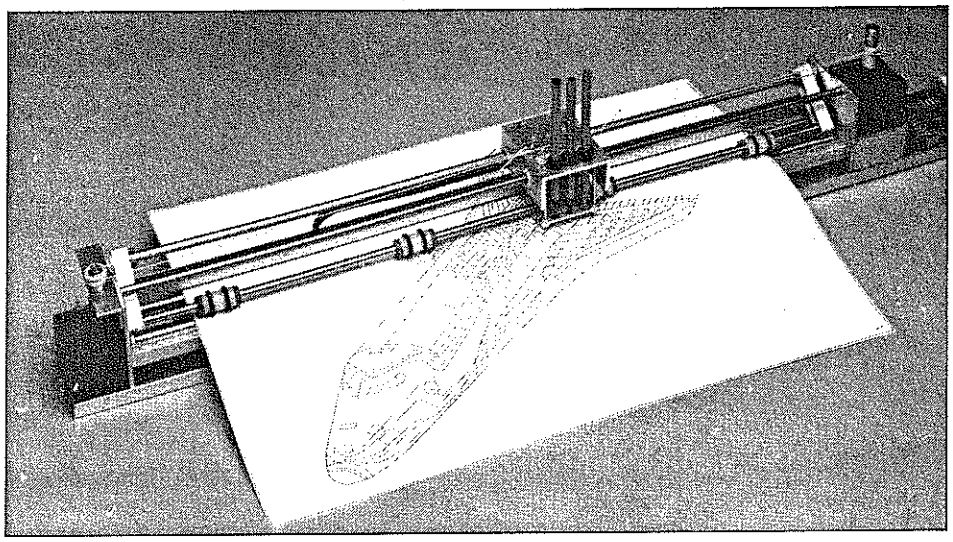
PLOTTER MARK-II

with a contribution by B. Lewetz



The plotter we published roughly two years ago is among our most popular projects thanks to a relatively simple mechanical construction and the availability of an associated stepper motor driver board. Although a number of readers have sent us suggestions for software drivers that would enable the plotter to be used with popular computers, only Mr. Lewetz' contribution proved to meet the requirements as regards use of the driver on IBM PCs, and (at least partial) compatibility with the industry-standard HPGL plotter command language. Before introducing the software, however, we avail ourselves of the opportunity to propose some improvements to the mechanical design of the plotter.

Like its predecessor (Ref. 1), the Mark-II version of the plotter uses paper movement for the Y-direction, and pen movement for the X-direction. As such, the operation of the plotter is not unlike that of a matrix printer. The platen which causes the paper movement is operated direct by a stepper motor. The pen carriage is coupled to another stepper motor via a string. Small solenoids control the pen up/down movement. The simple mechanical construction and the possibility of customizing the plotter width in accordance with the maximum required paper width are important factors that made us prefer the above arrangement over the more complex X-Y variant.

The plotter works in conjunction with a control board which translates a bit-pattern applied to its input into the corresponding control signals for the three solenoids and two stepper motors. The circuit is based on two special stepper motor driver ICs from Motorola which obviate complex bit-shift and timing operations for the control of the half-step and full-step modes as well as the forward/reverse movement of the stepper motors at the required accuracy. The chips, Type MC3479, allow the 8-bit wide input of the control board to be driven by a Centronics (printer-) port, which is available on almost any IBM PC-XT, AT or compatible. Connection details are given in Fig. 2.

The control board used for the new version of the plotter is that discussed in Ref. 1: no changes are required, and the circuit works in conjunction with the software package described further on.

Mechanical work

Since the mechanical construction of the plotter is discussed at length in Ref. 1, there is no need to repeat it here. The new working drawings, Figs. 1 and 3, and the associated parts list reflect most of the mechanical changes made to the original design. The most important change is that the Mark-II version is about 10 cm wider, which allows A2 paper to be used sideways and A3 paper lengthwise. Four paper rollers are used instead of two for improved accuracy of the Y-movement. Also, the platen is fitted with a 12 mm diameter bearing at the free side to reduce friction (see Fig. 4: the original had a nylon bushing).

Further improvements to the original design have been suggested by numerous readers. The use of a lathe to reduce the diameter of the platen at the locations of the sandpaper grips, for instance, may be gone round by covering the platen in flexible conduit. The same is suggested for the paper rolls. It should be noted, however, that these modifications may result in different step sizes for the horizontal and vertical movement, which may require software-controlled compensation.

Further suggestions as regards improving the mechanical stability of the plotter entail the use of 4-mm thick aluminium, stainless steel or silver steel. One of our readers in Greece, a lathe operator by profession, has built the plotter from stainless steel, using sintered metal for the

MAIN SPECIFICATIONS

Hardware:

- beam plotter for paper size up to DIN-A2 (594×420 mm)
- repeatability: <0.1 mm
- 3 colours
- simple construction
- control board with centronics input

Software:

- partially HPGL compatible (6 commands supported)
- plot commands sent via Centronics port
- compatible with *Elektor Electronics* plotter driver board
- software spooler
- configuration file
- programmable plot speed
- multitasking Turbo-C control program
- auxiliary programs for:
  - keyboard control
  - plot file formatting
  - full/half-step operation

bearings, and PTFE (teflon) for the rollers. The use of high-grade metals, however, requires a wide range of tools and other special materials from your local hardware shop, and, of course, access to a lathe.

The nylon string is a crucial part and requires special attention because it must be secured in a manner that eliminates any risk of slipping on the spindle of the X-motor. One string end is secured to the carriage at the side of the string wheel. From there, the string goes to the string wheel where it makes a left turn towards the X-motor. The carriage is pushed to the extreme left (X-motor side), and the string is wound on to the motor spindle (part id. 10) until one particular point in the string is always in contact with the spindle. This means that the total length of the wound part of the string is equal to or greater than the maximum X-distance that can be travelled by the carriage. The point in the string is secured at the top of the motor spindle with the aid of an M3 screw.

Software

The software driver developed for the plotter runs on IBM PCs and compatibles. The driver is written in Turbo-C (Borland version), and is capable of reading plot files with a reduced command set to the HPGL, Calcomp or Gould standard. The program converts the data and commands in these files into coordinate numbers in the relevant plot area before it sends, via the Centronics port, the necessary motor and pen control commands to the plotter driver board.

To be able to generate a usable plot file, the CAD program which is used to make the drawing must have plotter types

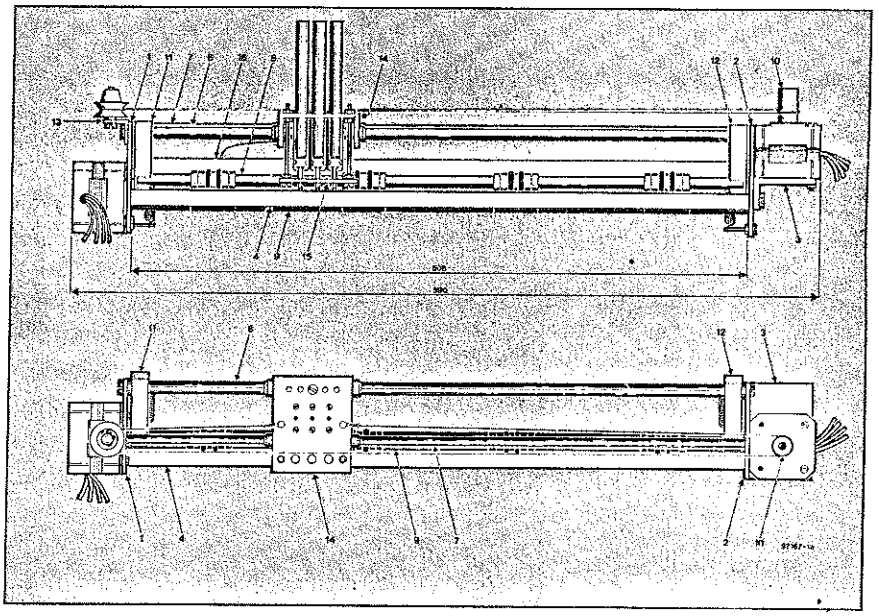


Fig. 1a. General parts identification of the plotter.

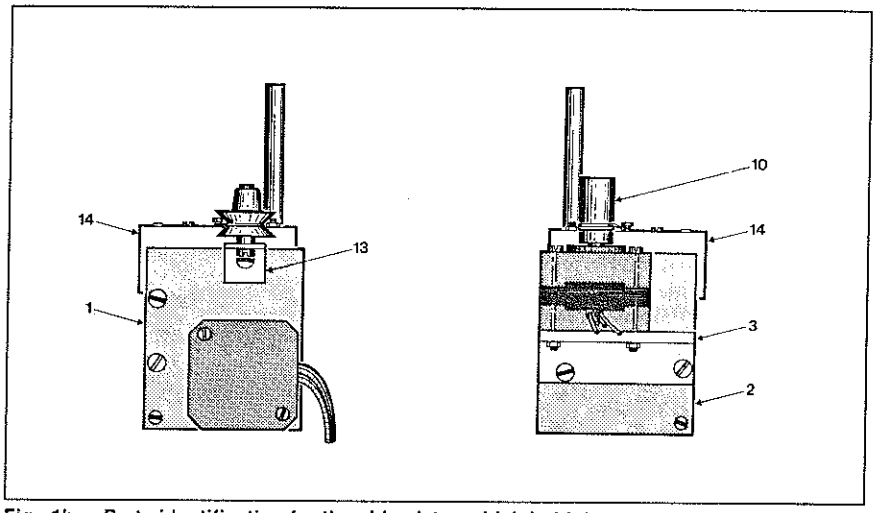


Fig. 1b. Parts identification for the side plates which hold the stepper motors.

AS = 3	Number of pens
PW = 0	Pause at pen change (0/1)
WB = 100	Wait time after pen actuation (clock cycles; 1–255)
2X = 0	X-difference between pen 1 and pen 2 (–500–500)
2Y = 0	Y-difference between pen 1 and pen 2 (–500–500)
3X = 0	X-difference between pen 2 and pen 3 (–500–500)
3Y = 0	Y difference between pen 2 and pen 3 (–500–500)
MX = 1700	Maximum X-coordinate (0–1000)
MY = 2000	Maximum Y-coordinate (0–10000)
SD = 4	Step duration (clock cycles; 1–255)
SS = 1	Parallel port number (1/2)
GS = 0	Full-step mode
PT = 55	System clock (1–255)
LA = 1	Loudspeaker on/off (0/1)
BV = 1	Slow/fast (0/1)
PS = 1	Plot language (1=Calcomp; 2=Gould; 3=HPGL)
RA = 1	Draw frame (0/1/2)
SX = 100	X-scale (1–1000%)
SY = 100	Y-scale (1–1000%)

Table 1. Parameters in the driver configuration file, MONDRIAN.SYS.

HP7220, Calcomp 81 or Gould 6200 in its device driver list. On completion of the drawing, the plot file is not sent direct to the Centronics port, but to a file which is temporarily stored on disk.

The plotter driver program, MONDRIAN.EXE, is called up with the plot file name as an extension, for instance:

MONDRIAN NOZZLE.CAL

To enable the driver program to find the plot file, it must either be listed in the same subdirectory, or the PATH configuration must be set accordingly.

The program starts with a menu screen which shows the current options and parameters. The lower window on the screen shows the plotter commands as they are read and converted.

The program works on two tasks in a quasi-simultaneous manner: the conversion of plot coordinates into step pulses for the motors, and, in the background, the sending of calculated values to the plotter control board via the Centronics interface. A problem may arise from the assignment of processor time to these tasks. If the calculations run too fast, the plotter forms a bottleneck after a relatively short time. Conversely, if the calculations run much slower than the actual plotter control, the plotter wastes time waiting for new commands from the computer. The time sharing problem is eliminated by an auxiliary program, REALTIME.COM, which establishes an optimum time ratio for the two processes on the basis of the computer type used.

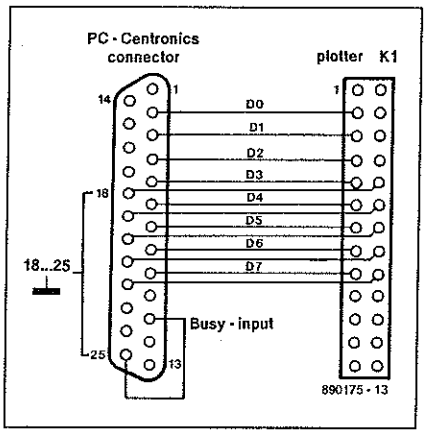


Fig. 2. Connections between the PC Centronics port and the input of the plotter driver board.

The driver program may be called up with a test switch:

MONDRIAN /T

to check quickly and without wasting paper whether the drawing fits on the required paper size. If not, the scale factors must be modified accordingly.

Parameters and configuration file

The plotter driver program is simple to configure for different mechanical constructions (as already noted, the constructor determines his own plotter width). The configuration file on the disk, MONDRIAN.SYS, contains the start parameters — an example is shown in Table 1. The file contains ASCII characters only and may be edited with a word processor. Each line starts with a two-letter parameter identification and a default value, which can take up to three digits. As shown in the example, each line is made complete with comment.

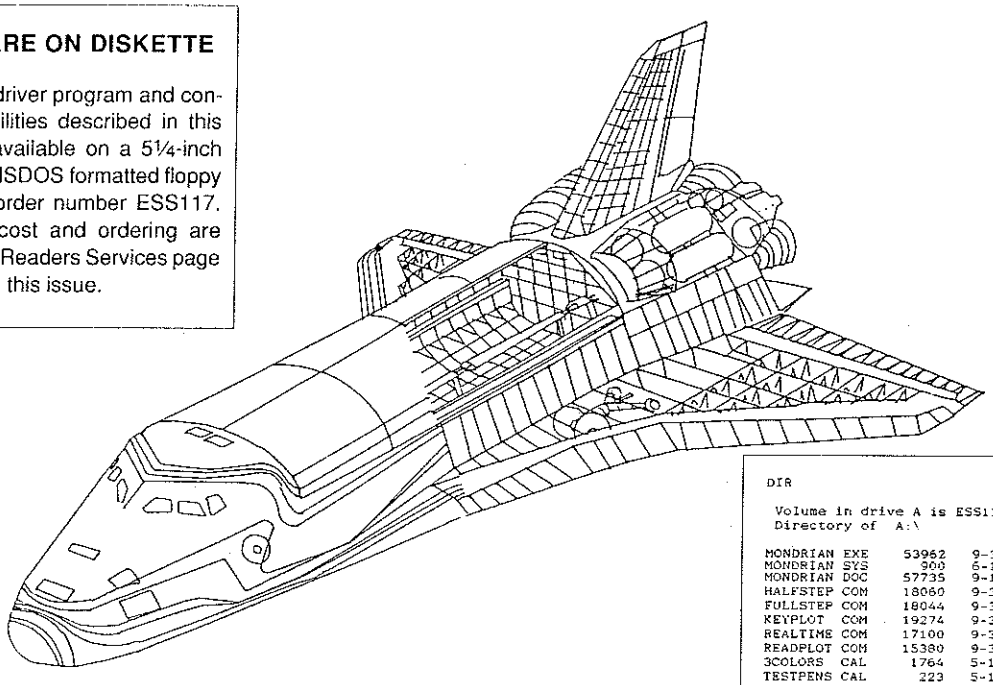
When called up, the control program searches for MONDRIAN.SYS and loads the user-defined configuration. If the file can not be found, default values are adopted for the parameters otherwise loaded from MONDRIAN.SYS. A fair number of configuration options is available, from the number of pens to the zoom factor and the plot language. The nX parameters (X-Y difference) allow drilling inaccuracies in the pen holes to be compensated: in this manner, the inaccuracy caused by a pen (= colour) change can be kept smaller than 0.1 mm.

Limitations

It should be noted that version 1.0 of MONDRIAN.EXE recognizes only six HPGL (Hewlett-Packard Graphics Language) commands, while the language has many more. The same goes for the Calcomp and Gould formats: only six commands are supported. Fortunately, many problems caused by this limitation may be prevented by using the right plotter driver. Most CAD programs allow the user to select a particular plotter driver from a menu during installation of the

SOFTWARE ON DISKETTE

The plotter driver program and configuration utilities described in this article are available on a 5¼-inch 360 KByte MSDOS formatted floppy disk under order number ESS117. Details on cost and ordering are given on the Readers Services page elsewhere in this issue.



```
DIR

 Volume in drive A is ESS117
 Directory of  A:\

MONDRIAN EXE     53962   9-30-89    9:05p
MONDRIAN SYS       900   6-15-89    7:20p
MONDRIAN DOC     57735   9-12-89   10:19p
HALFSTEP COM     18060   9-30-89    9:05p
FULLSTEP COM     18044   9-30-89    9:06p
KEYPLOT  COM     19274   9-30-89    9:06p
REALTIME COM     17100   9-30-89    9:07p
READPLOT COM     15380   9-30-89    9:07p
3COLORS  CAL      1764   5-15-89    8:19p
TESTPENS CAL       223   5-15-89    9:08p
NOZZLE   CAL     55213   5-15-89    8:38p
COLUMBIA CAL     25984   5-15-89    8:44p
ESCHER   CAL      9489   6-11-89   10:58a
README            957   9-30-89    9:02p
MONDRIAN MSG     2647   1-03-90    8:52a
UTILITY  MSG     2076   1-03-90    9:03a
       16 File(s)      56320 bytes free
```

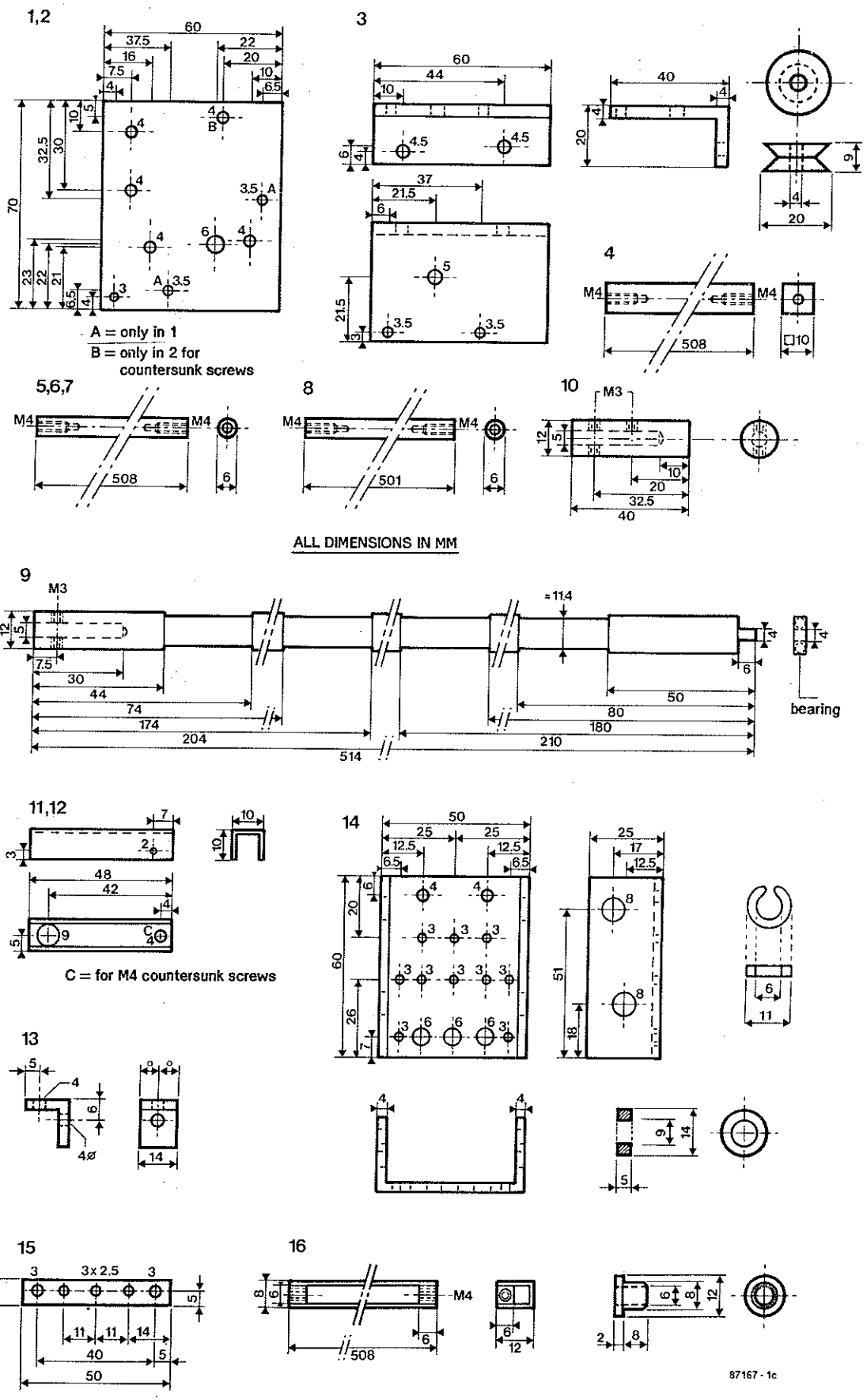


Fig. 3. Dimensions of all nylon and aluminium or stainless steel parts that must be cut, filed, turned and drilled.

MECHANICAL PARTS LIST

(all dimensions in mm)

1. side plate; left; aluminium; 60×70×3 mm.
2. side plate; right; aluminium; 60×70×3 mm.
3. angled support bracket for X motor; L-shaped aluminium; 20×40×4 mm; length 60 mm.
4. square connection bar; aluminium 10×10 mm; 508 mm long.
5. round connection bar; aluminium/stainless steel rod; dia. 6 mm; 508 mm long.
6. round support bar for pen carriage; dimensions as 5.
7. round guide bar for pen carriage; dimensions as 5.
8. round bar for pressure rolls; aluminium/stainless steel rod; dia. 6 mm; length 501 mm.
9. platen; round aluminium bar; dia. 12 mm; length 514 mm.
10. shaft; aluminium; dia. 12 mm; length 40 mm.
11. tilt lever for pressure rolls spindle; U-shaped aluminium beam 10×10×1 mm; length 48 mm.
12. see 11).
13. angled support bracket for string wheel; U-shaped aluminium beam 15×15×2 mm; length 14 mm.
14. pen carriage; U-shaped aluminium beam 25×50×3 mm; length 60 mm.
15. pen positioning plate; aluminium; 8×50×2 mm.
16. cable guide; U-shaped aluminium beam 12×8 mm; length 508 mm.

Miscellaneous parts:

6 off slide bearings; nylon; Skiffy 08-6.
1 off bushing for platen; nylon; Skiffy 08-4 or 08-6, or suitable ball bearing.
2 off washer rings for Y-motor; internal dia. 3 mm; thickness 2 mm.
2 off rubber pressure rolls (e.g. cable grommet).
4 off fixing rings for dia. 6 mm spindle (e.g. Skiffy 11-1-6).
1 off string wheel.
3 off cylinder head screws M4×5.
2 off cylinder head screws M4×10 (for fixing part no. 3).
1 off cylinder head screw M4×20 with 3 nuts.
5 off M4×5 screws with countersunk head.
4 off cylinder head screws M3×40 (for fixing stepper motors).
2 off cylinder head screws M3×50 (for fixing part no. 15).
2 off cylinder head screws M3×10 (for fixing string).
2 off cylinder head screws M3×15 (for fixing spring brackets).
4 off headless adjustment screws M3×3 (for fixing part nos. 9 and 10).
6 off bolts M2.6×5 (for fixing pen lift magnets).
16 off hexagonal nuts M3.
2 off springs for pressure rolls spindle.
string; e.g., wound fishing line
fine grade sandpaper (for securing on platen).

Electromechanical parts:

2 off stepper motors; 200 steps/rev.; dual-phase bipolar; 200 mA/phase (e.g. Berger as used in disk drives).
3 off pen lift electromagnets; 12 V; e.g. Binder Magnete Type 40031-09B00.

Distributor of Skiffy products in the UK is Salterfix Fasteners • Salter Springs & Pressings Limited • Spring Road • Smethwick • Warley • West Midlands B66 1PF. Telephone: (021 553) 2929. Telex: 337877.

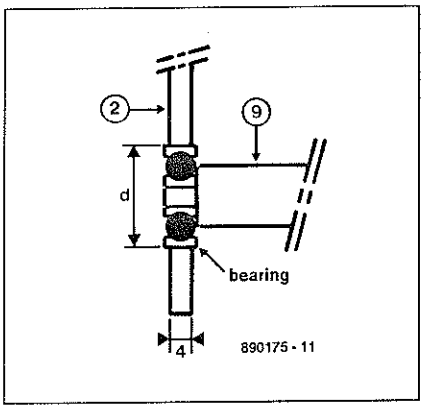


Fig. 4. A ball-bearing may be used where the plate is secured to the side plate.

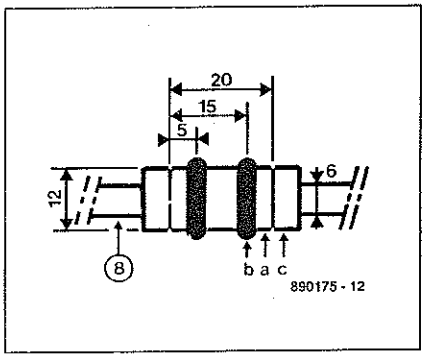


Fig. 5. Detailed construction of a paper roll.

package. Programs like AutoCad and AutoSketch, for instance, use only six plot commands if a Hewlett Packard plotter is installed: circles and ellipsoids are drawn with the aid of MOVE and PLOT sequences rather than with the much more powerful ARC command. This means that only a subset of basic HPGL commands is used. Since the present driver program, MONDRIAN.EXE, is capable of handling the six basic commands, it should be suitable for many CAD packages, provided they can be configured to save plot files with the reduced set of HPGL commands. ■

Reference:

1. Plotter. *Elektor Electronics* May 1988 and June 1988.

```
Elektor Plotter Driver      Version 1.0      (c) Copyright by Elektor, 1989

stop at new pens          OFF   |  file name                 nozzle.cal
full-step                 OFF   |  plot commands             CALCOMP
speaker                   ON    |  frame size                1700/2000
speed up/slow down        ON    |  scaling                   100%/100%
frame                     ON    |  clock                     0.99 ms
number of pens            3     |  clocks per step           4
parallel interface        1     |  clocks per pen movement   100

   41 : 1347/1115K     move to :1347/1115
   42 : H              pen up
   43 : 1325/1123K     move to :1325/1123
   44 : I              pen down
   45 : 1174/1274K     move to :1174/1274
   46 : 1168/1282K     move to :1168/1282
   47 : 1167/1291K     move to :1167/1291
   48 : 1168/1300K     move to :1168/1300
   49 : 1174/1308K     move to :1174/1308
   50 : 1659/1794K     move to :1659/1794
   51 : H              pen up

continue - press any key...   |  c - cancel  p - pause  s - stop
```

Fig. 6. Screen dump of the plotter driver program, MONDRIAN.EXE.