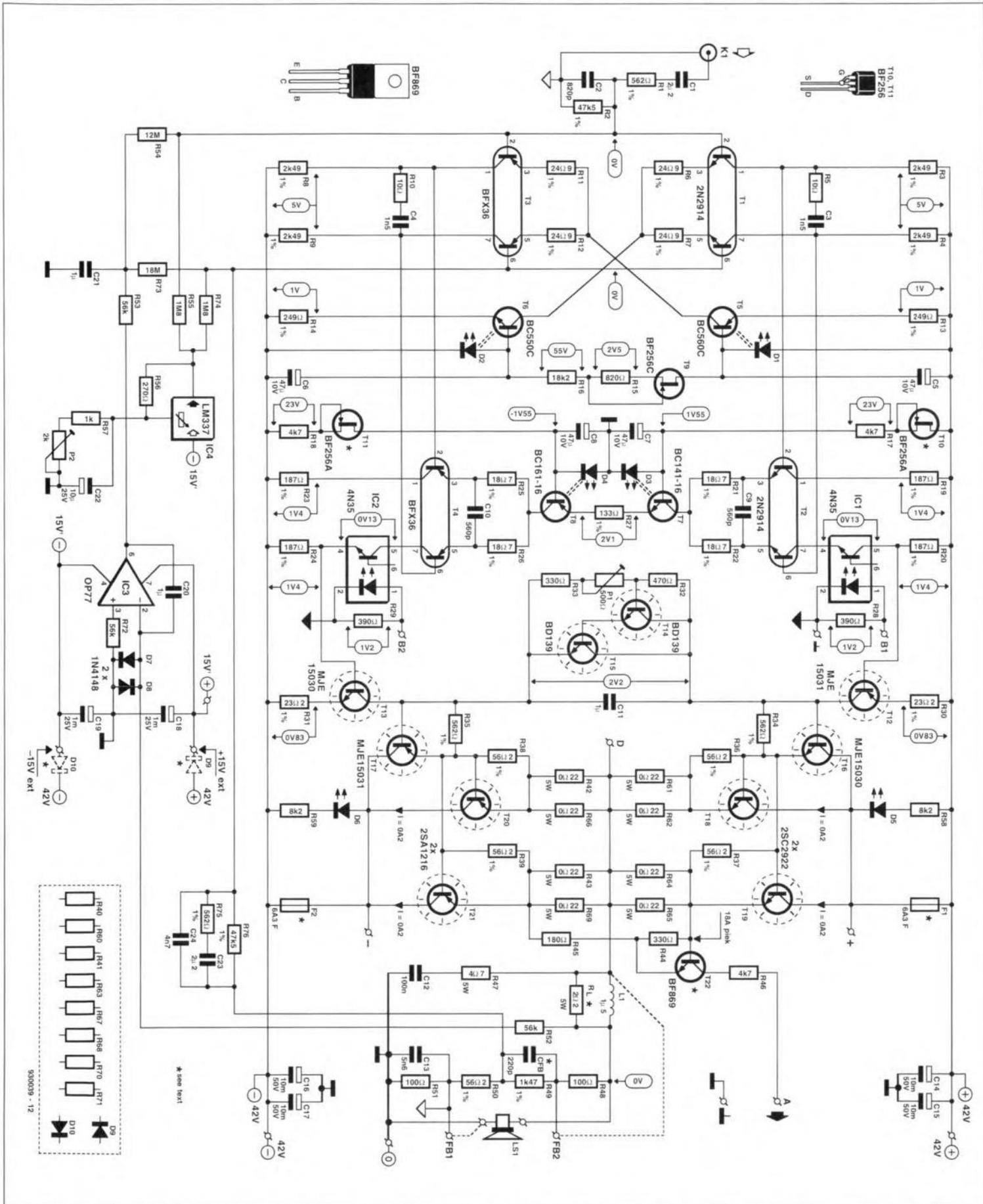

Fig. 3. Circuit diagram of the amplifier (one channel). The double dashed lines (e.g., D_1-T_5) indicate that thermal coupling is required. Transistors T_{14}-T_{21} must be mounted on a common heat sink.

is capacitive, and potential divider R_{48}-R_{51}. The ratio $R_{49}:R_{50}$ determines the feedback factor. The feedback voltage at the junction of these resistors is applied to the bases of T_{1b} and T_{3b}. Capacitor C_{fb} accelerates the action of the feedback circuit. Network R_{75}-R_{76}-C_{23}-C_{24} serves to

keep the base impedances at the left-hand and right-hand halves of the differential amplifier equal to ensure optimum common-mode suppression.

An additional stabilized voltage is produced with the aid of IC_4 to limit the offset voltage at the output to a minimum.

Fig. 4. Circuit diagram of the power supply.
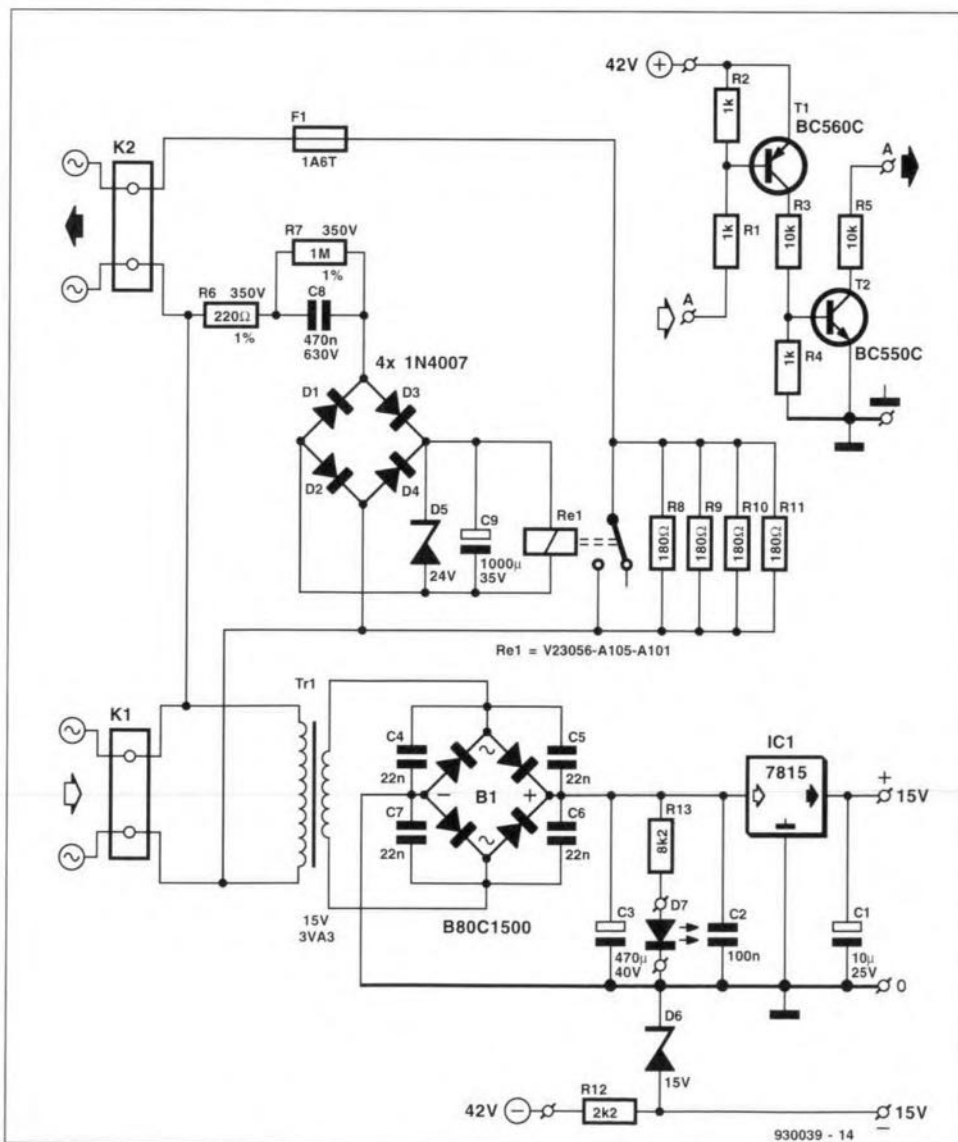
Fig. 5. Diagram of the auxiliary circuit.

The voltage is used to compensate the base currents of the input stage via R_{55} and R_{74} to such a degree that the direct voltage at the basis is virtually nil. Integrator IC_3 removes any residual direct voltage (caused by, for instance, temperature changes). Its output is used to adjust the base voltage of T_1 and T_3 via R_{53}-C_{21}, R_{54} and R_{73}.
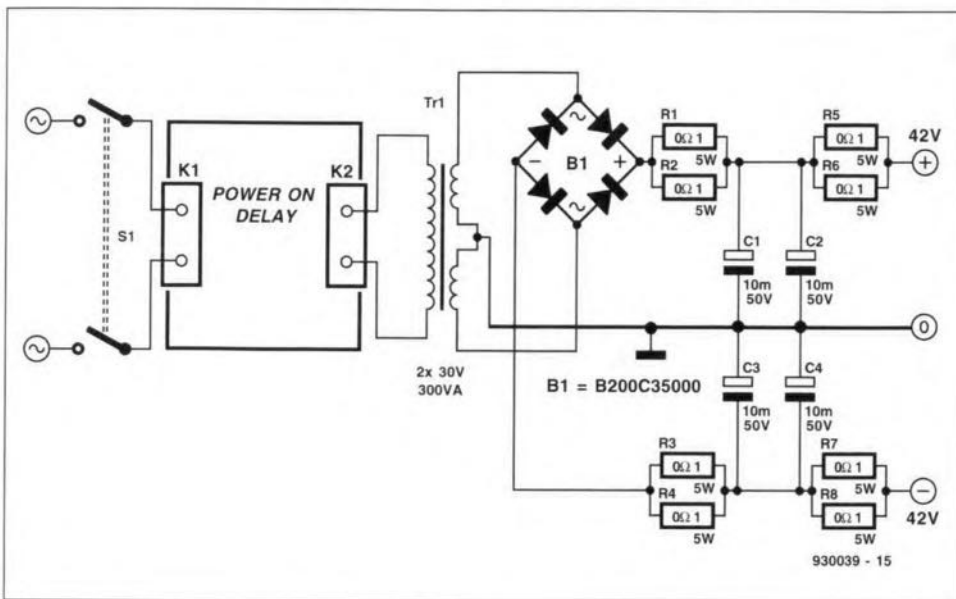
Protection circuit

The protection circuit, whose diagram is shown in **Fig. 2**, serves a number of functions.

Switch-on click. When the power is switched on, C_3 is charged slowly via R_4. After a short while, darlington T_7-T_8 comes on, whereupon the LEDs in the optoisolators begin to conduct gradually. When the potential across C_3 has risen to 1.7–1.8 V, the diodes light brightly. This situation remains because D_5 holds the base voltage of T_7 at a fixed level.

Switch-off click. As long as the mains is switched on, T_1 conducts every half period (since it is connected directly to the secondary of the mains transformer via D_1 and D_2), whereas T_2 and T_3 are off. When the mains is switched off, T_2 and T_3 are switched on within half a period. Schmitt trigger T_4-T_6 changes state, whereupon T_5 conducts and T_7 and T_8 are cut off, so that the optoisolators are deactuated. This state is indicated by the lighting of D_{11}.

Over-current. Current monitor T_{22} in the amplifier is linked to terminal A via the auxiliary circuit (**Fig. 5**). If the output current of the amplifier rises unduly, T_3 switches on, whereupon the optoisolators are deactuated as described earlier. At the same time, triacs Tri_1 and Tri_2 are switched on by T_{11} via D_8 and short-circuit the supply lines. If this drastic action is not acceptable, D_8 may be omitted.

Temperature. Transistor T_{12} functions as a temperature sensor diode which is mounted on the heat sink of T_{14}-T_{21}. The voltage across the transistor is compared by IC_{1a} with a preset (P_1) reference voltage. If the sensor voltage drops (temperature rises) below the reference potential, IC_{1a} changes state and the optoisolators are deactuated via D_6. Once the temperature has dropped below a safe value, the amplifier is switched on again.

Direct voltage. If there is a direct voltage greater than ±0.6 V at the output of the amplifier (point D), either T_9 or T_{10} is switched on via low-pass section R_{23}-C_8. In either case, the negative input of IC_{1b} is pulled to earth and its output changes from low to high. This results in the triacs being switched on via D_9 and T_{11}. At the same time, D_7 causes the Schmitt trigger to change state, resulting in the optoisolators being deactuated. This function may be disabled by omitting D_7 and D_9.
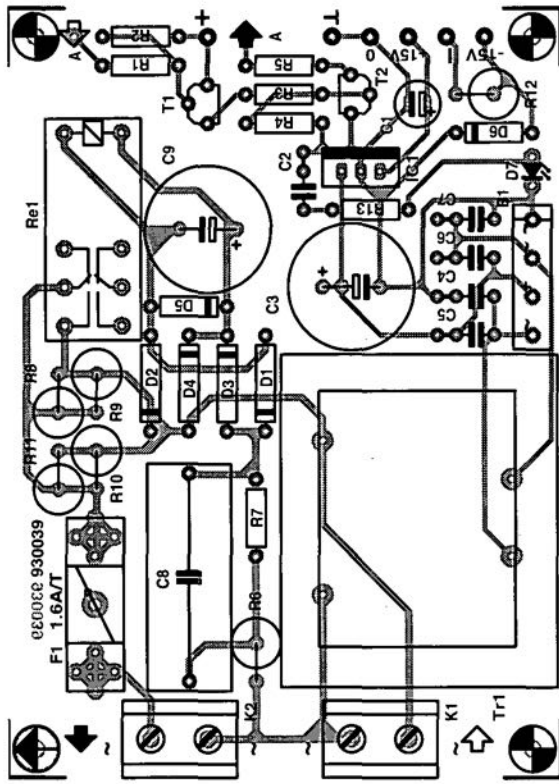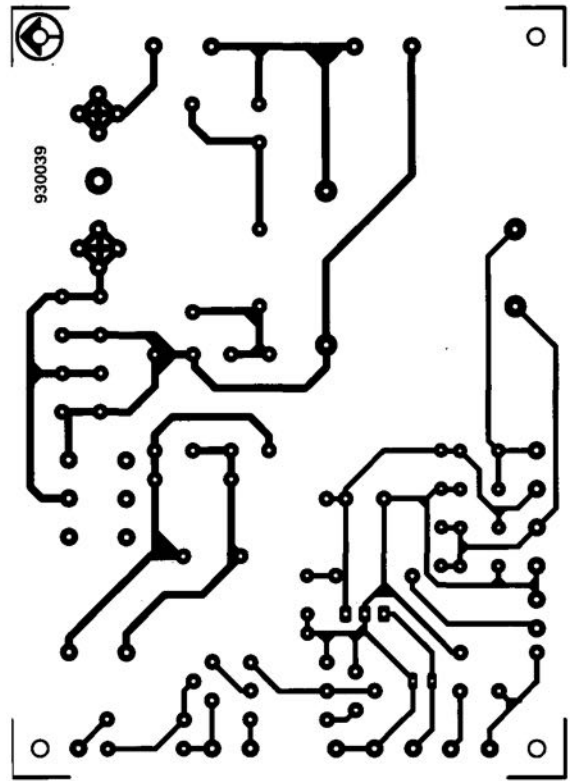
Fig. 6. Printed circuit board for the auxiliary circuit (scale 1:1).

Power supply

The power supply for the amplifier (see **Fig. 4**) is a traditional design. A double-pole mains switch and switch-on delay circuit are followed by the usual combination of transformer, bridge rectifier and electrolytic smoothing, buffer and reservoir capacitors. The series resistors limit the peaks in the charging currents of the electrolytic capacitors and, together with these capacitors, form an effective mains filter.

Auxiliary circuit

The auxiliary circuit (see **Fig. 5**) consists of a ±15 V supply and a mains on delay.

The ±15 V supply is provided by Tr_1, B_1 and various capacitors. The +15 V line is stabilized by a Type 7815 regulator,

but the –15 V line by a simple zener diode, D_6, since that line is further stabilized in the amplifier by a Type LM337 regulator (IC_4). Mains on indication is provided by R_{13} and D_7.

The section based on T_1 and T_2 acts as a monitor for the current protection. It is inserted between amplifier output A and terminal A on the protection board. The circuit transforms the potential measured by current sensor T_{22} into a much lower voltage (relative to earth) suitable for the protection circuit.

The design of the mains on delay circuit between K_1 and K_2 is straightforward. As soon as the mains at K_1 is switched

on, the amplifier is powered immediately via K_2, but the current to it is limited severely by R_8–R_{11}. This means that the electrolytic capacitors in the main power supply are charged relatively slowly and that the mains fuse does not have to cope with a substantial surge. Within a short while, C_9 is charged via R_6, C_8 and D_1–D_4 to such an extent that the potential across it is sufficient to energize relay Re_1. Parallel-connected resistors R_8–R_{11} are then short-circuited by the relay contact and full power is applied to the amplifier.

Diode D_5 limits the voltage across C_9, while R_7 ensures that 'a.c. resistor' C_8 is
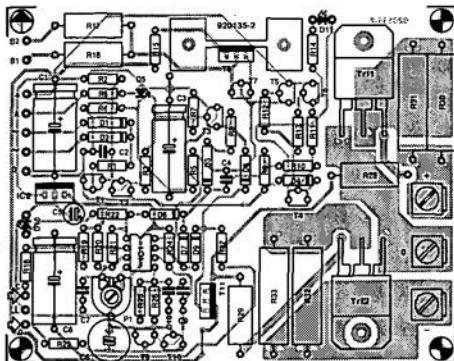

Fig. 7. Component layout of the PCB for the protection circuit (scale 1:2).
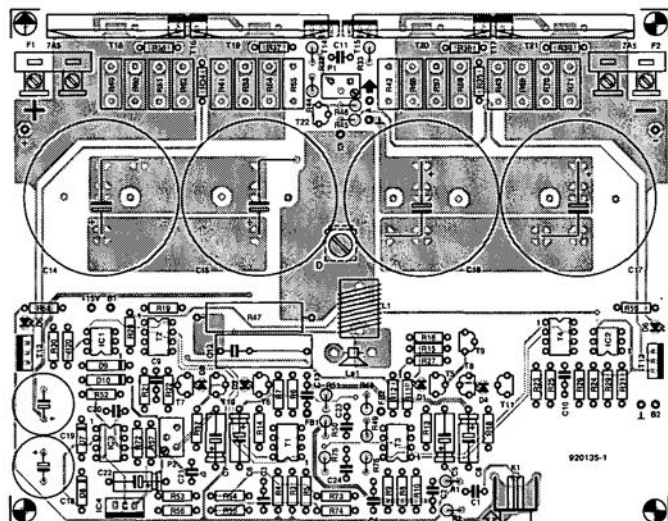

Fig. 8. Component layout (scale 1:2) of the PCB for the amplifier (one channel).

PARTS LIST (ONE CHANNEL)

AUXILIARY CIRCUIT

Resistors:
R_1; R_2; R_4 = 1 kΩ
R_3; R_5 = 10 kΩ
R_6 = 220 Ω 1 W; e.g., PR01 (Philips)
R_7 = 1 MΩ, 350 V; e.g., SFR25H (Philips)
R_8–R_{11} = 180 Ω, 5 W
R_{12} = 2.2 kΩ, 1 W; e.g., PR01
R_{13} = 8.2 kΩ

Capacitors:
C_1 = 10 µF, 25 V radial
C_2 = 100 nF ceramic
C_3 = 470 µF, 40 V, radial
C_4–C_7 = 22 nF, ceramic
C_8 = 470 nF, 630 V
C_9 = 1000 µF, 35 V, radial

Semiconductors:
B_1 = B80C1500
D_1–D_4 = 1N4007
D_5 = 24 V, 1.4 W
D_6 = 15 V, 0.4 W
D_7 = LED green, low current
T_1 = BC560C
T_2 = BC550C

Integrated circuits:
IC_1 = 7815

Miscellaneous:
K_1; K_2 = 2-way PCB terminal block, pitch 7.5 mm
Tr_1 = 15 V, 3.3 VA, e.g., VTR3115 (Monacor/Monarch)
Re_1 = V23056-A105-A101 (Siemens)
F_1 = 1A6 T w. PCB holder

PROTECTION BOARD

Resistors:
R_1 = 82 kΩ
R_2 = 1 MΩ
R_3; R_7; R_9; R_{25}; R_{26} = 100 kΩ
R_4 = 15 kΩ
R_5 = 100 Ω
R_6; R_{22} = 1 kΩ
R_8 = 47 Ω
R_{10} = 1.5 MΩ
R_{11} = 3.9 MΩ
R_{12}; R_{13} = 56 kΩ
R_{14}; R_{27} = 4.7 kΩ
R_{15} = 10 Ω
R_{16}; R_{17} = 390 Ω, 1 W
R_{18} = 15 Ω
R_{19} = 3.3 kΩ
R_{20} = 180 kΩ
R_{21} = 22 MΩ
R_{23} = 10 kΩ
R_{24} = 220 kΩ
R_{28}; R_{29} = 220 Ω, 1 W
R_{30}–R_{33} = 1.2 Ω, 5 W
P_1 = 50 kΩ preset H

Capacitors:
C_1 = 220 µF, 25 V
C_2; C_7 = 100 nF
C_3 = 470 µF, 6.3 V
C_4 = 1 µF
C_5 = 10 µF, 10 V, radial
C_6 = 220 µF, 16 V
C_8 = 100 µF, 10 V, radial, bipolar
C_9 = 39 nF
C_{10} = 220 nF

Semiconductors:
D_1,D_2 = 1N4004
D_3 = 1N4001
D_4 = 5.6V, 0.4 W
D_5 = LED green
D_6–D_9 = 1N4148 (fit w. connectors on PCB pins)
D_{10} = LED orange
D_{11} = LED, red, high efficiency
T_1; T_2; T_4; T_{10} = BC547B
T_3 = BC516
T_5; T_6; T_7 = BC557B
T_8 = BD140 + heatsink
T_9 = BC547A
T_{11} = BD679

Integrated circuits:
IC1 = CA3240
IC2 = 7805

Miscellaneous:
Tri_1;Tri_2 = TIC263M
3 off screw-mount spade terminal for PCB mounting
1 off PCB Ref. 920135-2 (see page 70)

AMPLIFIER BOARD

Resistors:
R_1; R_{34}; R_{35}; R_{75} = 562 Ω, 1%
R_2; R_{76} = 47.5 kΩ, 1%
R_3; R_4; R_8; R_9 = 2.49 kΩ, 1%
R_5; R_{10} = 10 Ω
R_6; R_7; R_{11}; R_{12} = 24.9 Ω, 1%
R_{13}; R_{14} = 249 Ω, 1%
R_{15} = 820 Ω
R_{16} = 18.2 kΩ, 1%
R_{17}; R_{18} = 4.7 kΩ
R_{19}; R_{20}; R_{23}; R_{24} = 187 Ω, 1%
R_{21}; R_{22}; R_{25}; R_{26} = 18.7 Ω, 1%
R_{27} = 133 Ω, 1%
R_{28}; R_{29} = 390 Ω
R_{30}; R_{31} = 23.2 Ω, 1%
R_{32} = 470 Ω
R_{33}; R_{44} = 330 Ω
R_{36}–R_{39}; R_{50} = 56.2 Ω, 1%
R_{42}; R_{43}; R_{61}; R_{62}; R_{64}; R_{65}; R_{66}; R_{69} = 0.22 Ω, 5 W, low-inductance
R_{40}; R_{41}; R_{60}; R_{63}; R_{67}; R_{68}; R_{70};R_{71} = not used
R_{45} = 180 Ω
R_{46} = 4.7 kΩ
R_{47} = 4.7 Ω, 5 W
R_{48}; R_{51} = 100 Ω
R_{49} = 1.47 kΩ, 1%
R_{52}; R_{53}; R_{72} = 56 kΩ
R_{54} = 12 MΩ
R_{55}; R_{74} = 1.8 MΩ
R_{56} = 270 Ω
R_{57} = 1 kΩ
R_{58}; R_{59} = 8.2 kΩ
R_{73} = 18 MΩ
R_L (in L_1) = 2.2 Ω, 5 W
P_1 = 500 Ω multiturn, vertical preset (Bourns 3296Y)
P_2 = 2 kΩ multiturn, vertical preset (Bourns 3296Y)

Capacitors:
C_1; C_{23} = 2.2 µF, 50 V, MKT
C_2 = 820 pF, polystyrene
C_3, C_4 = 1.5 nF
C_5–C_8 = 47 µF, 10 V
C_9; C_{10} = 560 pF, polystyrene
C_{11}; C_{20}; C_{21} = 1 µF
C_{12} = 100 nF
C_{13} = 5.6 nF
C_{14}–C_{17} = 10 000 µF, 50 V, radial, for PCB mounting
C_{18}; C_{19} = 1000 µF, 25 V, radial
C_{22} = 10 µF, 25 V
C_{24} = 4.7 nF
C_{fb} = 220 pF, polystyrene (mount at track side)

Semiconductors:
D_1–D_4 = LED, red (V_F = 1.6 V)
D_5 = LED, red (high efficiency)
D_6 = LED, green (high efficiency)
D_7; D_8 = 1N4148
D_9; D_{10} = not used
T_1; T_2 = 2N2914
T_3; T_4 = BFX36
T_5 = BC560C
T_6 = BC550C
T_7 = BC141-16
T_8 = BC161-16
T_9 = BF256C
T_{10}; T_{11} = BF256A (interconnect gate and source; cut off gate)
T_{12}; T_{17} = MJE15031
T_{13}; T_{16} = MJE15030
T_{14}; T_{15} = BD139
T_{18}; T_{19} = 2SC2922 (Toshiba)
T_{20}; T_{21} = 2SA1216 (Toshiba)
T_{22} = BF869 (interchange base and collector)

Integrated circuits:
IC_1;IC_2 = 4N35
IC_3 = OP77
IC_4 = LM337

Miscellaneous:
L_1 = 10 turns (15 mm dia.) of 1.5 mm dia. enamelled copper wire
K_1 = phono socket for PCB mounting (or two PCB pins).
F_1;F_2 = 6.3 A (with fuseholder).
5 off spade terminal, screw type.
1 off heat sink max. 0.5 K W^{-1}.
2 off heat sink for T_{12} and T_{13}
1 off PCB Ref. 920135-1 (see page 70)

POWER SUPPLY & ENCLOSURE

Tr_1 = ring core transformer, sec. 2×30V, 300 VA, e.g., 71017 (Amplimo or ILP)
B_1 = B200C35000 (200 V/35 A bridge)
R_1–R_8 = 0.1 Ω, 5 W
C_1–C_4 = 10 000µF, 50 V
1 off mains socket
1 off mains switch
2 off phono socket (gold-plated)
2 off loudspeaker terminal or banana socket
Enclosure : e.g., ESM Type ET38/13 (300 mm deep) (Maplin)

discharged rapidly when the supply is switched off.

Construction

The printed-circuit board for the auxiliary circuit is shown in **Fig. 6**, and the component layout of the PCB for the protection circuit and the amplifier in **Fig. 7** and **Fig. 8** respectively. The latter two were shown full-scale in Ref. 2 and Ref. 1 respectively. There is no board for the power supply of **Fig. 5**, so this must be constructed on a prototyping board. The PCBs are available ready made through our Readers' Services.

Building the auxiliary circuit is straightforward and consists merely of populating the board with reference to **Fig. 6** and the parts list.

The same applies to the protection circuit. Do not forget the heat sink for T_8 and use heavy duty terminals for the connections to the triacs.

As far as the amplifier board is concerned, a full description was given in Ref. 2, which includes a template for drilling the heat sink. The following description will concentrate on the more important details only and on the aspects resulting from the modifications in the present amplifier over that in Ref. 2.
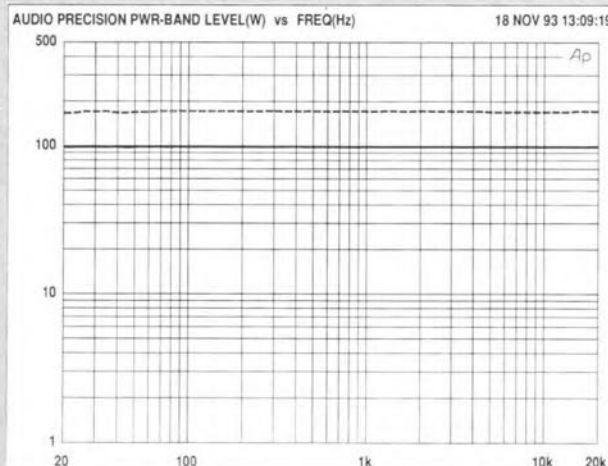
Mount most of the components on the board, but, for convenience's sake, leave the large electrolytic capacitors till a little later. Although different types of dual transistor are used in the T_1–T_4 positions, they are also housed in a TO-78 enclosure **and** they are pin-compatible with the
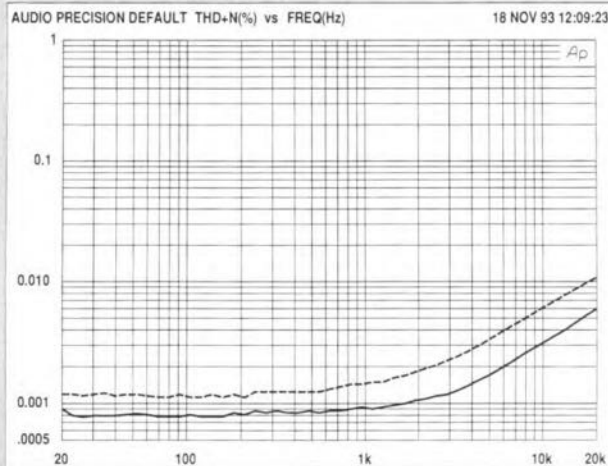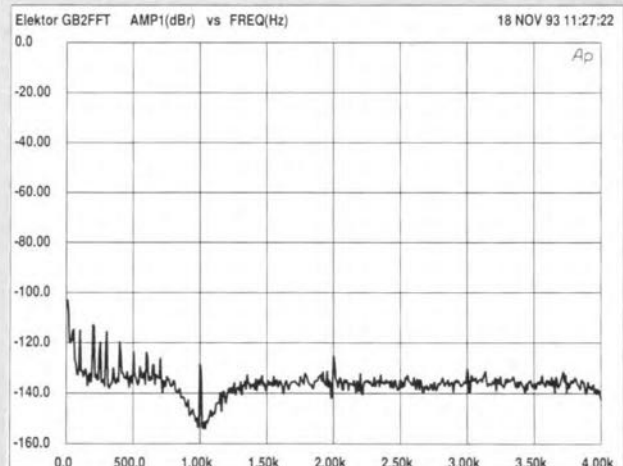

Characteristic A
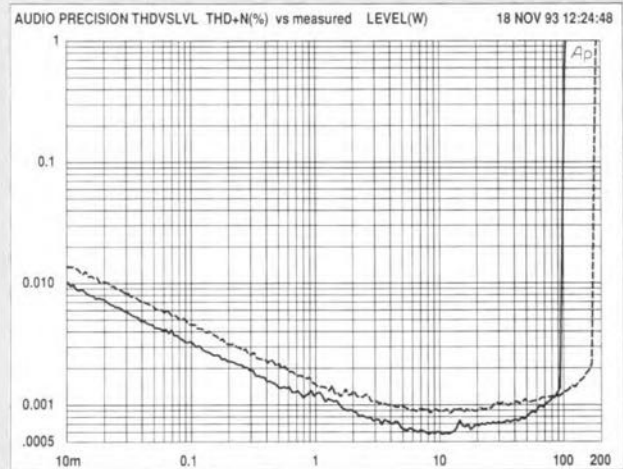
Characteristic B

Characteristic C

Characteristic D

The results of the measurements on the prototype are, without exception, very good. Noise and residual distortion are far removed from the human limits of observation. Pulse response and damping factor are almost ideal, although that is a strong word to use.

Listening tests confirm the measured values. Even the most demanding recordings from our record library were reproduced without any discernible hitch.

The four characteristics shown above,

obtained with an Audio Precision Analyser, illustrate these statements.

Characteristic A shows the total harmonic distortion plus noise (THD + N) over the frequency range 20 Hz to 20 kHz at an output power of 50 W.

Characteristic B illustrates the distortion at 1 kHz as a function of the drive level over the frequency range 22 Hz to 22 kHz. It is clear that between 10 W and 20 W the limits of the analyser were reached. The sharp bend at the right-hand side

of the curve is the clipping point.

Characteristic C shows the maximum power at a distortion of 0.1%; it will be seen that within the audio range the power is completely independent of frequency.

Characteristic D gives the Fourier analysis of a 1 kHz signal at an output of 1 W into 8 Ω with the fundamental frequency suppressed. The attenuation of the 2nd harmonic is about 125 dB, while the 3rd harmonic is lost in the noise.

Box 2. Four characteristics illustrating certain measurements on the prototype amplifier.

earlier types. The types of transistor used in the T_7 and T_8 positions are also pin-compatible with the earlier types, but they are slightly larger, which adds to the density on the board.

Field-effect transistors T_{10} and T_{11} need to be modified slightly before they can be fitted. Since their gate must not be connected to the board, the relevant pin must be linked to the source pin and as much of it cut off as possible. The result is a FET with only two pins which are to be inserted in the holes intended for the drain and source.

Since the board was originally intended for a BC550C, the collector pin of T_{22} (a BF869) must be inserted into the hole originally meant for the base, and the base pin into the original commector hole. Take care not to short-circuit these pins.

The same sort of thing needs to be done with T_{12} and T_{13}. Since the types now used are housed in a TO-220 case, they must be mounted on the board the wrong way around, that is, with the metal plane at the inside.

Resistor R_L must be mounted centrally **inside** air-cored inductor L_1. The coil consists of 10 turns of 1.5 mm diameter enamelled copper wire wound on a 15 mm diameter tube. Make small loops at the ends of the wire so that the coil can be mounted on the board with small bolts and nuts.

There are no holes provided for C_{fb}: this capacitor should be soldered at the track side of the board directly across R_{49}.

Diodes D_9 and D_{10} must **not** be used in the present amplifier. Fit PCB pins in the holes intended for these diodes and
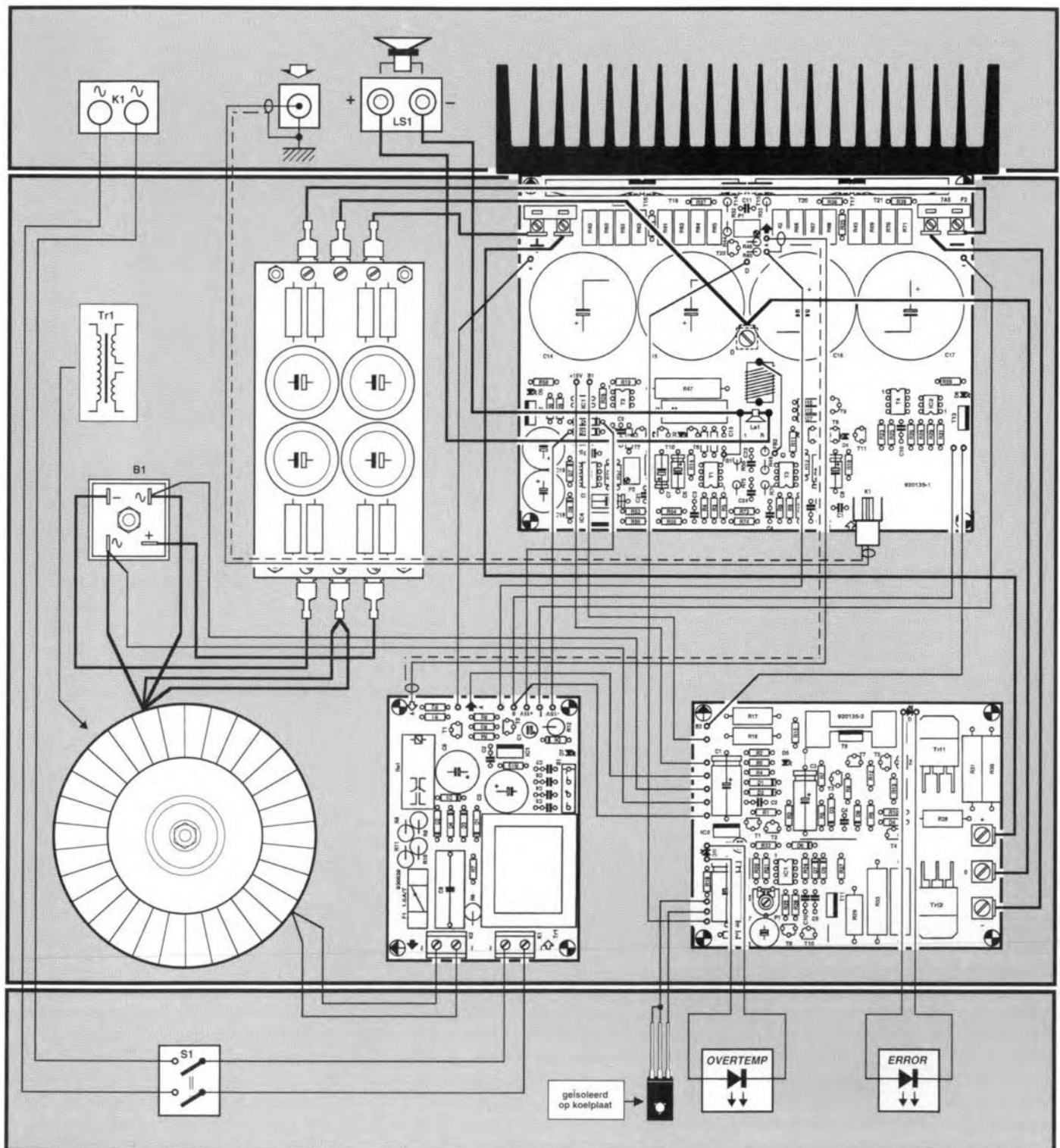
930039 - 16

Fig. 9. Wiring diagram for the amplifier (one channel).

link them to the ±15 V supply on the aux-
iliary circuit board.

Since sense lines to the loudspeaker(s)
are no longer used, terminal FB2 must
be linked to the junction L_1-R_{47}, and FB1
to the earth terminal of the loudspeaker
(clamp together with the loudspeaker
cable in the spring-loaded terminal).

If car-type fuses of 6.3 A are unob-
tainable, use a glass fuse mounted in a
traditional holder soldered on to the screw
type terminals.

Use flat car-type connectors for ter-
minating the supply lines and also for the
output lines (these come at the under-
side of the board).

The board is intended to form a (lat-
eral) 'T' with the heat sink. Screw the
power transistors and T_{14}-T_{17}, mounted
on the amplifier board, to the heat sink:
use insulating washers in all cases. Do
not yet fit T_{12} to the upper half of the heat
sink: see under 'Alignment'.

A completed single-channel amplifier
module is shown in **Fig. 10**. Its wiring di-
agram is given in **Fig. 9**. Use heavy-duty
wire (≥4 mm² cross-section) for the power
lines, output lines to the loudspeaker(s)
and the lines between the amplifier board
and the triacs on the protection board.
Use screened cable for the input lines.
Such cable is also recommended to link
points A on the three boards.

It proved impossible to obtain an en-
closure suitable for housing two ampli-
fier modules to form an integrated stereo
amplifier; the prototype stereo amplifier
therefore consists of two individual mono
amplifier modules.

Alignment

Set P_1 to maximum resistance: check
this with an ohmmeter. Switch on the
mains, and measure the voltage at the
various points shown in **Fig. 2** and **Fig. 3**.
If these are all as specified, measure the
voltage across one of the emitter resistors
of T_{18}-T_{21} with a digital voltmeter and
adjust P_1 until the meter reads 22 mV
(which corresponds to a quiescent cur-
rent of 200 mA per transistor).

Next, again with a digital voltmeter,
measure the direct voltage at the base of
T_1 or T_3; adjust P_2 to make the reading
exactly zero.

Then, measure the output voltage of
IC_4, which must be between 0 V and −11 V.
If the voltage is more negative, reduce the
values of R_{55} and R_{74} by about 10% (after
switching off the amplifier!).

Next, check the output voltage of IC_3
(pin 1). After the amplifier has been switched
on for a little while, this voltage should
remain within ±10 V. If this is not the
case, reduce R_{73} to the next lower E12
value.

Finally, connect T_{12} via a short length
of cable to terminals C and earth on the
protection board. Place the transistor in
a dish of warm water (about 60 °C), mak-
ing sure that the device's terminals are

not short-circuited by the water. Adjust
P_1 on the protection board until D_{10} on
the same board just lights. Then, fit T_{12}
to the heat sink. Bear in mind that the
temperature of the heat sink even in normal
operation becomes at least 20 °C higher
than ambient.   END

References:
1. 'Medium power a.f. amplifier', *Elektor
   Electronics*, October/November 1990

2. 'Output amplifier for ribbon loudspeakers',
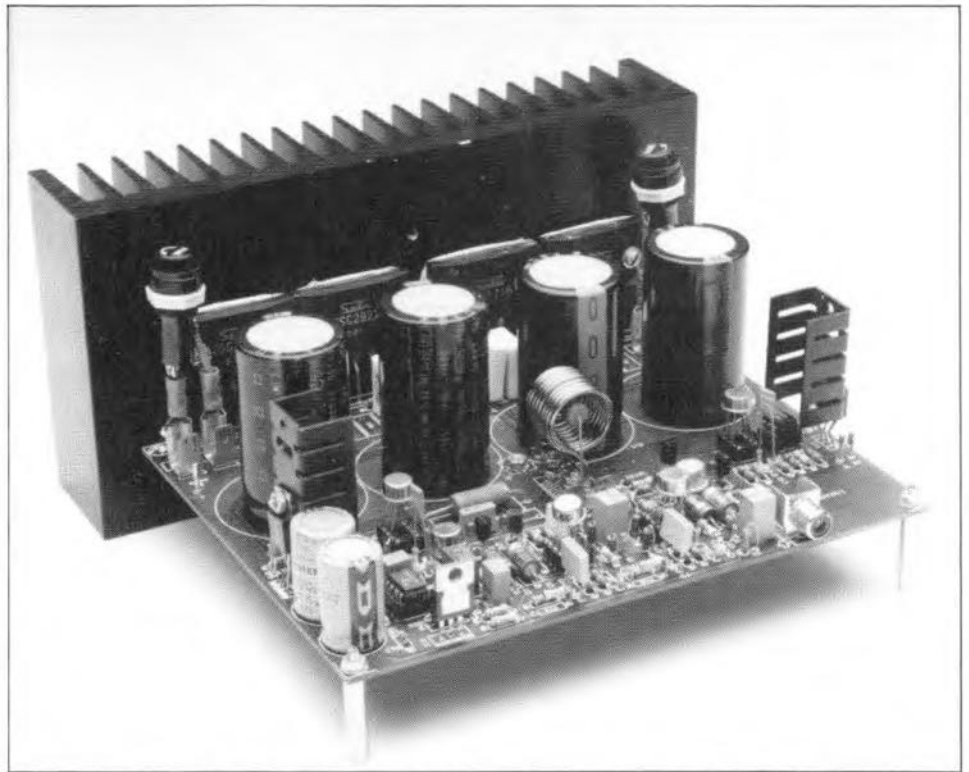   *Elektor Electronics*, November/December
   1992.

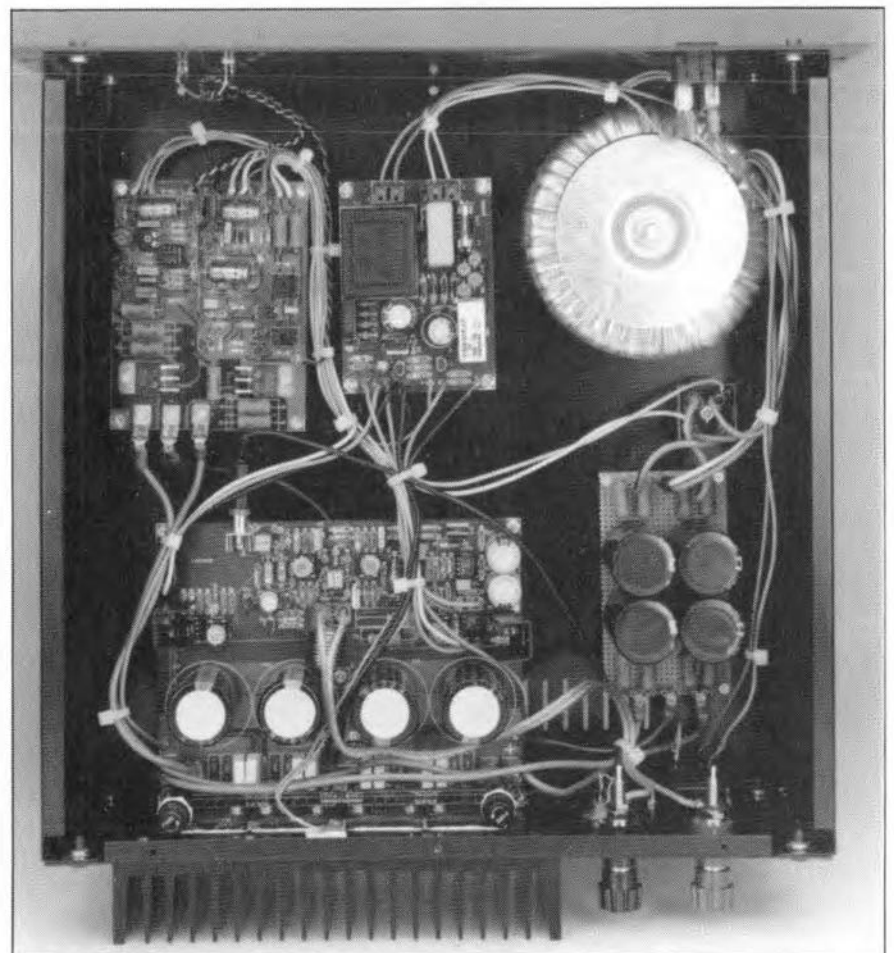Fig. 10. Completed single-channel (mono) amplifier module.

Fig. 11. Mono amplifier module seen from top with cover of enclosure removed.

PIC PROGRAMMER

The latest buzz in Programmable Logic Land is 'PIC', a RISC-based microcontroller manufactured by Microchip Technology Inc. Read all about it in this article! A programmer is described which enables a large number of PIC16Cx and PIC17Cx devices to be loaded with your own application programs. And there is more good news: software development for PIC controllers will be the subject of a short course to be featured in this magazine in the near future.
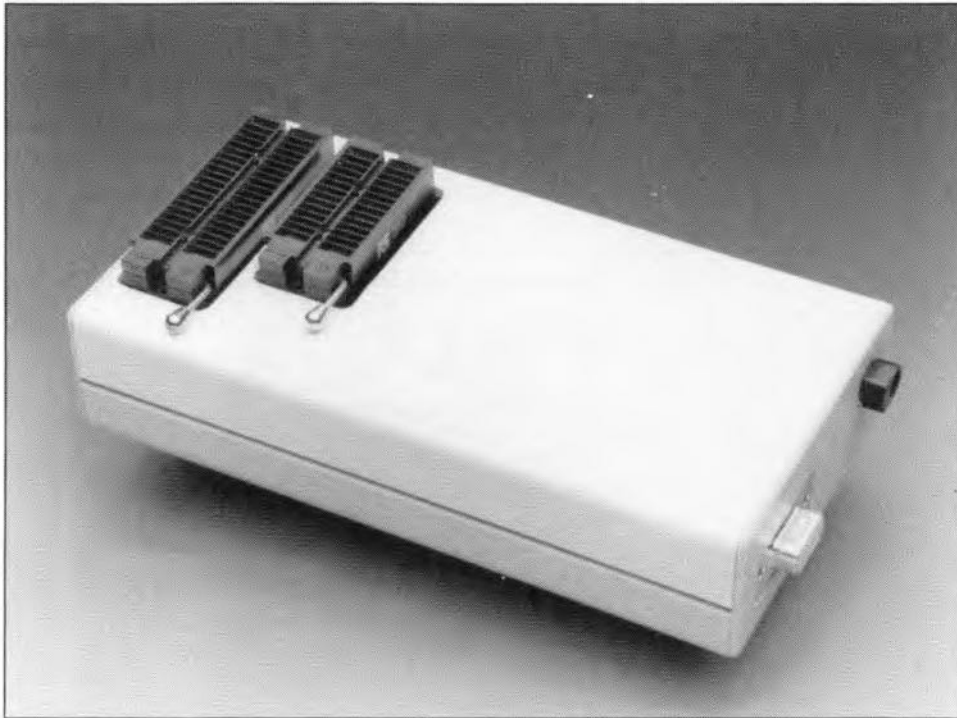
Design by M. Rose

THE sheer market force and impact of microcontroller families such as the MCS-51 and 68xx, manufactured by semiconductor 'giants' like Intel and Motorola, would make you almost forget that there exist competing companies in this field. One of these companies is Microchip Technology in the USA., who produce a remarkable family of microcontrollers designated with the type prefix 'PIC'.

PIC processors were developed for use in widely different surroundings and conditions. In the office environment, for instance, you may find them lurking in photocopying machines, typewriters and barcode scanners. Computer peripheral manufacturers use PICs in printers, scanners and disk drives. In the telecomms sector, PICs are found in a wide range of equipment, including fax machines and cellular telephones. The automotive industry, too, employs PICs in fuel

injection systems, police radar detectors and anti-block brake systems.

One of the intentions of this article is to make the advanced hobbyists and small-scale programmer familiar with PIC devices, and what better way to do this than to describe a compact and inexpensive programmer? Once you have built the programmer and completed the course on PIC software development, you are ready to use these interesting devices in a vast range of processor-controlled applications.

The programmer

The programmer circuit is designed such that it can be used for a large number of PIC devices. The hardware remains limited to an absolute minimum thanks to the use of ... a PIC microcontroller! The programmer is capable of burning the following devices: PIC16C54, PIC16C55,

MAIN SPECIFICATIONS

28-pin processors:	PIC16C52; -55; -56; -57; -71; -84
40-pin processors:	PIC17C42
Processor:	EPROM or OTP version
Programs:	Code memory and configuration word
IC sockets:	ZIF type (28-pin and 40-pin)
Software:	On-board in PIC17C42
Support:	via MS-DOS PC
RAM memory:	32KByte
Communication:	via RS232 interface

PIC16C56, PIC16C57, PIC16C71, PIC16C84 and PIC17C42. These ICs are connected to the programmer via two zero-insertion force (ZIF) sockets. The PIC17C42 is fitted into a 40-way ZIF socket, while the other PICs fit into a 28-way ZIF socket. If you do not envisage ever programming either a PIC16C or a PIC17C device, the relevant ZIF socket may be omitted without problems.

The programmer is controlled by software that runs on an MSDOS PC, in conjunction with the pre-programmed PIC17C42 in the programmer circuit itself. The latter PIC takes care of the communication with the PC, and generates the supply and programming voltages for the PIC to be programmed. The direct voltages used in the programmer circuit are 'tailored' with the aid of the PWM (pulse-width modulation) outputs of the PIC17C42. This obviates the need of a host of direct voltage sources usually found in programmers.

The hardware

The circuit diagram of the PIC programmer is given in **Fig. 1**. First, let us discuss the digital section of the circuit. The two ZIF sockets that receive the PIC devices to be programmed are marked U_{11} and U_{12}. The operation of the circuit is not so easy to explain in one go because the PIC devices that can be programmed have slightly different programming sequences. These sequences will, therefore, be described separately for each processor.
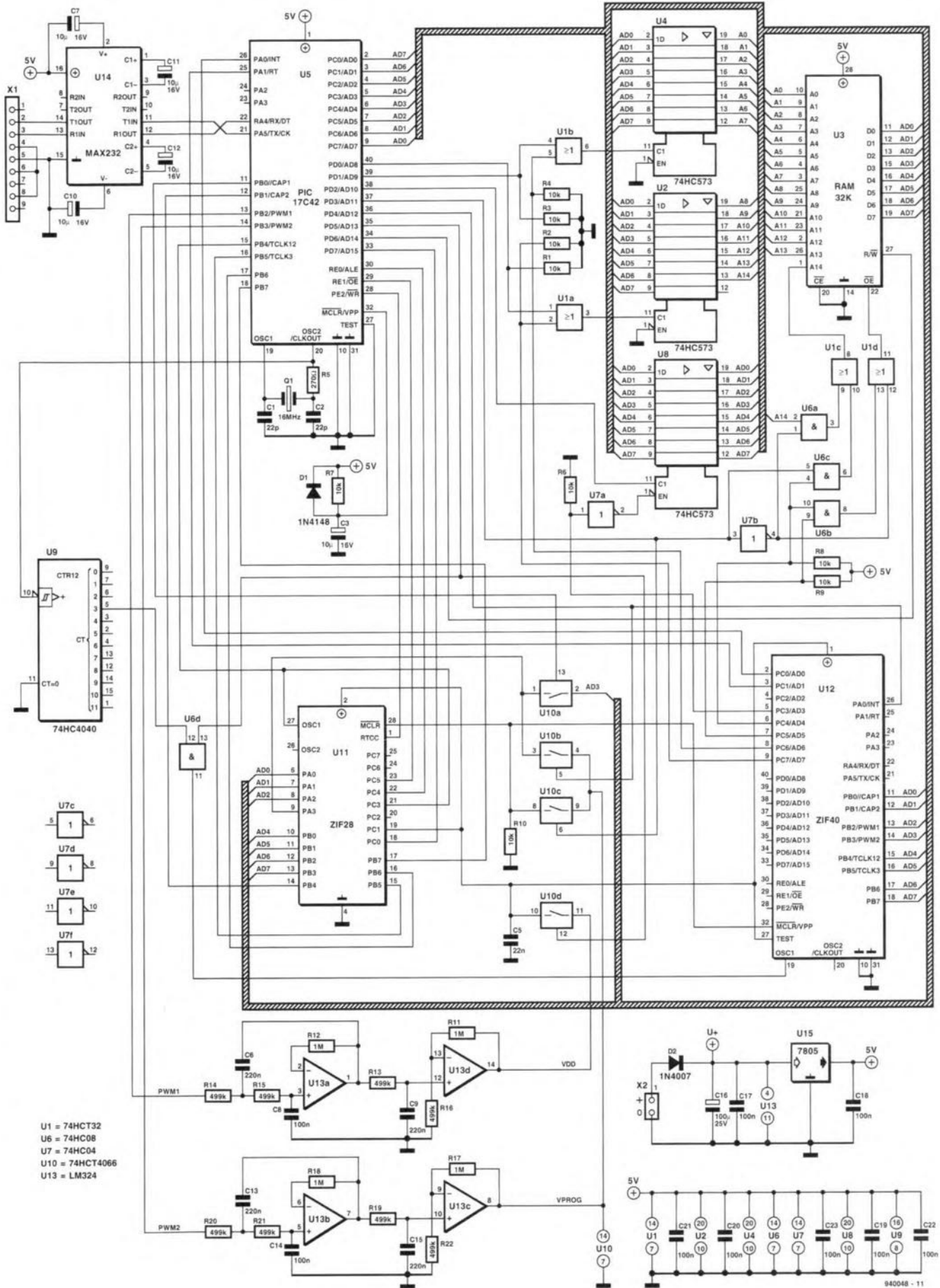
PIC17C42

The PIC17C42 has an internal ROM

Fig. 1. Circuit diagram of the PIC programmer. The circuit is a 'hybrid', i.e., a combination of digital and analogue electronics.

(read-only memory) which contains a program that enables the processor to program itself. To enable the it to make use of this programming routine, the processor must be given access to a small RAM (random access memory) area. This RAM is formed by U_3, a 32-KByte static memory type 62256 or 43256. Two octuple registers type 74HC573 (U_2 and U_4) act as a latch which allows 16-bit RAM address locations to be stored. The signals needed to store data into the memory are found on port connections PD0 and PD1 of the PIC microcontroller, U_5. During the programming operation, the control signals appear at port connections PC6 and PC7 of U_{12}, the controller to be programmed. The control signals are combined logically by two OR gates, U_{1A} and U_{1B}, contained in a 74HCT132.

A very special configuration is found around register U_8. It may strike you as odd that this memory is nearly always in high-Z mode, while its inputs and outputs are interconnected. This is not a mistake! While the IC is in high-Z mode (also called 3-state), the 'short-circuited' input and output connections carry the bit patterns to be stored in the RAM. The information conveyed over the bus may also be copied into the register by controlling the C input (pin 11). This happens with one byte only: the configuration word. As long as U_8 is in high-Z mode, the contents of the register remain 'hidden' in the IC. The PIC17C42 to be programmed reads the configuration stored in this register with the aid of a pulse on port PC3. Only during this pulse is the register released from its high-Z state. Since the outputs of U_5 and U_3 are then at high impedance, the contents of U_8 appear on the multiplexed data/address bus during this short read pulse. In other words, U_8 acts as a one-byte wide memory with a depth of one location, and is used for intermediate storage of the processor configuration word.

The processor configuration word is built by the software which runs on the MSDOS PC, and serves to define programming parameters including the type of clock generator used, and whether or not the PIC is to be protected from being read out.

The programming status information may be found on pins PC0 and PC1 of the PIC17C42 to be programmed. These outputs are low during the programming operation. If the programming sequence is successfully completed, PC0 goes high. If not, PC1 goes high.

The programming cycle is started by applying a programming voltage (Vpp) of 12.5 V to the reset input, MCLR, while the test input is made high. This

is achieved by analogue switch U_{10D} switching on the supply voltage of the PIC17C42, and closing U_{10C} about 1 μs later to put the programming voltage on the reset input of the processor. Next, the programming operation is started.

PIC16C55/57
These processors come in 28-pin DIL enclosures, and differ only in respect of the size of their memory. Contrary to the PIC17C42, the PIC16Cxx devices do not require an external memory for the programming sequence — data is simply placed word-by-word into the PIC16Cxx by the controller in the programmer circuit.

Since the 28-pin socket is also used to program 18-pin PICs, a number of signals on the socket must be configurable. The connection with U_5, the main processor, is established by closing U_{10A}. At the same time, the connection with the programming voltage must be broken. This is achieved with the aid of switch U_{10B}.

The programming cycle is started as soon as the supply voltage and the programming voltage are applied to the
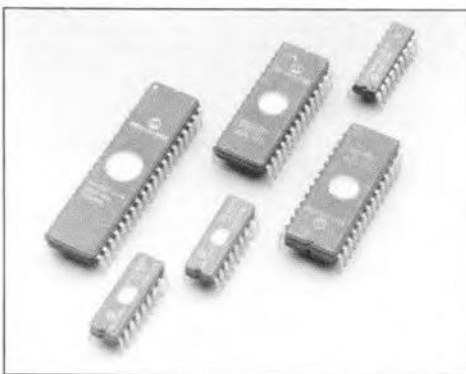
processor to be programmed. This is achieved with the aid of U_{10D} and U_{10C} respectively.

The programming algorithm used enables selected bytes to be programmed individually, and to be read back for verification. This allows the main microcontroller, U_5, to keep track of the complete programming sequence (which includes blank check, programming and verification) in a simple manner.

PIC16C54/56
For these controllers, the signal arrangement on the ZIF socket is modified. Switch U_{10A} is opened because pin 9 is to be used for the programming voltage. As with the 16C55/57, the supply voltage is applied to the socket via IC_{10D}, while U_{10B} connects the programming voltage. The programming algorithm is identical to that of the 16C55/57.

PIC16C71/84
These processors are programmed

using the same hardware settings as the PIC16C54/56, but a different programming algorithm. This is fairly complex, but fortunately we need not bother about that because everything is taken care of by the system software contained in the PIC17C42 (which is supplied ready-programmed through the Readers Services).

The analogue circuitry

Apart from digital circuitry, **Fig. 1** also shows a fair amount of analogue electronics. To begin with, there is a serial port based on the MAX232 single-chip RS232 interface. A big advantage of the MAX232 is its on-chip voltage converter which supplies the symmetrical voltages needed to comply with requirements as regards voltage swing on an RS232 link. This converter allows the programmer's power supply to be kept simple. Indeed, all that is needed is a standard 7805 which can easily supply the 50 mA or so drawn by the programmer. A heat-sink is not needed on the 7805.

The 7805 is powered by a mains adaptor with an output voltage between 15 V d.c. and 20 V d.c. The minimum value is required to ensure the proper programming voltage, while the maximum value must be observed to prevent the 7805 from being destroyed by a too high input voltage. The parts list mentions a 12-V mains adaptor. Most of these adaptors supply a considerably higher output voltage than the nominal value when the load current is relatively low. Just to make sure it is suitable for the job, the adaptor's output voltage should be checked with the programmer connected. If you use an adaptor with an internal regulator, be sure to set this for an output voltage between 15 and 20 V.

The desired programming voltage, Vprog, and the supply voltage, VDD, are regulated by the PWM1 and PWM2 outputs of the PIC17C42, U_5. These outputs are connected to two active second-order low-pass filters, and operate at a frequency of about 64 kHz. The roll-off frequency of the filters built from four opamps contained in an LM324, U_{13}, is set at about 1 kHz. The filtered output voltage has a value between 0 and 5 V depending on the duty factor of the PWM signal. Despite the simplicity of the filter sections, the direct output voltages are sufficiently stable, accurate and virtually free of ripple. The filter is followed by a d.c. amplifier wired for a gain of three. In this way, a variable output voltage of between 0 V and 15 V is obtained. In practice, VDD is usually between 4 V and 6.5 V, while VPROG lies between 12 V and 13.5 V. The output impedance of the opamps is low enough to

PIC PROCESSORS — PORTRAIT OF A FAMILY

Below is a short discussion of the block diagram of the generic PIC16C5x processor. For full data on all devices in the PIC family, consult the Microchip Technology data-books.

PIC16C5x

The PIC16C5x from Microchip Technology Inc. is a family of low-cost, 8-bit wide, fully static CMOS microcontrollers with on-chip EPROM. The core of the processor has a RISC structure, and has an instruction set of 33 instructions. A feature of the RISC structure is that the CPU is capable of executing one instruction per machine cycle, except the jump instructions, which take two machine cycles.

The 12-bit wide instructions have a very compact structure. Consequently, machine code generated for the PIC16C5x is claimed to be twice as compact as for other, comparable, 8-bit processors. Furthermore, PIC processors contain circuitry to reduce power drain and external component count of a complete system.

The internal power-on reset circuit and start-up timer ensure that the processor is properly initialized after the power supply is switched on. The usual hardware for this purpose may, therefore, be omitted.

A choice of four oscillator types is available, including a low-energy oscillator based on a crystal or a ceramic resonator, and an inexpensive RC oscillator. The EPROM versions of the PIC16C5x (indicated by the suffix JW) allow the user to select the oscillator type during the programming of the config-uration word. By contrast, the oscillator type selection is fixed by the manufacturer for OTP (one-time programmable) versions of the processor. The letters after the type number indicate which oscillators may be used with the processor. Extensions XT and HS indicate a crystal or a ceramic resonator; LP indicates a low-power oscillator; and RC

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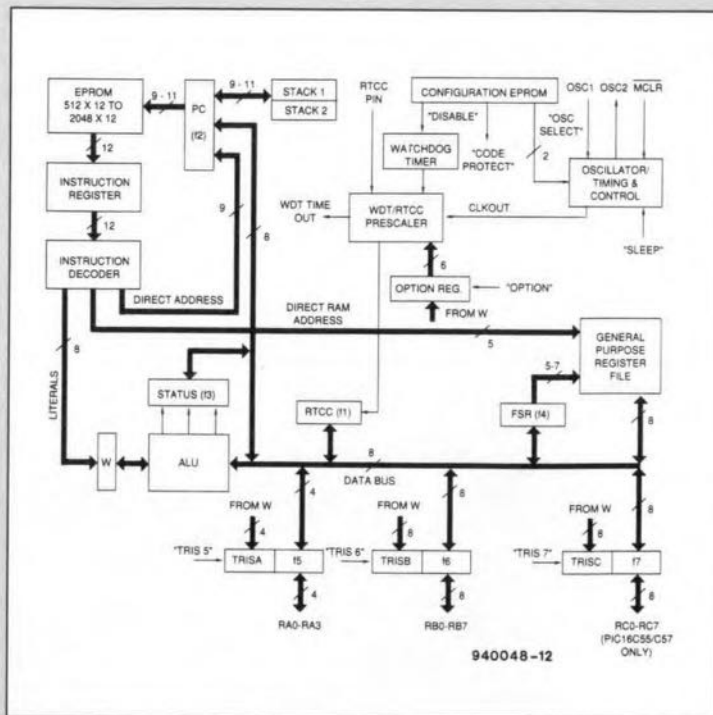
indicates a simple RC oscillator. The fourth oscillator option is the use of an already available clock signal, which may be used on all processors.

General specifications
Clock frequency: d.c. - 20 MHz
Instruction time: infinite to 200 ns
Instruction width: 12 bit
Bus width: 8 bit
EPROM memory: 512 - 2K × 12
Registers: 25 - 72 × 8 (SRAM)
Spec. func. registers: 7
Hardware stack: 2 levels
Addressing: direct, indirect and relative

I/O functions
I/O lines: 10 - 20
RTC/counter: 8 bit with 8-bit prescaler
Watchdog timer: internal, with RC oscillator
Protection: EPROM, via fuse
Energy reduction: via sleep mode

PIC16C71

This PIC processor is an up-graded derivative of the PIC16C5x. It features, among others, an integrated A-D converter. The processor handles 14-bit wide instructions, which are executed in one machine cycle. As with the 16C5x, two cycles are needed for a jump instruction. The processor recognizes four interrupt sources, and has an eight-level stack.

The on-chip A-D converter has four channels, a sample-and-hold function, and a resolution of 8 bits. The tolerance is ±1 LSB, while the complete conversion time is 30 µs.

General specifications
Clock frequency: d.c. - 16 MHz
Instruction time: infinite to 250 ns
Instruction width: 14 bit
Bus width: 8 bit
EPROM memory: 1K × 14
Registers: 36 × 8 (SRAM)
Spec. func. registers: 15
Hardware stack: 8 levels
Addressing: direct, indirect and relative

I/O functions
I/O lines: 13
RTC/counter: 8 bit with 8-bit prescaler
Watchdog timer: internal, with RC oscillator
A-D converter: 8 channels, 8-bit
Protection: EPROM, via fuse
Energy reduction: via sleep mode

PIC16C84

The PIC16C84 is also a static controller, only this type has an EEPROM program memory of 1K×14 and an EEPROM data memory of 64 bytes. Furthermore, the maximum clock frequency is lower than that of other PIC processors. In prac-

tice, a maximum of about 10 MHz is achieved, which results in a minimum machine cycle length of 400 ns.

General specifications
Clock frequency: d.c. - 10 MHz
Instruction time: infinite to 400 ns
Instruction width: 14 bit
Bus width: 8 bit
EPROM memory: 1K × 14
Registers: 36 × 8 (SRAM)
Spec. func. registers: 15
Hardware stack: 8 levels
Addressing: direct, indirect and relative

I/O functions
I/O lines: 10 - 20
RTC/counter: 8 bit with 8-bit prescaler
Watchdog timer: internal, with RC oscillator
Protection: EPROM, via fuse
Energy reduction: via sleep mode

PIC17C42

The 17C42 is largely similar to the other processors in the family. However, it has no fewer than 55 instructions, each of which is executed in one machine cycle. At a clock frequency of 16 MHz, a machine cycle lasts 250 ns. All op-codes are 16-bit wide, so that instructions can be packed in a single 'word'. This processor is capable of addressing a program memory of up to 64 K × 16. The internal program memory has a size of 2K × 16.

General specifications
Clock frequency: d.c. - 16 MHz
Instruction time: infinite to 250 ns
Instruction width: 16 bit
Bus width: 8 bit
EPROM memory: 2K × 16
Registers: 232 × 8
Spec. func. registers: 48
Hardware stack: 16 × 16
Pins: 40

I/O functions
I/O lines: max. 33
Interrupts: 11
16-bit counters/timers: 3
16-bit capture registers: 2
10-bit PWM outputs: 2
Serial ports: 1
RTC/counter: 8 bit with 8-bit prescaler
Watchdog timer: internal, with RC oscillator
Protection: EPROM, via fuse
Energy reduction: via sleep mode

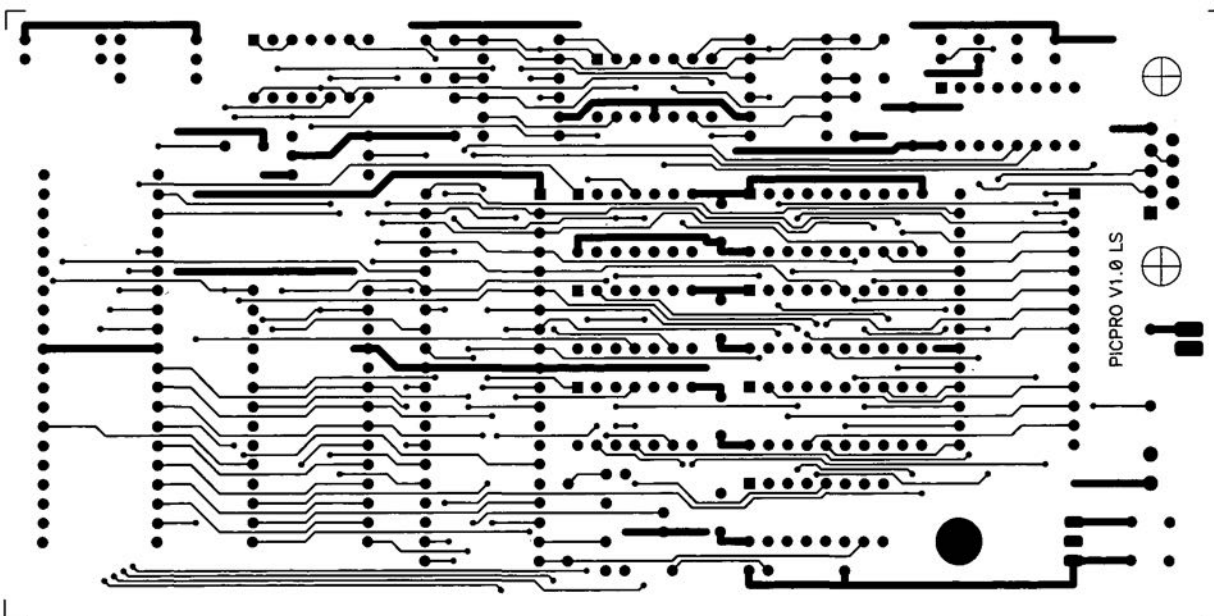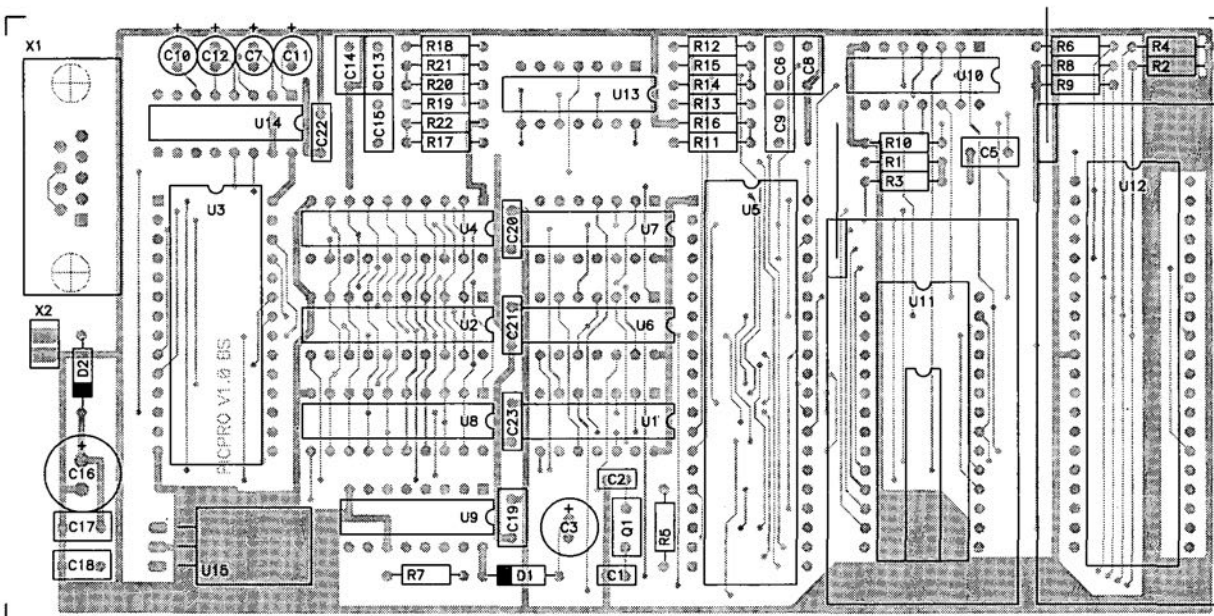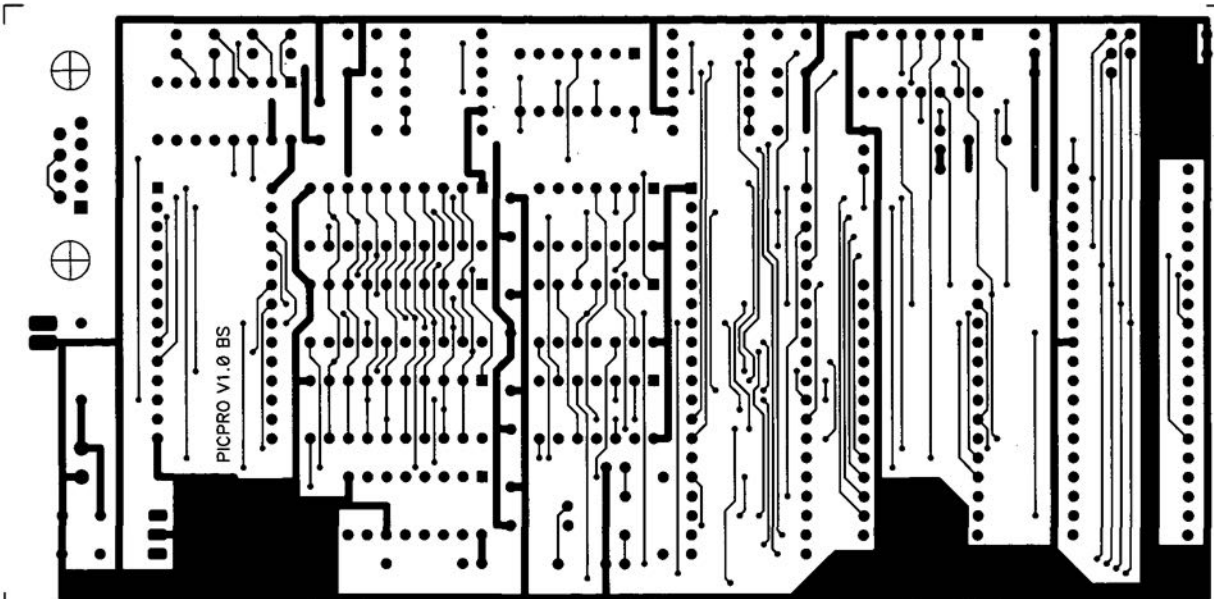| Type	EPROM	RAM	I/O	pins
PIC16C54	512x12	32x8	13	18
PIC16C55	512x12	32x8	21	28
PIC16C56	1Kx12	32x8	13	18
PIC16C57	2Kx12	80x8	21	28

Fig. 2. Track layouts (direct reading) and component mounting plan of the printed circuit board designed for the PIC programmer (PCB available ready-made).

COMPONENTS LIST

Resistors:
R1-R4;R6-R10 = 10kΩ
R5 = 270 Ω
R11;R12;R17;R18= 1MΩ
R13-R16;R19-R22 = 499kΩ 1%

Capacitors:
C1;C2 = 22pF
C3;C7;C10;C11;C12 = 10µF 16V (radial, pitch 2.5mm)
C5 = 22nF
C6;C9;C13;C15 = 220nF
C8;C14;C17-C23 = 100nF
C16 = 100µF 25V (radial)

Semiconductors:
D1 = 1N4148
D2 = 1N4007
U1 = 74HCT32
U2;U4;U8 = 74HC573
U3 = 62256 or 43256
U5 = PIC17C42 (order code 7161)
U6 = 74HC08
U7 = 74HC04
U9 = 74HC4040
U10 = 74HCT4066
U13 = LM324N
U14 = MAX232
U15 = 7805

Miscellaneous:
Q1 = 16MHz crystal.
X1 = 9-way sub-D socket, angled pins, PCB mount.
U11 = ZIF28 socket for wide and narrow ICs (e.g., ARIES, RS no. 403825).
U12 = ZIF40 socket (e.g., ARIES, RS no. 403831)
Printed circuit board and software package, order code 940048 (see page 70).
The project software (diskette and PIC17C42) is also available separately as order code 7161 (see page 70).
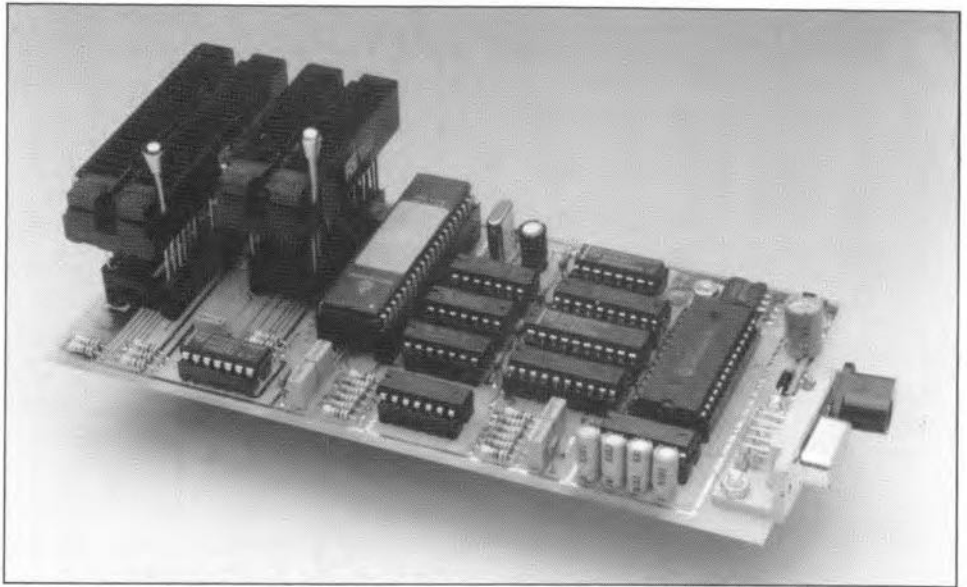

Fig. 3. Fully loaded printed circuit board before mounting in DB3 case.

short-circuits which can take hours to pinpoint and correct. The parts list and the component overlay on the PCB should enable you to populate the programmer board without problems. First, fit the passive components, taking good care to observe the polarity of the electrolytic capacitors. Have a good think about the ZIF sockets before you mount them. The idea is to make them protrude from the front panel of the plastic case. This is easily achieved by inserting the ZIF sockets into a stack of normal IC sockets. Alternatively, use wire-wrap sockets to enable the height of the ZIF sockets above the board to be trimmed accurately. The PCB is designed to fit into a type DB3 plastic enclosure from LTP. The advantage of this enclosure is that the PCB can be secured with the aid of two strips, which go round the problem of the absence of screw holes in the board.

The PIC17C42 (U5) is preferably fitted into an IC socket, so as to enable it to be replaced easily with an updated version. All other ICs may be soldered directly on to the PCB, although the use of IC sockets is recommended if you want to reduce fault-finding time.

Once all components are accommodated on to the board, the programmer may be connected to the PC's serial port. To keep this link as simple as possible, all necessary handshaking lines have been interconnected. The link is established by a 9-to-9 pin extension cable without crossed wires. If your PC has a 25-way serial port connector, use a 25-to-9 pin adaptor as supplied with many mouse packages.

Control software

The control software for the PIC programmer consists of two parts: (1) an MSDOS diskette containing the program to be run on a PC and (2) a ready-

programmed PIC17C42 which contains the program running on the programmer board. The software on the PC does all the communication with the programmer, and starts the necessary routines. Since the programmer board is also 'intelligent', the amount of traffic on the serial link is reduced to a minimum.

After starting the program PIC.EXE on the PC, you are first prompted to enter the PIC type to be programmed. Obviously, only types supported by the programmer can be selected. After the type selection, the program first displays the type of processor, the minimal and maximum supply voltage, the programming voltage, and the name of the file to be burned into the device. Also shown are the options contained in the configuration word. These options differ, depending on the PIC type selected. Finally, COM1: or COM2: allow you to select between these serial ports on your PC.

The file to be programmed into the PIC must already be present on the diskette or hard disk — it can **not** be generated by PIC.EXE. The file format and available instructions will be discussed in the 'PIC Programming Course' to be featured in future issues of this magazine. First, read the file using the 'File' menu option, and then program it by selecting the option 'Prog'. The configuration is burned into the processor by selecting the menu option 'Fuse'. Mind you, the oscillator type selection is fixed by the manufacturer, since it is hardware dependent. The 'Blank' option allows you to check whether the PIC to be programmed is empty. The function of 'Quit' is obvious. An overview of available commands may be called up by typing '?'. ∎

enable direct connection to the ICs to be programmed. The variable supply voltage is furnished by opamps U_{13a} and U_{13d}, and the variable programming voltage, by U_{13b} and U_{13c}. Note that the LM324 is supplied direct by the adaptor's output voltage.

Construction

The PIC programmer is simple to build on the double-sided, through-plated, printed circuit board of which the artwork is shown in **Fig. 2**. This board is best ordered ready-made through our Readers Services, and comes together with the PIC programmer's software package (MSDOS program diskette and PIC17C42). Solder carefully, and use solder tin sparingly. This prevents

FIGURING IT OUT

## PART 14 – VARYING INPUTS

By Owen Bishop

**This series is intended to help you with the quantitative aspects of electronic design:
predicting currents, voltage, waveforms, and other aspects of the behaviour of circuits.
Our aim is to provide more than just a collection of rule-of-thumb formulas.
We will explain the underlying electronic theory and, whenever
appropriate, render some insights into the mathematics involved.**

We continue the exploration of circuit modelling by extending it to deal with applied voltages or currents that vary in time. To model a circuit with both capacitive and inductive elements, we need a second-order differential equation. In Part 13 we showed that, if the elements are in series (**Fig. 118**) and the ap-
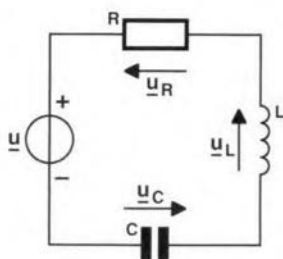
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Fig. 118

plied voltage is constant, the equation has the form:

$$\frac{d^2i}{dt^2}+\frac{R}{L}\frac{di}{dt}+\frac{1}{LC}\cdot i=0 \quad \text{[Eq. 94]}$$

But the right-hand side of the equation is zero only when we have made the simplifying assumption that the applied voltage is constant. This is an assumption that seldom can be made. More often, the voltage, u, varies in a regular manner. For example, it may ramp up or down at a fixed rate, it may vary sinusoidally, or it may increase or decrease exponentially. We need to be able to solve equations of the form

$$\frac{d^2i}{dt^2}+\frac{R}{L}\frac{di}{dt}+\frac{1}{LC}\cdot i=\frac{1}{L}\cdot\frac{du}{dt}$$

[Eq. 109]

in which u is a function of time. Part 13 shows how this equation is obtained. The form of the

equation for a parallel LCR circuit is similar (see Eq. 108 in Part 13). Remember that, although we are analysing only the simplest of series and parallel circuits, more complicated circuits can often be reduced to these cimple circuits by using the techniques of network reduction that we have discussed on several occasions in previous months.

Particular integral

Solving equations with the form of Eq. 109 is done in two stages. First we solve the equation as if the right-hand side equals zero. The method for doing this, based on the auxiliary equation, was described in Part 13. The result obtained is known as the **complementary function** (CF). At this stage we can say that:

complemetary function = 0.

Next, we need to find something else to include in the left-hand side of the equation, so that the right-hand side equals $(1/L)du/dt$. This 'something' is known as the **particular integral** (PI):

CF + PI = $(1/L)du/dt$.

An example shows how to find the particular integral. Suppose that in **Fig. 118**: $R = 500\ \Omega$, $C = 200\ \mu F$ and $L = 100\ mH$. Let u be a voltage that ramps up at a rate of $20t^2$. From these parameters, $R/L = 5000$; $1/LC = 50\ 000$; $(1/L)du/dt = 400t$. The modelling equation is:

$$\frac{d^2i}{dt^2}+5000\frac{di}{dt}+50\ 000i=400t$$

[Eq. 110]

To find the CF, put the right-hand side of Eq. 110 equal to

zero:

$$\frac{d^2i}{dt^2}+5000\frac{di}{dt}+50\ 000i=0$$

[Eq. 111]

The auxiliary equation of Eq. 111 is

$$m^2 + 5000m + 50\ 000 = 0.$$

Solving this by using the quadratic formula (Part 13), we find that it has real roots: $m_1 = -10.02$ and $m_2 = -4990$.
The CF is:

$$i = Ae^{-10.02t} + Be^{-4990t}$$

where A and B are arbitrary constants which can be determined if we are told two boundary conditions.

To find the particular integral, we assume that the right-hand side **of the solution** has the form:

$$i = Ct + D$$

where C and D are constants. If this is so, then:

$$di/dt = C$$

and

$$d^2i/dt^2 = 0.$$

Substituting these values in Eq. 110:

$$0+5000C+50\ 000(Ct+D)$$
$$=400t$$
$$\therefore\ 55\ 000Ct+50\ 000D=400t$$

[Eq. 112]

We solve this equation by looking at the coefficients of the powers of t. The highest power of t is t^1. On the left, its coefficient is 55 000C; on the right, its coefficient is 400. For Eq. 112 to be satisfied by all possible values of t, these coefficients must be

equal:

$$55\ 000C = 400$$
$$C = 400/55\ 000$$
$$= 7.27 \times 10^{-3}.$$

The coefficient of t^0 is D on the left. There is no term in t^0 on the right, so the coefficient is zero:

$$D = 0.$$

The PI is:

$$i = t(7.27 \times 10^{-3}).$$

The **complete** general solution is:

$$i = Ae^{-10.02t}+Be^{-4990t}$$
$$+t(7.27 \times 10^{-3})$$

[Eq. 113]

The first two terms in this general solution are like those obtained in Part 13 for a constant applied voltage. Now we have an additional term to allow for the fact that the voltage is ramping.

In this example we assumed that the right-hand side of the equation has the form $Ci + D$. This was based on the fact that on the right-hand side of Eq. 109 the highest power of t is t^1. If t is of higher power or there are

Form of RH side	Assumed function
k	C
kt	Ct + D
kt²	Ct² + D + E
k sin t	C cos t + D sin t
k cos t	
eᵏᵗ	Ceᵏᵗ

Box 1. Functions for particular integrals (k is a constant).

other functions of t, different assumptions are made. **Box 1** lists forms suitable for other cases.

We can now proceed, as usual, to find a particular solution (not to be confused with the particular integral). This is the solution obtained when two border conditions are satisfied. Let us assume that, when $t = 0$, $i = 0$. Also, when $t = 0.01$, $i = 1$ mA. Substituting the conditions for $t = 0$ in Eq. 113:

$$0 = A + B$$

$$\therefore\ B = -A.$$

The equation becomes:

$$i = Ae^{-10.02t} - Ae^{-4990t}$$
$$+ t(7.27 \times 10^{-3})$$
$$= A(e^{-10.02t} - e^{-4990t})$$
$$+ t(7.27 \times 10^{-3})$$

[Eq. 114]

Substituting in Eq. 114 the values when $t = 0.01$:

$$0.001 = A(e^{-0.1002} - e^{-49.9})$$
$$+ 7.27 \times 10^{-5}$$
$$= 0.9047A + 7.27 \times 10^{-5}$$

and

$$A = (0.001 - 7.27 \times 10^{-5})/0.9047$$
$$= 0.001025.$$

Substituting these values in Eq. 114, we obtain the particular solution:

$$i = 0.001025(e^{-10.02t} - e^{-4990t})$$
$$+ t(7.27 \times 10^{-3})$$

[Eq. 115]

The graph of Eq. 115 for $0 < t < 0.01$ appears as **Fig. 119**. It shows the rapid increase of current; this is necessary in order to meet the condition that $i = 1$ mA when $t = 0.01$ s. Remember that when we specified that $i = 0$ when $t = 0$, this only means that i is zero **at that instant**. In actuality, it is passing through zero at that instant to reach a relatively high level soon after. Specifying zero current at zero time does not mean that there is no charge on the capacitor and no magnetic flux in the inductor. These must have been present as the result of a voltage applied to the circuit before $t = 0$. This is why the current increases so rapidly. However, the effects of this die away and the current begins to decrease. After about 10 ms, the circuit begins to show the effects of the new voltage ramping up from 0 V at $t = 0$. The effects of this are better shown on the right of **Fig. 119**, which is
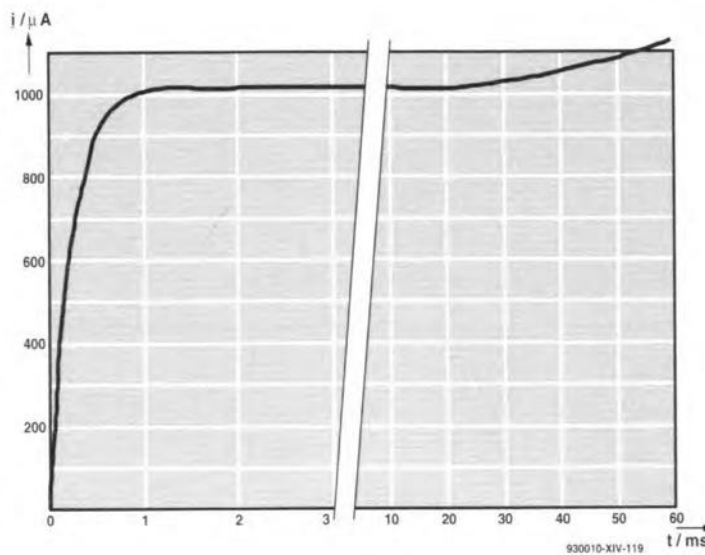

Fig. 119

plotted on a longer time scale. We can see that the current increases steadily, keeping pace with the upwardly-ramping applied voltage.

To simulate the conditions in which the current begins with no charge on the capacitor and no flux in the inductor, we make the first border condition $i = 0$ when $t = 0$ as before. The second condition is that $di/dt = 0$ when $t = 0$. In words, the current is constant at zero when $t = 0$. This makes B = $-$A as before and we obtain Eq. 114. Differentiating Eq. 114:

$$\frac{di}{dt} = A(-10.02e^{-10.02t}$$
$$+ 4990\,e^{-4990t}) + 7.27 \times 10^{-3}$$

Inserting the second border condition:

$$0 = A(-10.02 + 4990) + 7.27 \times 10^{-3}$$

and

$$A = (7.27 \times 10^{-3})/4979.8$$
$$= 1.46 \times 10^{-6}.$$

The particular equation is:

$$i = (1.46 \times 10^{-6})(e^{-10.02t} - e^{-4990t})$$
$$+ t(7.27 \times 10^{-3}).$$

It can be seen that, because A is so small, the final expression dominates the equation. Current increases at the rate of 7.27 mA per second without the appre-

ciable initial 'kick' of **Fig. 119**.

Operator D

Before we model any further circuits, we will look at a technique that often simplifies finding the solution of differential equations. This method is based on a different way of symbolizing differentiation. Instead of writing di/dt, we write Di. D is not a quantity or variable, but an **operator**, which means 'differentiate'. We usually refer to it as **operator D**. We are using it to represent differentiation of i with respect to t, but it can be used for any other pair of variables, for example x and y. Using this symbol, $Dx^3 = 3x^2$. The rules of differentiation apply exactly as usual.

The idea of D is extended to differentiating a differential. We obtain the second differential:

$$D(Di) = D^2 i = \frac{d^2 i}{dt^2}$$

Similarly, we have the reverse operation, represented by the symbol 1/D, which means 'integrate':

$$x^4/D = x^5/5.$$

Note that we do not introduce the constant of integration when we are working with D.

Representing Eq. 109 in terms

of operator D gives:

$$D^2 i + \frac{R}{L} \cdot Di + \frac{1}{LC} \cdot i = u$$

[Eq. 116]

Now comes the interesting point about D. Although we have said it is **not** a variable, it can be shown that it can be manipulated in equations and behave as if it were a variable. For example, we can factorize the left-hand side of Eq. 116:

$$(D^2 + \frac{R}{L} \cdot D + \frac{1}{LC}) \cdot i = u$$

There is no advantage in using operator D with such an equation, which is easy enough to solve by the method used above. Operator D really comes into its own when we are modelling circuits in which input voltages vary sinusoidally (or cosinusoidally) or exponentially. For example, consider a series LCR circuit as in **Fig. 118**, but with the following values: $R = 1.5\ \Omega$, $C = 1$ F and $L = 0.5$ H. The input voltage, $u = -(\cos 3t)/6$, is sinusoidal. Calculating coefficients gives: $R/L = 3$ and $1/LC = 2$. Differentiating u and dividing by L produces $\sin 3t$. The equation modelling this circuit is:

$$\frac{d^2 i}{dt^2} + 3\frac{di}{dt} + 2i = \sin 3t$$

[Eq. 117]

When using operator D, we first find the complementary function in the usual way. The auxiliary equation is:

$$m^2 + 3m + 2 = 0.$$

Although we nearly always need to use the quadratic formula to solve this equation, there are cases like this one in which it factorizes easily:

$$(m + 1)(m + 2) = 0,$$

so that $m_1 = -1$ and $m_2 = -2$. Both roots are real and so the CF is:

$$i = Ae^{-t} + Be^{-2t}.$$

We make use of operator D for finding the particular function.

The advantage of D is that there are three very helpful theorems associated with it. Their proofs are rather lengthy, so we do not have space here to explain them. The theorems are stated in **Box 2**. They look rather obscure, but they are easy to use as will be shown by this example. First, rewrite Eq. 117 in terms

---

1. $F(D)\,e^{ax} = e^{ax}\,F(a)$

2. $F(D)\{e^{ax} f(x)\} = e^{ax}\,F(D + a)\,f(x)$

3a. $F(D^2) \sin ax = F(-a^2) \sin ax$

3b. $F(D^2) \cos ax = F(-a^2) \cos ax$

Box 2. Operator D theorems.

of D:

$$D^2i + 3Di + 2i = \sin 3t.$$

Factorizing:

$$(D^2 + 3D + 2)i = \sin 3t,$$

whence

$$i = \frac{1}{D^2 + 3D + 2} \cdot \sin 3t$$

Notice how we move the terms in D across from one side of the equation to the other, just as if they were variables. Now look at Theorem 3a in **Box 2**. This tells us that, if we have a function of D which includes D^2, and this is multiplied by sin ax (in which a is a constant), we can replace D^2 by $-a^2$. In this example, we have t as the variable instead of x. The constant a is equal to 3, so we replace D^2 by -3^2, which is -9:

$$i = \frac{1}{-9 + 3D + 2} \cdot \sin 3t$$

$$= \frac{1}{3D - 7} \cdot \sin 3t$$

Having eliminated the D^2, it remains for us to eliminate the D. We juggle with the fraction on the right, multiplying top and bottom by 3D + 7:

$$i = \frac{3D + 7}{(3D - 7)(3D + 7)} \cdot \sin 3t$$

$$= \frac{3D + 7}{9D^2 - 49} \cdot \sin 3t$$

Once again, we have D^2 in the denominator, so we use Theorem 3a again and replace D^2 with -9:

$$i = \frac{3D + 7}{-81 - 49} \cdot \sin 3t$$

$$= -(3D + 7) \cdot \sin \frac{3t}{130}$$

$$= \frac{-(3D \sin 3t + 7 \sin 3t)}{130}$$

The term 3D sin $3t$ means 'three times the differential of sin $3t$', which equals 9 cos $3t$ and the PI becomes:

$$i = \frac{-(9 \cos 3t + 7 \sin 3t)}{130}$$

Thus, the general solution (CF + PI) is:

$$i = \frac{Ae^{-t} + Be^{-2t} - (9\cos 3t + 7\sin 3t)}{130}$$

[Eq. 118]

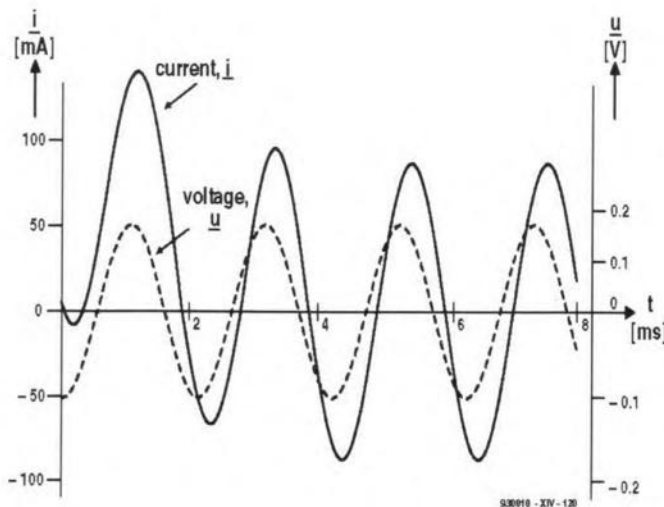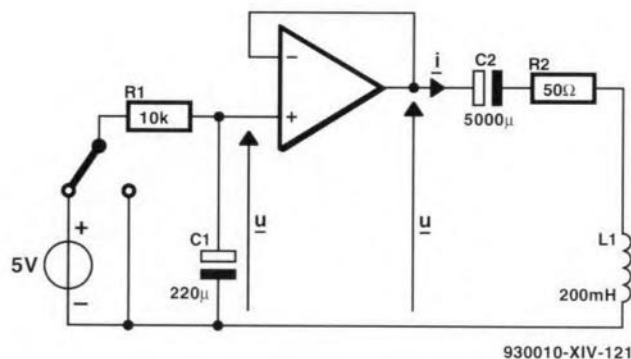Eq. 118 has two arbitrary constants so it can be solved, given

Fig. 120

Fig. 121

two border conditions. **Fig. 120** shows the graph of the solution, given $i = 0$ and di/d$t = 0$ at $t = 0$. Note how the curve begins with zero gradient (di/d$t = 0$). After the initial upsurge, the current settles down to a sinusoidal form, symmetrical about the x-axis, and lagging slightly behind the input voltage.

Exponential input

In **Fig. 121** the input to the operational amplifier rises exponentially. The opamp is a voltage follower, so the input to the LCR circuit follows the same curve. The switch is set to charge C_1 to 5 V. When $t = 0$, the switch is set to discharge C_1. It can be shown by the methods described in Part 12 that:

$$u = 5e^{-0.4545t}.$$

The coefficients for the equation modelling the LCR circuit are

$R/L = 250$ and $1/LC = 1000$. The equation is:

$$\frac{d^2i}{dt^2} + 250 \cdot \frac{di}{dt} + 1000i$$

$$= -11.3625e^{-0.4545t}$$

[Eq. 119]

The auxiliary equation is:

$$m^2 + 250m + 1000 = 0$$

and its roots are $m_1 = -4$ and $m_2 = 246$ (approximately). The CF is:

$$i = Ae^{-4t} + Be^{-246t}.$$

As before, we use D to find the PI. Writing Eq. 119 in terms of D:

$$(D^2 + 250D + 1000)i$$
$$= -11.3625e^{-0.4545t}$$

$$i = \frac{-11.3625e^{-0.4545t}}{D^2 + 250D + 1000}$$

Theorem 1 is the appropriate choice since the right-hand side of Eq. 119 is simply an exponential term involving t only in the index of e. To apply the theorem, we have only to write the exponential term as it stands, but to replace D by a. This makes the calculation easier than the previous example. In this example, a = -0.4545, so we find:

$$i = \frac{-11.3625^{-0.4545t}}{-0.4545^2 + 250 \times -0.4545 + 1000}$$

$$= -0.0128e^{-0.4545t}$$

This is the PI. Adding this to the CF, we obtain the complete solution:

$$i = Ae^{-4t} + Be^{-246t}$$
$$+ (-0.0128e^{-0.4545t})$$

Given two border conditions, we can find A and B in the usual way and so obtain the particular solution.

This month, we have modelled only series LCR circuits, but parallel circuits can be modelled in a very similar way and solved using operator D.

[To be continued]

Test yourself

1. Given the complete solution of Eq. 118 and the border conditions that $i = 0$ and di/dt = 0 when $t = 0$, find the particular solution.

2. Given the complete solution of Eq. 119 and the border conditions that $i = 0$ when $t = 0$, and $i = 10$ mA when $t = 100$ ms, find the particular solution and calculate i when $t = 250$ ms.

3. Given a circuit as in **Fig. 118**, with $R = 100 \Omega$, $C = 2000$ μF, $L = 10$ mH, and $u = 0.08e^{0.5t}$, write the modelling equation and the general solution. Given that when $t = 0$, $i = 0$ mA and di/d$t = 4$ A s^{-1}, find the particular solution. Calculate the current when $t = 100$ ms.

Answers to Test yourself (Part 13)

1. $i = -0.01e^{-2500t} \cos 9354t - 0.03457e^{-2500t} \sin 9354t$. Underdamped. At 0.0008 s, $i = -4.85$ mA.

2. $i = 1.0097e^{-9.1t} - 0.9097e^{-9990.9t}$. After 0.5 ms the current peaks at 1 A, then falls to 0.406 A at 100 ms. It falls to 0.01 A after 255 ms.

DIRECT CONVERSION RECEIVERS (PART 1)

SOME NOTES ON DESIGN AND CONSTRUCTION TECHNIQUES

The direct conversion or synchrodyne receiver was invented several decades ago, but only with the advent of modern semiconductor technology has it come into its own as a viable design alternative. Although most designs are intended for novices, and lack certain features of high-grade superheterodyne receivers, the modern direct conversion receiver (DCR) is capable of exciting performance.

By Joseph J. Carr, B.Sc., MSEE

A case can be made for the assertion that the modern DCR is capable of performing as good as many middle grade communications receivers. Although that assertion may seem very bold indeed, the results of my literature search and experience building several different models bears it out. While no one, least of all this author, would represent the DCR as capable of the best possible performance, modern designs are no longer in the hobbiest curiosity category. In this two-part article you will find the basic theory of operation, some of the appropriate circuits, and some of the actual designs tried on the workbench.

Basic theory of operation

The DCR is similar to the superheterodyne in underlying concept: the receiver radio frequency (RF) signal is translated in frequency by nonlinear mixing with a local oscillator (LO) signal ('heterodyning'). **Figure 1** shows the basic block diagram for the 'front end' of both types of receiver. The mixer is a nonlinear element that combines the two signals, F_{RF} and F_{LO}. The output of the mixer contains a number of different frequencies that obey the relationship:

$$F_o = m F_{RF} \pm n F_{LO} \qquad [1]$$

Where:
F_o is the output frequency;
F_{RF} is the frequency of the received radio signal;
F_{LO} is the frequency produced by the local oscillator;
(All frequencies in same units).
m and n are integers (0, 1, 2, 3, ...).

All frequencies other than F_{RF} and F_{LO} are **product frequencies**. In general, we are only interested in the cases where m and n are either 0 or 1, so the output frequency spectrum of interest is limited
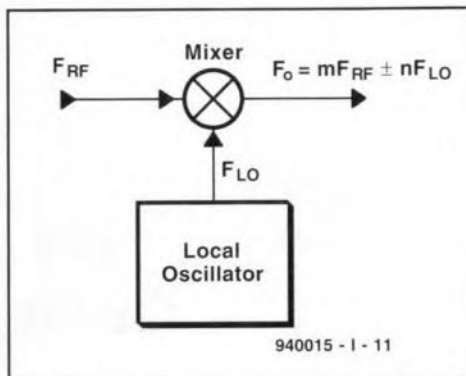
Fig. 1. Block diagram of the heterodyne frequency conversion circuit that forms the basis of both the superheterodyne and direct conversion receivers (DCR). In the DCR, $F_{LO} = F_{RF}$.

to F_{RF} and F_{LO} plus the product frequencies $(F_{RF}+F_{LO})$, and $(F_{RF}-F_{LO})$. The latter two are called **sum** and **difference intermediate frequencies** (IF). Other products are certainly present, but for purposes of this discussion are regarded as negligible.

In a superheterodyne radio receiver, a tuned bandpass filter will select either the sum IF or the difference IF, while rejecting the other IF, the LO and RF signals. Most of the gain (which helps determine sensitivity) and the selectivity of the receiver are accomplished at the IF frequency. In older receivers it was almost universally true that the difference IF frequency was selected (455 KHz and 460 KHz being very common), but in modern communications receivers either or both might be selected. For example, it is common to use a 9-MHz IF amplifier on high frequency (HF) band shortwave receivers. On bands below 9 MHz, the sum IF is selected while on bands above 9 MHz the difference IF is selected. A popular combination on amateur radio receivers uses a 9-MHz IF combined with a 5 to 5.5-MHz variable frequency oscillator. To receive the 75/80-meter band (3.5 to 4.0 MHz), the sum IF is used. The same combination of LO and IF frequencies will also receive the 20-meter (14.0 to 14.4 MHz) band if the difference IF (i.e., 14.0–5 = 9 MHz) is used.

In a DCR, on the other hand, only the difference IF frequency is used (see **Fig. 2**). Because the DCR LO operates at the same frequency as the RF carrier, or on a nearby frequency in the case of CW
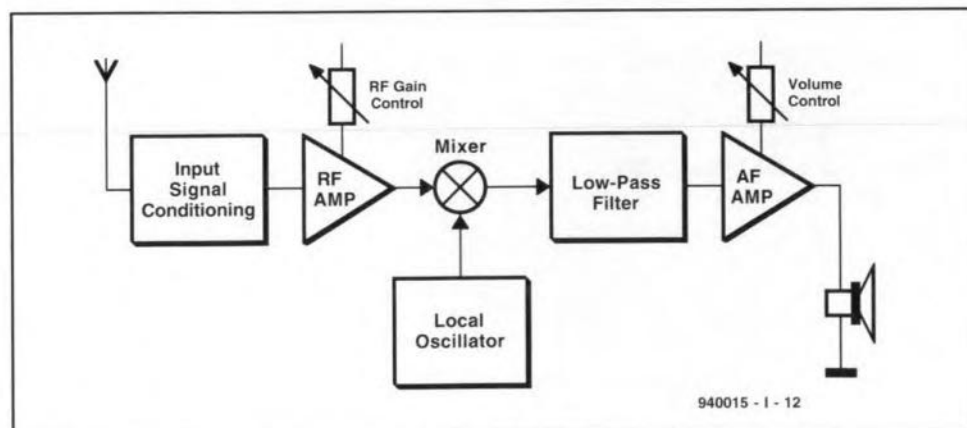
Fig. 2. Block diagram of a generic direct conversion receiver.

and SSB reception, the difference frequency represents the audio modulation of the radio signal. Amplitude modulated (AM) signals are accommodated by zero-beating the LO to the radio signal signal making $F_{LO} = F_{RF(carrier)}$. Thus, only the recovered upper and lower sidebands will pass through the system, and they are at audio frequency.

For CW signals (morse code on-off telegraphy), and single sideband signals, it is necessary to offset the LO frequency slightly to recover the signal. For the CW case one must select a comfortable tone (which is an individual preference). In my own case, I am most comfortable using an 800-Hz note when copying CW, so will offset the LO from the RF by 800 Hz. For example, when copying a CW signal at, say, 3650 KHz, the LO will be tuned to either 3649.2 KHz or 3650.8 KHz. In either case, the beat note heard in the output is 800 Hz. Single sideband (SSB) reception requires an offset of the order of 1.8 to 2.8 KHz for proper reception.

As was true in the superheterodyne receiver, most of the gain and selectivity in the DCR is provided by the stages after the first mixer. While the superheterodyne uses the IF amplifier chain for this purpose, followed by second detection and audio amplification, the DCR must use only the audio amplifier chain. Thus, it becomes necessary to provide some very high gain audio amplifiers and audio bandpass filtering in the DCR design.

One implication of DCR operation is the lack of single signal operation. Both CW and SSB signals will appear on **both** sides of the zero-beat point ($F_{RF}=F_{LO}$ exactly). While this feature can be a problem, it has at least one charming attribute on SSB reception: the DCR will receive LSB signals on one side of zero-beat and USB signals on the other side of zero-beat. There have been attempts to provide single-signal reception of SSB signals on DCRs[1] by using audio and VFO phasing circuits (in the manner of the phasing method of SSB generation). That approach greatly increases the complexity of the receiver, which may make other design approaches more reasonable than DCRs.[2]

The most basic implementation of the DCR (**Fig. 2**) required only a mixer stage, a local oscillator and an audio amplifier. In fact, if the mixer has a high enough output signal level, and high impedance earphones are used to detect the audio, some designs can make do without the audio amplifier. These are, however, a rarity and the one version that I tried did not work very well.

In some DCR designs, there will be optional RF input signal conditioning consisting of either a low-pass filter, high-pass filter, or bandpass filter (as appropriate) to select the desired signal or reject undesired signals. Without some
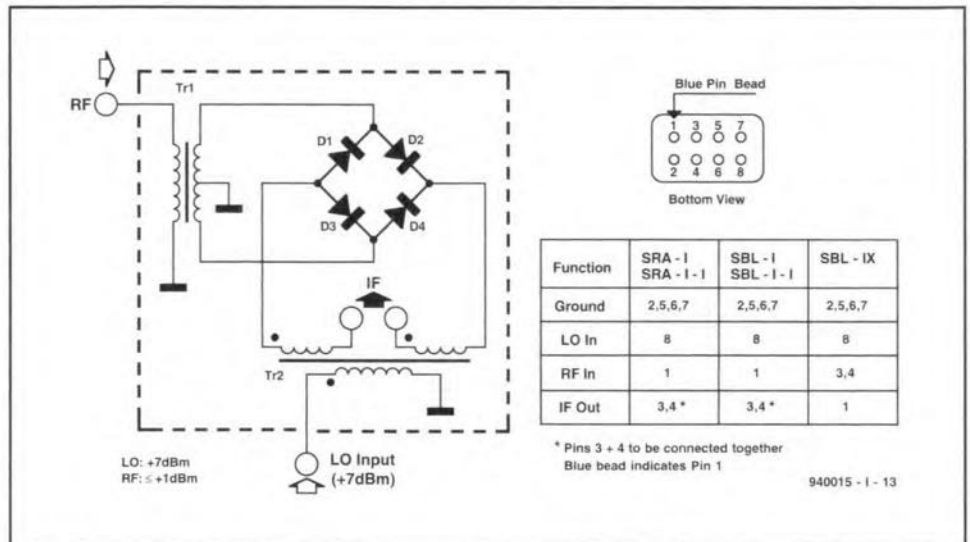

Fig. 3. Internal circuit of the SRA-1 and SBL-1 passive double balanced mixers. Inset shows pin-outs on device package.

frequency selection at the front end, the mixer is wide open with respect to frequency, and may be unable to prevent some unwanted signal, or spurious combinations of signals, from entering the receiver circuits. Some designs will include more than one style of filter. For example, a popular combination uses a single staged tuned resonant circuit at the input of the mixer to select the RF signal to be received and a high-pass filter — with a cut-off frequency, F_{co}, of 2,200 KHz — which is designed to exclude AM broadcast band signals. The reason for such an arrangement is that the AM signal may be quite intense, being of local origin, and is therefore capable of overriding the minor selectivity provided by the tuned circuit.

The RF amplifier used in the front-end is also optional, and is used to provide extra gain, and possibly some selectivity. The gain is needed to overcome losses or inherent insensitivity in the mixer design. Not all mixers require the RF amplifier, so it is frequently deleted in published designs. In general, RF amplifiers are used only in DCRs operating above 14 MHz. Below 14 MHz, signals tend to be relatively strong and man-made noise tends to be much stronger than inherent mixer noise.[3]

Mixer circuits

The principal element in any direct conversion receiver (DCR) is the mixer. The mixer is a nonlinear circuit that exhibits changes of impedance over cyclical excursions of the input signals. When mixing linear, one signal will ride on the other as an algebraic sum, but the product frequencies are not generated. A mixer that produces product frequencies can be used either in DCRs or superheterodyne receivers. In superheterodyne receiver terminology it is common to call the frequency translation mixer that produces the IF a **first detector**, and the

mixer that recovers the audio modulation either a product detector or **second detector**, even though the same type of circuit can be used for both cases.

There are any number of mixer circuits used in radio receivers, and most of them are candidates for use in direct conversion receivers. As you will see, however, not all mixers are created equal, so some are better suited to DCR applications than others. In nearly all cases, the output circuit of the mixer will be a low-pass filter that passes audio frequencies, but not RF frequencies.

Two issues seem to predominate mixer selection: **sensitivity** and **dynamic range**. The former determines how small a signal can be detected, while the latter determines the ratio between the minimum detectable signal and the maximum detectable signal. There are some passive mixers that produce so much loss, so much noise and require so much signal strength to operate in the first place that they are simply not suited to DCR design unless adequate preamplification is provided. Such detectors can sometimes be put to good use in superheterodyne receivers because they are preceded by the gain of the front-end and the IF amplfier chains, which can be considerable.

There are two issues that must be accounted for when selecting or building the mixer element of the DCR. First, there is always the possibility of radiation of the local oscillator (LO) signal through the antenna. In order to prevent this problem, it is necessary to keep the mixer unilateral, i.e. signal flowing only in one direction. Some mixers are inherently good in this respect, while others are a bit problematical. In cases where LO radiation might occur it is recommended that an RF amplifier be used ahead of the mixer, regardless of whether or not it is needed for purposes of improving sensitivity.
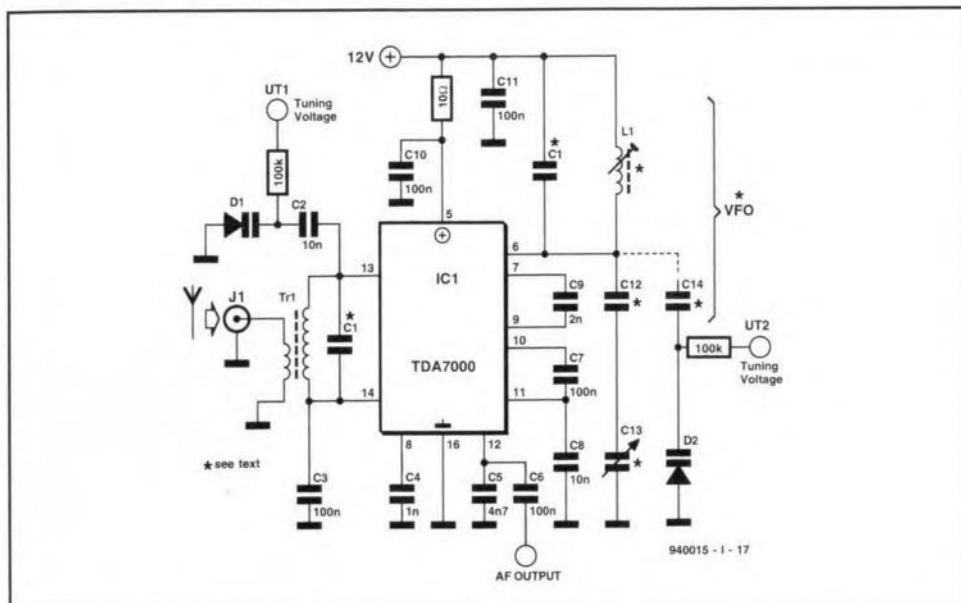
The second problem that must be rec-

Fig. 4. Balanced mixer based on the CA-3028A IC device.

ognized is transmission of the RF or LO signals to the output of the mixer. Many forms of mixer are particularly bad in this respect, while others are considerably better. Theoretically any mixer can be used for the front-end of the DCR, however, the simple halfwave rectifier diode envelope detectors are not at all recommended.

Perhaps the best passive form of mixer is the **double balanced mixer** (DBM) of **Fig. 3**. This circuit provides superior suppression of the LO and RF signals in the output, leaving only the sum and difference IF frequencies. This type of mixer uses the same sort of diode ring circuit as the single balanced mixer discussed above, but adds a second transformer to the circuit for the RF signal. In this circuit, the LO signal is driven in push-pull across two opposite nodes of the diode ring, while the RF signal drives the alternate nodes in push-pull.

All of these diode mixers can be made with either hot carrier diodes (preferred) or ordinary silicon small-signal or switching diodes (those in the 1N914 and 1N4148 class are suitable). In either case, performance is improved if the diodes are matched. While matching is best done on an oscillographic curve tracer, silicon switching diodes can be crudely matched by comparing forward

and reverse resistance readings obtained with an ohmmeter. Although not an optimal match, the resistance matching scheme results in superior performance over randomly selecting the diodes.

One of the most popular forms of commercial DBM is the **Mini-Circuits** (P.O. Box 166, Brooklyn, NY, 11235, USA; phone 718-934-4500) SRA-series and SBL-series devices. The pin pattern for the shielded case of these mixers is shown as an inset to **Fig. 3**, while the pin assignments are shown in the associated table. Note that pin 1 is indicated by a blue bead insulator around the pin, while the other pins will have a different color. Also, on the top of the mixer case the letters 'MCL' appear (which is the manufacturer's logo), and the 'M' is positioned directly above pin 2. These mixers are used in many published DCR designs, where they have proved an excellent choice. They are designed for 50-Ω input and output impedances, so are relatively easy to match with tuned circuits and *LC* filters. The RF signal must be kept at +1 dBm or below, while the LO signal must be around +7 dBm. At an impedance of 50 Ω, the +7-dBm signal level represents about 5 mW, or 500 mV$_{rms}$ (1.4 V$_{pp}$).

An active mixer can be built with any of several different integrated circuits, or their discrete equivalents. One approach uses analog multiplier circuits, while another uses simple differential amplifier circuits. The mixer of **Fig. 4** is based on the CA-3028A differential IF/RF amplifier IC. The differential input impedance (pins 1 to 5) is of the order of 1 kΩ, while the differential output impedance (pins 6 to 8) is 8 kΩ. For an input circuit, therefore, a transformer is needed that converts the antenna impedance (typically 50 Ω) to 1000 Ω. This transformer can have a tapped primary that matches

50 Ω at the tap, while still providing tuning action to select input signals. The output network consists of an audio transformer with a 10-kΩ primary and a lower impedance secondary. The audio output of this circuit is quite low, despite being an active circuit, so it must be followed by considerable audio gain (80 to 100 dB).

Considerations for good DCR designs

It probably does not surprise many readers that there are some principles of good design that result in superior DCR performance. Some of these principles were discussed by Campbell[3] and others[4]. Even relatively simple DCR designs, including those based on the Signetics NE602 integrated circuit double balanced modulator[5] and the popular LM386 audio amplifier, have proven to be very sensitive and free of hum and microphonics, even though that combination is not without critics. Dillon's design, which was tested in the laboratories of the American Radio Relay League (ARRL), proved remarkably free of the problems often associated with simple DCR designs.[6]

One method for terminating the mixer is to place a resistor-capacitor (*RC*) network across the IF OUT terminals of the mixer and ground (see **Fig. 5**). The SBL-1 is designed for 50 Ω input and output impedances, so the device is terminated in it characteristic impedance at RF frequencies by the 51-Ω resistor (R1). Because capacitor C$_1$ has a value that produces a high reactance at audio frequencies (AF), and a low reactance at RF, the mixer is terminated for any residual LO and RF signal (which are absorbed by R$_1$), but AF is transmitted to the low-pass filter.

Fig. 5. Block diagram of mixer output circuit used in direct conversion receivers.

Fig. 6. Direct conversion H.F. receiver using the NE602 and LM386 integrated circuits.

Fig. 7. Direct conversion receiver based on the TDA7000 integrated circuit.

Some practical design approaches

The NE602 type of DCR is relatively easy to build, and provides reasonable performance for little effort. The NE602 chip is relatively easy to obtain, and for the most part is well behaved in circuits (i.e. it does what it is supposed to do). It has about 20 dB of conversion gain, so can help overcome some circuit losses, and reduces slightly the amount of gain required of the audio amplifier that follows. The NE602 can provide very good sensitivity, on the order of 0.3 µV is relatively easy to obtain, but lacks something in dynamic range. Although the specifications of the device allow it to accept signals up to –15 dBm, at least one source recommended a maximum signal level of –25dBm[7]. At higher input signal levels, the NE602 tends to fall apart.[8] The newer NE612 is basically the same chip, but has improved dynamic range. While I have not personally tried the newer variety, it is reputed to be a greatly improved device compared to the NE602.

The Dillon design shown in **Fig. 6** uses the push-pull outputs of the NE602 (i.e. both pins 4 and 5), and is superior to the single-ended variety. According to Dillon, the balanced output approach improves the performance, especially in regard to AM BCB breakthrough. Also helping the breakthrough problem is the use of a 47-nF capacitor across the output terminals of the NE602.

Daulton takes exception to the use of the NE602 as the DCR front-end, and prefers instead to use the TDA7000 chip. While functionally similar to the NE602, the TDA7000 is more complex and is said to deliver superior performance with respect to dynamic range and signal overload characteristics. **Figure 7** shows a DCR front-end circuit based on the TDA7000 after Daulton's design. This

circuit uses the same balanced front-end as other designs and, like the typical NE602 design, uses the internal oscillator for the variable frequency oscillator (VFO). The circuit following this front-end should be of the sort typically found in the NE602 designs. This particular variant uses the internal operational amplifiers of the TDA7000 to provide active bandpass filtering.

Figure 8a shows the passive diplexer used by Campbell[9]. It consists of several inductor, resistor and capacitor elements that form both low-pass and high-pass filter sections. The values of the inductors (L_1, L_2 and L_3) are selected with their d.c. resistance in mind, so it is important to use the originally specified components, or their **exact** equivalents in replicating the project. Campbell used Toko Type 10RB inductors: L_1 is a 181LY-392J, L_2 a 181LY-273J and L_3 a 181LY-273J.

The matched 50-Ω audio preamplifier is shown in **Fig. 8b**, and is an improved version of the Lewallen circuit. According to Campbell, this circuit provides about 40 dB of gain, and offers a noise figure of about 5 dB. The range of input signals that it will accommodate ranges from about 10 nV to 10 mV, without undue distortion. These specifications make the amplifier a good match to the DBM. Like the Lewallen circuit, the Campbell circuit uses a grounded base input amplifier (T_1), and an active decoupler (T_2). But Campbell also adds an emitter follower/buffer amplifier (T_3).

A set of three passive audio filters, which can be switched into or out of the circuit, is shown in **Fig. 8c**. These filters are designed for termination in an impedance of 500 Ω. Three different band-passes are offered: 1 KHz, 3 KHz and 4 KHz. The 4-KHz filter is a fifth order Butterworth design, while the 3-KHz filter is a seventh order elliptical design after Niewiadomski[10]. The 1000 Hz de-
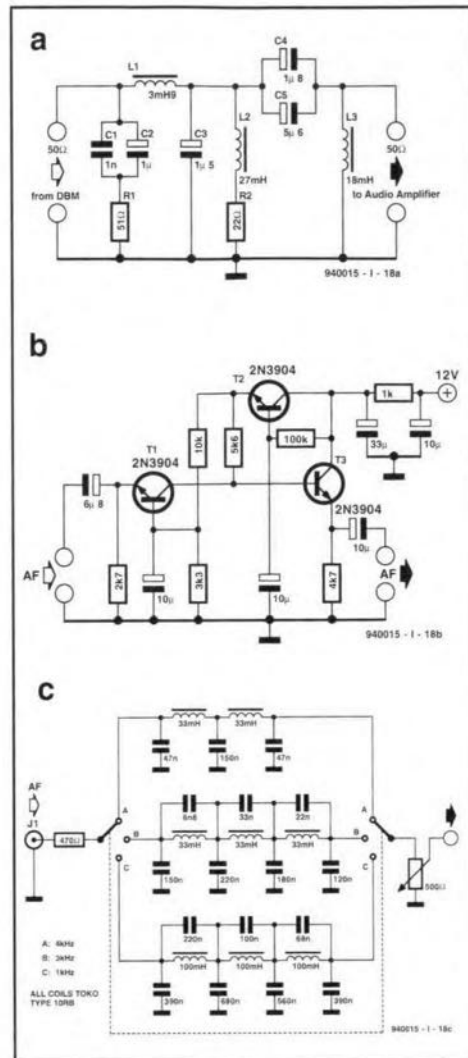

Fig. 8. a) Diplexer circuit used to terminate the mixer and filter the audio; b) audio preamplifier for direct conversion receiver; c) audio bandpass filters with three switch selectable bandpass characteristics.

sign is scaled from the 3000 Hz design. Campbell claims that these filters offered a shape factor of 2.1:1, with an essentially flat passband "...with rounded corners, no ripple and no ringing."

Campbell implied the use of switching, as shown in **Fig. 8c**, but did not actually show the circuitry. As shown here, the switching involves use of a pair of ganged SP3P rotary switches. In a short time in the future I will be working on a PIN diode switched variant for a different purpose, and see no immediate reason why it shouldn't work.

A complex DCR was designed by Breed, and reported in the amateur radio literature as a direct conversion single sideband receiver.[1] The single sideband (SSB) mode is properly called **single sideband suppressed carrier amplitude modulation**, for it is a variant of AM that reduces the RF carrier and one of the two AM sidebands to negligible levels. This mode is used in HF transmissions because it reduces the bandwidth required by half, and removes the carrier that produces heterodyne squeels on the shortwave bands.
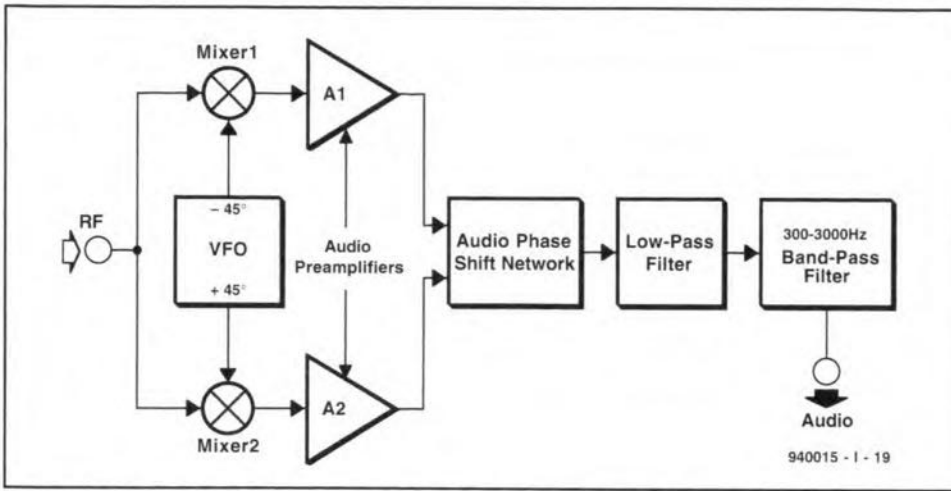
Fig. 9. Phasing-style direct conversion receiver for improved single sideband reception.

There are two methods for generating SSB. The most common today uses a double balanced modulator to combine a fixed carrier and the audio signal to produce a double sideband suppressed carrier output signal; the unneeded sideband is then removed by filtering. The older and more complex variant uses a phasing method of SSB generation. Breed uses the inverse process to demodulate SSB signals in a clever, but complex, receiver design (**Fig. 9**). This circuit splits the incoming RF signal into two components and then feeds them both to separate mixers. These mixers are driven 90 degrees out of phase by a VFO that produces −45° and +45° outputs. The respective outputs of the mixers are amplified and then fed to bilateral 90° audio phase shift networks where they are recombined. The output of the phase shift network is filtered in a low-pass filter and bandpass filter, to provide the recovered modulation.

Audio circuits

The audio chain in the direct conversion receiver tends to be very high gain in order to compensate for the low output levels usually found on the mixer circuits. The principal job of the audio amplifier is to increase the signal level by

an amount that will create a comfortable listening level, while also tailoring the bandpass characteristics of the overall receiver to limit noise and other artifacts. Although any number of discrete and integrated circuit (IC) circuits are suitable, most designers today tend to use the IC versions. **Figure 10** shows a simple LM-386 design, while the published literature shows many other designs as well.[11]

The LM386 design of **Fig. 10** is the single-ended configuration for the LM386 low-power audio stage. This IC device contains both preamplifiers and power amplifiers for a nominal output power of 250 mW. The LM386 series of audio power ICs are easy to use, but because of the high gain needed will oscillate if layout is not correct, or if grounding is not proper. There are two basic circuit configurations for the LM386. The differential version was shown in **Fig. 6** (Dillon's design), while **Fig. 10** shows the more common single-ended design. The gain of the circuit can be either 46 dB (×200) when capacitor C_2 is used, or 26 dB (×20) when C_2 is deleted (leave pins 1 and 8 open-circuited).

Local oscillator circuits

The local oscillator (LO) for a continuously tunable receiver of any description is basically a variable frequency oscillator (VFO). Although higher grade receivers today typically use frequency synthesis techniques for generating the LO signal, the standard inductor-capacitor (LC) controlled VFO still has appeal for less complex receivers. The VFO used for the LO in receivers is pretty much the same as the VFO in transmitters, so transmitter VFOs are frequently used. There are some cases, however, where a receiver LO has at least one specification that is more rigid than the transmitter equivalent: many receivers have a requirement for low FM phase noise. In the main, however, amateur radio applications of direct conversion receivers typically use the transmitter VFO for the

receiver as well.

Several different VFO designs are used for receiver LOs: Armstrong, Hartley, Colpitts/Clapp and an amplitude limiting design. The first three of these circuits are recognized according to the nature of their respective feedback networks, while the other is recognized by the special connection of a transformer. Note that the Colpitts and Clapp are basically the same circuit, except that the Colpitts uses a parallel tuned LC frequency setting network and a Clapp oscillator uses a series tuned LC network.

VFO circuits consist of an active element (transistor, IC, etc.) and a feedback network that must meet the **Barkhausen criteria** for feedback oscillators: 1) the loop gain of the circuit must be unity or greater, and 2) the feedback must be in-phase with the amplifier input signal. In most circuits, there is 180 degrees of phase inversion between input and output, so the feedback network must provide an additional 180 degrees at the desired frequency of oscillation. In practical terms, for HF VFO circuits these criteria result in a need for a gain-bandwidth product (F_t) in a bipolar transistor of 250 MHz or more and a gain (H_{fe}) greater than ten. The high F_t prevents unplanned phase changes at higher frequencies within the VFO range. For field effect transistors a transconductance of 2,000 siemens or more is usually required. In this article I have somewhat arbitrarily selected the
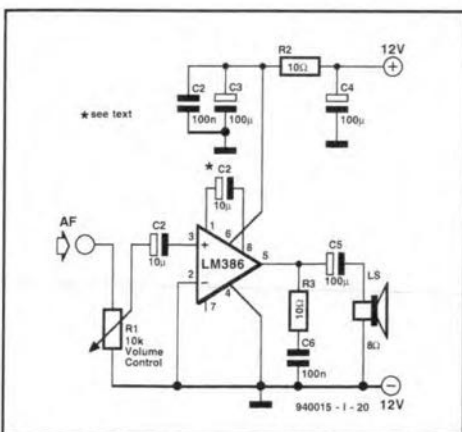

Fig. 11. Hartley VFO circuit.

Fig. 12. Colpitts VFO circuit.

Fig. 10. Audio stage based on the LM386 audio integrated circuit.
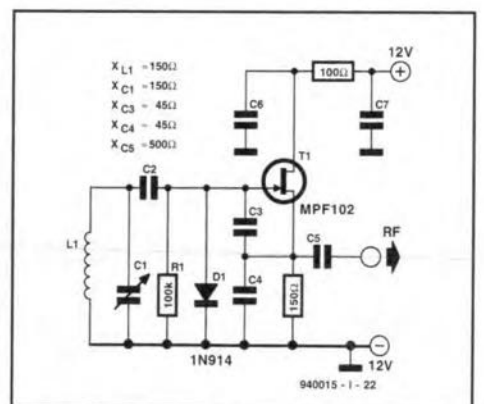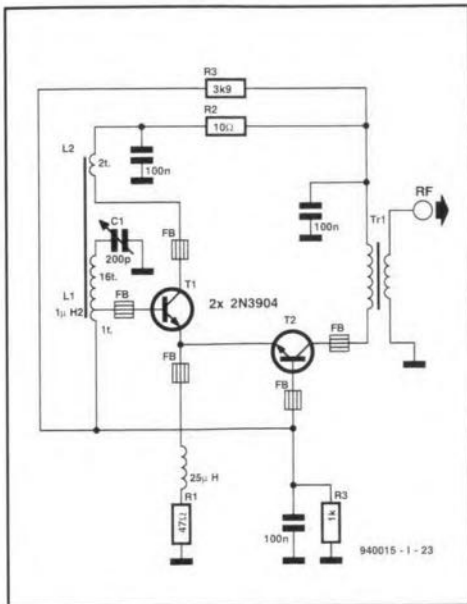
Fig. 13. Low-noise HF VFO circuit.

junction field effect transistor (JFET) of the MPF102 class to serve in the circuit illustrations. In addition, because the NE602 is so popular amongst DCR builders I have also included the three principle forms of oscillator circuit used with that chip: Hartley, Colpitts and Clapp.

Figure 11 shows a Hartley oscillator circuit. This type of oscillator is identified by use of a tapped inductor in the frequency setting network as part of the feedback network. The source of the JFET is connected to ground through the tap, so its current becomes the feedback signal. The top end of the coil is connected to the resonating capacitor and then to the gate of the JFET. Output can be taken from the drain, gate, or source terminals of the JFET, as well as from either a special tap on L_1 or a second winding on the same core as L_1. It is common practice to use a small value capacitor at the source terminal for output so as to lightly load the oscillator. The normal ideal is to have a capacitance that is large enough to permit fast starting every time the circuit is turned on, but small enough to not seriously load the LC network.

The tuned circuit that sets operating frequency consists of L_1 and C_1, with L_1 being tapped for feedback purposes. In most cases, the tap is between 20 and 40 percent of the total inductance. The coupling capacitor between the LC network and the JFET is a very small value so as to prevent loading. The diode in **Fig. 11** is used to provide a limitation on amplitude variations. This diode is a small signal silicon diode of the 1N914 or 1N4148 class.

Figure 12 shows the Colpitts VFO circuit. This circuit can be configured with a series resonant circuit, in which case it is called a Clapp oscillator. Both types of oscillator are identified by the tapped capacitor voltage divider provid-

ing feedback. The oscillating frequency is set by L_1-C_1, although the effects of C_2, C_3-C_4 and the gate capacitance of the JFET must also be considered.

Figure 13 shows a VFO circuit that uses the transformer core to provide output amplitude stability with a low-noise operation.[12] The inductor, which not only helps control frequency but also limits amplitude variations, is wound on an Amidon T-68-6 toroidal core. The main coil (L_1) consists of 17 turns of #26 AWG wire, and is tapped at 1 turn for the base of T_1. A feedback coil consists of 2 turns of the same wire on the same form.

Oscillator stability

Local oscillator stability is always important, but a case can made that it is more so in DCR receivers. Several factors are involved in VFO stability, and if these guidelines are followed result in a stable oscillator more often than not.[13] Some guidelines that will result in a more stable VFO are:

» Avoid excessive temperatures in the oscillator. Also avoid wide variation in temperature.
» Use only as much feedback as needed to ensure quick starting of the oscillator.
» Use an output buffer amplifier to isolate the VFO circuit from changes in the external load.
» Use an IC voltage regulator that serves only the oscillator device (but not the buffer amplifier).
» Rigidly mount the frequency determining capacitors and inductors.
» Prefer air core inductors over ferrite or powdered iron core inductors; prefer slug-tuned coils over toroids.
» Trimmer and main tuning capacitors should be air dielectric types, rather than mica or other materials.
» Small capacitors in the frequency determining network, or used as coupling from the frequency determining network, should be zero temperature coefficient types (NP0 disk ceramics preferred).
» Lightly load the frequency determining LC network by using a small capacitance (1-10 pF) between the tank circuit and the gate or base of the oscillator transistor.
» If an air variable capacitor is used for the main tuning control, then it should be a double bearing model.
» If a varactor diode is used for the main tuning control, then it should use a tuning voltage supply that is regulated by a varactor controller device such as the MVS-460-2/ZTK33B.

These guidelines are neither exhaustive nor absolute, but following them as closely as possible will result in a superior VFO stability.

In the second and final part of this article we will look at some practical designs of direct conversion receivers.

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3. Rick Campbell, KK7B, 'High performance Direct-Conversion Receivers', *QST* August 1992, pp. 19-28.
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7. *Ibid.* (Covington).
8. *Ibid.* (Daulton).
9. *Ibid.* (Campbell).
10. S. Niewiadomski, 'Passive Audio Filter Design' *Ham Radio* September 1985, pp. 17-30; cited in Campbell (*op-cit.*).
11. Ray Marston, 'Audio Amplifier ICs', *Radio-Electronics*. April 1990, pp. 53-57. See also the *National Semiconductor Linear Data Books*, or the data books of other major IC manufacturers for applications information and device data.
12. From an article by L. Gunn, K7HFD, discussed and cited in W. Hayward and D. DeMaw, *Solid-State Design for the Radio Amateur*, American Radio Relay League (Newington, CT, USA, 1977).
13. These criteria were developed from W. Hayward and D. DeMaw, *Solid-State Design for the Radio Amateur (op-cit.*).

MINI I/O CARD FOR CASIO FX850/880P

A marked difference between large and small computers is the number of
possibilities available for communication with peripheral devices. In particular
pocket-size personal computers, like the Casio FX850/880P, could do with a few
communication extensions. The I/O extension card described in this article adds an
RS232 interface and a parallel printer port to the Casio FX850/880 pocket computer.

Design by M. Fänrich (hardware) and G.J. Klasens (software)

O VER the past few decades, calcu-
lators have evolved from simple
slide rules to fairly powerful miniature
computers. This trend is typified by,
among others, the change from a sim-
ple one-row LED display on those early
machines to an extensive graphics
LCD screen on some of the most recent
models.

Likewise, the possibilities to pro-
gram the calculator have gone through
many changes. Until recently, pro-
gramming a calculator was restricted
to typing long strings of primitive cal-
culation instructions. What were then
called advanced machines were capa-
ble of storing these instructions on a
magnetic tape, which prevented the
'program' from being lost when the cal-
culator was switched off.

That has all changed with the ar-
rival of higher programming languages
like BASIC, Pascal and C. Further, the
programs are now stored in non-
volatile memories (usually static
CMOS RAMs). There are even pocket
computers around with a memory of
more than 4 MByte.

Not surprisingly, users have an in-
creasing need of 'connectivity', i.e.,
being able to link their pocket com-
puter to other equipment, including a
'normal' PC. Entering and editing pro-
grams using the miniature keyboard
on the pocket computer is far less con-
venient than on the normal PC.
Consequently, many users would like
to have a serial interface that allows
data to be exchanged between the PC
and the pocket computer. Likewise, a
printer port is useful in many cases,
particularly if hard copy of calculation
results is required. Fortunately, the
Casio FX850/880P has an extension
connector which has all signals needed
to implement a serial and a parallel
port.

The circuit

The circuit diagram of the extension
card, **Fig. 1**, shows that two gates from
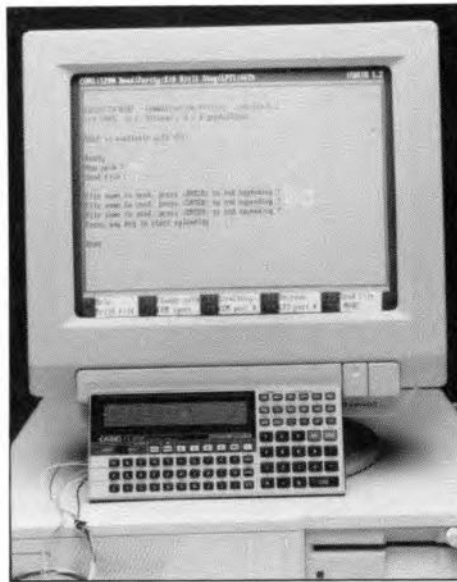
a 4049, IC1c and IC1d, are responsible
for the buffering of the two serial sig-
nals, TxD (transmit) and RxD (receive)
on the Casio extension connector. The
zener diode connected across the out-
put of the TxD driver, IC1c, is a protec-
tive device, which starts to conduct
when the output level of the driver be-
comes too high, for instance, as a re-
sult of a supply voltage increase. Since
the output stage of the driver contains
a resistor, the current through the
protection diodes in the gate is limited,
and the voltage level cannot rise above
5.6 V. This prevents peripheral equip-
ment connected to the computer from
being damaged. Conversely, resistor
R2 ensures that the TxD output is
short-circuit resistant. Furthermore,
the current through the zener diode is
automatically limited should the out-
put be accidentally connected to the
output of another device.

The input buffer, IC1d, is also pro-
tected. Negative voltages at the input
are blocked by diode D2, while resistor
R3 serves to establish a 0-V reference
level. High input voltage levels are

eliminated by the internal protection
circuit contained in the gates.

The parallel port extension for the
printer consists of a latch, IC3, and six
logic gates. Gates IC1a and IC1b invert
the WE and CS signal respectively,
whereupon IC2b combines these sig-
nals into a strobe pulse for the latch.
The latch serves to store the eight
dataline levels needed for the printer.
In addition to the data, the printer
needs three control signals: $\overline{STROBE}$,
$\overline{BUSY}$ and $\overline{INIT}$. Three buffers, IC2a,
IC2c and IC2d, enable the PC and the
Casio to exchange these signals as re-
quired.

Construction

To make the construction of the inter-
face easier, a printed circuit board was
designed. The artwork is given in
Fig. 2. Unfortunately, this board is not
available ready-made through our
Readers Services.

Start the construction by fitting the
six wire links, the two sub-D connec-
tors (K1 and K2), the pinheader (K3),
and the other passive components.
Next, mount the diodes and the voltage
regulator on to the board, paying due
attention to the polarity of these de-
vices. Finally, mount the three digital
ICs.

The connector is likely to be a real
problem, because it is, to the authors'
knowledge, not available as a standard
component. The only way of getting
hold of it is to salvage it from a faulty
interface or another electronic device,
or to order it as a spare part. A further
alternative could be an SMA (surface
mount assembly) connector salvaged
from a piece of electronic surplus.
These connectors usually have the
same raster. Real hobbyists, however,
should have a go at making their own
connector by inserting a number of
stiff wires, or thin needles, into the
connector openings. Next, a small
piece of thin plastic sheet is inserted
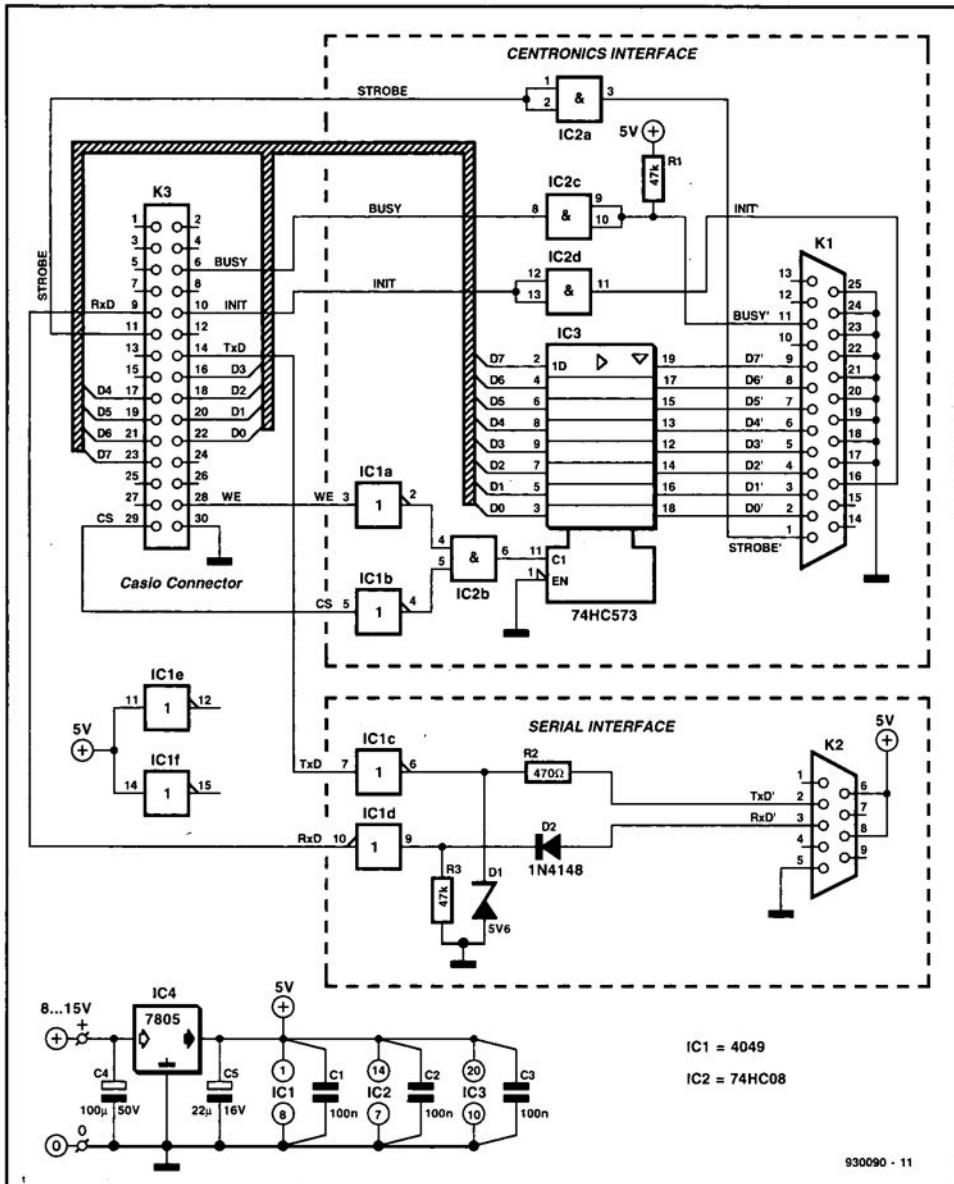between the two pin rows for isolation.

Fig. 1. Circuit diagram of the mini I/O interface for the Casio FX850/880P pocket computer.

A few drops of epoxy resin are then sufficient to turn these components into a solid whole.

Once the board is complete and inserted into the Casio extension connector, it is time to connect it to a mains adapter (8-15 VDC output), and start using it.

Software

Fortunately, the Casio FX850/880P has built-in software protocols to support communication with peripherals via the serial and parallel ports you have just added. The serial port is described as COM0 in CASIO BASIC. The commands that can make use of COM0 are OPEN, CLOSE, PRINT#, INPUT#, SAVE and LOAD. The parameters that may be used with these commands are listed in the user manual.

Diskette 1921 which is available through our Readers Services contains the program 'Casio', which arranges the serial data traffic between a Casio computer and an MS-DOS PC. This program is invaluable for exchanging data between the Casio and the hard disk in the PC. By virtue of its clear structure and built-in Help function, the program is readily used, even without a manual.

The printer port may be enabled by selecting Mode 7 on the Casio ('enable printer'). Further, all BASIC instructions that have to do with the printer, like LLIST and LPRINT, make use of the parallel port. ∎
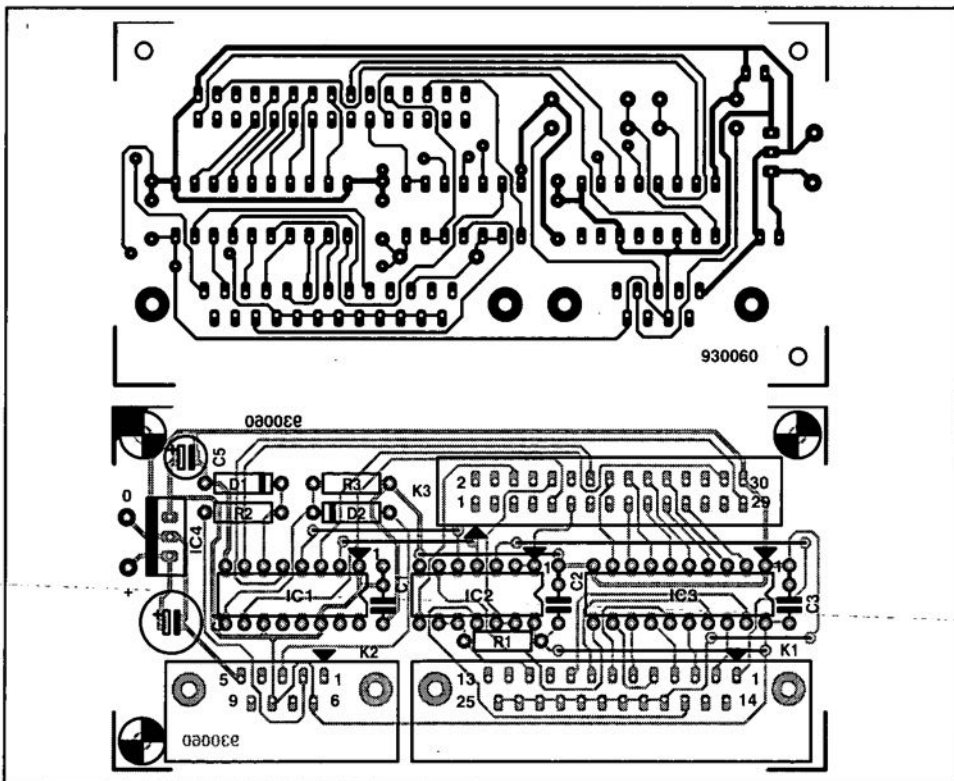

Fig. 2. Artwork of the PCB designed for the interface (PCB not available ready-made).

COMPONENTS LIST

Resistors:
2	47kΩ	R1;R3
1	470Ω	R2

Capacitors:
3	100nF	C1;C2;C3
1	100µF 50V radial	C4
1	22µF 16V radial	C5

Semiconductors:
1	5V6 0.4W zener diode	D1
1	1N4148	D2
1	4049	IC1
1	74HC08	IC2
1	74HC573	IC3
1	7805	IC4

Miscellaneous:
1	25-way sub-D socket, angled pins, PCB mounting	K1
1	9-way sub-D socket, angled pins, PCB mounting	K2
1	30-way 2-row pin header	K3
1	Diskette 1921 (see page 70)	

g40052

DX TELEVISION

A two-monthly column by Keith Hamer and Garry Smith

Finnish 3rd network FuBK test pattern. Regional identification is sometimes incorporated. The service operates mainly at UHF, but reception in the United Kingdom could be possible given the right atmospheric conditions.

OCTOBER was a vast improvement on the previous month for reception with a relatively high number of sporadic-E openings for the same year, with activity on at least nine days. Signals were mostly from Spain, Italy and Portugal with strong, stable pictures of excellent quality at times.

Towards the end of the month, intense tropospheric activity dominated the scene, producing spectacular DX reception in Band III and at UHF. Signals were identified from as far away as Spain, Switzerland and Sweden. Both bands were virtually choc-a-bloc over a period of several days; the opening lasted into the first few days of November. The remainder of November was fairly mundane with only a handful of sporadic-E signals, mainly from Spain and Portugal. However, an unexpected tropospheric opening occurred on the 18th with a deluge of signals from transmitters as far away as Poland and Finland.

Reception reports

Andrew Jackson (Birkenhead) commented that the tropospheric opening 'seemed to go on for ever'. Several 'firsts' were notched up, including a host of Danish and Swedish transmitters, in addition to several unusual ones from deepest Germany. The best reception was on November 1st and 2nd, with a host of German stations broadcasting test cards, making regional identification relatively easy.

On the 27th, Andrew identified transmissions from the Danish DR network on channels E7, E10 and E31, plus the TV-2 service on channels E22, E26, E27, E30, E35, E40, E48, E56 and E58. During the same opening, the Swedish transmitter at Halmstad was received on channel E24. All in all, it was quite a remarkable catch considering that the Pennines were in the reception path! The 28th produced many unusual German ARD-1 stations in Band III.

Stephen Michie (Bristol), Garry Smith (Derby) and Tim Tebbs (New Romney) all report high-level colour signals from various Dutch stations on the 29th. Further afield, various German regional broadcasts were identified during the same opening, including WDR-1, West-3, NDR-1 and MDR-3.

On the 30th, Tim Tebbs received German transmitters from the SWF pro-

gramme region, notably Haardtkopf (channel E55) and Ahrweiler (E56), and also their respective ZDF channels.

Several enthusiasts saw the new Dutch station 'ZH-TV' on channel E49 showing colour bars with identification. The station is still undergoing experimental tests.

On October 31st, Bob Brooks (South Wirral), Andrew Jackson, Tim Tebbs and Garry Smith logged many German stations from regions such as WDR-1 on channels E9 and E11; West-3 E48 and E55; NDR-1 E11, E43, E50 and E53; NDR-3 E47; WDR-3 E48; RB-1 (Radio Bremen) E22; ZDF E21, E26, E34 and E35; MDR-3 E31 (Inselberg). On the same day, the Swedish TV4 network was resolved on channel E50 by Andrew Jackson.

November 1st and 2nd brought in many more German stations. Andrew Jackson caught Bayerischer Rundfunk showing the FuBK test card with the transmitter identification 'Dillberg' on channel E6, and 'Buttelberg' on E55. There were also relays of SAT-1 E42, VOX E39, and RTL+ present on channels E35 and E36. Bob Brooks noted the Swiss test card on channel E6 from the transmitter atop the Rigi during the opening on the 2nd sporting the '+PTT SRG-1' identification.

The unexpected tropospheric opening on the 18th produced several rare catches for Simon Hamer (New Radnor). These included Polish TVP-1 signals on channel R8 from either the Bialystok or Katowice transmitter, plus the YLE-1 test card from the Espoo transmitter in Finland on channel E6. This is the first ever report of this transmitter being received in the United Kingdom. Other goodies, although Simon has been receiving these fairly regularly, include Norway's 2nd network on channel E12, and the Swedish 4th network on channel E50.

Keith Greenwell (Luton) identified Spanish stations at UHF during the late October tropospherics. During the same opening, scores of French stations were noted, including relays of ARTE at UHF.

There were at least four instances of transatlantic TV reception via sporadic-E throughout the 1993 sporadic-E season, but the precise source of the signals, on channel A2, could not be identified at the time. Fortunately, Peter Chalkley (Luton) recorded some of his reception,
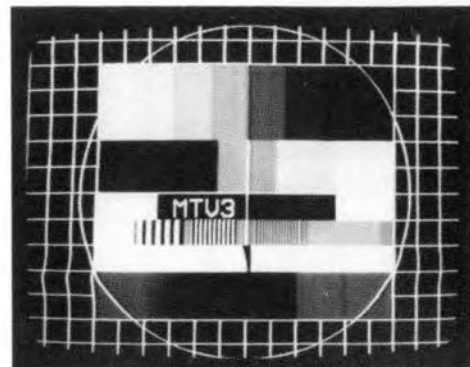
and recent examination clearly shows Canadian TV's maple leaf emblem in the background of a game show. The likeliest transmitter is CKCW-TV located at Moncton, New Brunswick with an ERP of 56 kW.

Log for October

04.10.93: An early afternoon sporadic-E opening with Spain, Portugal and Norway.

07.10.93: Denmark E3; Norway E2 and E4; Italy IA.

08.10.93: Italy IA.

15.10.93: Denmark E3; Spain TVE-1 E2, E3 and E4; Spain TVE-2 E2; Italy IA; Portugal E3.

18.10.93: Netherlands at UHF via tropospheric reception.

19.10.93: Norway E3; Sweden E3; Italy IA and IB; CIS R1 and R2; Poland R1; Slovakia R2; Switzerland E2; Germany E2.

20.10.93 - 02.11.93: Tropospheric reception in Band III and at UHF included: Spain, Switzerland, Norway, Sweden, Denmark, France, Germany, Netherlands, Belgium, Luxembourg and Eire.

Log for November

06.11.93: Sporadic-E signals from Spain, Portugal, Corsica and Italy between 1130 and 1400 UTC.

18.11.93: Intense tropospheric activity included Poland, Finland, Sweden, Norway, Denmark, Germany, Eire, France, Netherlands, Luxembourg and Belgium.

Receiving alternative ITV regions

Over the years, the subject of receiving an alternative ITV region has cropped up, sometimes out of curiosity. For instance, in many parts of Derby, Yorkshire TV from Belmont on channel 25 is available as an alternative ITV region with good quality colour, but only a handful of potential viewers realize it.

One problem is, of course, that aerial riggers are reluctant to recommend, or experiment with, an installation which may only produce mediocre or varying results. Despite the technical difficulties involved, most viewers seem to expect perfect results or none at all!

Richard Irving (Holt, Wiltshire) questions the possibility of receiving good colour reception from the Crystal Palace transmitter on channel 23 at his location east of Bristol. Unfortunately it is unlikely because under normal reception conditions, high-power TV signals can only be successfully received up to approximately 50-60 miles from the transmitter.

As DX-TV enthusiasts know, atmospheric bending can increase this range, but it all depends on the prevailing conditions. With a high-gain aerial and an amplifier, it may be possible to pick up very weak traces of a signal in excess of this distance under 'flat' conditions, but these would not provide 'entertainment' quality viewing. Only when the signal improves would this be possible.

In Derby, Channel 4 from the Crystal Palace outlet is detectable, but signals are very weak and fluttery; turning the aerials to the east produces very weak signals from the Lopik transmitter in the Netherlands. This is using a standard 18-element Group A aerial raised to about 10 m, and fitted with a 'Supreme' low-noise amplifier.

When conditions are good, the signals come up in colour, but reception is unpredictable. Signals from

Tyne Tees TV (Bilsdale channel 29), Border TV (Caldbeck channel 28) and Anglia TV (Sandy Heath channel 24) were detectable (in the case of Anglia TV, in colour) before several local relays came on-air.

For anyone wishing to assess alternative ITV reception at their particular location, it is best to obtain a copy of a transmitter list such as the handouts supplied by the BBC, etc., with all four channels listed. The closest transmitter will not always provide the best results. Particular attention should be given to any local topographical features, and also watch out for local and semi-local relays sharing the same group of channels.

If there are signs of an alternative region on the existing aerial, then success may be assured using a dedicated array fitted with an amplifier. For general experimentation, a wideband aerial is a worthwhile choice because it will respond to the whole of the UHF spectrum.

Service information

Netherlands: The Nozema has plans for an encrypted pay-TV service on the NED-1 and NED-2 networks during the night between 0200 and 0700 local time. This will mean that all the Dutch transmitters will be on-air 24 hours a day.

Part of the Finnish MTV-3 opening sequence.

Spain: There are changes to the identification on the GTE test card shown via the 1st network. Instead of 'tve' in large letters in the upper half of the pattern, a stylised '1' inside a rectangular outline is shown.

Portugal: The first programme of RTP is now called 'CANAL 1'. The logo in the left-hand corner is 'C1' with a miniature globe inside the letter 'C'. The second programme is called 'TV2', and there is also a logo in the top left-hand corner of the picture.

The unidentified transmissions received on channel E2 this season (with zero offset frequency) originate from a new TV2 transmitter, the ERP and location of which are, at present, unknown.

Czech Republic: All transmitters operating on channel R4 are to be closed down and transferred to UHF channel R55 by the end of 1994.

Germany: A satellite channel dedicated to travel is due to be launched later this year. The broadcasts will be via Eutelsat, and the services will be called 'Reise-TV' (Travel-TV). The broadcasts will originate from outside Germany because the programmes are regarded as advertising.

The following information concerns various German TV regions:

Bayern: New transmitters assigned for 'Deutsches Sportfernsehen' (DSF) are as follows: München channel E37; Regensburg E38, Neu-Ulm E48; Ansbach E49 and Bamberg E54. A local TV service called 'TV Weiß-blau' (TV White-blue) commenced on 01.09.93 in München using channel E51. Transmissions are between 1200-0100, local time. Text pages with local information are shown outside these times.

Berlin/Brandenburg: The regional service '1A Brandenburg' commenced last November via the transmitter at Berlin-Alexanderplatz on channel E5 with 100 kW ERP.

In Berlin there are several experimental broadcasts currently undergoing tests. On 200 MHz (Band III) and also on 107.5 MHz (FM radio band) there is a music programme using DAB (digital audio broadcasting). On channels E47 and E49 there are transmissions using the new PAL-Plus system; these originate from Alexanderplatz (approx.

500 W), and the SFB Broadcasting House (approx. 5 W).

On channel R59 (400 W) Telekom are testing four digital TV signals (Videnet) which occupy the bandwidth of only one normal TV channel. over the coming months, there will be many more additional tests emerging.

Mecklenburg-Vorpommern: The following transmitters have been assigned for the first private TV network to operate in the region: Marlow E43; Bergen E57; Schwerin E41 and Züssow E55. All transmitters have an ERP of 100 kW.

Various companies have applied to operate the network. These include Babel-Hilm and Video GmbH, MVTV-Regional Fernseh GmbH i.G.; Pro-7; Rügen-TV; SAT-1 and Television Mecklenburg-Vorpommern GmbH.

Niedersachen: Telekom has a new TV tower in north-western Hannover. The 1-kW transmitter on channel E28 is radiating the FuBK test pattern on weekdays.

Hamburg: Channel E34 is assigned for a new local TV station.

Switzerland: The opening of 'S-Plus' from Geneva (E38) and Montreux (Mt. Pelerin E52) has been delayed. 'Telecine TCR' on channel E96 ceased operation on 17.09.93 with 'S-Plus' taking over the channel on the same day.

All three networks come on air at 0600 UTC with Euronews, the sound channel being in French, German or Italian depending on the network. It can also be heard in Spanish and English by viewers with stereo receivers by switching to the second intercarrier sound channel as follows:

DRS Net. CH1 in German, CH2 in Spanish;

SSR Net. CH1 in French, CH2 in English;

TSI Net. Ch1 in Italian, CH2 in French.

However, Euronews is already running into financial difficulties with huge losses incurred for 1993. Most of the financial resources for the service, which is also distributed by cable, are believed to come from Swiss banks with the support of SSR and SRG which are both shareholders.

Scandinavia: There are plans to introduce a terrestrial channel which can be received 'all over Scandinavia'. Tele-X, as it may be known, could be a joint venture between Denmark, Norway and Sweden.

This month's service information was kindly supplied by Gösta van der Linden and the Benelux DX Club, Netherlands; Reflexion, Germany; Pertti Salonen, Finland; Roger Bunney, UK; Garry Smith, UK; Thomas Pahlke, Germany; Bernd Trutenau, Lithuania.

Please send any news about DX-TV in your part of the world to Keith Hamer, 7 Epping Close, Derby DE3 4HR, England.
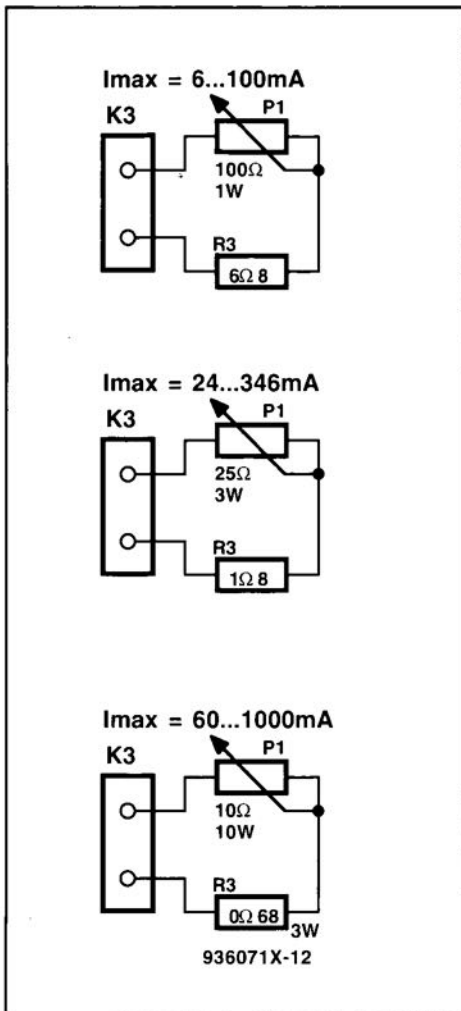
ELECTRONIC FUSE

We tend to forget about fuses until one has blown, when it is time to locate and investigate an electrical overload problem. Once that is fixed, a new fuse must be installed. Typically, this will not be handy at the required rating, and the shops are closed. What a drag to serious experimenting! Fortunately, these problems can be overcome with the present circuit. The fuse described here never needs to be replaced, and is as good as new any time the reset switch is pressed.

Design by K. Walraven

THE little circuit described in this article is the electronic version of the well-known glass fuse, which melts when it carries a current exceeding its 'A' (ampère) specification. By melting, the wire in the fuse interrupts the current flow in the circuit, and so protects an electrical device against damage caused by overheating. Unfortunately, the common wire fuse (usually contained in a small glass tube with metal end caps) is not re-usable, and has to be replaced with a new one every time an overload condition occurs. Obviously, this is annoying when faultfinding in equipment, or experimenting with a circuit whose maximum current drain is not accurately known yet. Ideally, a fuse would have to be resettable, and, you guessed it, that is a feature *par excellence* of the present circuit.

How it works

As shown in **Fig. 1**, the circuit consists of little more than two transistors and one thyristor. The electronic fuse is inserted into the supply line of the equipment to be protected. The current at which the circuit is actuated is defined with the aid of a single resistor, R_3, which is connected as an external part to connector K_3.

The operation of the circuit is simple. Darlington transistor T_2 functions as a current-controlled switch, its collector-emitter junction carrying the current flowing into the load connected to K_2. Since T_1 feeds a current into the base of T_2, the 'switch' is normally closed, and the load powered. T_1 functions as a current source, with the base of the transistor held at a constant voltage by LED D_1. Consequently, the emitter resistor of R_2 will supply a constant voltage, which, in turn, results in a constant emitter current (and collector current), of which the magnitude is determined by the value of R_2. Here, the constant current is just over 10 mA, which is ample to keep T_2 conducting.

The load current also flows through resistor R_3. As soon as the current rises to a value that causes a voltage drop of about 0.6 V across R_3, thyristor Th_1 starts to conduct. This causes the base of T_2 to be pulled to the ground line of the power supply. Consequently, T_2 is switched off, and breaks the current flow to the load. The current remains broken because the current supplied by T_1 is a little above the 'hold' level of the thyristor. The current is interrupted the moment switch S_1 is pressed, when Th_1 is switched off. That is, if the load current has dropped below the critical value. If not, the thyristor will start to conduct again.

The fuse value

The current level at which the electronic fuse is actuated is simple to calculate using Ohm's law. As already

Fig. 1. circuit diagram of the electronic fuse. The fuse actuation level is determined by the value of resistor R3. Once actuated by an overload condition, the fuse can be reset by pressing S1 (a push-to-break contact).

936071X-11

Fig. 2. **The fuse actuation current can be made variable by connecting a fixed resistor and a potentiometer in series on connector K3.**

COMPONENTS LIST

Resistors:
R1 = 4kΩ7
R2 = 68Ω
R3 = see text

Capacitors:
D1 = red LED
T1 = BD140
T2 = DB679
Th1 = TIC106

Miscellaneous:
K1;K2;K3 = 2-way PCB terminal block; raster 5mm
S1 = push-to-break button

Fig. 3. **Track layout and component mounting plan of the printed circuit board designed for the electronic fuse (PCB not available ready-made).**

mentioned, the fuse is actuated at a voltage of 0.6 V across R_3. Therefore, the fuse comes into action at a current of 600 mA (0.6 A) with R_3 = 1 Ω. Similarly, the actuation current is 125 mA with R_3 = 4.7 Ω, or 50 mA with R_3 = 12 Ω.

Looking at the most commonly used low-power fuse values, the value of R_3 will usually lie between 1.2 Ω and 12 Ω. The minimum value that may be used is 0.68 Ω, which results in a 'trip' value of 1 A. That corresponds to the maximum current this circuit can handle safely.

Assuming that the electronic fuse is built into a power supply for use in your workshop, it is, of course, useful to make the current limiting action switchable or continuously variable. The former is achieved by fitting a rotary switch and a number of resistors. A continuously variable fuse actuation level is implemented by connecting a potentiometer in series with R_3. Note, however, that most ordinary pots can withstand a dissipation of about one watt only. Relatively high currents therefore call for a wirewound potentiometer. The resistor/potentiometer

combinations shown in **Fig. 2** are intended as suggestions to help you on the way.

Finally, still on component values, be sure to use a power resistor in position R_3 at currents exceeding 500 mA.

Construction and practical use

Consisting of an absolute minimum number of components, the electronic fuse should be a simple construction project for anyone with a basic knowledge of electronics. The less experienced constructors among you will be pleased to know that artwork is available to make a printed circuit board for the present project — see **Fig. 3**. Unfortunately this printed circuit board is not available ready-made through the Readers Services.

When connecting the electronic fuse, keep in mind that it introduces a voltage loss in the supply line to the load to be protected. As already mentioned, a voltage drop is introduced by
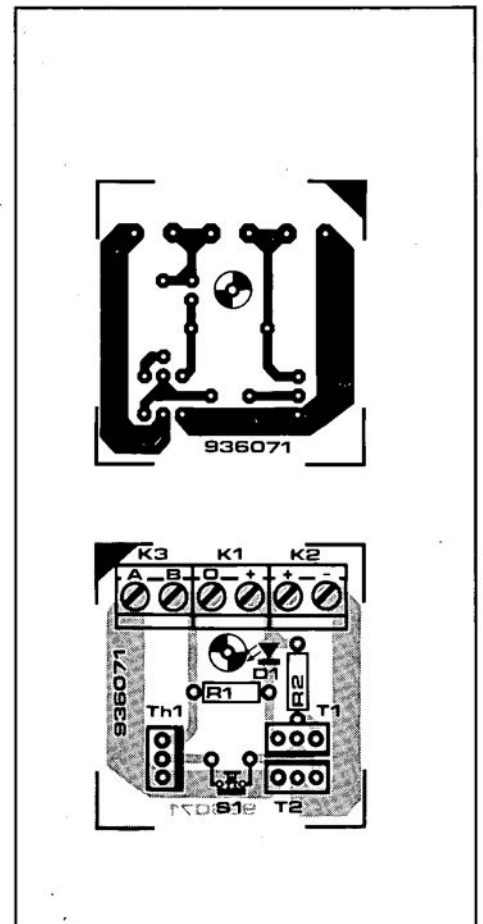
R_3, but also by the collector-emitter junction of the conducting darlington transistor, T_2 (approx. 1 V). In most cases, this will not be a problem, but you are well advised to take the drop into account when the circuit is used to protect a load which operates at low voltages.   ∎
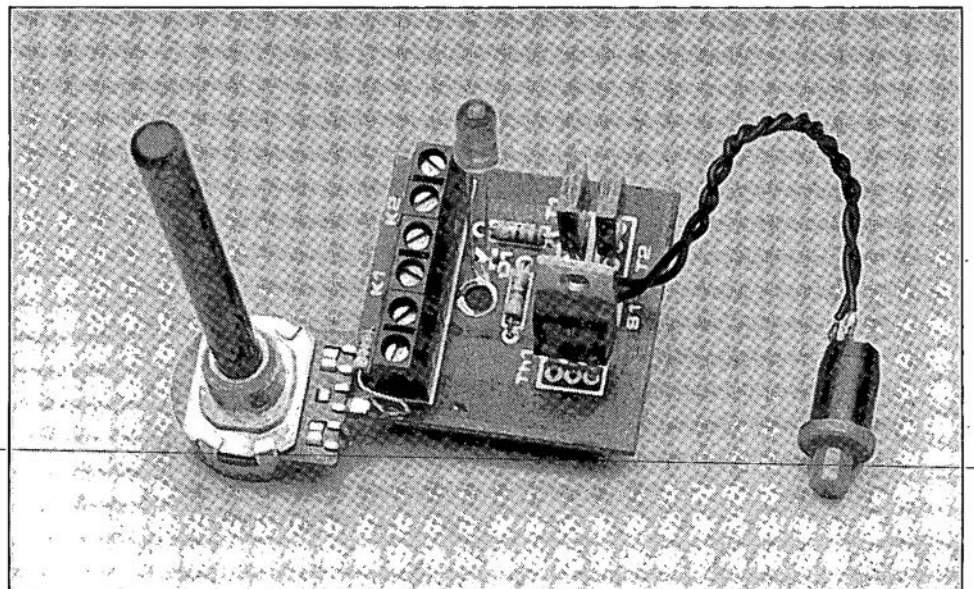
Fig. 4. **Completed prototype with external current-determining resistor and potentiometer fitted to K3.**

CORRECTIONS AND UPDATES

80C535 Extension card

June 1994, p. 8-11
The PCD8584 may be switched to '6800' mode if a WR signal arrives without a CS signal. The problem may be solved by combining WR and CS in a diode-AND gate as shown below. Pin 18 if IC_4 is taken out of the IC socket and connected to ground via a 10-kΩ resistor. The WR signal is found on socket pin 18, and CS on pin 10 of IC_5. Also note that the PCD8584 is currently supplied as the PCF8584.

940025 - L
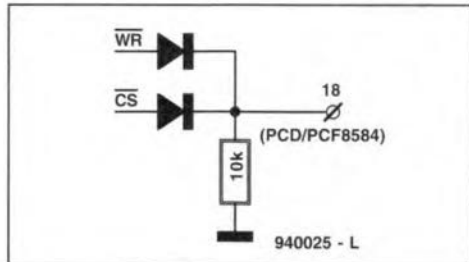
Dual-purpose LED display

December 1994, p. 90
Resistor R_{33} should be connected to ground, not to +12 V as shown in the circuit diagram.

Experimentation board for PICs

July/August 1994, p. 74.
In the circuit diagram, the signals on pins 7 and 8 of both connectors K_1 should be swapped. MCLR is on pin 8, and RTCC on pin 7. The relevant PCB is all right.

Mains signalling system (2)

May 1994, p. 10-14.
The instructions for command 'T' should read: 'T' must be followed by the address in ASCII, and terminated with a semicolon (';').

The baudrate for the communication software should be set to 300, format: 8 bits, 1 startbit, 1 stop bit, no parity.

Electronic fuse

March 1994, p. 56.
To prevent transistor T_2 from burning out when the reset switch is pressed during an overload condition, switch S_1 should be connected between the collector of T_1 and the base of T_2.

CAR BATTERY VOLTAGE MONITOR

Design by L. Pijpers

It is particularly during the autumn and winter months, when a car battery is called upon to provide a lot of energy, that more is sometimes taken from it than put back. The inevitable result is a flat battery. Moreover, during these wetter months a battery is required to be in tip-top condition to be able to cope with condensation on the sparking plugs. Problems may arise in the warmer months as well, however. It may happen, for instance, that the voltage regulator, the alternator (or, in old cars, the dynamo) or the rectifiers are faulty. Such a fault may result in much too high a charging voltage, which severely lowers the life of the battery, or too low a charging voltage so that the battery is hardly charged. In all these cases, a battery voltage monitor is indispensable.

The monitor described in this article uses three LEDs: green to show that all is well, red to indicate that the charging voltage is too high, and yellow to show that the charging voltage is too low.

The circuit in **Fig. 1** may be built on a piece of prototyping board or on the DIY printed-circuit board shown in **Fig. 3**. In the latter case, the board may be built into a car-type cigarette lighter.

If you have ever tried to start your car and found the battery (almost) as flat as a pancake, you will appreciate this miniature monitor, which fits in the car's cigarette lighter Its LED indicators tell you when the battery voltage drops dangerously low and also when the charging voltage is too high.

Circuit description

The circuit (**Fig. 1**) is a fairly simple design based on a window comparator, IC_1. A window comparator consists of two separate comparators, each of which monitors whether its input signal is below or above a level preset by the user. The combination of two comparators enables two different levels to be monitored simultaneously. It can, therefore, indicate whether an input signal is lower or higher than the two threshold levels, or whether the signal lies between the two, that is, within the so-called window. This is exactly what is needed for the present monitor, since this must show whether the battery voltage is too low, too high, or just right (within the window).

The upper and lower threshold levels are determined by potential divider R_3-R_5. The potential at pin 10 of IC_1 is a constant 6 V, derived from a regulator on board IC_1. The values of R_3-R_5 have been chosen to give a voltage at junction R_3-R_4 of 3.6 V and one of 2.9 V at junction R_4-R_5. This means that the window ranges from 2.9 V to 3.6 V.

The input voltage is derived from the battery via potential divider R_1-R_2 and is applied to pin 8 of IC_1. The potential at junction R_1-R_2 is exactly a quarter of the battery voltage. Thus, if the battery voltage is 12 V, the input signal at pin 8 is

3 V. This level falls within the window and is, therefore, considered to be good.

From the ratio $R_1 : R_2$, it follows that the battery voltage is all right if it is between 11.6 V and 14.4 V. Below 11.6 V it is too low and above 14.4 V it is too high.

To ensure that the monitor does not follow any variation in the battery voltage, the circuit is designed to react only to slow variations. Low-pass filter R_1-C_1 suppresses any fast changes, such as those caused by the car's ignition system, for instance. Such peaks are short-circuited to earth by C_1.

Depending on the input signal, one of the three LEDs at the output of IC_1 lights: the green one (D_2) when the battery voltage is between 11.6 V and 14.4 V; the yellow one (D_1) when the voltage is too low; and the red one (D_3) when the voltage is too high.

Apart from low-pass filter R_1-C_1, the circuit has another facility that prevents too rapid switching between LEDs: hysteresis. This is set by potential divider R_6-R_7, which has a ratio of 1 : 100. Thus, the potential of 6 V at pin 10 is brought down to 60 mV at pin 9. The hysteresis

is exactly twice this value, i.e., 120 mV. This means that only variations in battery voltage greater than 120 mV can cause a switch from one LED to another.

Construction

Although the design is aimed at keeping the unit as small as possible, as shown by the printed-circuit in **Fig. 3** (not available ready made), it is, of course, not necessary to make it that small, in which case it may be constructed on a suitable piece of prototyping board. If the monitor is constructed on the PCB, it can be built into a cigarette-lighter plug.

Note that C_1, R_1, R_4 and IC_1 are fitted on to the board as shown in **Fig. 4**. Keep the terminals of all these components as short as feasible to prevent short-circuits.

Cut the terminals of the three flat LEDs to a length of about 5 mm. and solder the diodes to the board as shown in **Fig. 4** and **Fig. 5**.

Next, solder the remaining resistors to the track side of the board as in **Fig. 5**: start with R_8. Here again, cut the terminals of these components as short as fea-
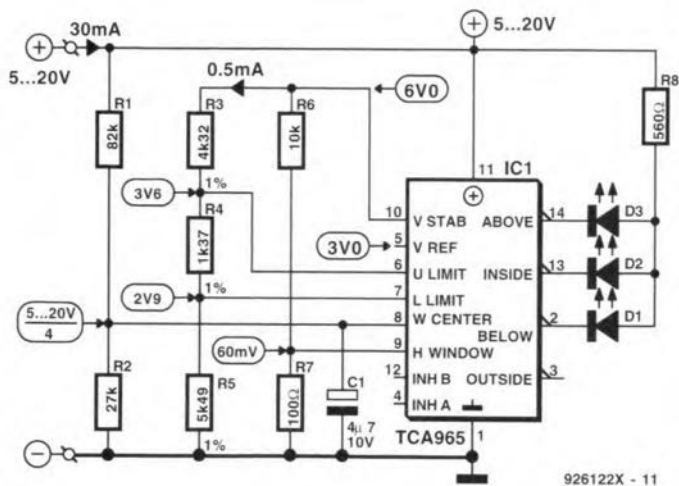
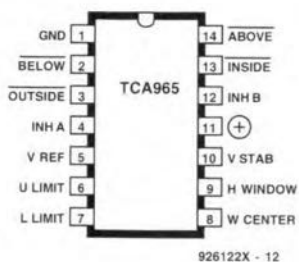Fig. 1. Circuit diagram of the car battery voltage monitor

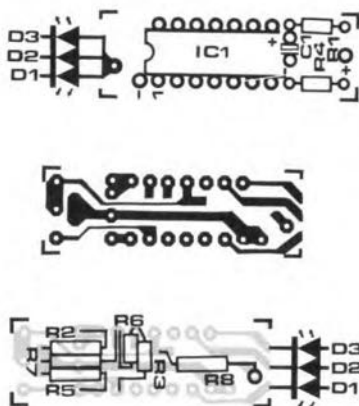Fig. 2. Pinout of IC$_1$.

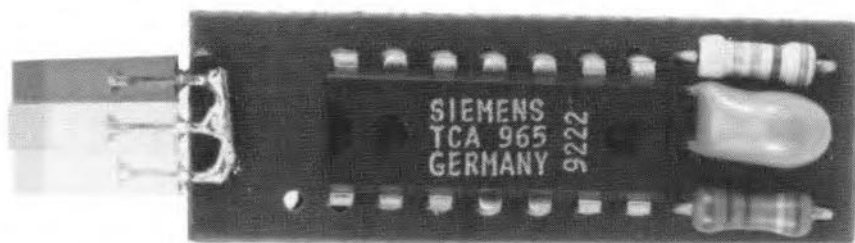Fig. 3. The PCB for the monitor
is not available ready made

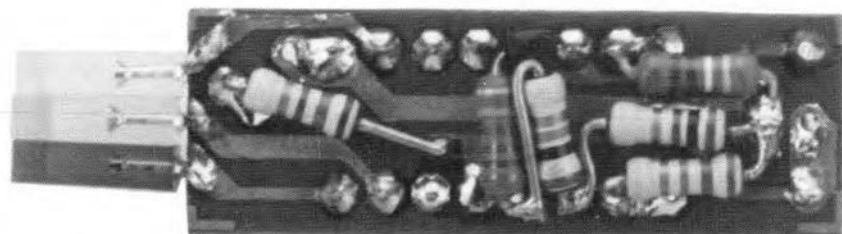
Fig. 4. Completed PCB (component layout side)

Fig. 5. Completed PCB (track side)

sible. Solder R$_6$ and R$_3$ in place last. Be careful not to cause a short-circuit when soldering R$_3$ 'around' R$_6$. Some sleeving around its terminals will help. The risk of a short-circuit is greatest near pin 6 of IC$_1$ and between pins 10 and 11 of the IC.

When all components have been fitted, carry out a thorough visual inspection. When this is satisfactory, connect a variable power source (0–20 V) to the board. Increase the voltage slowly from 0 V to 20 V when first the yellow, then the green and finally the red LED should light. If this test is satisfactory, the board can be built into the cigarette lighter plug.

Great care has to be taken to prevent short-circuits caused by shifting components. It may be necessary to bend the metal clip slightly outwards so that it fits neatly around the IC. It is recommended to wrap some insulating tape around the clip and earth it with a short length of wire.

If the monitor has been constructed on a prototyping board, the same visual inspection and electrical test should be carried out, after which the unit may be fitted in a suitable small enclosure.

The current drawn by the monitor depends to large extent on the battery voltage: it is about 10 mA at 5 V, 30 mA at 12 V and 40 mA at 20 V.

The threshold voltages can be altered by changing the values of R$_3$–R$_5$. The potential at junction R$_4$-R$_5$ is R$_5$/(R$_3$+R$_4$+R$_5$) times 6 V. That at junction R$_3$-R$_4$ is (R$_4$+R$_5$)/(R$_3$+R$_4$+R$_5$) times 6 V. The window may be moved up or down by altering the scale factor R$_2$/(R$_1$+R$_2$). With values specified for the present design it is $1/4$. Some constructors may find it desirable to use 1% resistors here also.

Parts list

Resistors:
R$_1$ = 82 kΩ
R$_2$ = 27 kΩ
R$_3$ = 4.32 kΩ, 1%
R$_4$ = 1.37 kΩ, 1%
R$_5$ = 5.49 kΩ, 1%
R$_6$ = 10 kΩ
R$_7$ = 100 Ω
R$_8$ = 560 Ω

Capacitors:
C$_1$ = 4.7 µF, 10 V, tantalum

Semiconductors:
D$_1$ = LED, yellow, flat
D$_2$ = LED, green, flat
D$_3$ = LED, red, flat

Integrated circuits:
IC$_1$ = TCA965

Miscellaneous:
1 off car-type cigarette lighter plug

R2 R6
R5 R8
D3 D2 D1

g26108X
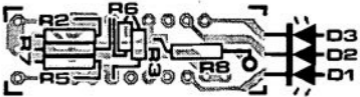
BUILDING ELECTRONIC CIRCUITS

Although ready-made printed circuit boards are available for most projects described in this magazine, there are cases where a 'real' PCB is not necessary. For instance, with small-scale experiments, or if the design is simply not critical as regards component layout. In such cases, prototyping board (also called stripboard or veroboard) is a very useful, easy to handle, alternative.

By our design staff

AS many of you will be aware, a printed circuit board is a key element in almost any electronics construction project, since it ensures compactness, reliability and safety. Unfortunately, making a printed circuit board for a particular circuit is often more difficult and time consuming than actually building the project, i.e., soldering and wiring. None the less, printed circuit boards are produced at home or in the hobbyist's workshop by skilful experimenters who are not daunted by the amount of work, which is mostly chemistry and photography.

After etching and cleaning, the printed circuit board is drilled using a suitable drilling machine. Next, the copper tracks are smoothed with a piece of wire wool, and then sprayed with solder lacquer to give them a protective coating. Optionally, a component layout is printed on the component side of the board.

As already mentioned, making one's own printed circuit boards is time consuming and certainly not easy, and not everyone will have the time and means necessary to achieve satisfying results.

If a certain printed circuit board is not available ready-made, or if no artwork is provided, construction on prototyping board should be considered. On prototyping board, components are soldered at the desired locations, and then interconnected using short lengths of enamelled copper wire, which run at the solder side. This method is well-proven, if only by the fact that nearly all circuits described in this magazine are built in this way by *Elektor Electronics* design staff before a printed circuit board layout is drawn.

The circuit diagram

Construction on a prototyping board is best illustrated with the aid of a practical example, in this case, building a simple generator.

Figure 1 shows the circuit diagram of a sine-wave generator which produces a fairly clean 1-kHz tone. The output level is adjusted with preset P_1. This tone generator is ideal if you want

to test and adjust audio circuits, but do not have a full-blown function generator. Since our main concern in the present article is the construction of a tone generator, a description of its operation is not given.

First, let us have a look at the tools and materials needed to build the circuit on prototyping board.

Tools and materials

Fortunately, the tools and materials needed to build a circuit on prototyping board are fairly common, and will be found even in the 'poor man's' workshop.

The materials shown in **Fig. 2** include a small piece of prototyping board cut to size. The connections between the components on the board are made in 0.2 mm dia (SWG36) enamelled copper wire. Note that this diameter is given as guidance only — connections carrying large currents should be made in thicker wire. Also needed is a soldering iron with a power rating of about 30 W. Obviously, there is nothing against using a temperature-controlled soldering station with adjustable solder temperature (350-400 °C). The relatively high solder temperature is needed, among others, to make the enamel lacquer coating at the wire ends melt, so that the copper wire can be tinned and soldered.

A sponge and a plastic flask containing a little water should be kept handy to enable the tip of the solder iron to be cleaned from time to time. The flask saves you having to walk to a tap every half hour or so to moisten the sponge. Several types of small flask or bottle may be used. The flask shown in **Fig. 2** used to contain contact lens cleaning/storage liquid, and was chosen because of its nozzle and solid sealing cap.

Furthermore, you need flat nose pliers, solder tin (type 40/60 alloy), PCB solder pins and, of course, the components that make up the circuit.

A component lead preforming aid is useful, but not indispensable. The same goes, basically, for a circuit board holder that can be used during the testing phase also. Finally, before you start soldering, make a copy of the circuit diagram on paper, and have a colour felt pen handy. Enlarge the diagram if it is complex.

Practical construction

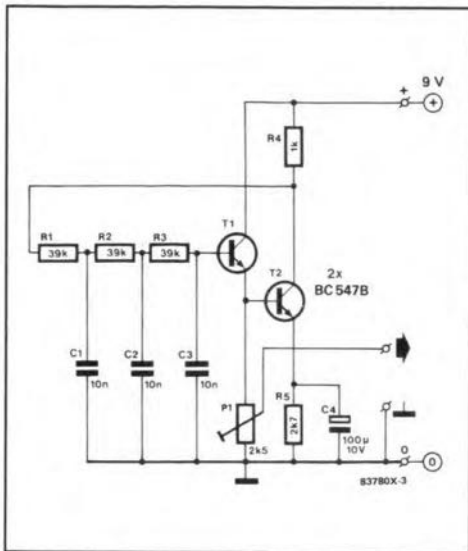Although the example circuit works at a voltage which is quite safe to touch,

Fig. 1. The example circuit discussed in this article is a simple sine-wave oscillator. Always useful as a signal source for testing audio circuits!

it is always useful to bear in mind the requirements for electrical safety when dealing with higher voltages, such as the mains. Wherever the mains voltage (240 V) is present on a printed circuit board, a minimum isolation distance of 6 mm should be observed between solder points. On prototyping board, this is easily achieved by removing all copper spots within a distance of 6 mm of, for instance, the spots to which the primary terminals of a PCB-mount mains transformer are soldered. The spots to be removed are firmly heated with the solder iron. The heat partly melts the

glue between the spot and the board material, and will cause the spot to come loose (**Fig. 3**), so that it can be picked up with the tip of the iron, or simply pushed off the board surface.

Start the construction by fitting the part with the highest number of terminals, or the largest size. This is done to prevent lack of space for this component later. For small parts, it is much easier to find a place if you find that one or two have been overlooked.

Transistor T_1 is selected as the central part in the sine wave oscillator, and it is fitted first, observing the size of preset P_1. Next, fit capacitor C_3 so that one of its terminals is close to the base of T_1 (see **Fig. 4**). Next, bend the capacitor terminal to the transistor base terminal, and join the two by soldering (**Fig. 5**). Mark this connection in the circuit diagram by running the felt pen over the relevant line in the drawing (**Fig. 6**). Make a habit of marking the interconnections in this way immediately after soldering — it may save you a lot of trouble later.

Next, fit preset P_1 in the vicinity of the emitter of T_1. The connection between the emitter and the preset is made using a short piece of copper wire. Make sure the solder iron is hot, apply some fresh solder tin to the tip, and then pre-tin the end of the enamelled copper wire which is still on the reel. Clean the solder tip by wiping it across the sponge — this is necessary because most of the solder resin will have evaporated at the high temperature. Do not cut off the wire as yet —

COMPONENTS LIST

Resistors:
R1;R2;R3 = 39kΩ
R4 = 1kΩ
R5 = 2kΩ7
P1 = 2kΩ5 preset

Capacitors:
C1;C2;C3 = 10nF
C4 = 100µF 10V

Semiconductors:
T1;T2 = BC547B
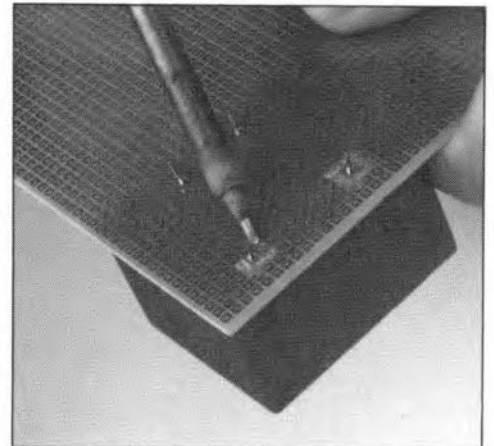
Fig. 3. All copper spots within 6 mm distance of a terminal at mains potential should be removed. This is readily achieved by heating spots with the solder iron, and then pushing them off the board.
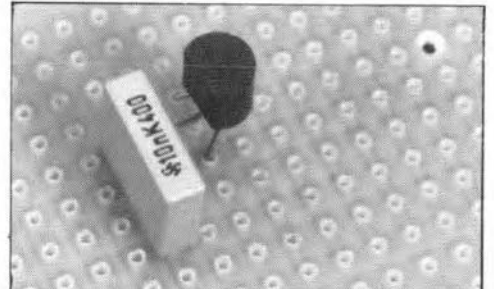

Fig. 4. Lack of space on a circuit board space may be avoided by first fitting the larger components. Since the connections are made with wires, the constructor is free to determine the position of the parts on the board (within limits, of course). Evidently, parts that are interconnected are mounted as close as possible to one another.
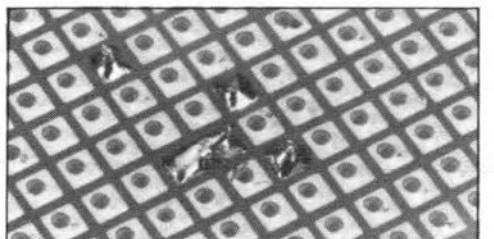

Fig. 5. Here, you do not need a wire. The connection between capacitor C3 and the base of transistor T1 consists of a bent terminal of capacitor C3.

Fig. 2. Most of the tools necessary for working with prototyping board will be available in your toolcase. A water flask, a component wire preforming tool and a circuit board holder are optional to make construction easier.

that would leave you with a short wire which is difficult to handle.

Solder the wire end to the emitter or the preset terminal. Next, run the wire to the other point to be connected, cut, and pre-tin the end. Clean the solder iron tip, apply fresh solder tin, and join the wire to the solder spot (**Fig. 7**). Mark the connection you have just made in the circuit diagram (**Fig. 8**). In
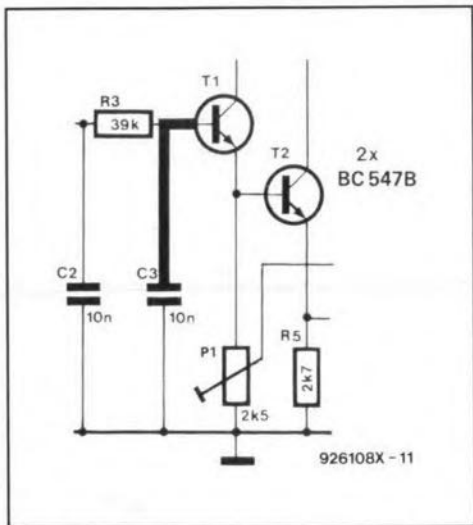

Fig. 7. Example of an interconnection made in enamelled copper wire at the solder side of the board. Thanks to the isolation formed by a thin enamel coating, wires are allowed to cross freely without affecting the operation of the circuit.

this way, all components are fitted on to the board, and interconnected as indicated by the circuit diagram. The connections with the 'outside world' (battery connections and signal output) are best made with the aid of solder terminals.

If there are no more components left (inspect the floor or the carpet also!), examine the circuit diagram copy to see if all interconnections have been marked. If this is the case, you may

reasonably expect the circuit to work spot-on. A careful last check on all connections and component polarities (where appropriate) will, of course, give you even more certainty.

To test the circuit, connect the power supply (in this case, a 9-V battery), and examine the output waveform on an oscilloscope.
∎

Fig. 6. The 'prototyping board' method works only if the connections made by soldering are consistently marked in (a copy of) the circuit diagram.
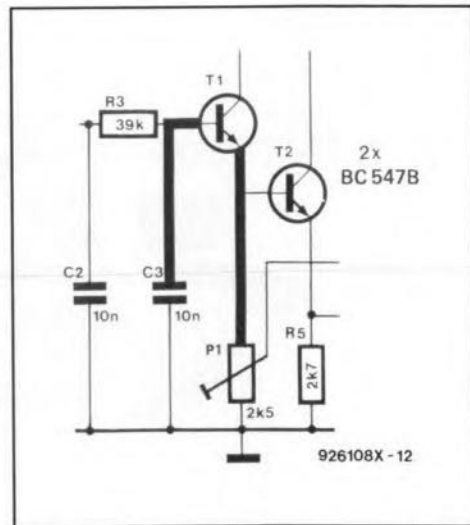
Fig. 8. The second connection made on the board is marked in the circuit diagram, by running a colour marker pen over the relevant line in the circuit diagram.

READERS' CORNER

BOLTON INSTITUTE, ALUMNI ASSOCIATION

May I appeal to any readers who are former students of Bolton Institute of Higher Education or who, prior to 1982, attended Bolton College of Education (Technical) or Bolton Institute of Technology. Indeed, we shall be glad to hear from anyone who during the last fifty years or so, prior to the Institute's creation, pursued a higher-level course in Bolton, e.g., at Bolton College of Art or Bolton Technical College.

Bolton Institute is establishing an Alumni Association (an association of former students of an educational institution) and we are trying to trace anyone who has studied at the institute, no matter when, as we want to reestablish contact with them.

We are inviting all former students to write and let us know what they are doing now and to join the Bolton Institute Alumni Association.

This year we hope the Institute will become Bolton's University, and former students will be invited to celebrate with us. We hope also to establish **International Alumni Associations** in other countries. We will be arranging reunions, giving information of new developments and sharing news about former students through the Alumni Magazine, the first issue of which was published in January.

Please write to: Jan Lancaster, Alumni Relations Officer, Bolton Institute, Deane Road, Bolton BL3 5AB, or phone (0204) 28851, extension 3808, or fax us on (0204) 399074.

PRODUCT NEWS

NEW EPROM EMULATOR FROM SQUAREWAVE ELECTRONICS

Squarewave Electronics has launched the MicroRom, a revolutionary new type of EPROM Emulator.

The MicroRom is a conventional EPROM

Emulator miniaturized into a module only 11 mm high that plugs directly into your EPROM socket. Unlike conventional emulators, there is no messy ribbon cable. Once programming is complete and the computer connection removed, the emulator can remain in circuit like a normal EPROM. Because of its non-volatile storage, the emulator can be used with any computer that has a Centronics printer port. No software is needed to run the emulator; just send an ASCII file containing systems information (such as EPROM size, data format type, any offsets, high or low reset), followed by the datafile, to the printer port. It can download a 27512 binary file in only 2 seconds.

Consider the MicroRom as an EPROM with an inbuilt programmer that has an unlimited number of write cycles.

For further information, contact Squarewave Electronics, Unit 25, Imperial House, 64 Willoughby Lane, London N17 0SP; telephone/fax +44 (0)81 880 9889. See also advert on page 59.

NEW EMULATORS FROM MICROAMPS

Dvelopers working with the 8031/51 microcontroller can get a low-cost, full function, In-Circuit Emulator from MicroAmps.

The ICE51+ features include small size (110×65 mm), operation up to 16 MHz, 64 kbytes of battery-backed memory partionable in 4 kbyte blocks between program and on-board or off-board data, 64 k hardware breakpoints in program and external data memory, single step and software trace together with a host of other facilities.

The BICEPS51 In-Circuit Emulator is capable of supporting almost al 8051 derivatives using a new technique that combines the best features of an EPROM emulator with a full-function In-Circuit Emulator.

The BICEPS51 replaces the EPROM in the circuit on test with 64 kbytes of emulation RAM that can be partitioned in 4 kbyte

blocks. The device requires a single adaptor to emulate almost all 8051 derivatives. The package comes with high-level debugging, hardware breakpoint capability, cross assembler and real-time trace buffer that can be interrogated 'on the fly'.

For more information contact Micro AMPS 66 Smithbrook Kilns, Cranleigh GU6 8JJ; telephone +44 (0)483 268 999; Fax +44 (0)483 268 397. See also advert on page 41.

SPICEAGE 3 FOR WINDOWS FROM THOSE ENGINEERS

V3 of SpiceAge for Windows gives an order of magnitude of speed rise for logic simulation over SpiceAge 2, previously believed to be the fastest analogue simulator of its type available. V3 benchmarks at 9 seconds on the digital test compared with 120 seconds on V2. Speed gains are also apparent on some analogue circuits. To support this, a new 32-channel logic analyser display is available, more digital models are provided and input signal bus structures are supported. The Zetex SPICE library of analogue semiconductor models is shipped with V3 and the analogue side is further expanded by a brand new opamp model especially developed to exploit the linear extrapolation pragmas provided in SpiceAge's polynomial functions. Not only is this topology more accurate than many SPICE models, but is faster to analyse.

For further information, contact Those Engineers Ltd, 31 Birkbeck Road, London NW7 4BP. Telephone +44 (0)81 906 0155; fax +44 (0)81 906 0969. See also advert on page 58.

IMPULSE RESPONSE MEASUREMENT AND PROCESSING

The dedicated IMP board from Falcon Acoustics, which is similar in operatio n to the KEF and Bowers & Wilkins impulse measurement, generates an impulse which is sent to the loudspeaker via an amplifier (your hi-fi

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COMPONENT RATINGS

In resistor and capacitor values, decimal points and large numbers of zeros are avoided wherever possible. Small and large values are usually abbreviated as follows:

p (pico-)	$= 10^{-12}$
n (nano-)	$= 10^{-9}$
μ (micro-)	$= 10^{-6}$
m (milli-)	$= 10^{-3}$
k (kilo-)	$= 10^{3}$
M (mega-)	$= 10^{6}$
G (giga-)	$= 10^{9}$

Note that nano-farad (nF) is the international way of writing 1000 pF or 0.001 μF.
Resistors are $^1/_3$ watt, 5% metal film types un-

less otherwise specified.

The direct working voltage of capacitors (other than electrolytic or tantalum types) is assumed to be ≥60 V. As a rule of thumb, a safe value is about 2× direct supply voltage.

Direct test voltages are measured with a 20 kΩ/V meter unless otherwise specified.

Mains (power line) voltages are not listed in the articles. It is assumed that our readers know what voltage is standard in their part of the world.

Readers in countries that use 60 Hz supplies, should note that our circuits are usually designed for 50 Hz. This will not normally cause problems, although if the mains frequency is used

for synchronization, some modification may be required.

The international letter symbol 'U' is used for voltage instead of the ambiguous 'V'. The letter V is reserved for 'volts'.

The size of a metric bolt or screw is defined by the letter M followed by a number corresponding to the overall diameter of the thread in mm, the × sign and the length of the bolt or screw, also in mm. For instance, an M4×6 bolt has a thread diameter of 4 mm and a length of 6 mm. The overall diameter of the thread in the BA sizes is: 0 BA = 6.12 mm; 2 BA = 4.78 mm; 4 BA = 3.68 mm; 6 BA = 2.85 mm; 8 BA = 2.25 mm.

amplifier?). The output pulse is picked up by a microphone and fed back into the IMP where it is digitized and then fed into an IBM (compatible) computer via the printer port. The IMP software then analyses the input via Fourier transforms and outputs the results on to the computer screen in graphical form in the shape of amplitude and phase response curves. Full control is via the PC. The amplifier output can be sampled via a probe to correct for errors in the pulse spectrum and amplifier response.

IM P allows the collection and analysis of 12-bit analogue data up to 4,095 samples in length and sample rates are selectable at either 61.441 kHz or 1.92 kHz which, along with the internal filtering, allows measurements from several hertz to 20 kHz.

Further information from Falcon Acoustics Ltd, Tabor House, Norwich Road, Mulbarton, Norfolk NR14 8JT, England. Telephone +44 (0)508 78272; fax +44 (0)508 70986.

CORRECTIONS

DIGITAL DIAL (January 1994)
An attentive reader has drawn our attention to the fact that the digital dial can not be used in conjunction with the receiver illustrated (a Yaesu Type FRG-7) since the IF of that receiver is much too high for the dial. Sorry for that oversight! [Editor]

VHF/UHF TUNER (Oct/Nov 1993)
The tuner module used in this design is no longer in production with Philips and its availability will thus become a problem. Fortunately, the Type UV916H is an excellent alternative. The snag is, however, that this unit is slightly smaller than the UV816,

so that the antenna connector no longer protrudes from the enclosure. This can be overcome by terminating the antenna cable into a coaxial plug and making the entrance hole slightly larger. Moreover, one of the two earth tags of the UV916H must be connected at a different position.

LETTERS

SCART SWITCHING BOX
(December 1993)
I have a few problems with this project, which I believe have to do with the connections. Pin 1 of one connector is linked to pin 2 of the other. The same is true of pins 3 and 19, which are linked to pins 6 and 20 respectively. All other pins are interlinked as one would expect, i.e., pin 5 to pin 5, pin 10 to pin 10, and so on.
L. Bastiaenssen

In a SCART cable, the wires for the video and audio connections are always crossed. That is why the video output (pin 19) at one end of the cable is linked to the video input (pin 20) at the other end. This arrangement ensures that the input of one piece of equipment is always connected properly to the output of another. There is, therefore, nothing wrong with your cable.

Note that two pieces of equipment must never be connected simultaneously to K_3 and K_5/K_6. Use SCART connector K_3 or the phono plugs K_5/K_6, but not both at the same time! [Editor]

PRECISION CLOCK FOR PCs
(November 1993)
I have encountered a problem with the Precision

clock for PCs. I have an IBM (compatible) PC486 and have, as stated in the article, complemented the CONFIG.SYS file with the following (last) line:
DEVICE C:\MSDOS\DCFCLOCK.SYS.

I should be pleased if you would tell me:
1. Where to should the files of the software provided (DCFCLOCK.ASM, DCFCLOCK.DOC and DCFCLOCK.SYS be copied? To the root, the MSDOS or a separate directory?
2. Once the files have been loaded, how is the program called up to initialize the driver and to fill the options P, I, S, B and D?
(M. Meersschaut)

The file DCFCLOC.ASM is the assembler listing of the program, which you no longer need (it is of interest only to dyed-in-the-wool programmers). The file DCFCLOCK.DOC contains the instructions for the program, which you can read with a word processing program. It is not necessary to store this file on a hard diksk.

The only program that you need to copy to the hard disk is DCFCLOCK.SYS. Place this file in the directory containing the DOS commands (e.g., C:\DOS). Add a line that indicates where the computer can find that program to CONFIG.SYS (in C:\), e.g. DEVICE = C:\DOS\DCFCLOCK.SYS. Other suffixes may be added for changing certain settings (see DOC file), but even without these the system should work correctly.

Note, however, that the receiver circuit must be connected to the COM port 2 and that the computer must be restarted after the software has been installed. The program will then automatically set the correct time in the internal clock of the PC every minute.
[Editor]