



REINTRODUCING TYPE 3 FONTS TO THE WORLD OF TEX

Wlodek Bzyl
matwb@univ.gda.pl

Abstract

Nowadays, a great number of documents are produced every day. Many authors would like their documents to stand out from the rest not only by content but also by typographic design. For this purpose one may use decorative letters, ornaments, dingbats and special fonts. If each document would have to look different from all the others a great many fonts and font deviations are needed. This could be achieved by combining the METAPOST language with the type 3 font format. This new font creation technology enables users endless single-use-only variations in weight and width, style and size, and in color. A new level of control over the embellishment level of fonts in documents is thereby achieved.

INTRODUCTION

For the past five centuries type has been cut in wood and cast in metal. The idea that a computer program could design type where letterforms are represented by procedures which draw each letter with lines and beziér curves has appeared recently. More than twenty centuries of build-up knowledge about geometry and curves proved to be applicable in this transition.

In 1977 the first METAFONT fonts were created by D. E. Knuth. In 1984 the first PostScript Type 1 fonts were created by Adobe Systems.

In Knuth's approach, shapes are designed in a declarative manner and are drawn with 'simulated pens'. In other words, the relationships which convey the idea of the design are encapsulated in a set of parameters and described in the language of algebra. Computer has to figure how to satisfy those conditions and produce the digitized image. For example, we could state that one curve should touch another in the middle, or that a pair of curves should cross at right angle. The Adobe approach is simpler. Shapes are described in an imperative manner. The outline of the letter is described by a series of curves and this outline is filled with 'ink'. Although Knuth's programs allow to generate endless variations of shapes, the world wide standard become Adobe's Type 1 outline font system, possibly because it is much easier to draw something than to explain how to draw it.



The PostScript language contains another method for defining a font named Type 3. It employs almost all the usual PostScript operators including color. Color inclusion could be viewed as an important extension to the old metal technology where letters are printed in ink color. Unfortunately current versions of PostScript do not cache color or grey images, so they are executed each time they are printed. This could slow down printing considerably. Maybe this extra added inefficiency made Type 3 fonts so rare species. But, even with today technology, there are areas where these fonts could make printed texts more readable, personalized and attractive. These include [2, p. 8–9]:

- Display fonts—designed to catch the eye. Used in titles, headings, posters, signs and adverbs.
- Decorative fonts—designed to convey a statement or a particular mood. Their choice depends on the job at hand. They are very susceptible to the vagaries of fashion. These include: initial caps, ornaments, tilings, emotional (smileys), logos.
- Speciality fonts—designed for particular purposes. Areas catered for include: phonetic symbols, mathematical operators, musical notation, dingbats and various oddities.

In 1989 the METAPOST system appeared. The author, J. D. Hobby, realised the power of Knuth’s approach and its weakness in outputting black & white bitmaps. So he created a system which implements a picture drawing language like Knuth’s METAFONT except it outputs PostScript commands instead of bitmaps. Because Type 3 fonts have a very simple format it is possible to postprocess METAPOST output and to create a Type 3 font.

I start with a quick glance into the past to show the use of special fonts in old books. Then, back to the future. In this section, I would like to draw your attention to several examples of Type 3 fonts usage. In the next two sections, I describe how to create a Type 3 font with METAPOST and how easy is to open Pandora’s fonts box. There I propose a way of controlling of multitude derived fonts. In appendices, I present a detailed description of Type 3 font format and basic METAPOST library supporting development of Type 3 fonts.

TYPOGRAPHICAL JOURNEY

The first two figures are taken from the books published by the Kelmscott Press. This publishing house was established and run by William Morris. Letterforms are derived from his own studies in printing history. The letterforms are chosen for their decorative quality. The third figure is taken from “The Art of Illuminating” by Matthew Dingby Wyatt and W. R. Tymms. This book described the pioneering efforts of its authors in the research of letterforms and manuscript illumination.

Note the use of ornaments and initial caps in Fig. 1. There is no ‘bézierness’ in their shapes, so I can hardly imagine to program them. In Fig. 2, in the text at



Fig. 1. Kelmscott Press: *The Story*, 1891

the bottom, dingbats are used to fill unwanted white space. Similar shapes can be found in contemporary computer fonts. The letter ‘P’ in Fig. 3 was hand colored. I think that existing computer tools cannot make creating such a beauty possible. Knuth [8] writes: “I do not believe that mathematical methods will resolve all the problems of digital typography; but I do believe that mathematics will help.” This should be no surprise. It will always be possible to create shapes with a brush or chisel for which there is no mathematical description of their elegance and magic. But I do believe that new font technologies will make typographers and programmers collaborate eventually in a similar manner as today designers and architects do.



So, let’s go on and explore what new computers have to offer.

BACK TO THE FUTURE

Colored fonts. In traditional typography fonts could not be multicolored. “Poor men” substitutes for coloring is overlaying letters with patterns or using color inks. With Type 3 fonts created in METAPOST, shape, size, sidebearings, weight and colors could be adjusted to match surrounding text.

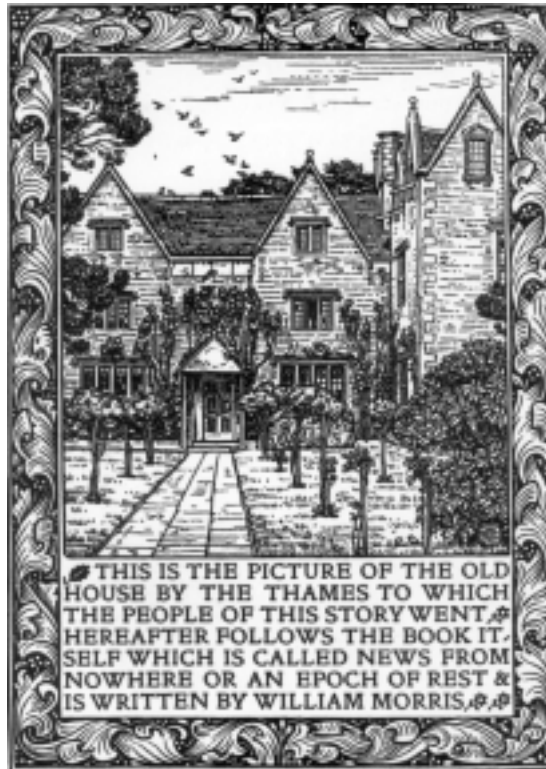


Fig. 2. Frontispiece: *News from Nowhere*, 1892



Computer Typography

1. Introduction to MetaPost
 2. Constructions with compass and ruler
 3. Introduction to T_EX
 4. Typography basics
 5. Computer fonts
-



Fig. 3. M. D. Wyatt. *The Art of Illuminating*

Special symbols. In [11, p. v] Knuth writes: “In order to make it possible for many types of users to read this manual effectively, a special sign is used to designate material that is for wizards only: When the symbol



appears at the beginning of a paragraph, it warns of a ‘dangerous bend’ in the train of thought; don’t read the paragraph unless you need to.” This idea calls for more special symbols. Here are a few more examples [18, 19, 10].



No man can be a pure specialist without being in the strict sense an idiot.

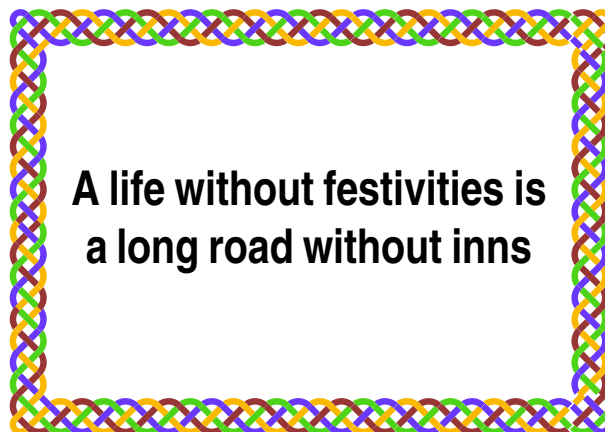


Were we faultless, we would not derive such satisfaction from remarking the faults of others.



Type design can be hazardous to your other interests. Once you get hooked, you will develop intense feelings about letterforms; the medium will intrude on the messages that you read. And you will perpetually be thinking of improvements to the fonts that you see everywhere, especially those of your own design.

Frames. In [5] Gibbons writes: “Sadly, there is a shortage of good symbols for creating such ornaments; not many typographic elements come in eight different orientations! However, there is nothing to stop you designing your own symbols.” You can not agree with that statement, can you [19].



Various oddities Math is plenty difficult in normal type. Programmers realized that their programs are easier to comprehend when typeset in color. So, what about coloring math formulas?

$$\sum_{a \leq k < b} f(k) \approx \int_a^b f(x) dx + \sum_{k=1}^m \frac{B_k}{k!} f^{(k-1)}(x) \Big|_a^b$$

$$\binom{n}{k} \equiv \binom{\lfloor n/p \rfloor}{\lfloor k/p \rfloor} \binom{n \bmod p}{k \bmod p} \pmod{p}$$

$$2 \uparrow\uparrow k \stackrel{\text{def}}{=} 2^{2^{2^{\cdot^{\cdot^{\cdot^2}}}}} \Big\}^k$$

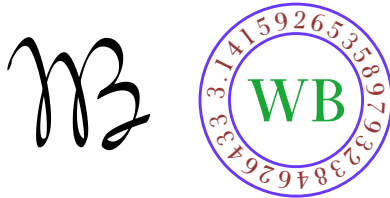
$$M = \begin{matrix} & C & I & C' \\ \begin{matrix} C \\ I \\ C' \end{matrix} & \begin{pmatrix} 1 & 0 & 0 \\ b & 1-b & 0 \\ 0 & a & 1-a \end{pmatrix} \end{matrix}$$

$$k = 1.38 \times 10^{-16} \text{ erg}/^\circ\text{K}$$

$$\bar{\phi} \subset NL_1^*/N = \bar{L}_1^* \subseteq \dots \subseteq NL_n^*/N = \bar{L}_n^*$$

$$\sin 18^\circ = \frac{1}{4}(\sqrt{5} - 1)$$

Or about having your own signature and stamps:



In this article I have used more Type 3 fonts than was really necessary, so it is high time to show how to create one.

DEVELOPING TYPE 3 FONT

Fonts are collections of shapes. A computer font is prepared in the form of a computer program. There are several kinds of fonts. Each type of font has its own convention for organizing and representing the information within it. The PostScript language defines the following types of fonts [3, p. 322]: 0, 1, 2, 3, 9, 10, 11, 14, 32, 42. Text fonts are mostly of Type 1. They are programmed with the special procedures. To execute efficiently and to produce more legible output, these procedures, use features common to collection of black & white letter-like shapes. They may not be used outside Type 1 font. While any graphics symbol may be programmed as a character in a Type 1 font, non-letter shaped symbols are better served by the Type 3 font program which defines shapes with ordinary PostScript procedures including these which produce color. Other font types are used infrequently.

Although Type 3 fonts are PostScript programs I prefer to program shapes in the METAPOST language and convert `mpost` output into Type 3 font, because the METAPOST language simplifies the programming due to its declarative nature. In PostScript each curve is build from lines, arcs of circle and beziér curves. For complicated shapes this requires a lot of nontrivial programming. METAPOST implements ‘a magic recipe’ [10] for joining points in a pleasing way. This helps a lot. Even if you are not satisfied with the shape, you can give the program various hints about what you have in mind, therefore improving upon automatically generated curve.

To use a font with `TEX` the font metric file is required. It contains data about width, height and depth of each shape from the font. Because `mpost` could generate metric file on demand, fonts prepared with METAPOST are immediately usable with `TEX`.



Creation of a Type 3 font is multi step process.

1. A font must be imagined and designed.
2. It must be programmed. METAPOST does not support that, but a specially created library of procedures does.
3. The program must be compiled.
4. The files thus created must be assembled into a font. This task is done by a PERL program.

Additionally, the font must be made available to \TeX and instructions must be given to tell \TeX to switch to this font.

METAPOST itself does not support font creation. So I have written a special `type3` library. It provides very basic routines for font creation. These include macros for glyph and font administration, macros for annotations of hardcopy proofs, and finally, macros which helps in the process of converting separate glyphs into a font. The conversion is done by a PERL program named `mptot3`. This program was designed after MF2PT3 tool [16] that generates a Type 3 font that correspond to a METAFONT program.

Here is an example.

Let us create a font which contain one character—plus. Use an ascii text editor, it does not have to be your favorite—any such editor works, to create a file called `plus-000.mp` that contains the following lines of text.

Each font program should name the font it creates.

```
font_name "Plus-000";
```

These names are merely comments which help to understand large collections of PostScript fonts.

```
family_name "Plus";
font_version "0.0final";
is_fixed_pitch true;
```

and following names play similiar rôle in the \TeX world.

```
font_identifier:="PLUS 000";
font_coding_scheme:="FONT SPECIFIC";
```

The `mpost` program does all its drawing on its internal ‘graph paper’. We establish 100×100 coordinate space on it.

```
grid_size:=100;
```

The font matrix array is used to map all glyphs to 1×1 coordinate space. This PostScript convention allows consistent scaling of characters which come from different fonts.

```
font_matrix
(1/grid_size,0,0,1/grid_size,0,0);
```

This particular font matrix will scale a plus shape by the factor $1/100$ in the x dimensions and by the same factor in the y dimension. If we had choosen scaling by the factor $1/50$ then plus shape would have appeared twice bigger comparing to characters from other fonts.

The data below provides information about how to typeset with this font. A font quad is the unit of measure that a \TeX user calls one ‘em’ when this font is selected. The normal space, stretch, and shrink parameters define the interword spacing when text is being typeset in this font. A font like this is hardly ever used to typeset anything apart from the plus, but the spacing parameters have been included just in case somebody wants to typeset several pluses separated by quads or spaces.


```
font_quad:=100;
font_normal_space:=33;
font_normal_stretch:=17;
font_normal_shrink:=11;
```

Another, more or less, ad hoc unit of measure is `x_height`. In \TeX this unit is available under the name `'ex'`. It is used for vertical measurements that depend on the current font, for example for accent positioning.

```
font_x_height:=100;
```

The plus font is an example of a parametrized font. A single program like this could be used to produce infinite variations of one design. For example, by changing the parameters below we could make the plus character to print in different color, change width or change the stem width.

```
color stem_color;
stem_color:=red;
u:=1; % unit width
stem_width:=10;
```

The `mode_setup` macro could be used to override all the settings done above. Typically, it is used to tell the `mpost` program to generate a font metric file or proofsheets. Additionally, `mode_setup` could execute any piece of valid METAPOST code at this point. For example, we could change the stem color to blue and the stem width to 5 units. The code to be executed could be read from a separate file (see the next section how to prepare and use such a file). Thus we can make a variation of this design or *re-parameterize* the font without changing the master `plus-000.mp` file. Such a mechanism is required. Otherwise, we populate our hard disks with similar files.

```
mode_setup;
```

Type3 library makes it convenient to define glyphs by starting each one with:

```
beginpic (<code>, <width>, <height>, <depth>)
```

where `<code>` is either a quoted single character like `"+"` or a number that represents the glyph position in the font. The other three numbers say how big the glyph bounding box is. The `endpic` finishes the plus glyph.

Each `beginpic` operation assigns values to special variables called `w`, `h`, and `d`, which represent respective width, height, and depth of the current glyph bounding box. Other pseudo-words are part of METAPOST language and are explained in [6].

```
beginpic("+",100u,100,0); "+ plus";
interim linecap=butt;
drawoptions(withcolor stem_color);
pickup pencircle scaled stem_width;
draw (0,h/2)--(w,h/2);
draw (w/2,0)--(w/2,h);
endpic;
```

Finally, each font program should end with the `bye` command.

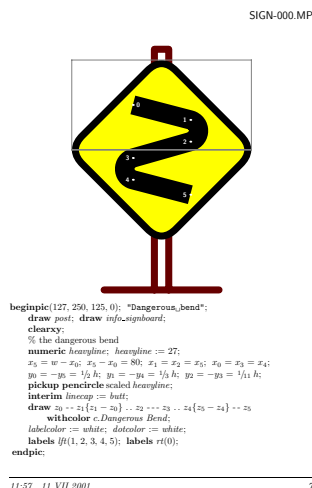


Fig. 4. Hardcopy proof of Signpost-500

bye

The last two steps are easy. We compile this file under LINUX with a command (or something analogous for other operating systems)†:

```
mpost -mem=type3 plus-000.mp
```

This step produces the font metric file and the PostScript commands which draw the plus shape. Finally, we collect the results of compilation into a Type 3 font with the PERL program:

```
mptot3 plus-000
```

To use ‘plus font’ in a T_EX document it suffices to insert these lines:

```
\font\plusf=plus-000 at 10pt
\centerline{\plusf +\quad+ +++ +\quad+}
```

This code produces the seven pluses below.

+ +++++ +

A font cannot be proved faultless. If some glyphs are defective, the best way to correct them is to look at big hardcopy proof that shows what went wrong. For example, the hardcopy proof above could be generated with the following shell commands:

```
mpost -mem=type3 '\mode=proof ; \
input sign-000.mp'
tex \input mproof sign-000.127
dvips mproof -o
```

† Unfortunately, the author does not know such commands for other operating systems.

Actually, the proof above contains some code which was pretty printed with `mft` tool (which is also a part of any `TEX` distribution).

MANAGING FONTS

Note that it is not wise to make one-time-only variation of a font by changing the font source. This kind of data multiplication resembles viruses spreading. To change font parameters `mode_setup` in conjunction with `change_mode` macro should be used. Again, I think that this concept is best explained by an example.

Assume that fictitious document `doc.tex` uses two fictitious Type 3 fonts named: *SuperFoo*, *SmashingBar*, and the font programs reside in the files `foo.mp`, `bar.mp`.

To re-parameterize these fonts create file `doc.mp` with the following content:

```
mode_def doc_foo =
  final_ ; % create metric file and execute:
  metapost code for SuperFoo
enddef;
mode_def doc_bar =
  final_ ;
  metapost code SmashingBar
enddef;
```

Then create font metric files, Type 3 fonts, and `dvips` fontmap files with the following commands (see Appendix B for an explanation):

```
mpost -mem=type3 \
  '\change_mode("doc","doc_foo"); \
  input foo.mp'
mptot3 -fontmap=foo.map foo.mp
mpost -mem=type3
  '\change_mode("doc","doc_bar"); \
  input bar.mp'
mptot3 -fontmap=bar.map bar.mp
```

It is convenient to concatenate fontmap files:

```
cat foo.map bar.map > doc.map
```

Now, we can compile `doc.tex` with:

```
tex doc.tex
```

and convert produced `doc.dvi` to PostScript with the command:

```
dvips -u doc.map doc.dvi -o
```

This should generate file named `doc.ps` which could be viewed and printed, for example with the `gv` program.

FONT DESIGN TO THE PEOPLE

Although the problems of letterform design are extremely subtle, more than most people think, because our machines and our eyes interact with the shapes in

complicated ways [8], these arguments do not necessarily apply to Type 3 fonts. Special purpose designs, for example geometric ones, could be programmed even by a rank one amateur designer and programmer. The article proves this last statement, I hope.

The font design is a fun. So, I decided to make available over a WEB all the tools and fonts created during preparation of this manuscript.

The master sources, which hopefully reached the beta stage, could be picked up from the following URL:

`ftp.gust.org.pl/pub/TeX/fonts/mtype3.`

There you will find the file named `README`. It contains detailed installation instructions. Then turn to the files called `Makefile`. Most of them are very simple. They encapsulate actions needed to create hardcopy proofs, fonts, etc. There are separate directories with examples of use and a booklet presenting all fonts.

REFERENCES

- [1] Adobe Systems Incorporated. 1985. *Tutorial and Cookbook*. Addison Wesley, 221–228.
- [2] Adobe Systems Incorporated. 1992. *The PostScript Font Handbook*. Addison Wesley.
- [3] Adobe Systems Incorporated. 1999 (3rd ed.). *PostScript Language Reference Manual*. Addison Wesley.
- [4] Per Cederqvist et al. 1993. *Version Management with CVS* (for version 1.10.8). Available online with the CVS package. Signum Support AB.
- [5] Jeremy Gibbons. 1999. “Hey—it works!” (Hints & Tricks). *TUGboat* **20**, 367–370.
- [6] John D. Hobby. 1992. *A user’s Manual for MetaPost*. Technical Report 162. AT&T Bell Laboratories, Murray Hill / New Jersey. Available online as a part of METAFONT distribution.
- [7] Bogusław Jackowski et al. 1999. “Antykwa Półtawskiego: a parametrized outline font”. EuroTeX 99 Proceedings. Ruprecht-Karls-Universität Heidelberg, 117–141.
- [8] Donald E. Knuth. 1982. “The Concept of a Meta-Font”. *Visible Language* **16**, 3–27.
- [9] Donald E. Knuth. 1985. “Lessons Learned from METAFONT”. *Visible Language* **19**, 35–53.
- [10] Donald E. Knuth. 1986. *The METAFONTbook*. American Mathematical Society and Addison Wesley.
- [11] Donald E. Knuth. 1988. “A Punk Meta-Font”. *TUGboat* **9**, 152–168.
- [12] Donald E. Knuth. 1988. “Virtual Fonts: More Fun for Grand Wizards”. *TUGboat* **11**, 13–23.
- [13] Donald E. Knuth. 1992. *Computer Modern Typefaces*. Addison Wesley.
- [14] Donald E. Knuth. 1994. *The TeXbook*. American Mathematical Society and Addison Wesley.

- [15] Richard M. Stallman and Roland McGrath. 2000. *GNU Make* (for version 3.79). Available online as a part of GNU MAKE package.
- [16] Apostolos Syropoulos. 2000. The MF2PT3 tool. Available online from www.obelix.ee.duth.gr/~apostolo.
- [17] La Rochefoucauld. 1655-1678. *Maxims*.
- [18] George B. Shaw. 1903. *From the Revolutionist's Handbook*.
- [19] Democritus. ca 400 B.C. *Ethical Precepts*.

APPENDIX A

Here the format of Type 3 font is described. This description is somehow simplified with the respect to examples to be found in [1] and [3].

Each font should begin with two lines of comments.

```

%!PS-Adobe-2.0: Square 1.00
%%CreationDate: 1 May 2001

```

A Type 3 font consists of a single dictionary, possibly containing other dictionaries, with certain required entries. The dictionary of size 99 should suffice for fonts which consists of several characters.

```
99 dict begin
```

This dictionary should include following entries:

- Variable `FontType` indicates how the character information is organized; for Type 3 fonts it has to be set 3.
- Variable `LanguageLevel` set to minimum language level required for correct behavior of the font.
- Array `FontMatrix` transforms the character coordinate system into the user coordinate system. This matrix maps font characters to one-unit coordinate space, which enables PostScript interpreter to scale font characters properly. This font uses 1000-unit grid.
- Array of four numbers `FontBBox` gives lower-left (l_x, l_y) and upper-right (u_x, u_y) coordinates of the smallest rectangle enclosing the shape that would result if all characters of the font were placed with their origins coincident, and then painted. This information is used in making decisions about character caching and clipping. If all four values are zero, no assumptions about character bounding box are made.

```

/FontType 3 def
/LanguageLevel 2 def
/FontMatrix [ 0.001 0 0 0.001 0 0 ] def
/FontBBox [ 0 0 1000 1000 ] def

```

`FontInfo` dictionary is optional. All info stored there is entirely for the benefit of PostScript language programs using the font, or for documentation.

- `FamilyName`—a human readable name for a group of fonts. All fonts that are members of such a group should have exactly the same `FamilyName`.

- **FullName**—unique, human readable name for an individual font. Should be the same name as one used when registering the font with `definefont` operator below.
- **Notice**—copyright, if applicable.
- **Weight**—name for the “boldness” attribute of a font.
- **version**—version number of the font program.
- **ItalicAngle**—angle in degrees counterclockwise from the vertical of the dominant vertical strokes of the font.
- **isFixedPitch**—if true, indicates that the font is a monospaced font; otherwise set false.
- **UnderlinePosition**—recommended distance from the baseline for positioning underlining strokes (*y* coordinate).
- **UnderlineThickness**—recommended stroke width for underlining, in units of the character coordinate system.

```

/FontInfo <<
  /FamilyName (Geometric)
  /FullName (Square)
  /Notice (Type 3 Repository.
    Copyright \(C\) 2001 Anonymous.
    All Rights Reserved.)
  /Weight (Medium)
  /version (1.0)
  /ItalicAngle 0
  /isFixedPitch true
  /UnderlinePosition 0.0
  /UnderlineThickness 1.0
>> def

```

Array `Encoding` maps character codes (integers) to character names. All unused positions in encoding vector must be filled with the name `.notdef`. It is special in only one regard: if some encoding maps to a character name that does not exist in the font, `.notdef` is substituted. The effect produced by executing `.notdef` character is at the discretion of the font designer, but most often it is the same as space.

```

/Encoding 256 array def
0 1 255 {Encoding exch /.notdef put} for

```

`CharacterProcedures` dictionary contains individual character definitions. This name is not special. Any name could be used, but this name is assumed by the `BuildGlyph` procedure below.

```

/CharacterProcedures 256 dict def

```

Each character must invoke `setcachedevice` or `setcharwidth` operator before executing graphics operators to define and paint the character. The `setcachedevice` operator stores the bitmapped image of the character in the font cache. However, caching will not work if color or gray is used. In such cases

the `setcharwidth` operator should be used. It is similar to `setcachedevice` (explained below), but it declares that the character being defined is not to be placed in the font cache.

```

 $w_x$   $w_y$   $l_x$   $l_y$   $u_x$   $u_y$  setcachedevice -
     $w_x$ ,  $w_y$  — comprise the basic width vector, ie. the normal position of the
    origin of the next character relative to origin of this one
     $l_x$ ,  $l_y$ ,  $u_x$ ,  $u_y$  — are the coordinates of this character bounding box
 $w_x$   $w_y$  setcharwidth -
     $w_x$   $w_y$  — comprise the basic width vector of this character

CharacterProcedures /.notdef {
    1000 0 0 0 1000 1000 setcachedevice
    1000 0 moveto
} put
Encoding 32 /space put
CharacterProcedures /space {
    1000 0 0 0 1000 1000 setcachedevice
    1000 0 moveto
} put
Encoding 83 /square put % ASCII 'S'
CharacterProcedures /square {
    1000 0 setcharwidth
    0 1 1 0 setcmykcolor % red
    0 0 1000 1000 rectfill
} put

```

Procedure `BuildGlyph` is called within the confines of a `gsave` and a `grestore`, so any changes `BuildGlyph` makes to the graphics state do not persist after it finishes.

`BuildGlyph` should describe the character in terms of absolute coordinates in the character coordinate system, placing the character origin at (0,0) in this space.

The Current Transformation Matrix (CTM) and the graphics state is inherited from the environment. To ensure predictable results despite font caching, `BuildGlyph` must initialize any graphics state parameters on which it depends. In particular, if `BuildGlyph` executes the `stroke` operator, it should explicitly set: dash parameters, line cap, line join, line width. These initializations are unnecessary, when characters are not cached, for example if the `setcachedevice` operator is not used.

When a PostScript language interpreter tries to show a character from a font, and the character is not already present in the font cache it pushes on the operand stack: *current font dictionary* and *character name*. The `BuildGlyph` procedure must remove these two objects from the operand stack and use this information to render the requested character. This typically involves finding the character procedure and executing it.

```

/BuildGlyph { % stack: font charname
  exch
  begin
  % initialize graphics state parameters
  % turn dashing off: solid lines
    [ ] 0 setdash
  % projecting square cap
    2 setlinecap
  % miter join
    0 setlinejoin
  % thickness of lines rendered by
  % execution of the stroke operator
    50 setlinewidth
  % the miter limit controls the stroke
  % operator's treatment of corners;
  % this is the default value and it
  % causes cuts off mitters at
  % angles less than 11 degrees
    10 setmiterlimit
    CharacterProcedures exch get exec
  end
} bind def
currentdict
end % of font dictionary

```

Finally, we register the font name as a font dictionary defined above and associate it with the key `Square`. Additionally the `definefont` operator checks if the font dictionary is a well-formed.

```
/Square exch definefont pop
```

If the following lines are not commented out the Ghostscript program (a public domain PostScript interpreter) will show the text below online. Obviously, these lines should be commented out in the final version of the font program.

```

/Square findfont
  72 scalefont setfont
0 72 moveto (S) show
showpage

```

METAPOST MACROS FOR TYPE 3 FONTS

TYPE 3 DRIVER FILE

This driver file serves as chief executive for the files which supports Type 3 font generation process.

When the equality below is true, this file has been input.

```
if base_name = "type3": endinput fi
```

The first few lines usually give the base file a name and version number.

```
string base_name, base_version; base_name = "type3"; base_version = "1.27";
message "Preloading the type3 mem file, version" & base_version;
```

Supporting macros are divided into several files.

```
input type3adm % glyph and font administration.
input type3mop % modes of operation
input type3pf % support for hardcopy proofs
input type3ps % PostScript specific items.
```

```
endinput
```

GLYPH AND FONT ADMINISTRATION

Each glyph is build between **beginpic** . . . **endpic**. The **beginpic** was designed after plain **beginchar** macro. Each **beginpic** begins a group, which end at the next **endpic**. Then the given glyph code is stored and character box dimensions in **mpost** internal variables *charwd*, *charht*, *chardp* and it sets box dimensions *w*, *h*, and *d*. Finally it clears the *z* variables, the current picture, and the current pen. **T**_E**X** needs to know the size of each characters's "bounding box". A total of four dimensions is given for each character:

- *charwd*, the width of the bounding box
- *charht*, the height above baseline of the bounding box
- *chardp*, the depth below baseline of the bounding box
- *charic*, the character "italis's correction".

The **mpost** records the value of its internal quantities, and writes them onto **tfm** file, at the time of **shipit** command.

```
def # = /(grid_size/designsize) enddef;
```

```
def beginpic(expr c, width, height, depth) = % character code c
  begingroup
  charcode := if known c: byte c else: 0 fi;
  w := width; h := height; d := depth;
  charic := 0; clearxy; clearit; clearpen;
  drawoptions();
  scantokens extra_beginpic;
```

```
enddef;
```

```
def italcorr expr x = if x > 0: charic := x# fi enddef;
```

```
newinternal proofscale; proofscale := 1;
```

Glyph widths are written onto file named $\langle\text{jobname}\rangle$.pcw. These widths are read by `mptot3` script which uses them as parameters to the PostScript `setcharwidth` operator.

```
def endpic = scantokens extra_endpic;
  write decimal charcode & ":" & decimal w to jobname & ".pcw";
  charwd := w#; charht := h#; chardp := d#;
  if proofing > 0: makebox(proofrule);
    currentpicture := currentpicture scaled proofscaled;
  fi
  shipit;
endgroup
enddef;

def shipit = if proofing ≥ 0:
  shipout currentpicture transformed (identity shifted (xoffset, yoffset)) fi
enddef;
newinternal xoffset, yoffset;

string extra_beginpic, extra_endpic;
extra_beginpic = extra_endpic = "";
```

The *designsize* of a font is another internal quantity that is output to `tfm` file. When a \TeX user asks for a font ‘`at`’ a certain size, the font is scaled by the ratio between the “at size” and the “design size”.

The *designsize* must be at least 1 pt and must be less than 2048 pt and every dimension of the font should be less than 16 times the design size in absolute value.

The “design size” is an imprecise notion, because there need be no connection between the design size and any specific measurement in a font. It is something like dress size or shoe sizes. **For Type 3 fonts we set the design size to 100 bp**, which seems to be a good compromise between the accuracy of the `mpost` calculations and the maximum size of a grid.

```
designsize := 100;
```

It is suggested that fonts use a 1000-unit grid. This is the default grid size used in Type 1 fonts programs.

```
newinternal grid_size; grid_size := 1000;
```

The other type information that appears in `tfm` file applies to a font as a whole. These include numeric data specified in “fontdimen” commands. Note that math symbols fonts are required to have at least 22 fontdimen parameters and math extensions at least 13.

```
def font_slant expr x = fontdimen 1: x enddef; % no hash here!
def font_normal_space expr x = fontdimen 2: x# enddef;
def font_normal_stretch expr x = fontdimen 3: x# enddef;
```

```

def font_normal_shrink expr x = fontdimen 4: x# enddef;
def font_x_height expr x = fontdimen 5: x# enddef;
def font_quad expr x = fontdimen 6: x# enddef;
def font_extra_space expr x = fontdimen 7: x# enddef;

def font_identifier expr x = font_identifier_ := x enddef;
def font_coding_scheme expr x = font_coding_scheme_ := x enddef;

string font_identifier_, font_coding_scheme_;
font_identifier_ = font_coding_scheme_ = "UNSPECIFIED";

```

TeX relies on lots of parameters when it typesets math formulas. He will not typeset a math formula unless symbol fonts contain at least 22 fontdimen parameters.

```

vardef font_num @# expr x = if (@# < 1) or (@# > 3):
  errmessage "Wrong suffix to font_num:" & decimal @#
else: fontdimen 7 + @#: x# fi
enddef;

vardef font_denom @# expr x = if (@# < 1) or (@# > 2):
  errmessage "Wrong suffix to font_denom" & decimal @#
else: fontdimen 10 + @#: x# fi
enddef;

vardef font_sup @# expr x = if (@# < 1) or (@# > 3):
  errmessage "Wrong suffix to font_sup" & decimal @#
else: fontdimen 12 + @#: x# fi
enddef;

vardef font_sub @# expr x = if (@# < 1) or (@# > 2):
  errmessage "Wrong suffix to font_sub" & decimal @#
else: fontdimen 15 + @#: x# fi
enddef;

def font_sup_drop expr x = fontdimen 18: x# enddef;
def font_sub_drop expr x = fontdimen 19: x# enddef;

vardef font_delim @# expr x = if (@# < 1) or (@# > 2):
  errmessage "Wrong suffix to font_delim" & decimal @#
else: fontdimen 17 + @#: x# fi
enddef;

def font_axis_height expr x = fontdimen 22: x# enddef;

Extension fonts should contain at least 13 fontdimen parameters.

def font_default_rule_thickness expr x = fontdimen 8: x# enddef;

vardef font_big_op_spacing @# expr x = if (@# < 1) or (@# > 5):
  errmessage "Wrong suffix to font_big_op_spacing" & decimal @#

```

```

    else: fontdimen 8 + @#: x# fi
enddef;
endinput

```

MODES OF OPERATION

The standard way to create a Type 3 font is to start up the `mpost` program by saying

```
mpost -mem=type3 \mode=<mode name>; input <font program>
```

and afterwards to collect glyphs created by `mpost` into a Type 3 font with Perl script

```
mptot3 <font program>
```

The `mode` is omitted if `mode=final`. The mode name should have been predeclared in your base file, by the `mode_def` routine below. If, however, you need special modes that aren't in the base, you can put its commands into a file (e.g., 'specmodes.mp') and invoke it by saying

```
mpost -mem=type3 \change_mode("specmodes", <mode name>);
input <font program>
```

instead of giving a predeclared mode name.

Here is the `mode_setup` routine, which is usually one of the first macros to be called after a font program establishes the values of all font parameters. The first 'scantokens' in `mode_setup` either reads a special file or calls a macro that expands into commands defining the mode.

```

transform currenttransform; def t_ = transformed currenttransform enddef;

def mode_setup = if unknown mode: mode = final; fi
numeric aspect_ratio; transform currenttransform;
if unknown aspect_ratio: aspect_ratio = 1; fi
if string mode: scantokens("input_" & mode);
  for i := 1 upto number_of_modes:
    if mode_name[i] = requested_mode_: scantokens mode_name[i]; fi
  endfor
else: scantokens mode_name[mode];
fi
scantokens extra_setup; % the user's special last-minute adjustments
currenttransform :=
  if unknown currenttransform: identity else: currenttransform fi
  yscaled aspect_ratio;
clearit;
enddef;

def change_mode(expr file_name, mode_name) =
  string mode; mode := file_name;

```

```

    requested_mode_ := mode_name & "_"
enddef;
string requested_mode_;

string extra_setup, mode_name[];
extra_setup = ""; % usually there's nothing special to do

```

When a mode is defined (e.g., ‘`proof`’), a numeric variable of that name is created and assigned a unique number (e.g., 1). Then an underscore character is appended, and a macro is defined for the resulting name (e.g., ‘`proof_`’). The `mode_name` array is used to convert between number and name (e.g., `mode_name1 = proof_`).

```

def mode_def suffix $ =
    $ := incr number_of_modes;
    mode_name[$] := str $ & "_";
    expandafter quote def scantokens mode_name[$]
enddef;
newinternal number_of_modes;

```

Three basic modes are now defined, starting with two for proofing.

Proof mode — for initial design of characters.

```

mode_def proof =
    proofing := 2; % yes, we're making full proofs
    fontmaking := 0; % no, we're not making a font
    tracingtitles := 1; % yes, show titles online
enddef;

```

Smoke mode — for label-free proofs.

```

mode_def smoke =
    proof_; % same as proof mode, except:
    proofing := 1; % yes, we're making unlabeled proofs
    fontmaking := 0; % no, we're not making a font
    let makebox = maketicks; % make the boxes less obtrusive
enddef;

```

Final mode — a typical mode for font generation (note, that we get a `TeX` font metric file if `mpost` internal quantity `fontmaking` is positive at the end of our job).

```

mode_def final =
    proofing := 0; % no, we're not making proofs
    fontmaking := 1; % yes, we are making a font
    tracingtitles := 0; % no, don't show titles at all
    prologues := -2; % high resolution bounding box.
enddef;

```

```

newinternal grayproofing;

mode_def grayproof =
  proofing := 2; % yes, we're making full proofs
  fontmaking := 0; % no, we're not making a font
  tracingtitles := 1; % yes, show titles online
  grayproofing := 1; % use 'proofcolor' for drawing
enddef;

localfont := final; % the mode most commonly used to make fonts

```

It is not likely that additional modes are needed, but if they are, additional `mode_def` commands should be in another input file that gets loaded after the plain base. The auxiliary file should set `base_version := base_version & "/localname"`

PROOF LABELS AND RULES

The next main section of `type3.mp` is devoted to macros for the annotations on proofsheets.

```

newinternal proofing; % < 0 to suppress output; > 1 to do labels
color proofcolor; % color for output when proofing > 0
proofcolor = .3[white, black];
color background; background = white;
color dotcolor, labelcolor; dotcolor = black; labelcolor = black;

newinternal defaultdotsize; defaultdotsize := 3;
newinternal defaultrulethickness; defaultrulethickness := 1;

```

Labels are generated at the lowest level by `makelabel` and `makepiclabel`:

Put string s near point z .

```

vardef makelabel @#(expr s, z) = picture p;
  if proofing > 1: if known z:
    p = s infont defaultfont scaled defaultscale;
    draw p shifted
    (z + labeloffset * laboff_@# -
    (labxf_@# * lrcorner p + labyf_@# * ulcorner p + (1 - labxf_@# - labyf_@#) * llcorner p))
    withcolor labelcolor;
    interim linecap := rounded;
    draw z withpen pencircle scaled defaultdotsize
    withcolor dotcolor;
  fi
fi
enddef;

```

Put string s near point z shifted by $shift$ and scaled by $scale$.

```

vardef makepiclabel @#(expr s, z, shift, scale) =

```

```

    save zz; pair zz; zz = z shifted shift scaled scale;
    makelabel @#(s, zz);
enddef;

```

Users generally don't invoke **makelabel** directly, because there's a convenient shorthand. For example, `'labels(1, 2, 3)'` expands into `'makelabel("1", z1); makelabel("2", z2); makelabel("3", z3)'` (But nothing happens if *proofing* ≤ 1.)

```

vardef labels @#(text t) =
    forsuffices $ = t: makelabel @#(str $, z$); endfor
enddef;

```

```

vardef piclabels @#(expr shift, scale)(text t) =
    forsuffices $ = t: makepiclabel @#(str $, z$, shift, scale); endfor
enddef;

```

```

vardef penlabels @#(text t) = forsuffices $$ = l, , r: forsuffices $ = t:
    makelabel @#(str $$$, z$.$); endfor endfor
enddef;

```

```

vardef picpenlabels @#(expr shift, scale)(text t) =
    forsuffices $$ = l, , r: forsuffices $ = t:
        makepiclabel @#(str $$$, z$.$, shift, scale); endfor endfor
enddef;

```

When there are lots of purely numeric labels, you can say, e.g.,

```
labels(1, range 5 thru 9, range 100 thru 124, 223)
```

which is equivalent to `'labels(1, 5, 6, 7, 8, 9, 100, 101, . . . , 124, 223)'`. Labels are omitted from the proofsheets if the corresponding z value isn't known, so it doesn't hurt (much) to include unused subscript numbers in a range.

```

def range expr x = numtok[x] enddef;
def numtok suffix x = x enddef;
tertiarydef m thru n = m for x = m + 1 step 1 until n: , numtok[x] endfor
enddef;

```

A straight line will be drawn on the proofsheets by **proofrule**.

```

def proofrule(expr w, z) =
    begingroup interim linecap := squared;
    draw w .. z withpen pencircle scaled defaultrulethickness
    withcolor proofcolor
    endgroup
enddef;

```

You can produce lots of proof rules with **makegrid**, which connects an arbitrary list of x coordinates with an arbitrary list of y coordinates:

```

def makegrid(text xlist, ylist) =
  xmin_ := min(xlist); xmax_ := max(xlist);
  ymin_ := min(ylist); ymax_ := max(ylist);
  for x = xlist: proofrule((x, ymin_), (x, ymax_)); endfor
  for y = ylist: proofrule((xmin_, y), (xmax_, y)); endfor
enddef;

vardef labelfont suffix $ = defaultfont := str $ enddef;

def makebox(text r) =
  for y = 0, h, -d: r((0, y), (w, y)); endfor
  for x = 0, w: r((x, -d), (x, h)); endfor
enddef;

def maketicks(text r) =
  for y = 0, h, -d: r((0, y), (w/10, y)); r((w - w/10, y), (w, y)); endfor
  for x = 0, w: r((x, h/10 - d), (x, -d)); r((x, h - h/10), (x, h)); endfor
enddef;

```

MACROS FOR FILLING AND ERASING

```

def pc_ = hide(if grayproofing > 0: def pc_ = do_pc_ enddef; else: def pc_ =
enddef; fi) pc_
enddef;
def do_pc_ = withcolor proofcolor enddef;

def fill expr c = addto currentpicture contour c t_ _op_ pc_ enddef;

def draw expr p = addto currentpicture
  if picture p: also p
  else: doublepath p t_ withpen currentpen
  fi _op_ pc_
enddef;

def filldraw expr c = addto currentpicture contour c t_ withpen currentpen
  _op_ pc_
enddef;

def drawdot expr z = addto currentpicture contour makepath currentpen
  shiftedz t_ _op_ pc_
enddef;

endinput

```

TTYPE 3 SPECIFIC ITEMS

One of required entries in each font dictionary is the array **FontMatrix**. This array is used by a PostScript interpreter to transform *glyph coordinate system*

into the user system coordinate system. This matrix maps font characters to one-unit coordinate space, which enables PostScript interpreter to scale font characters properly. It is suggested that fonts use a 1000-unit grid. This implies the following **FontMatrix**:

```
FontMatrix [ .001 0 0 .001 0 0 ] def
```

But what matrix is used is up to user, as long as the **FontMatrix** would be adjusted accordingly. The **FontMatrix** will be read from a file named `<jobname>.par`. The parameters written to this file are read by the `mptot3` script.

A two dimensional transformation is described in math as 2×3 matrix

$$\begin{bmatrix} a & b & t_x \\ c & d & t_y \end{bmatrix}$$

In the PostScript language, this matrix is represented as a six-element array object

```
[ a b c d t_x t_y ]
```

For example, scaling by the factor s_x in the x dimension and s_y in the y dimension is accomplished by the matrix:

$$\begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \end{bmatrix}$$

or by an array object:

```
[ s_x 0 0 s_y 0 0 ]
```

```
def font_matrix(expr a, b, c, d, t_x, t_y) = write "FontMatrix_" & " " &
  decimal a & " " & decimal b & " " & decimal c & " " & decimal d &
  " " & decimal t_x & " " & decimal t_y & " " to jobname & ".par"
enddef;
```

Each PostScript font has a name and belongs to some family, has attached version etc. These parameters are written onto `jobname.par` file too.

```
def font_name expr name = write "FontName_" & name to jobname & ".par"
enddef;
```

```
def family_name expr name = write "FamilyName_" & name to jobname &
".par"
enddef;
```

```
def font_version expr x = write "FontVersion_" & x to jobname & ".par"
enddef;
```

```
def is_fixed_pitch expr b = write "isFixedPitch_" &
  if b: "true" else: "false" fi to jobname & ".par"
enddef;
```

```
endinput
```