MULTIFUNCTION MEASUREMENT CARD FOR PCs

PART 2: CONSTRUCTION, ADJUSTMENT, SOFTWARE AND PRACTICAL USE

Following last month's formal description of the operation of the measurement card, many of you will be keen on tackling the more practical side of things. In this second and final instalment we concentrate mostly on the construction, which is fairly easy, and on the powerful, menu-driven control software package that brings the card alive on your PC.

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Reorienting

Having digested all the information on the design and operation of the measurement card presented in last month's instalment, we can now start to look at the construction of the unit. As shown in the photograph of our prototype, the printed-circuit board is fitted with a support bracket of the type used in PCs to secure insertion cards to a frame at the rear side of the computer. The PCB accommodates four connectors used for the various types of measurement. The upper two connectors, K1 and K3, are for the analogue measurements, while the lower one, K2, forms the protected digital input for frequency and pulse measurements. The other digital inputs are provided on connector K6, which is located next to the two PPIs (8255s) on the left-hand part of the PCB. Between connectors K2 and K3 we find LED D4, an indicator which that lights during the gate time when measurements are carried out on digital signals.

The lower edge of the PCB has the familiar PC extension bus connector, which consists of gold-plated contact fingers. To the top, at the right, we find the three multiturn presets, P1, P2 and P3, and switch S1. As will be detailed later, these components play an important role in the adjustment of the card. During the adjustment, the switch is used to generate two calibration signals. The two PCB solder pins to the right of P3 (marked 'adj.') form an adjust output, which is used during the alignment of the ADC only.

Building the card

The track layouts and the component mounting plan of the printed-circuit board are given in Fig. 3. As a matter of course, this PCB is double-sided and through-plated. Having noted that the PC bus extension con-

COMPONENTS LIST

Resistors:

1	10Ω	R1 (see text)
2	13kΩ 1%	R2;R4
2	6kΩ19 1%	R3;R5
*	see text	R6–R19
2	22kΩ	R20;R34
1	24kΩ3 1%	R21
1	1kΩ0 1%	R22
1	280Ω 1%	R23
1	953 Ω 1%	R24
1	3kΩ09 1%	R25
5	10kΩ 1%	R26;R39–R42
1	32kΩ4 1%	R27
1	110kΩ 1%	R28
1	453kΩ 1%	R29
1	22MΩ	R30
1	523kΩ 1%	R31
1	487kΩ 1%	R32
1	10kΩ	R33
3	330Ω	R35;R37;R38
1	100Ω	R36
1	2MΩ2	R43
1	820Ω	R44
3	500Ω multiturn preset	P1;P2;P3

Capacitors:

5	100nF ceramic	C1;C4;C7;C9;C10
2	47µF 25V tantalum	C2;C8
1	10 µF 25V tantalum	C3
2	56pF	C5;C6
7	22nF ceramic	C13;C14; C19–C22;C40
2	470nF 63V MKT	C11;C12
8	47µF 16V radial	C15–C18; C23–C26
7	100nF	C27–C32;C42
7	optional; see text	C33–C39
1	470nF	C41
1	1nF	C43
3	100nF ceramic SMD	C44–C46
1	10µF 25V tantalum	C47

Semiconductors:

3	BAT85 (PC)	D1;D5;D6
2	1N4148	D2;D3
1	LED red 3 mm	D4
2	TL431CLP (TI)	D7;D8
1	BC557B	T1
1	74HCT245	IC1
1	74HCT240	IC2
1	74HCT244	IC3
1	AD7572AJN03 (AD)	IC4
1	74HCT08	IC5
3	74HCT74	IC6;IC19;IC20
1	PAL 16L8 (ESS561)	IC7
1	74HCT02	IC8
1	OP200 (PMI)	IC9
2	74HCT4051	IC10;IC12
1	TLC2652 (TI)	IC11
2	82C55 (I;UMC)	IC13;IC14
1	74HCT86	IC15
1	74LS292	IC16
1	79L08	IC17
1	74HCT153	IC18
1	LS7060 (LSI)	IC21
1	74HCT151	IC22
1	78L08	IC23

Miscellaneous:

1	10-MHz oscillator block	OSC1
2	PCB-mount phono socket	K1;K2
1	16-way box header with angled pins	K3
1	26-way box header	K6
1	SPDT slide switch	S1
1	4 MHz quartz crystal	X1
1	PC card support bracket BICC-Vero type G99	
1	printed circuit board	900124

Manufacturer codes:

TI = Texas Instruments
PMI = Precision Monolithics Inc
PC = Philips Components
I = Intel
UMC = Umited MicroElectronics Corp
LSI = LSI Computer Systems Inc.
AD = Analogue Devices

nector is gold-plated for optimum contact with the slot connector in the PC, you will agree that is hard, if not impossible, to produce this PCB yourself and match the quality of the one supplied ready-made

It is recommended to use thin solder tin and a low-power solder bit with a very fine tip. Those of you confident of their soldering skills may want to do without IC sockets in the analogue section of the circuit (the analogue section essentially consists of the ADC the two multiplexers and the three associated opamps) In practice, it is often found that soldered connections are better than (inexpensive) IC sockets, which tend to develop bad contacts. If you are hesitant about soldering the (fairly expensive) components in the analogue section, consider the use of IC sockets with turned pins

Overall, the construction of the card is simple and straightforward if you follow the parts list and the component overlay printed in white on the PCB One area that deserves special attention, though, is the decoupling of the ADC chip. To enable the ADC to achieve the specified accuracy, it requires decoupling capacitors that are fitted as close as possible to the IC If the decoupling is inadequate, a number of the lower significant bits are not stable, making the measurements unreliable From the PCB layout it is seen that the ADC chip is fitted with three surface-mount assembly (SMA) decoupling capacitors, C44, C45 and C46, which can be mounted very close to the IC because they have no leads It should noted that C44 is mounted only when the -A type ADC is used A further decoupling capacitor, C47, is a tantalum bead type mounted at the solder side (i e the non-component side) of the board

The special decoupling of the ADC, together with the filter function of the software ensures that the measurement results are degraded only by the ±1-bit error of the LSB (least-significant bit). As discussed last month, this error occurs in all analogue-to-digital conversion processes and can not be eliminated

The final accuracy of the frequency measurement is basically achieved by the software, which has a filter function that builds the actual measurement value from up to a thousand measurement results obtained from very fast sampling. By evaluating all these measurement results, the software is capable of eliminating errors caused by, say, a small spike, or random interference

Jumpers JP2 to JP8 need not be fitted as yet, because the software will also function without hardware interrupts implemented As detailed last month, jumper JP1 sets the base address of the card Install it as required, with reference to Table 1

Jumper JP9 must be set to position C when the on-board 10-MHz oscillator is used Position D is used when an external reference oscillator is connected The function and use of jumper JP10 is discussed later in connection with the adjustment of the ADC

Depending on the desired measurement

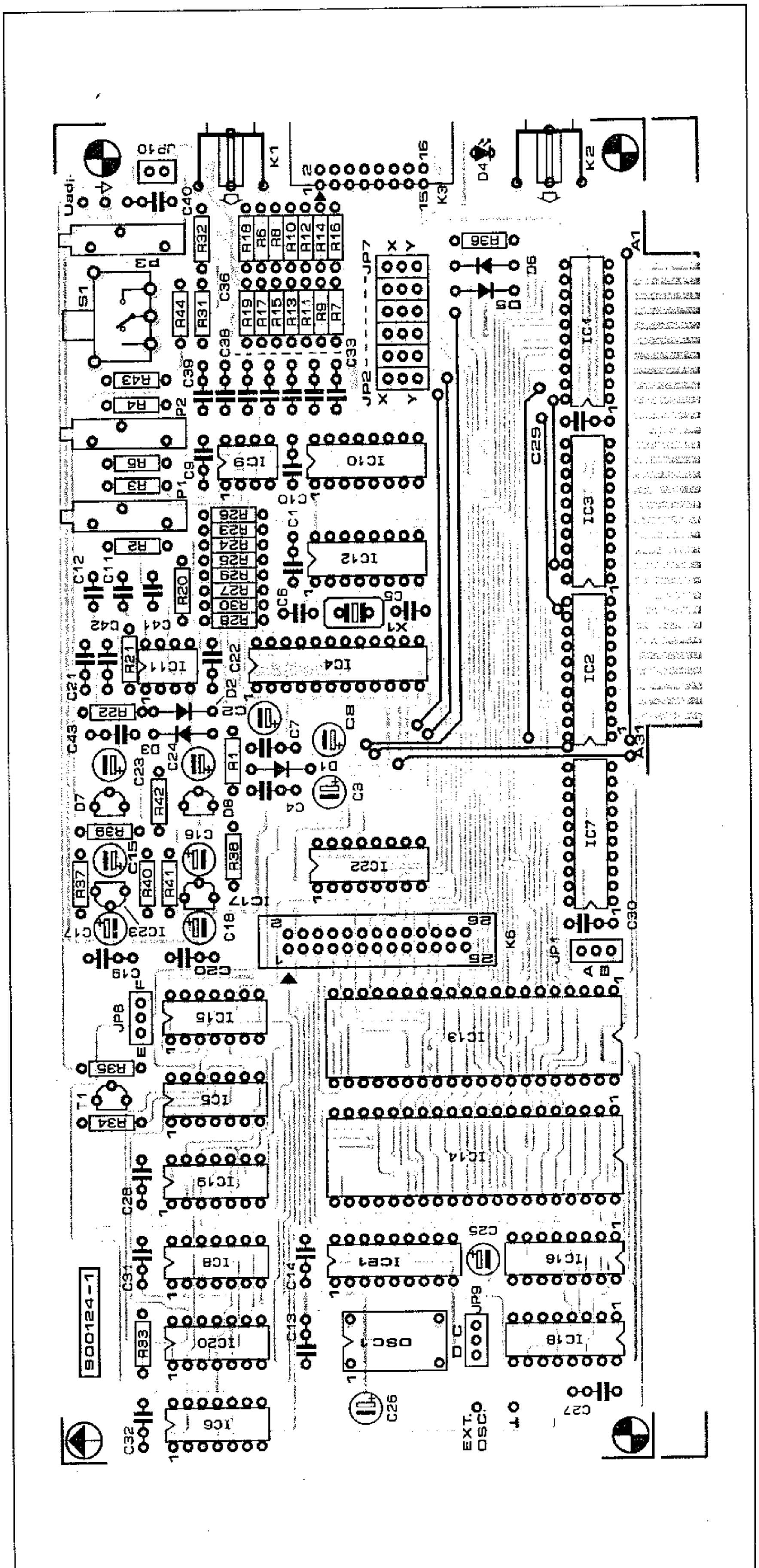


Fig. 3a. Component overlay of the double-sided, through-plated printed circuit board

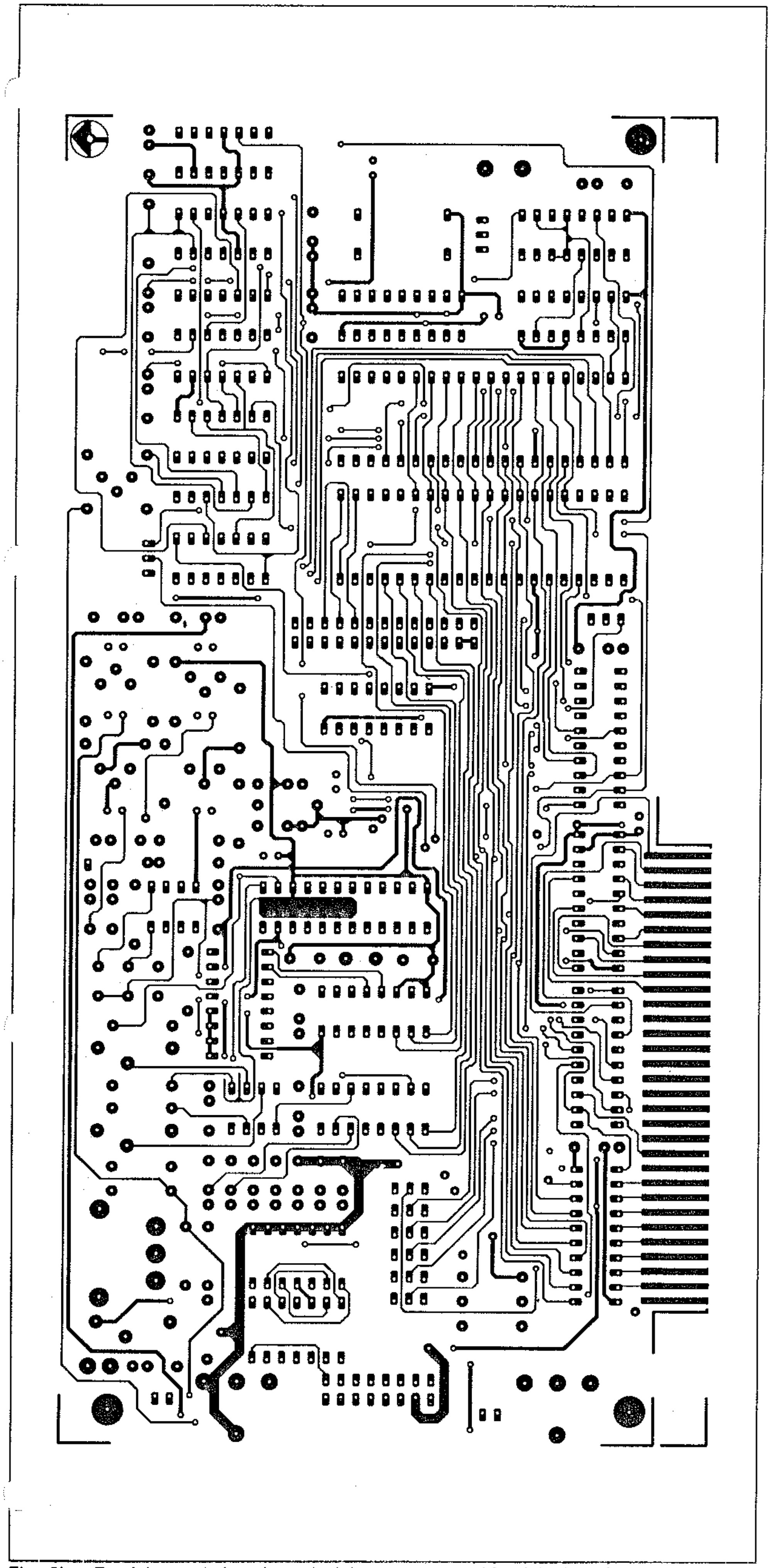


Fig. 3b Track layout (mirror image) of the component side of the board.

SOFTWARE SERVICE

This project is supported by two items in the Elektor Software Service (ESS) range:

- a diskette, order number 1461, containing the control program (MS-DOS format, 5¼-inch, 360 k);
- a ready-programmed PAL type 16L8 (IC7), order number 561.

For prices and details on ordering these products, please refer to the Readers Services page elsewehere in this issue.

range on multiplex channels I1 to I7, you must dimension resistors R_6 to R_{19} yourself. To prevent measurement errors caused by large ground currents these resistors preferably take high values. For the same reason, do not load the +8 V reference voltage on connector K_3. As indicated in the circuit diagram, the junction of each potential divider may be decoupled for alternating voltages with the aid of a capacitor (C_{33} to C_{39}).

Software

In all fairness a piece of high-tech electronics like the PC measurement card is of little use when you have no software to control it properly. Fortunately, such software exists, and is available in a ready-to-go state on a diskette for all PC-XT/AT MS-DOS computers.

The control program developed for the measurement card has been written in Turbo Pascal, and uses a large number of coloured menus to show the various measurement results. The software is uncritical as regards the type of PC, and can be used with video adapters such as the Hercules, EGA and VGA (not with the CGA). The software for the prototype card was written and successfully tested on a PC-AT with a hard disk, 640 kB of memory, MS-DOS version 3.2, and an EGA video card. A hard disk is not strictly required for the software to be used, but it does offer the additional comfort of faster switching between parts of the program.

If you have a hard disk create a subdirectory for the measurement card, and copy all the files from the distribution floppy disk into this subdirectory. If you do not have a hard disk, make a working copy of the distribution disk, and store the latter safely for use as a back-up. Make sure that the working copy is not write-protected.

The diskette supplied for the project has two EXE files: PCV.EXE, which starts the voltmeter program, and PCF.EXE, which starts the program for time-related measurements. Also on the disk are a number of configuration files used by the two programs.

Before using PCV.EXE or PCF.EXE, make sure that the configuration contained in ADCF.CFG is correct. If you inspect this file, you will find that the defaults are:

- base address: $0300
- reference frequency: 10 MHz, on-board XTO
- maximum gate time: 410 s
- full-scale voltage: 2.5 V

In most cases, the default settings allow PCF and PCV to be used straight away, unless you require a change in the base address. If necessary, edit the ADCF.CFG configuration file with the aid of a (simple) word processor such as EDLIN, PCTools, Norton or SideKick.

PCV, the PC-controlled Voltmeter

After fitting the card in the PC, leave the cover open as yet to provide access to the three multiturn presets. Run PCV, and check that the main menu appears (see Fig. 4). If the program reports that the card is not found, you have a problem. Not to worry, though: check for the correct base address in software (the configuration file) and in hardware (jumper JP1). If this is all right, a section of the hardware may not function properly, or the card causes an address conflict in the PC. Investigate and rectify the problem before proceeding.

Once you are looking at the main menu, you may confidently embark on the adjustment of the card. The adjustment procedure effectively matches the software to the hardware, ruling out the effect of component tolerances on the measurement results.

Adjust

Start by selecting the 'Adjust' option from the main menu. The information presented by this option, shown in Fig. 5, is clear and allows the ADC on the card to be calibrated quickly and efficiently. As already mentioned in part 1 of this article, channel I1 is used for the calibration of the ADC. Therefore, do not forget to disconnect R19, and fit R18 (or, if applicable, a wire link) on the PCB. The program then performs the adjust routine and provides all the instructions and help you need to achieve satisfactory results.

Learn

On completion of the 'Adjust' routine, return to the main menu. From there, select the 'Learn' option to calibrate the attenuators on the eight analogue inputs. The 'Learn' routine allows you to tell the program which attenuation is applicable at the inputs of the various analogue channels. The software automatically eliminates the tolerances in the ladder attenuators, and offers a number of options that allow you to select the analogue channel of which the transfer function (i.e., the attenuation) is to be 'learned'. As long as inputs I1 to I7 are not connected to additional attenuators, their maximum input voltage range is ±2.5 V at a conversion factor of 1. Nonetheless, these inputs need to be calibrated to enable the program to be initialised.

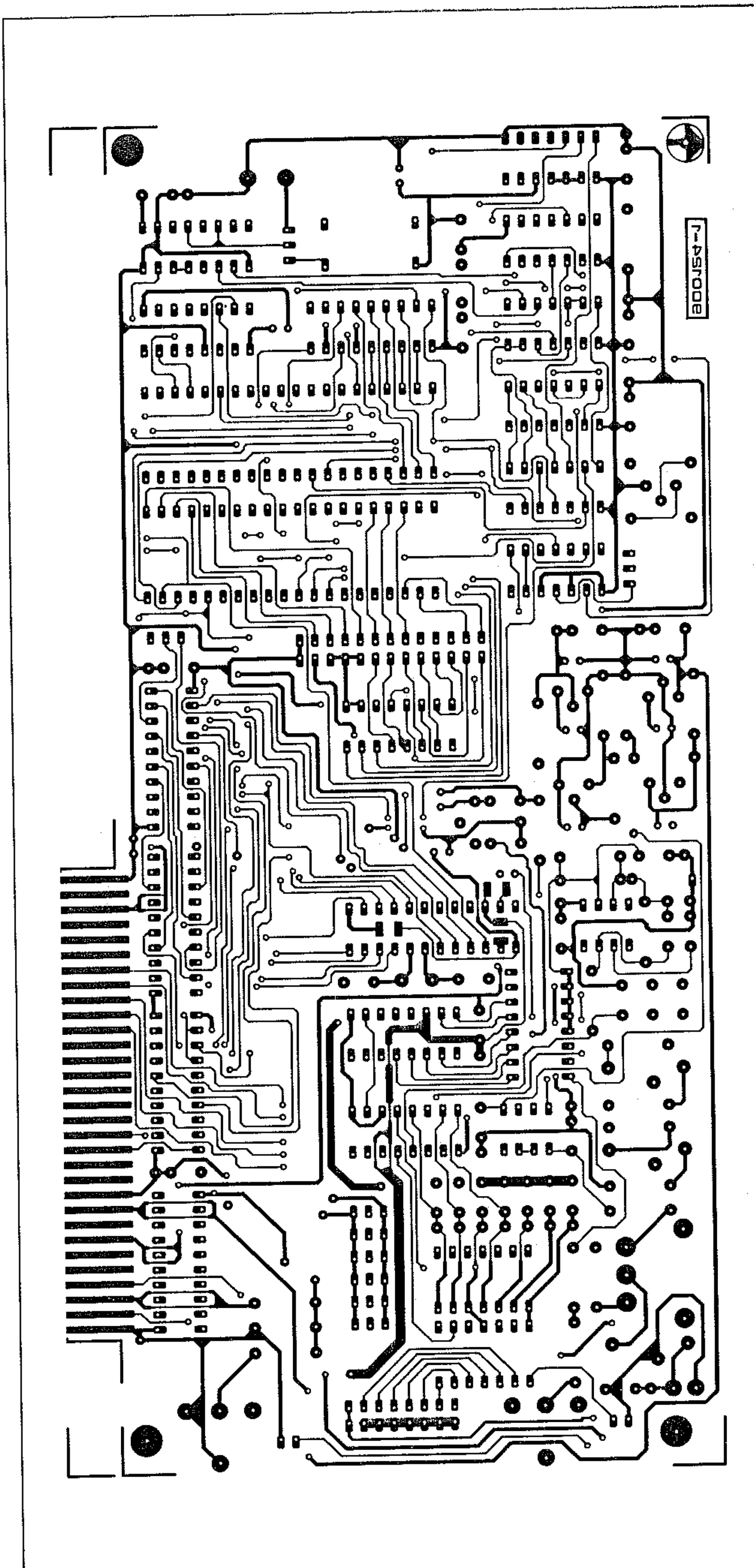
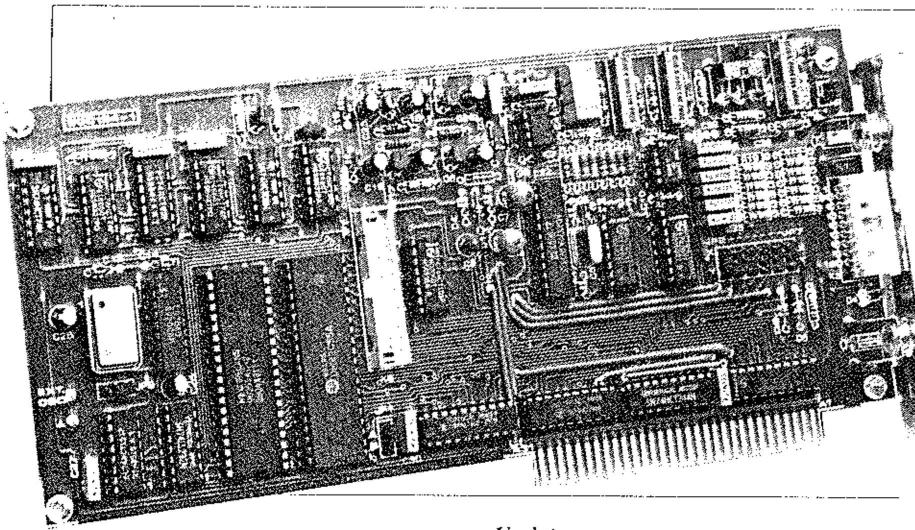


Fig. 3c. Track layout (mirror image) of the solder side of the board



The calibration is equally important on channel 0, since the passive attenuator used here may give rise to measurement errors. That is why the program calculates the exact attenuation for each attenuator position. The switching between the attenuation factors is performed by multiplexer IC12. Attenuator position '0' corresponds to a measurement range in which voltages up to 0.1 V can be measured. The highest measurement range, 300 V, is selected by position '7'. All positions between '1' and '7' must be calibrated one by one in the 'Learn' routine.

Since the results of the calibration are stored in a file, the software is capable of accurately determining the values of the input voltages every time it is used. If the attenuation changes after a while owing to ageing effects, the correction factors may be updated simply by running the 'Learn' routine. A further advantage of the software-controlled calibration is that the actual attenuator can be kept relatively simple, and based on resistor values from the E96 series.

The 'Learn' option is relatively simple to use. Connect a test voltage of about half the maximum value to the relevant analogue input. Monitor this voltage with an accurate digital voltmeter (DVM). Select the 'Edit' option to open a small window in which the value of the input voltage is entered (see Fig. 6). This input voltage is read from the DVM. Next, the software computes the conversion factor and the maximum input voltage that may be applied to the input in this range before the ADC starts to produce overflows. Overflows must not occur until the input voltage exceeds the maximum level defined for the particular range. If the maximum measurement value is not reached in a particular range, the relevant resistor in the attenuator must be made a little smaller. If this is not done, the maximum level can never be measured, making it impossible for the autoranging function to work properly (remember, the software does not select the next higher range until the maximum level in the currently used range is exceeded).

Update

When all measurement ranges (and channels) have been calibrated, the conversion factors may be written to a file on disk. This is accomplished automatically on selection of the 'Update' function. The conversion factors are stored in a file called RATIO.CFG for use by the program when this is started.

After this calibration procedure, the card is ready for use. It is recommended to store the different CFG files on a separate diskette for use as back-ups when, for some reason or other, the files on the hard disk or the working copy of the floppy disk, are lost or corrupted (which would force you to go through the calibration routine again).

PCV

To start the PC Voltmeter, simply select the option 'PCV' from the main menu. The result is shown in Fig. 7: the measured value is displayed in the form of large numbers on the screen. Below the voltage indication is a bar-graph showing a corresponding value. The associated menu allows a number of preferences to be set. For example, the 'Sound' option enables a short beep to be produced when an overflow occurs. The optional filter function uses an algorithm to produce an average measurement value on the basis of a large number of measurements, thus reducing the risk of errors to a minimum.

```
Adjust the 12-bit ADC
 ***  Elektor  Electronics  ***
  ***  Copyright (C) -> 1990  ***
   ***  ESS: 146 (1, 2, 3, 4)  ***

      PCV
      Learn          PCV
      Adjust
      Quit                      >> V1.0/JR <<
```

900124-II-11

Fig. 4. **Screendump of the PCV main menu**

```
Adjust the 12-bit ADC
 ***  Elektor  Electronics  ***
  ***  Copyright (C) -> 1990  ***
   ***  ESS: 146 (1  2  3  4)  ***

              ADC ADJUST
   Offset must be adjusted before full-scale error. This
   is achieved by applying an analogue input of 0.61 mV. So
   switch S1 to position "H" and adjust P3 until the volt-
   meter reads exactly 0.61 mV.
   Now adjust P1 until the ADC output code flickers between
   1000 0000 0000 and 1000 0000 0001.

   Press ENTER or click left mouse button to continue....

     ADC OUTPUT
   1000 0000 0000
```

900124-II-12

Fig. 5 **On selecting the 'Adjust' option from the above menu, you enter a guided calibration procedure for the ADC**

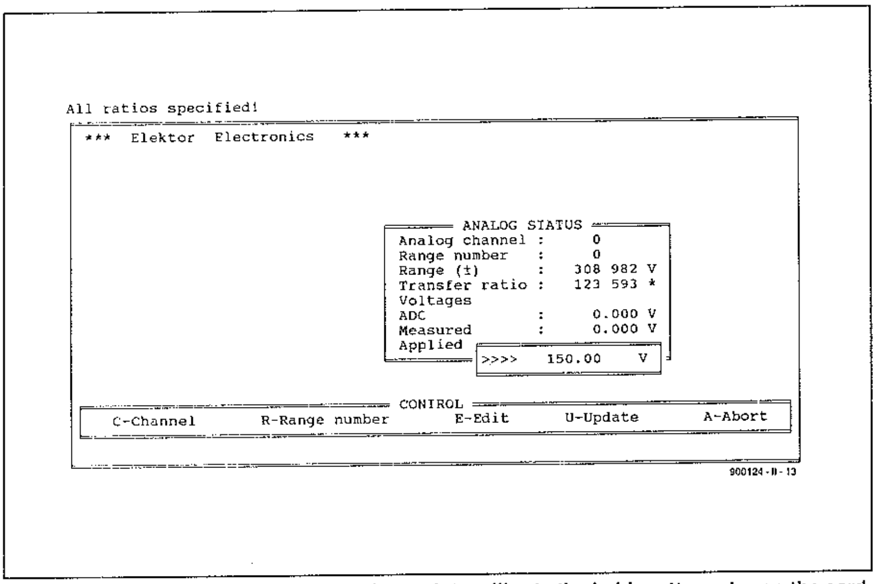


Fig. 6. The 'Learn' sub-menu of PCV is used to calibrate the ladder attenuator on the card.

The 'Channel' function enables you to select the channel of which the measurement results are shown in the large window.

Finally, a maximum input voltage level may be defined individually for each channel. A screen indication is provided when this value is exceeded. This indication takes the form of an exclamation mark (!) in the eight small windows at the bottom of the screen, a short beep, and a special 'Check-Lim' indicator in the large window.

Quit

When the 'Quit' option is selected, the most recent settings are stored in the file PCV.CFG. These settings are called up automatically by PCV when the program is started.

PCF, the PC-controlled Frequency/Pulse Meter

The PCF.EXE program is used for all time-related measurements on digital signals. As already mentioned in part 1 of this article, the available measurements are very accurate, covering the basic signal parameters frequency, period time, pulse/pause (on/off) ratio, and pulse time.

The program PCF.EXE does it all. Like PCV, it is user-friendly and features menus as well as windows for the measurement results. The menu allows you to select frequency measurement, event count, period time, duty cycle, or pulse time of the input signal. The screen shows the most recent results obtained from a measurement. These results are not updated until the relevant measurement is performed again. To keep you informed about what is being measured, the current type of measurement is underlined.

The event count and pulse time measurement each offer two submenus which allow the trigger edge and the on or off time to be selected respectively. The desired input channel is also selected via a submenu.

During the measurements, the measurement window indicates the current channel and the lapsed gate time. The latter indication is particularly useful for measurements involving relatively long gate times. When an option is selected that requires additional information to be entered via a submenu (for instance, the 'Channel' option which takes the channel number in this way) the measurement window shows the indication 'Waiting for instructions!'. The relevant measurement does not start until you have entered the requested additional information.

The last menu option, 'Chain', provides an 'all-in-one' type of measurement, returning values on frequency, duty cycle, period time and pulse time (pulse 'on' as well as pulse 'off'). Since it has little meaning in the case of continuous signals, the event count function is excluded from the 'Chain' measurement, which, without doubt, is a good starting point for most measurements. ■

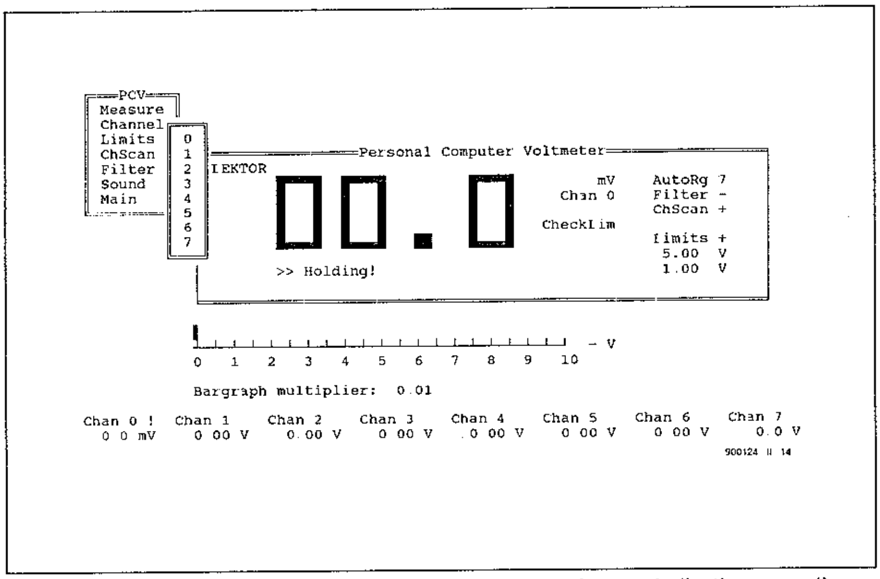


Fig. 7. The PCV in action. The display shows a large voltmeter indication as well as a bargraph read-out.

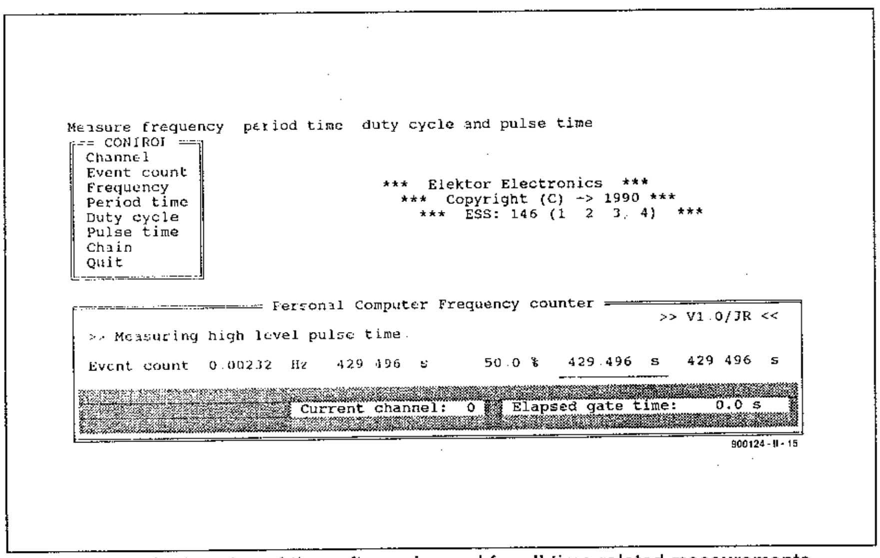


Fig. 8. The PCF function of the software is used for all time-related measurements.