

## An Expansion Power Lemma

Sonja Maus

Most applications of the famous Power Theorem (*The T<sub>E</sub>Xbook*, p. 202) use expansion of tokens in T<sub>E</sub>X's "mouth", and some primitive commands; the latter (in particular assignments) are done in T<sub>E</sub>X's "stomach" and can influence subsequent expansion. As an example of

**Lemma 2.** *T<sub>E</sub>X's expansion alone is also powerful,*

the macro `\Copies` makes any number of copies of an argument *by expansion*. Here is the definition, to be read when @ is a letter:

```

1. \def\beforefi#1\fi{\fi#1}
2. \def\h@lve#1#2#3{\ifcase#1#2 0\or0\or
3.   1\or1\or2\or2\or3\or3\or4\or4\or5\or
4.   5\or6\or6\or7\or7\or8\or8\else9\fi
5.   \ifx#3:\else\expandafter\h@lve\number
6.   0\ifodd#2 1\fi\beforefi\space#3\fi}
7. \def\copies#1.#2{\ifodd#1 #2\fi
8.   \ifnum#1>\@ne\expandafter\copies
9.   \number\h@lve0#1:\beforefi.#2#2\fi}
10. \def\nocopies#1.#2{}
11. \def\Copies#1{\ifx#1-%
12.   \expandafter\nocopies\else
13.   \beforefi\copies#1\fi}
14. \def\Copies#1{\expandafter\Copies
15.   \number#1.}

```

Examples of how to use `\Copies` and `\copies`:

```

16. \chardef\n=27 % or \newcount\n \n=...
17. \edef\asts{\Copies\n*}

```

is another solution of the `\asts` problem, see *The T<sub>E</sub>Xbook*, Appendix D, section 1.

```

18. \message{\copies 79.-}

```

makes a row of 79 minus signs on the screen.

```

19. $$\chardef\n=4 {1+\sqrt5 \over 2}=
20. \Copies\n{1+\bgroup 1\over}\ldots
21. \Copies\n\egroup\;.$$

```

displays the continued fraction

$$\frac{1 + \sqrt{5}}{2} = 1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{\dots}}}$$

```

22. \newcount\m \newcount\n
23. \m=\dimen0 \divide\m by\baselineskip
24. \advance\m by1 \n=\m \advance\n by1
25. \parshape\n
26. \Copies\m{Opt 0.5\hsize} Opt \hsize

```

defines a paragraph shape (*The T<sub>E</sub>Xbook*, p. 101) which leaves space for a half-column picture of height `\dimen0`.

```

27. \Copies{\copies10.1}{}

```

keeps T<sub>E</sub>X's jaw muscles busy for a few seconds and expands to 1111111111 copies of nothing.

The general syntax is

```

\Copies{<number>}<argument>
or \copies<integer constant>.12<argument>

```

with `<number>` and `<integer constant>` as in *The T<sub>E</sub>Xbook*, p. 269. A single-token `<number>` does not need the braces. `<argument>` is an argument for an undelimited macro parameter: that is a sequence of tokens in explicit braces, or one token. The `<number>` will be expanded after `\Copies` has seen it, whereas the `<integer constant>.12` must be explicit before `\copies` is expanded. The `<argument>` (with braces stripped off as usual) is copied as many times as the `<number>` or `<integer constant>` says; a negative `<number>` counts 0.

Although the macros are hard to read, the way they work is easy to understand. With `\Copies`, the `<number>` is expanded by `\number (15.)`, and `\C@pies` reads the first digit or minus sign and rules out negative numbers. The remaining tokens match the syntax for `\copies`. The expansion of `\copies` is best illustrated by some intermediate steps for (17.):

```

\copies 27.*
*\copies 13.{**}
***\copies 6.{****}
***\copies 3.{*****}
*****\copies 1.{*****}
*****

```

Here the desired number of '\*'s is composed of powers of two. Division by 2 in this algorithm is done by `\number\h@lve0#1: (9.)`, stepping through the (decimal) digits from left to right and carrying down a 1 for an odd digit (the #1 (2.) will always be 0 or 1). In (6.,9.) `\beforefi` removes a `\fi` (tail recursion, see *The T<sub>E</sub>Xbook* p. 219). When `\number (9.)` is complete, `\copies (8.)` expands again. Eventually, `\ifnum#1>\@ne (8.)` turns false, and expansion finishes.

"Mouth & stomach" macros are usually simpler and more versatile than "pure expansion" macros. The latter are independent of grouping (20-21.) and can work in a context where commands cannot be executed (17.,18.,26.). For such rare occasions, Lemma 2 can be applied successfully.

◇ Sonja Maus  
Memelweg 2  
5300 Bonn 1  
Germany