1 Introduction

In electrotechnics it is common a notation for variables taking on complex values. First of all any nonzero complex number $z$ admits a unique representation as

$$z = \varrho(\cos \alpha + i \sin \alpha)$$

where $\varrho$ is a positive real number and $\alpha$ is a real number in the interval $[0, 2\pi)$. In technical applications $\alpha$ is expressed in degrees, with figures such as $30^\circ$. The conversion is very easy by considering $^\circ$ as the multiplicative constant $\pi/180$. By Euler formulas, we can write

$$z = \varrho(\cos \alpha + i \sin \alpha) = \varrho e^{i\alpha}$$

but Steinmetz, in the nineteenth century, started to express this in a simplified form:

$$z = \varrho \angle \alpha$$

which has however the disadvantage to be difficult to interpret when the angle is the result of some algebraic expression. This is where this package helps: indeed we can write

$$z=\varrho\varhbox{\phase}\{\alpha+\beta\}$$

which gives

$$z = \varrho \angle (\alpha + \beta)$$

making it clear what is the angle to consider. Some textbooks in electrotechnics use this notation and some users asked how to produce it in \LaTeX.

Dependencies

Note that this package requires \texttt{pict2e}, so a fairly recent version of \LaTeX is needed. In order to typeset this document, you have to generate the package file, by running \LaTeX on \texttt{steinmetz.ins}, unless it’s already in your distribution.
Table 1: Results from the various choices of the optional argument to $\texttt{\phase}$

<table>
<thead>
<tr>
<th>Command</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A\phase{\alpha}$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>$A\phase{30^\circ}$</td>
<td>$A/30^\circ$</td>
</tr>
<tr>
<td>$A\phase[0]{\alpha}$</td>
<td>$A\alpha$</td>
</tr>
<tr>
<td>$A\phase[1]{\alpha}$</td>
<td>$A\alpha$</td>
</tr>
<tr>
<td>$A\phase[2]{\alpha}$</td>
<td>$A\alpha$</td>
</tr>
<tr>
<td>$A\phase[3]{\alpha}$</td>
<td>$A\alpha$</td>
</tr>
<tr>
<td>$A\phase[0]{\frac{\alpha}{2}}$</td>
<td>$A/\frac{\alpha}{2}$</td>
</tr>
<tr>
<td>$A\phase[1]{\frac{\alpha}{2}}$</td>
<td>$A/\frac{\alpha}{2}$</td>
</tr>
<tr>
<td>$A\phase[2]{\frac{\alpha}{2}}$</td>
<td>$A/\frac{\alpha}{2}$</td>
</tr>
<tr>
<td>$A\phase[3]{\frac{\alpha}{2}}$</td>
<td>$A/\frac{\alpha}{2}$</td>
</tr>
</tbody>
</table>

2 Commands

\texttt{\phase} This package provides only one command, $\texttt{\phase}$, which takes as argument the angle to be enclosed in the Steinmetz symbol. It may receive also an optional argument, an integer number from 0 to 3 (default 1). This optional argument tells $\LaTeX$ to typeset the angle in the various mathematical styles, as exemplified in table 1.

Recall that the command $\texttt{\phase}$ should be given only in math mode. Since the command is usually written in display or text style, it should be uncommon to need the optional argument, unless you have to force a particular style for fractions.

If you have more than one of these symbols in a row, it can help alignment to put $\texttt{\mathstrut}$ in the argument.

3 Acknowledgments

The macro has been developed based on ideas of Stefano Di Gennaro (Università dell’Aquila, Italy) and his student Andrea Tonelli. Both have suffered from the earthquake of April 5, 2009: I wish them, their families and their university a prompt recover.

4 Implementation

\begin{verbatim}
\RequirePackage{pict2e}[2004/07/06]
\end{verbatim}

*This document corresponds to steinmetz v1.0, dated 2009/06/14.
We need the extended slopes provided by \texttt{pict2e}.

\begin{verbatim}
\newsavebox{\stm@phasebox}
\newlength{\stm@phasedp}
\newlength{\stm@phaseht}
\newlength{\stm@phasetot}
\newlength{\stm@phasewd}
\newcommand{\phase}[2][1]{
\sbox{\stm@phasebox}{\ifcase#1\relax
\displaystyle\or\textstyle\or\scriptstyle\or\scriptscriptstyle
\fi#2$}
\stm@phaseht=\ht{\stm@phasebox}
\stm@phasedp=\dp{\stm@phasebox}
\stm@phasetot=\stm@phasedp \advance{\stm@phasetot} .35ex
\advance{\stm@phasetot} \stm@phaseht
\stm@phasewd=\wd{\stm@phasebox}
\advance{\stm@phasewd} .5\stm@phasetot
\setbox{\stm@phasebox}=\vbox to\stm@phaseht{
\hbox{\setlength{\unitlength}{1pt}\linethickness{.6pt}\
\edef{\ph@x}{\strip@pt{\stm@phasewd}}\edef{\ph@y}{\strip@pt{\stm@phasetot}}\
\dimen@ .5\stm@phasetot \edef{\ph@dx}{\strip@pt{\dimen@}}\
\begin{picture}(\ph@x,\ph@y)
\put(0,0){\circle*{.4}}
\put(0,0){\line(1,0){\ph@x}}\put(0,0){\line(1,2){\ph@dx}}
\put(\ph@dx,1.5){\raise\stm@phasedp\vbox{\box{\stm@phasebox}}}
\end{picture}\
\advance{\stm@phasedp} .35ex \advance{\stm@phasedp} .6pt
\dimen@{\stm@phasedp} \advance{\dimen@} \stm@phasewd
}\vss}
\advance{\stm@phasedp} .35ex \advance{\stm@phasedp} .6pt
\dp{\z@}={\stm@phasedp} \box{\stm@phasebox}
\end{verbatim}

We set the box register to a formula containing the argument in the style chosen by the optional argument (default is text style).

\begin{verbatim}
\stm@phaseht=\ht{\stm@phasebox}
\stm@phasedp=\dp{\stm@phasebox}
\stm@phasetot=\stm@phasedp \advance{\stm@phasetot} .35ex
\advance{\stm@phasetot} \stm@phaseht
\stm@phasewd=\wd{\stm@phasebox}
\advance{\stm@phasewd} .5\stm@phasetot
\setbox{\stm@phasebox}=\vbox to\stm@phaseht{
\hbox{\setlength{\unitlength}{1pt}\linethickness{.6pt}\
\edef{\ph@x}{\strip@pt{\stm@phasewd}}\edef{\ph@y}{\strip@pt{\stm@phasetot}}\
\dimen@ .5\stm@phasetot \edef{\ph@dx}{\strip@pt{\dimen@}}\
\begin{picture}(\ph@x,\ph@y)
\put(0,0){\circle*{.4}}
\put(0,0){\line(1,0){\ph@x}}\put(0,0){\line(1,2){\ph@dx}}
\put(\ph@dx,1.5){\raise\stm@phasedp\vbox{\box{\stm@phasebox}}}
\end{picture}\
\advance{\stm@phasedp} .35ex \advance{\stm@phasedp} .6pt
\dimen@{\stm@phasedp} \advance{\dimen@} \stm@phasewd
}\vss}
\advance{\stm@phasedp} .35ex \advance{\stm@phasedp} .6pt
\dp{\z@}={\stm@phasedp} \box{\stm@phasebox}
\end{verbatim}

We do some measuring; the name of the registers should be self-explaining.

\begin{verbatim}
\begin{picture}()
\put(0,0){\circle*{.4}}
\put(0,0){\line(1,0){\ph@x}}\put(0,0){\line(1,2){\ph@dx}}
\put(\ph@dx,1.5){\raise\stm@phasedp\vbox{\box{\stm@phasebox}}}
\end{picture}
\end{verbatim}

The picture environment draws the angle. In its vertex we put a small circle to masquerade the connections. Inside the angle we print the expression given as argument, freeing the box register so that it can be used again (by the macro itself).

\begin{verbatim}
\begin{picture}()
\put(0,0){\circle*{.4}}
\put(0,0){\line(1,0){\ph@x}}\put(0,0){\line(1,2){\ph@dx}}
\put(\ph@dx,1.5){\raise\stm@phasedp\vbox{\box{\stm@phasebox}}}
\end{picture}\
\addvspace{}
\advance{\stm@phasedp} .35ex \advance{\stm@phasedp} .6pt
\advance{\dimen@{\stm@phasewd}}\addvspace{}
\advance{\stm@phasedp} .35ex \advance{\stm@phasedp} .6pt
\dp{\z@}={\stm@phasedp} \box{\stm@phasebox}
\end{verbatim}

We close the vbox, correct its depth and print it.

\section{An example}

The following will generate an example file.

\begin{verbatim}
\documentclass{article}
\usepackage{steinmetz}
\end{verbatim}
We will indicate the amplitude and phase relationship through the use of complex notation: a complex number is used to indicate only the amplitude and phase of voltages and currents in the circuit (since the sinusoidal time variation factor is common to all terms). For example, a circuit described by the equation

\[ i(t)=I_0 \cos(\omega t+\theta) \]

can be written in complex exponential form as

\[ i(t) = \Re\{I_0 e^{j(\omega t+\theta)}\} = \Re\{I_0 e^{j\theta} e^{j\omega t}\}, \]

and in polar complex form as

\[ i(t) = \Re\{I_0 \phase{\theta} e^{j\omega t}\}. \]

Finally, we can simplify the notation by dropping the implied \( e^{j\omega t} \) term and the \( \Re\{\} \) operator, leaving the phasor notation:

\[ \mathbf{I} = I_0 \phase{\theta} = I_0 e^{j\theta} = I_0 (\cos\theta + j\sin\theta), \]

where the boldface \( \mathbf{I} \) reminds us that the phasor quantity \( \mathbf{I} \) is a complex number. The important advantage of this approach is that the mathematics involves mostly simple algebraic operations on the magnitudes and phases.

It is interesting to look at the complex ratio of phasor voltage and phasor current, \( \mathbf{V}/\mathbf{I} \), which is called the **impedance** \( \mathbf{Z} \). For the basic circuit elements we find:

- **Resistor**, \( R \): \( \mathbf{Z} = R \),
- **Inductor**, \( L \): \( \mathbf{Z} = j\omega L = \omega L \phase{90^\circ} \),
- **Capacitor**, \( C \): \( \mathbf{Z} = \frac{1}{j\omega C} = \frac{1}{\omega C} \phase{-90^\circ} \).

\[ \text{Change History} \]

v1.0
General: Initial version ........ 1
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