File I
Implementation

1 l3backend-basics Implementation

```
⟨*package⟩
```

Whilst there is a reasonable amount of code overlap between backends, it is much clearer to have the blocks more-or-less separated than run in together and DocStripped out in parts. As such, most of the following is set up on a per-backend basis, though there is some common code (again given in blocks not interspersed with other material).

All the file identifiers are up-front so that they come out in the right place in the files.

```
\ProvidesExplFile
⟨*dvipdfmx⟩
  {l3backend-dvipdfmx.def}{2021-02-18}{}
  {L3 backend support: dvipdfmx}
⟨/dvipdfmx⟩
⟨*dvips⟩
  {l3backend-dvips.def}{2021-02-18}{}
  {L3 backend support: dvips}
⟨/dvips⟩
⟨*dvisvgm⟩
  {l3backend-dvisvgm.def}{2021-02-18}{}
  {L3 backend support: dvisvgm}
⟨/dvisvgm⟩
⟨*luatex⟩
  {l3backend-luatex.def}{2021-02-18}{}
  {L3 backend support: PDF output (LuaTeX)}
⟨/luatex⟩
⟨*pdftex⟩
  {l3backend-pdftex.def}{2021-02-18}{}
  {L3 backend support: PDF output (pdfTeX)}
⟨/pdftex⟩
⟨*xetex⟩
  {l3backend-xetex.def}{2021-02-18}{}
  {L3 backend support: XeTeX}
⟨/xetex⟩
```

Check if the loaded kernel is at least enough to load this file. The kernel date has to be at least equal to `\ExplBackendFileDate` or later. If `\__kernel_dependency_version_check:Nn` doesn't exist we're loading in an older kernel, so it's an error anyway. With time, this test should vanish and only the dependency check should remain.

```
\cs_if_exist:NTF \__kernel_dependency_version_check:nn
  {
    \__kernel_dependency_version_check:nn {2020-09-01}
⟨dvipdfmx⟩      {l3backend-dvipdfmx.def}
⟨dvips⟩      {l3backend-dvips.def}
⟨dvisvgm⟩      {l3backend-dvisvgm.def}
⟨luatex⟩      {l3backend-luatex.def}
⟨pdftex⟩      {l3backend-pdftex.def}
⟨xetex⟩      {l3backend-xetex.def}
```

```
  }
  {
    \cs_if_exist_use:cF { @latex@error } { \errmessage }
      {
        Mismatched~LaTeX~support~files~detected. \MessageBreak
        Loading~aborted!
      }
      { \use:c { @ehd } }
    \tex_endinput:D
  }
```

The order of the backend code here is such that we get somewhat logical outcomes in terms of code sharing whilst keeping things readable. (Trying to mix all of the code by concept is almost unmanageable.) The key parts which are shared are

- Color support is either `dvips`-like or LuaTEX/pdfTeX-like.
- LuaTEX/pdfTeX and `dvipdfmx`/XƎTEX share drawing routines.
- XƎTEX is the same as `dvipdfmx` other than image size extraction so takes most of the same code.

`\__kernel_backend_literal:e`
`\__kernel_backend_literal:n`
`\__kernel_backend_literal:x`

The one shared function for all backends is access to the basic `\special` primitive: it has slightly odd expansion behaviour so a wrapper is provided.

```
\cs_new_eq:NN \__kernel_backend_literal:e \tex_special:D
\cs_new_protected:Npn \__kernel_backend_literal:n #1
  { \__kernel_backend_literal:e { \exp_not:n {#1} } }
\cs_generate_variant:Nn \__kernel_backend_literal:n { x }
```

(*End definition for* `\__kernel_backend_literal:e`.)

1.1 `dvips` backend

```
⟨*dvips⟩
```

`\__kernel_backend_literal_postscript:n`
`\__kernel_backend_literal_postscript:x`

Literal PostScript can be included using a few low-level formats. Here, we use the form with no positioning: this is overall more convenient as a wrapper. Note that this does require that where position is important, an appropriate wrapper is included.

```
\cs_new_protected:Npn \__kernel_backend_literal_postscript:n #1
  { \__kernel_backend_literal:n { ps:: #1 } }
\cs_generate_variant:Nn \__kernel_backend_literal_postscript:n { x }
```

(*End definition for* `\__kernel_backend_literal_postscript:n`.)

`\__kernel_backend_postscript:n`
`\__kernel_backend_postscript:x`

PostScript data that does have positioning, and also applying a shift to `SDict` (which is not done automatically by `ps:` or `ps::`, in contrast to `!` or `"`).

```
\cs_new_protected:Npn \__kernel_backend_postscript:n #1
  { \__kernel_backend_literal:n { ps: SDict ~ begin ~ #1 ~ end } }
\cs_generate_variant:Nn \__kernel_backend_postscript:n { x }
```

(*End definition for* `\__kernel_backend_postscript:n`.)

PostScript for the header: a small saving but makes the code clearer. This is held until the start of shipout such that a document with no actual output does not write anything.

```
\bool_if:NT \g__kernel_backend_header_bool
  {
    \cs_if_exist:NTF \AtBeginDvi
      { \AtBeginDvi }
      { \use:n }
        { \__kernel_backend_literal:n { header = l3backend-dvips.pro } }
  }
```

__kernel_backend_align_begin:
__kernel_backend_align_end:

In dvips there is no built-in saving of the current position, and so some additional PostScript is required to set up the transformation matrix and also to restore it afterwards. Notice the use of the stack to save the current position "up front" and to move back to it at the end of the process. Notice that the [begin]/[end] pair here mean that we can use a run of PostScript statements in separate lines: not *required* but does make the code and output more clear.

```
\cs_new_protected:Npn \__kernel_backend_align_begin:
  {
    \__kernel_backend_literal:n { ps::[begin] }
    \__kernel_backend_literal_postscript:n { currentpoint }
    \__kernel_backend_literal_postscript:n { currentpoint~translate }
  }
\cs_new_protected:Npn \__kernel_backend_align_end:
  {
    \__kernel_backend_literal_postscript:n { neg~exch~neg~exch~translate }
    \__kernel_backend_literal:n { ps::[end] }
  }
```

(*End definition for* __kernel_backend_align_begin: *and* __kernel_backend_align_end:.)

__kernel_backend_scope_begin:
__kernel_backend_scope_end:

Saving/restoring scope for general operations needs to be done with dvips positioning (try without to see this!). Thus we need the ps: version of the special here. As only the graphics state is ever altered within this pairing, we use the lower-cost g-versions.

```
\cs_new_protected:Npn \__kernel_backend_scope_begin:
  { \__kernel_backend_literal:n { ps:gsave } }
\cs_new_protected:Npn \__kernel_backend_scope_end:
  { \__kernel_backend_literal:n { ps:grestore } }
```

(*End definition for* __kernel_backend_scope_begin: *and* __kernel_backend_scope_end:.)

```
⟨/dvips⟩
```

1.2 LuaTEX and pdfTEX backends

```
⟨*luatex | pdftex⟩
```

Both LuaTEX and pdfTEX write PDFs directly rather than via an intermediate file. Although there are similarities, the move of LuaTEX to have more code in Lua means we create two independent files using shared DocStrip code.

__kernel_backend_literal_pdf:n
__kernel_backend_literal_pdf:x

This is equivalent to \special{pdf:} but the engine can track it. Without the direct keyword everything is kept in sync: the transformation matrix is set to the current point automatically. Note that this is still inside the text (BT . . . ET block).

```
\cs_new_protected:Npn \__kernel_backend_literal_pdf:n #1
  {
⟨*luatex⟩
    \tex_pdfextension:D literal
⟨/luatex⟩
⟨*pdftex⟩
```

```
    \tex_pdfliteral:D
⟨/pdftex⟩
      { \exp_not:n {#1} }
  }
\cs_generate_variant:Nn \__kernel_backend_literal_pdf:n { x }
```

(*End definition for* `\__kernel_backend_literal_pdf:n`.)

`\__kernel_backend_literal_page:n`

Page literals are pretty simple. To avoid an expansion, we write out by hand.

```
\cs_new_protected:Npn \__kernel_backend_literal_page:n #1
  {
⟨*luatex⟩
    \tex_pdfextension:D literal ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfliteral:D
⟨/pdftex⟩
      page { \exp_not:n {#1} }
  }
```

(*End definition for* `\__kernel_backend_literal_page:n`.)

`\__kernel_backend_scope_begin:`
`\__kernel_backend_scope_end:`

Higher-level interfaces for saving and restoring the graphic state.

```
\cs_new_protected:Npn \__kernel_backend_scope_begin:
  {
⟨*luatex⟩
    \tex_pdfextension:D save \scan_stop:
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfsave:D
⟨/pdftex⟩
  }
\cs_new_protected:Npn \__kernel_backend_scope_end:
  {
⟨*luatex⟩
    \tex_pdfextension:D restore \scan_stop:
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfrestore:D
⟨/pdftex⟩
  }
```

(*End definition for* `\__kernel_backend_scope_begin:` *and* `\__kernel_backend_scope_end:`.)

`\__kernel_backend_matrix:n`
`\__kernel_backend_matrix:x`

Here the appropriate function is set up to insert an affine matrix into the PDF. With pdfTEX and LuaTEX in direct PDF output mode there is a primitive for this, which only needs the rotation/scaling/skew part.

```
\cs_new_protected:Npn \__kernel_backend_matrix:n #1
  {
⟨*luatex⟩
    \tex_pdfextension:D setmatrix
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfsetmatrix:D
⟨/pdftex⟩
```

```
        { \exp_not:n {#1} }
  }
\cs_generate_variant:Nn \__kernel_backend_matrix:n { x }
```

(*End definition for* `\__kernel_backend_matrix:n`.)

```
⟨/luatex | pdftex⟩
```

1.3 `dvipdfmx` backend

```
⟨*dvipdfmx | xetex⟩
```

The `dvipdfmx` shares code with the PDF mode one (using the common section to this file) but also with XeTeX. The latter is close to identical to `dvipdfmx` and so all of the code here is extracted for both backends, with some `clean up` for XeTeX as required.

`\__kernel_backend_literal_pdf:n`
`\__kernel_backend_literal_pdf:x`

Undocumented but equivalent to pdfTeX's `literal` keyword. It's similar to be not the same as the documented `contents` keyword as that adds a `q`/`Q` pair.

```
\cs_new_protected:Npn \__kernel_backend_literal_pdf:n #1
  { \__kernel_backend_literal:n { pdf:literal~ #1 } }
\cs_generate_variant:Nn \__kernel_backend_literal_pdf:n { x }
```

(*End definition for* `\__kernel_backend_literal_pdf:n`.)

`\__kernel_backend_literal_page:n`

Whilst the manual says this is like `literal direct` in pdfTeX, it closes the `BT` block!

```
\cs_new_protected:Npn \__kernel_backend_literal_page:n #1
  { \__kernel_backend_literal:n { pdf:literal~direct~ #1 } }
```

(*End definition for* `\__kernel_backend_literal_page:n`.)

`\__kernel_backend_scope_begin:`
`\__kernel_backend_scope_end:`

Scoping is done using the backend-specific specials. We use the versions originally from `xdvidfpmx` (`x:`) as these are well-tested "in the wild".

```
\cs_new_protected:Npn \__kernel_backend_scope_begin:
  { \__kernel_backend_literal:n { x:gsave } }
\cs_new_protected:Npn \__kernel_backend_scope_end:
  { \__kernel_backend_literal:n { x:grestore } }
```

(*End definition for* `\__kernel_backend_scope_begin:` *and* `\__kernel_backend_scope_end:`.)

```
⟨@@=sys⟩
```

`\c__kernel_sys_dvipdfmx_version_int`

A short excursion into the `sys` module to set up the backend version information.

```
\group_begin:
  \cs_set:Npn \__sys_tmp:w #1 Version ~ #2 ~ #3 \q_stop {#2}
  \sys_get_shell:nnNTF { extractbb~--version }
    { \char_set_catcode_space:n { `\  } }
    \l__sys_internal_tl
    {
      \int_const:Nn \c__kernel_sys_dvipdfmx_version_int
        {
          \exp_after:wN \__sys_tmp:w \l__sys_internal_tl
            \q_stop
        }
    }
    { \int_const:Nn \c__kernel_sys_dvipdfmx_version_int { 0 } }
\group_end:
```

(*End definition for* `\c__kernel_sys_dvipdfmx_version_int`.)

```
⟨@@=⟩
⟨/dvipdfmx | xetex⟩
```

1.4 dvisvgm backend

```
⟨*dvisvgm⟩
```

`\__kernel_backend_literal_svg:n`
`\__kernel_backend_literal_svg:x`

Unlike the other backends, the requirements for making SVG files mean that we can't conveniently transform all operations to the current point. That makes life a bit more tricky later as that needs to be accounted for. A new line is added after each call to help to keep the output readable for debugging.

```
\cs_new_protected:Npn \__kernel_backend_literal_svg:n #1
  { \__kernel_backend_literal:n { dvisvgm:raw~ #1 { ?nl } } }
\cs_generate_variant:Nn \__kernel_backend_literal_svg:n { x }
```

(*End definition for* `\__kernel_backend_literal_svg:n`.)

`\g__kernel_backend_scope_int`
`\l__kernel_backend_scope_int`

In SVG, we need to track scope nesting as properties attach to scopes; that requires a pair of `int` registers.

```
\int_new:N \g__kernel_backend_scope_int
\int_new:N \l__kernel_backend_scope_int
```

(*End definition for* `\g__kernel_backend_scope_int` *and* `\l__kernel_backend_scope_int`.)

`\__kernel_backend_scope_begin:`
`\__kernel_backend_scope_end:`
`\__kernel_backend_scope_begin:n`
`\__kernel_backend_scope_begin:x`
`\__kernel_backend_scope:n`
`\__kernel_backend_scope:x`

In SVG, the need to attach concepts to a scope means we need to be sure we will close all of the open scopes. That is easiest done if we only need an outer "wrapper" `begin`/`end` pair, and within that we apply operations as a simple scoped statements. To keep down the non-productive groups, we also have a `begin` version that does take an argument.

```
\cs_new_protected:Npn \__kernel_backend_scope_begin:
  {
    \__kernel_backend_literal_svg:n { <g> }
    \int_set_eq:NN
      \l__kernel_backend_scope_int
      \g__kernel_backend_scope_int
    \group_begin:
      \int_gset:Nn \g__kernel_backend_scope_int { 1 }
  }
\cs_new_protected:Npn \__kernel_backend_scope_end:
  {
      \prg_replicate:nn
        { \g__kernel_backend_scope_int }
        { \__kernel_backend_literal_svg:n { </g> } }
    \group_end:
    \int_gset_eq:NN
      \g__kernel_backend_scope_int
      \l__kernel_backend_scope_int
  }
\cs_new_protected:Npn \__kernel_backend_scope_begin:n #1
  {
    \__kernel_backend_literal_svg:n { <g ~ #1 > }
    \int_set_eq:NN
      \l__kernel_backend_scope_int
      \g__kernel_backend_scope_int
    \group_begin:
      \int_gset:Nn \g__kernel_backend_scope_int { 1 }
  }
\cs_generate_variant:Nn \__kernel_backend_scope_begin:n { x }
\cs_new_protected:Npn \__kernel_backend_scope:n #1
  {
    \__kernel_backend_literal_svg:n { <g ~ #1 > }
    \int_gincr:N \g__kernel_backend_scope_int
  }
\cs_generate_variant:Nn \__kernel_backend_scope:n { x }
```

(*End definition for* `\__kernel_backend_scope_begin:` *and others.*)

```
⟨/dvisvgm⟩
⟨/package⟩
```

2 l3backend-box Implementation

```
⟨*package⟩
⟨@@=box⟩
```

2.1 dvips backend

```
⟨*dvips⟩
```

`\__box_backend_clip:N` The `dvips` backend scales all absolute dimensions based on the output resolution selected and any TEX magnification. Thus for any operation involving absolute lengths there is a correction to make. See `normalscale` from `special.pro` for the variables, noting that here everything is saved on the stack rather than as a separate variable. Once all of that is done, the actual clipping is trivial.

```
\cs_new_protected:Npn \__box_backend_clip:N #1
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_align_begin:
    \__kernel_backend_literal_postscript:n { matrix~currentmatrix }
    \__kernel_backend_literal_postscript:n
      { Resolution~72~div~VResolution~72~div~scale }
    \__kernel_backend_literal_postscript:n { DVImag~dup~scale }
    \__kernel_backend_literal_postscript:x
      {
        0 ~
        \dim_to_decimal_in_bp:n { \box_dp:N #1 } ~
        \dim_to_decimal_in_bp:n { \box_wd:N #1 } ~
        \dim_to_decimal_in_bp:n { -\box_ht:N #1 - \box_dp:N #1 } ~
        rectclip
      }
    \__kernel_backend_literal_postscript:n { setmatrix }
    \__kernel_backend_align_end:
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
    \skip_horizontal:n { \box_wd:N #1 }
  }
```

(*End definition for* `\__box_backend_clip:N`.)

__box_backend_rotate:Nn
__box_backend_rotate_aux:Nn

Rotating using **dvips** does not require that the box dimensions are altered and has a very convenient built-in operation. Zero rotation must be written as `0` not `-0` so there is a quick test.

```
\cs_new_protected:Npn \__box_backend_rotate:Nn #1#2
  { \exp_args:NNf \__box_backend_rotate_aux:Nn #1 { \fp_eval:n {#2} } }
\cs_new_protected:Npn \__box_backend_rotate_aux:Nn #1#2
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_align_begin:
    \__kernel_backend_literal_postscript:x
      {
        \fp_compare:nNnTF {#2} = \c_zero_fp
          { 0 }
          { \fp_eval:n { round ( -(#2) , 5 ) } } ~
        rotate
      }
   \__kernel_backend_align_end:
   \box_use:N #1
   \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_rotate:Nn` *and* `\__box_backend_rotate_aux:Nn`.)

__box_backend_scale:Nnn

The **dvips** backend once again has a dedicated operation we can use here.

```
\cs_new_protected:Npn \__box_backend_scale:Nnn #1#2#3
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_align_begin:
    \__kernel_backend_literal_postscript:x
      {
        \fp_eval:n { round ( #2 , 5 ) } ~
        \fp_eval:n { round ( #3 , 5 ) } ~
        scale
      }
    \__kernel_backend_align_end:
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_scale:Nnn`.)

```
⟨/dvips⟩
```

2.2 LuaTEX and pdfTEX backends

```
⟨*luatex | pdftex⟩
```

__box_backend_clip:N

The general method is to save the current location, define a clipping path equivalent to the bounding box, then insert the content at the current position and in a zero width box. The "real" width is then made up using a horizontal skip before tidying up. There are other approaches that can be taken (for example using XForm objects), but the logic here shares as much code as possible and uses the same conversions (and so same rounding errors) in all cases.

```
\cs_new_protected:Npn \__box_backend_clip:N #1
```

```
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_literal_pdf:x
      {
        0~
        \dim_to_decimal_in_bp:n { -\box_dp:N #1 } ~
        \dim_to_decimal_in_bp:n { \box_wd:N #1 } ~
        \dim_to_decimal_in_bp:n { \box_ht:N #1 + \box_dp:N #1 } ~
        re~W~n
      }
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
    \skip_horizontal:n { \box_wd:N #1 }
  }
```

(*End definition for* `\__box_backend_clip:N`.)

`\__box_backend_rotate:Nn`
`\__box_backend_rotate_aux:Nn`
`\l__box_backend_cos_fp`
`\l__box_backend_sin_fp`

Rotations are set using an affine transformation matrix which therefore requires sine/cosine values not the angle itself. We store the rounded values to avoid rounding twice. There are also a couple of comparisons to ensure that `-0` is not written to the output, as this avoids any issues with problematic display programs. Note that numbers are compared to 0 after rounding.

```
\cs_new_protected:Npn \__box_backend_rotate:Nn #1#2
  { \exp_args:NNf \__box_backend_rotate_aux:Nn #1 { \fp_eval:n {#2} } }
\cs_new_protected:Npn \__box_backend_rotate_aux:Nn #1#2
  {
    \__kernel_backend_scope_begin:
    \box_set_wd:Nn #1 { 0pt }
    \fp_set:Nn \l__box_backend_cos_fp { round ( cosd ( #2 ) , 5 ) }
    \fp_compare:nNnT \l__box_backend_cos_fp = \c_zero_fp
      { \fp_zero:N \l__box_backend_cos_fp }
    \fp_set:Nn \l__box_backend_sin_fp { round ( sind ( #2 ) , 5 ) }
    \__kernel_backend_matrix:x
      {
        \fp_use:N \l__box_backend_cos_fp \c_space_tl
        \fp_compare:nNnTF \l__box_backend_sin_fp = \c_zero_fp
          { 0~0 }
          {
            \fp_use:N \l__box_backend_sin_fp
            \c_space_tl
            \fp_eval:n { -\l__box_backend_sin_fp }
          }
        \c_space_tl
        \fp_use:N \l__box_backend_cos_fp
      }
   \box_use:N #1
   \__kernel_backend_scope_end:
  }
\fp_new:N \l__box_backend_cos_fp
\fp_new:N \l__box_backend_sin_fp
```

(*End definition for* `\__box_backend_rotate:Nn` *and others.*)

`\__box_backend_scale:Nnn`

The same idea as for rotation but without the complexity of signs and cosines.

```
\cs_new_protected:Npn \__box_backend_scale:Nnn #1#2#3
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_matrix:x
      {
        \fp_eval:n { round ( #2 , 5 ) } ~
        0~0~
        \fp_eval:n { round ( #3 , 5 ) }
      }
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_scale:Nnn`.)

```
⟨/luatex | pdftex⟩
```

2.3 dvipdfmx/XƎTEX backend

```
⟨*dvipdfmx | xetex⟩
```

`\__box_backend_clip:N`

The code here is identical to that for LuaTEX/pdfTEX: unlike rotation and scaling, there is no higher-level support in the backend for clipping.

```
\cs_new_protected:Npn \__box_backend_clip:N #1
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_literal_pdf:x
      {
        0~
        \dim_to_decimal_in_bp:n { -\box_dp:N #1 } ~
        \dim_to_decimal_in_bp:n { \box_wd:N #1 } ~
        \dim_to_decimal_in_bp:n { \box_ht:N #1 + \box_dp:N #1 } ~
        re~W~n
      }
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
    \skip_horizontal:n { \box_wd:N #1 }
  }
```

(*End definition for* `\__box_backend_clip:N`.)

`\__box_backend_rotate:Nn`
`\__box_backend_rotate_aux:Nn`

Rotating in `dvipdmfx`/XƎTEX can be implemented using either PDF or backend-specific code. The former approach however is not "aware" of the content of boxes: this means that any embedded links would not be adjusted by the rotation. As such, the backend-native approach is preferred: the code therefore is similar (though not identical) to the `dvips` version (notice the rotation angle here is positive). As for `dvips`, zero rotation is written as `0` not `-0`.

```
\cs_new_protected:Npn \__box_backend_rotate:Nn #1#2
  { \exp_args:NNf \__box_backend_rotate_aux:Nn #1 { \fp_eval:n {#2} } }
\cs_new_protected:Npn \__box_backend_rotate_aux:Nn #1#2
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_literal:x
      {
        x:rotate~
        \fp_compare:nNnTF {#2} = \c_zero_fp
          { 0 }
          { \fp_eval:n { round ( #2 , 5 ) } }
      }
    \box_use:N #1
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_rotate:Nn` *and* `\__box_backend_rotate_aux:Nn`.)

`\__box_backend_scale:Nnn` Much the same idea for scaling: use the higher-level backend operation to allow for box content.

```
\cs_new_protected:Npn \__box_backend_scale:Nnn #1#2#3
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_literal:x
      {
        x:scale~
        \fp_eval:n { round ( #2 , 5 ) } ~
        \fp_eval:n { round ( #3 , 5 ) }
      }
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_scale:Nnn`.)

```
⟨/dvipdfmx | xetex⟩
```

2.4 dvisvgm backend

```
⟨*dvisvgm⟩
```

`\__box_backend_clip:N`
`\g__box_clip_path_int`

Clipping in SVG is more involved than with other backends. The first issue is that the clipping path must be defined separately from where it is used, so we need to track how many paths have applied. The naming here uses `l3cp` as the namespace with a number following. Rather than use a rectangular operation, we define the path manually as this allows it to have a depth: easier than the alternative approach of shifting content up and down using scopes to allow for the depth of the TeX box and keep the reference point the same!

```
\cs_new_protected:Npn \__box_backend_clip:N #1
  {
    \int_gincr:N \g__box_clip_path_int
    \__kernel_backend_literal_svg:x
      { < clipPath~id = " l3cp \int_use:N \g__box_clip_path_int " > }
    \__kernel_backend_literal_svg:x
      {
        <
          path ~ d =
            "
              M ~ 0 ~
                  \dim_to_decimal:n { -\box_dp:N #1 } ~
              L ~ \dim_to_decimal:n { \box_wd:N #1 } ~
                  \dim_to_decimal:n { -\box_dp:N #1 } ~
              L ~ \dim_to_decimal:n { \box_wd:N #1 }  ~
```

```
                    \dim_to_decimal:n { \box_ht:N #1 + \box_dp:N #1 } ~
                L ~ 0 ~
                    \dim_to_decimal:n { \box_ht:N #1 + \box_dp:N #1 } ~
                Z
              "
          />
        }
      \__kernel_backend_literal_svg:n
        { < /clipPath > }
```

In general the SVG set up does not try to transform coordinates to the current point. For clipping we need to do that, so have a transformation here to get us to the right place, and a matching one just before the TEX box is inserted to get things back on track. The clip path needs to come between those two such that if lines up with the current point, as does the TEX box.

```
      \__kernel_backend_scope_begin:n
        {
          transform =
            "
              translate ( { ?x } , { ?y } ) ~
              scale ( 1 , -1 )
            "
        }
      \__kernel_backend_scope:x
        {
          clip-path =
            "url ( \c_hash_str l3cp \int_use:N \g__box_clip_path_int ) "
        }
      \__kernel_backend_scope:n
        {
          transform =
            "
              scale ( -1 , 1 ) ~
              translate ( { ?x } , { ?y } ) ~
              scale ( -1 , -1 )
            "
        }
      \box_use:N #1
      \__kernel_backend_scope_end:
    }
\int_new:N \g__box_clip_path_int
```

(*End definition for* `\__box_backend_clip:N` *and* `\g__box_clip_path_int`.)

`\__box_backend_rotate:Nn` Rotation has a dedicated operation which includes a centre-of-rotation optional pair. That can be picked up from the backend syntax, so there is no need to worry about the transformation matrix.

```
\cs_new_protected:Npn \__box_backend_rotate:Nn #1#2
  {
    \__kernel_backend_scope_begin:x
      {
        transform =
          "
            rotate
            ( \fp_eval:n { round ( -(#2) , 5 ) } , ~ { ?x } , ~ { ?y } )
          "
      }
    \box_use:N #1
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_rotate:Nn`.)

`\__box_backend_scale:Nnn` In contrast to rotation, we have to account for the current position in this case. That is done using a couple of translations in addition to the scaling (which is therefore done backward with a flip).

```
\cs_new_protected:Npn \__box_backend_scale:Nnn #1#2#3
  {
    \__kernel_backend_scope_begin:x
      {
        transform =
          "
            translate ( { ?x } , { ?y } ) ~
            scale
              (
                \fp_eval:n { round ( -#2 , 5 ) } ,
                \fp_eval:n { round ( -#3 , 5 ) }
              ) ~
            translate ( { ?x } , { ?y } ) ~
            scale ( -1 )
          "
      }
    \hbox_overlap_right:n { \box_use:N #1 }
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__box_backend_scale:Nnn`.)

```
⟨/dvisvgm⟩
⟨/package⟩
```

3 l3backend-color Implementation

```
⟨*package⟩
⟨@@=color⟩
```

Color support is split into parts: collecting data from LaTeX 2ε, the color stack, general color, separations, and color for drawings. We have different approaches in each backend, and have some choices to make about `dvipdfmx`/XeTeX in particular. Whilst it is in some ways convenient to use the same approach in multiple backends, the fact that `dvipdfmx`/XeTeX is PDF-based means it (largely) sticks closer to direct PDF output.

3.1 Collecting information from LaTeX 2ε

3.1.1 dvips-style

```
⟨*dvisvgm | dvipdfmx | dvips | xetex⟩
```

__color_backend_pickup:N
__color_backend_pickup:w

Allow for LaTeX 2ε color. Here, the possible input values are limited: dvips-style colors can mainly be taken as-is with the exception spot ones (here we need a model and a tint). The x-type expansion is there to cover the case where xcolor is in use.

```
\cs_new_protected:Npn \__color_backend_pickup:N #1 { }
\cs_if_exist:cT { ver@color.sty }
  {
    \cs_set_protected:Npn \__color_backend_pickup:N #1
      {
        \exp_args:NV \tl_if_head_is_space:nTF \current@color
          {
            \tl_set:Nx #1
              {
                { \exp_after:wN \use:n \current@color }
                { 1 }
              }
          }
          {
            \exp_last_unbraced:Nx \__color_backend_pickup:w
              { \current@color } \s__color_stop #1
          }
      }
    \cs_new_protected:Npn \__color_backend_pickup:w #1 ~ #2 \s__color_stop #3
      { \tl_set:Nn #3 { {#1} {#2} } }
  }
```

(*End definition for* __color_backend_pickup:N *and* __color_backend_pickup:w.)

```
⟨/dvisvgm | dvipdfmx | dvips | xetex⟩
```

3.1.2 LuaTeX and pdfTeX

```
⟨*luatex | pdftex⟩
```

__color_backend_pickup:N
__color_backend_pickup:w

The current color in driver-dependent format: pick up the package-mode data if available. We end up converting back and forward in this route as we store our color data in dvips format. The \current@color needs to be x-expanded before __color_-backend_pickup:w breaks it apart, because for instance xcolor sets it to be instructions to generate a color

```
\cs_new_protected:Npn \__color_backend_pickup:N #1 { }
\cs_if_exist:cT { ver@color.sty }
  {
    \cs_set_protected:Npn \__color_backend_pickup:N #1
      {
        \exp_last_unbraced:Nx \__color_backend_pickup:w
          { \current@color } ~ 0 ~ 0 ~ 0 \s__color_stop #1
      }
    \cs_new_protected:Npn \__color_backend_pickup:w
      #1 ~ #2 ~ #3 ~ #4 ~ #5 ~ #6 \s__color_stop #7
      {
        \str_if_eq:nnTF {#2} { g }
          { \tl_set:Nn #7 { { gray } {#1} } }
          {
            \str_if_eq:nnTF {#4} { rg }
              { \tl_set:Nn #7 { { rgb } { #1 ~ #2 ~ #3 } } }
```

```
                {
                  \str_if_eq:nnTF {#5} { k }
                    { \tl_set:Nn #7 { { cmyk } { #1 ~ #2 ~ #3 ~ #4 } } }
                    {
                      \str_if_eq:nnTF {#2} { cs }
                        {
                          \tl_set:Nx #7 { { \use:n #1 } { #5 } }
                        }
                        {
                          \tl_set:Nn #7 { { gray } { 0 } }
                        }
                    }
                }
            }
        }
    }
```

(*End definition for* `\__color_backend_pickup:N` *and* `\__color_backend_pickup:w`.)

```
⟨/luatex | pdftex⟩
```

3.2 The color stack

For PDF-based engines, we have a color stack available inside the specials. This is used for concepts beyond color itself: it is needed to manage th graphics state generally. The exact form depends on the engine, and for `dvipdfmx`/XeTeX the backend version.

3.2.1 Common code

```
⟨*dvipdfmx | luatex | pdftex | xetex⟩
```

`\l__color_backend_stack_int` pdfTeX, LuaTeX and recent `(x)dvipdfmx` have multiple stacks available, and to track which one is in use a variable is required.

```
\int_new:N \l__color_backend_stack_int
```

(*End definition for* `\l__color_backend_stack_int`.)

```
⟨/dvipdfmx | luatex | pdftex | xetex⟩
```

3.2.2 `dvipdfmx`/XeTeX

```
⟨*dvipdfmx | xetex⟩
```

`\__kernel_color_backend_stack_init:Nnn`
`\g__color_backend_stack_int`
`\c__color_backend_main_stack_int`

In `(x)dvipdfmx`, the base color stack is not set up, so we have to force that, as well as providing a mechanism more generally.

```
\int_compare:nNnTF \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
  { \cs_new_protected:Npn \__kernel_color_backend_stack_init:Nnn #1#2#3 { } }
  {
    \int_new:N \g__color_backend_stack_int
    \cs_new_protected:Npx \__kernel_color_backend_stack_init:Nnn #1#2#3
      {
        \int_gincr:N \exp_not:N \g__color_backend_stack_int
        \int_const:Nn #1 { \exp_not:N \g__color_backend_stack_int }
        \cs_if_exist:NTF \AtBeginDvi
          { \exp_not:N \AtBeginDvi }
          { \exp_not:N \use:n }
          {
            \__kernel_backend_literal:x
              {
                pdfcolorstackinit ~
                \exp_not:N \int_use:N \exp_not:N \g__color_backend_stack_int
                \c_space_tl
                \exp_not:N \tl_if_blank:nF {#2} { #2 ~ }
                (#3)
              }
          }
      }
    \cs_if_exist:cTF { main@pdfcolorstack }
      {
        \int_set:Nn \l__color_backend_stack_int
          { \int_use:c { main@pdfcolorstack } }
      }
      {
        \__kernel_color_backend_stack_init:Nnn \c__color_backend_main_stack_int
          { page ~ direct } { 0 ~ g ~ 0 ~ G }
        \int_set_eq:NN \l__color_backend_stack_int
          \c__color_backend_main_stack_int
      }
  }
```

(*End definition for* `\__kernel_color_backend_stack_init:Nnn`, `\g__color_backend_stack_int`, *and* `\c__color_backend_main_stack_int`.)

__kernel_color_backend_stack_push:nn
__kernel_color_backend_stack_push:nx
__kernel_color_backend_stack_pop:n

Simple enough but needs a version check.

```
\int_compare:nNnF \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
  {
    \cs_new_protected:Npn \__kernel_color_backend_stack_push:nn #1#2
      {
        \__kernel_backend_literal:x
          {
            pdfcolorstack ~
            \int_eval:n {#1} ~
            push ~ (#2)
          }
      }
    \cs_generate_variant:Nn \__kernel_color_backend_stack_push:nn { nx }
    \cs_new_protected:Npn \__kernel_color_backend_stack_pop:n #1
      {
        \__kernel_backend_literal:x
          {
            pdfcolorstack ~
            \int_eval:n {#1} ~
            pop
          }
      }
  }
```

(*End definition for* `\__kernel_color_backend_stack_push:nn` *and* `\__kernel_color_backend_stack_pop:n`.)

```
⟨/dvipdfmx | xetex⟩
```

3.2.3 LuaTeXand pdfTeX

```
⟨*luatex | pdftex⟩
```

__kernel_color_backend_stack_init:Nnn

```
\cs_new_protected:Npn \__kernel_color_backend_stack_init:Nnn #1#2#3
  {
    \int_const:Nn #1
      {
⟨*luatex⟩
        \tex_pdffeedback:D colorstackinit ~
⟨/luatex⟩
⟨*pdftex⟩
        \tex_pdfcolorstackinit:D
⟨/pdftex⟩
        \tl_if_blank:nF {#2} { #2 ~ }
        {#3}
      }
  }
```

(*End definition for* `\__kernel_color_backend_stack_init:Nnn`.)

__kernel_color_backend_stack_push:nn
__kernel_color_backend_stack_push:nx
__kernel_color_backend_stack_pop:n

```
\cs_new_protected:Npn \__kernel_color_backend_stack_push:nn #1#2
  {
⟨*luatex⟩
    \tex_pdfextension:D colorstack ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfcolorstack:D
⟨/pdftex⟩
      \int_eval:n {#1} ~ push ~ {#2}
  }
\cs_generate_variant:Nn \__kernel_color_backend_stack_push:nn { nx }
\cs_new_protected:Npn \__kernel_color_backend_stack_pop:n #1
  {
⟨*luatex⟩
    \tex_pdfextension:D colorstack ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfcolorstack:D
⟨/pdftex⟩
      \int_eval:n {#1} ~ pop \scan_stop:
  }
```

(*End definition for* `\__kernel_color_backend_stack_push:nn` *and* `\__kernel_color_backend_stack_pop:n`.)

```
⟨/luatex | pdftex⟩
```

3.3 General color

3.3.1 dvips-style

```
⟨*dvips | dvisvgm⟩
```

__color_backend_select_cmyk:n
__color_backend_select_gray:n
__color_backend_select_rgb:n
__color_backend_select:n
__color_backend_reset:
color.sc

Push the data to the stack. In the case of `dvips` also saves the drawing color in raw PostScript.

```
\cs_new_protected:Npn \__color_backend_select_cmyk:n #1
  { \__color_backend_select:n { cmyk ~ #1 } }
\cs_new_protected:Npn \__color_backend_select_gray:n #1
  { \__color_backend_select:n { gray ~ #1 } }
\cs_new_protected:Npn \__color_backend_select_rgb:n #1
  { \__color_backend_select:n { rgb ~ #1 } }
\cs_new_protected:Npn \__color_backend_select:n #1
  {
    \__kernel_backend_literal:n { color~push~ #1 }
⟨*dvips⟩
    \__kernel_backend_postscript:n { /color.sc ~ { } ~ def }
⟨/dvips⟩
    \group_insert_after:N \__color_backend_reset:
  }
\cs_new_protected:Npn \__color_backend_reset:
  { \__kernel_backend_literal:n { color~pop } }
```

(*End definition for* `\__color_backend_select_cmyk:n` *and others. This function is documented on page* **??**.)

```
⟨/dvips | dvisvgm⟩
```

3.3.2 LuaTEX and pdfTEX

```
⟨*dvipdfmx | luatex | pdftex | xetex⟩
```

\l__color_backend_fill_tl
\l__color_backend_stroke_tl

```
\tl_new:N \l__color_backend_fill_tl
\tl_new:N \l__color_backend_stroke_tl
```

(*End definition for* `\l__color_backend_fill_tl` *and* `\l__color_backend_stroke_tl`.)

__color_backend_select_cmyk:n
__color_backend_select_gray:n
__color_backend_select_rgb:n
__color_backend_select:nn
__color_backend_reset:

Store the values then pass to the stack.

```
\cs_new_protected:Npn \__color_backend_select_cmyk:n #1
  { \__color_backend_select:nn { #1 ~ k } { #1 ~ K } }
\cs_new_protected:Npn \__color_backend_select_gray:n #1
  { \__color_backend_select:nn { #1 ~ g } { #1 ~ G } }
\cs_new_protected:Npn \__color_backend_select_rgb:n #1
  { \__color_backend_select:nn { #1 ~ rg } { #1 ~ RG } }
\cs_new_protected:Npn \__color_backend_select:nn #1#2
  {
    \tl_set:Nn \l__color_backend_fill_tl {#1}
    \tl_set:Nn \l__color_backend_stroke_tl {#2}
    \__kernel_color_backend_stack_push:nn \l__color_backend_stack_int { #1 ~ #2 }
    \group_insert_after:N \__color_backend_reset:
  }
\cs_new_protected:Npn \__color_backend_reset:
  { \__kernel_color_backend_stack_pop:n \l__color_backend_stack_int }
```

(*End definition for* `\__color_backend_select_cmyk:n` *and others.*)

```
⟨/dvipdfmx | luatex | pdftex | xetex⟩
```

3.3.3 dvipmdfx/XƎTEX

```
⟨*dvipdfmx | xetex⟩
```

These backends have the most possible approaches: it recognises both dvips-based color specials and it's own format, plus one can include PDF statements directly. Recent releases also have a color stack approach similar to pdfTEX. Of the stack methods, the dedicated the most versatile is the latter as it can cover all of the use cases we have. Thus it is used in preference to the dvips-style interface or the "native" color specials (which have only one stack).

__color_backend_select_cmyk:n
__color_backend_select_gray:n
__color_backend_select_rgb:n
__color_backend_reset:

Push the data to the stack.

```
\int_compare:nNnT \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
  {
    \cs_gset_protected:Npn \__color_backend_select_cmyk:n #1
      {
        \__kernel_backend_literal:n { pdf: bc ~ [#1] }
        \group_insert_after:N \__color_backend_reset:
      }
    \cs_gset_eq:NN \__color_backend_select_gray:n \__color_backend_select_cmyk:n
    \cs_gset_eq:NN \__color_backend_select_rgb:n \__color_backend_select_cmyk:n
    \cs_gset_protected:Npn \__color_backend_reset:
      { \__kernel_backend_literal:n { pdf: ec } }
  }
```

(*End definition for* __color_backend_select_cmyk:n *and others.*)

```
⟨/dvipdfmx | xetex⟩
```

3.4 Separations

Here, life gets interesting and we need essentially one approach per backend.

```
⟨*dvips⟩
```

__color_backend_select_separation:nn
__color_backend_select_devicen:nn

```
\cs_new_protected:Npn \__color_backend_select_separation:nn #1#2
  { \__color_backend_select:n { separation ~ #1 ~ #2 } }
\cs_new_eq:NN \__color_backend_select_devicen:nn \__color_backend_select_separation:nn
```

(*End definition for* __color_backend_select_separation:nn *and* __color_backend_select_devicen:nn.)

__color_backend_separation_init:nnnnn
__color_backend_separation_init:nxxnn
__color_backend_separation_init_aux:nnnnn
lor_backend_separation_init_/DeviceCMYK:nnn
lor_backend_separation_init_/DeviceGray:nnn
olor_backend_separation_init_/DeviceRGB:nnn
__color_backend_separation_init_Device:Nn
__color_backend_separation_init:nnn
__color_backend_separation_init_count:n
__color_backend_separation_init_count:w
__color_backend_separation_init:nnnn
__color_backend_separation_init:w
__color_backend_separation_init:n
__color_backend_separation_init:nw
__color_backend_separation_init_CIELAB:nnn

Initialising here means creating a small header set up plus massaging some data. This comes about as we have to deal with PDF-focussed data, which makes most sense "higher-up". The approach is based on ideas from https://tex.stackexchange.com/q/560093 plus using the PostScript manual for other aspects.

```
\cs_new_protected:Npx \__color_backend_separation_init:nnnnn #1#2#3#4#5
  {
    \bool_if:NT \g__kernel_backend_header_bool
      {
        \cs_if_exist:NTF \AtBeginDvi
          { \exp_not:N \AtBeginDvi }
          { \use:n }
            {
              \exp_not:N \__color_backend_separation_init_aux:nnnnn
                {#1} {#2} {#3} {#4} {#5}
            }
        }
    }
\cs_generate_variant:Nn \__color_backend_separation_init:nnnnn { nxx }
\cs_new_protected:Npn \__color_backend_separation_init_aux:nnnnn #1#2#3#4#5
  {
    \__kernel_backend_literal:e
      {
        !
        TeXDict ~ begin ~
        /color \int_use:N \g__color_model_int
          {
            [ ~
              /Separation ~ ( \str_convert_pdfname:n {#1} ) ~
              [ ~ #2 ~ ] ~
                {
                  \cs_if_exist_use:cF { __color_backend_separation_init_ #2 :nnn }
                    { \__color_backend_separation_init:nnn }
                      {#3} {#4} {#5}
                }
            ] ~ setcolorspace
          } ~ def ~
        end
      }
  }
\cs_new:cpn { __color_backend_separation_init_ /DeviceCMYK :nnn } #1#2#3
  { \__color_backend_separation_init_Device:Nn 4 {#3} }
\cs_new:cpn { __color_backend_separation_init_ /DeviceGray :nnn } #1#2#3
  { \__color_backend_separation_init_Device:Nn 1 {#3} }
\cs_new:cpn { __color_backend_separation_init_ /DeviceRGB :nnn } #1#2#3
  { \__color_backend_separation_init_Device:Nn 2 {#3} }
\cs_new:Npn \__color_backend_separation_init_Device:Nn #1#2
  {
    #2 ~
    \prg_replicate:nn {#1}
      { #1 ~ index ~ mul ~ #1 ~ 1 ~ roll ~ }
    \int_eval:n { #1 + 1 } ~ -1 ~ roll ~ pop
  }
```

For the generic case, we cannot use `/FunctionType 2` unfortunately, so we have to code that idea up in PostScript. Here, we will therefore assume that a range is *always* given. First, we count values in each argument: at the backend level, we can assume there are always well-behaved with spaces present.

```
\cs_new:Npn \__color_backend_separation_init:nnn #1#2#3
  {
   \exp_args:Ne \__color_backend_separation_init:nnnn
     { \__color_backend_separation_init_count:n {#2} }
     {#1} {#2} {#3}
  }
\cs_new:Npn \__color_backend_separation_init_count:n #1
  { \int_eval:n { 0 \__color_backend_separation_init_count:w #1 ~ \s__color_stop } }
\cs_new:Npn \__color_backend_separation_init_count:w #1 ~ #2 \s__color_stop
  {
    +1
    \tl_if_blank:nF {#2}
      { \__color_backend_separation_init_count:w #2 \s__color_stop }
  }
```

Now we implement the algorithm. In the terms in the PostScript manual, we have $\mathbf{N} = 1$ and $\mathbf{Domain} = [0\ 1]$, with **Range** as `#2`, **C0** as `#3` and **C1** as `#4`, with the number of output components in `#1`. So all we have to do is implement $y_i = \mathbf{C0}_i + x(\mathbf{C1}_i - \mathbf{C0}_i)$ with lots of stack manipulation, then check the ranges. That's done by adding everything to the stack first, then using the fact we know all of the offsets. As manipulating the stack is tricky, we start by re-formatting the **C0** and **C1** arrays to be interleaved, and add a `0` to each pair: this is used to keep the stack of constant length while we are doing the first pass of mathematics. We then working through that list, calculating from the last to the first value before tidying up by removing all of the input values. We do that by first copying all of the final y values to the end of the stack, then rolling everything so we can pop the now-unneeded material.

```
\cs_new:Npn \__color_backend_separation_init:nnnn #1#2#3#4
  {
    \__color_backend_separation_init:w #3 ~ \s__color_stop #4 ~ \s__color_stop
    \prg_replicate:nn {#1}
      {
        pop ~ 1 ~ index ~ neg ~ 1 ~ index ~ add ~
        \int_eval:n { 3 * #1 } ~ index ~ mul ~
        2 ~ index ~ add ~
        \int_eval:n { 3 * #1 } ~ #1 ~ roll ~
      }
    \int_step_function:nnnN {#1} { -1 } { 1 }
      \__color_backend_separation_init:n
    \int_eval:n { 4 * #1 + 1 } ~ #1 ~ roll ~
    \prg_replicate:nn { 3 * #1 + 1 } { pop ~ }
    \tl_if_blank:nF {#2}
      { \__color_backend_separation_init:nw {#1} #2 ~ \s__color_stop }
  }
\cs_new:Npn \__color_backend_separation_init:w
  #1 ~ #2 \s__color_stop #3 ~ #4 \s__color_stop
  {
    #1 ~ #3 ~ 0 ~
    \tl_if_blank:nF {#2}
      { \__color_backend_separation_init:w #2 \s__color_stop #4 \s__color_stop }
  }
\cs_new:Npn \__color_backend_separation_init:n #1
  { \int_eval:n { #1 * 2 } ~ index ~ }
```

Finally, we deal with the range limit if required. This is handled by splitting the range into pairs. It's then just a question of doing the comparisons, this time dropping everything except the desired result.

```
\cs_new:Npn \__color_backend_separation_init:nw #1#2 ~ #3 ~ #4 \s__color_stop
  {
     #2 ~ #3 ~
     2 ~ index ~ 2 ~ index ~ lt ~
       { ~ pop ~ exch ~ pop ~ } ~
       { ~
         2 ~ index ~ 1 ~ index ~ gt ~
           { ~ exch ~ pop ~ exch ~ pop ~ } ~
           { ~ pop ~ pop ~ } ~
```

```
          ifelse ~
        }
    ifelse ~
    #1 ~ 1 ~ roll ~
    \tl_if_blank:nF {#4}
      { \__color_backend_separation_init:nw {#1} #4 \s__color_stop }
  }
```

CIELAB support uses the detail from the PostScript reference, page 227; other than that block of PostScript, this is the same as for PDF-based routes.

```
\cs_new_protected:Npn \__color_backend_separation_init_CIELAB:nnn #1#2#3
  {
    \__color_backend_separation_init:nxxnn
      {#2}
      {
        /CIEBasedABC ~
            << ~
              /RangeABC ~ [ ~ \c__color_model_range_CIELAB_tl \c_space_tl ] ~
              /DecodeABC ~
                [ ~
                  { ~ 16 ~ add ~ 116 ~ div ~ } ~ bind ~
                  { ~ 500 ~ div ~ } ~ bind ~
                  { ~ 200 ~ div ~ } ~ bind ~
                ] ~
              /MatrixABC ~ [ ~ 1 ~ 1 ~ 1 ~ 1 ~ 0 ~ 0 ~ 0 ~ 0 ~ -1 ~ ] ~
              /DecodeLMN ~
                [ ~
                  { ~
                    dup ~ 6 ~ 29 ~ div ~ ge ~
                      { ~ dup ~ dup ~ mul ~ mul ~ ~ } ~
                      { ~ 4 ~ 29 ~ div ~ sub ~ 108 ~ 841 ~ div ~ mul ~ } ~
                    ifelse ~
                    0.9505 ~ mul ~
                  } ~ bind ~
                  { ~
                    dup ~ 6 ~ 29 ~ div ~ ge ~
                      { ~ dup ~ dup ~ mul ~ mul ~ } ~
                      { ~ 4 ~ 29 ~ div ~ sub ~ 108 ~ 841 ~ div ~ mul ~ } ~
                    ifelse ~
                  } ~ bind ~
                  { ~
                    dup ~ 6 ~ 29 ~ div ~ ge ~
                      { ~ dup ~ dup ~ mul ~ mul ~ } ~
                      { ~ 4 ~ 29 ~ div ~ sub ~ 108 ~ 841 ~ div ~ mul ~ } ~
                    ifelse ~
                    1.0890 ~ mul ~
                  } ~ bind
                ] ~
              /WhitePoint ~
                [ ~ \tl_use:c { c__color_model_whitepoint_CIELAB_ #1 _tl } ~ ] ~
            >>
      }
      { \c__color_model_range_CIELAB_tl }
      { 100 ~ 0 ~ 0 }
      {#3}
  }
```

(*End definition for* `\__color_backend_separation_init:nnnnn` *and others.*)

`\__color_backend_devicen_init:nnn`

Trivial as almost all of the work occurs in the shared code.

```
\cs_new_protected:Npn \__color_backend_devicen_init:nnn #1#2#3
  {
    \__kernel_backend_literal:e
      {
        !
        TeXDict ~ begin ~
        /color \int_use:N \g__color_model_int
          {
            [ ~
              /DeviceN ~
              [ ~ #1 ~ ] ~
              #2 ~
              { ~ #3 ~ } ~
            ] ~ setcolorspace
          } ~ def ~
        end
      }
  }
```

(*End definition for* `\__color_backend_devicen_init:nnn`*.*)

```
⟨/dvips⟩
⟨*dvisvgm⟩
```

`\__color_backend_select_separation:nn`
`\__color_backend_select_devicen:nn`

No support at present.

```
\cs_new_protected:Npn \__color_backend_select_separation:nn #1#2 { }
\cs_new_protected:Npn \__color_backend_select_devicen:nn #1#2 { }
```

(*End definition for* `\__color_backend_select_separation:nn` *and* `\__color_backend_select_devicen:nn`*.*)

`\__color_backend_separation_init:nnnnn`
`\__color_backend_separation_init_CIELAB:nnn`

No support at present.

```
\cs_new_protected:Npn \__color_backend_separation_init:nnnnn #1#2#3#4#5 { }
\cs_new_protected:Npn \__color_backend_separation_init_CIELAB:nnnnnn #1#2#3 { }
```

(*End definition for* `\__color_backend_separation_init:nnnnn` *and* `\__color_backend_separation_-init_CIELAB:nnn`*.*)

```
⟨/dvisvgm⟩
⟨*dvipdfmx | luatex | pdftex | xetex⟩
```

`\__color_backend_select_separation:nn`
`\__color_backend_select_devicen:nn`
`\__color_backend_select:n`

Although `(x)dvipdfmx` has a built-in approach to color spaces, that can't be used with the generic color stacks. So we take an approach in which we share the same code as for pdfTEX.

```
\cs_new_protected:Npn \__color_backend_select_separation:nn #1#2
  { \__color_backend_select:nn { /#1 ~ cs ~ #2 ~ scn  } { /#1 ~ CS ~ #2 ~ SCN } }
\cs_new_eq:NN \__color_backend_select_devicen:nn \__color_backend_select_separation:nn
```

(*End definition for* `\__color_backend_select_separation:nn`*,* `\__color_backend_select_devicen:nn`*, and* `\__color_backend_select:n`*.*)

__color_backend_separation_init:nnnnn
__color_backend_separation_init:n
__color_backend_separation_init_CIELAB:nnn

Initialising the PDF structures needs two parts: creating an object containing the "real" name of the Separation, then adding a reference to that to each page. We use a separate object for the tint transformation following the model in the PDF reference.

```
\cs_new_protected:Npn \__color_backend_separation_init:nnnnn #1#2#3#4#5
  {
    \pdf_object_unnamed_write:nx { dict }
      {
        /FunctionType ~ 2
        /Domain ~ [0 ~ 1]
        \tl_if_blank:nF {#3} { /Range ~ [#3] }
        /C0 ~ [#4] ~
        /C1 ~ [#5] /N ~ 1
      }
    \__color_backend_separation_init:n
      {
        /Separation ~
        / \str_convert_pdfname:n {#1} ~ #2 ~
        \pdf_object_ref_last:
      }
    \cs_if_exist:NT \pdfmanagement_add:nnn
      {
        \use:x
          {
            \pdfmanagement_add:nnn
              { Page / Resources / ColorSpace }
              { color \int_use:N \g__color_model_int }
              { \pdf_object_ref_last: }
          }
      }
  }
\cs_new_protected:Npn \__color_backend_separation_init:n #1
  {
    \pdf_object_unnamed_write:nx { array } {#1}
  }
```

For CIELAB colors, we need one object per document for the illuminant, plus initialisation of the color space referencing that object.

```
\cs_new_protected:Npn \__color_backend_separation_init_CIELAB:nnn #1#2#3
  {
    \pdf_object_if_exist:nF { __color_illuminant_CIELAB_ #1 }
      {
        \pdf_object_new:nn { __color_illuminant_CIELAB_ #1 } { array }
        \pdf_object_write:nx { __color_illuminant_CIELAB_ #1 }
          {
            /Lab ~
            <<
             /WhitePoint ~
               [ \tl_use:c { c__color_model_whitepoint_CIELAB_ #1 _tl } ]
             /Range ~ [ \c__color_model_range_CIELAB_tl ]
            >>
          }
      }
    \__color_backend_separation_init:nnnnn
      {#2}
      { \pdf_object_ref:n { __color_illuminant_CIELAB_ #1 } }
      { \c__color_model_range_CIELAB_tl }
      { 100 ~ 0 ~ 0 }
      {#3}
  }
\cs_if_exist:NF \pdf_object_unnamed_write:nn
  {
    \cs_gset_protected:Npn \__color_backend_separation_init_CIELAB:nnn #1#2#3
      { }
  }
```

(*End definition for* `\__color_backend_separation_init:nnnnn`, `\__color_backend_separation_init:n`, *and* `\__color_backend_separation_init_CIELAB:nnn`.)

__color_backend_devicen_init:nnn
__color_backend_devicen_init:w
__color_backend_devicen_init:n

Similar to the Separations case, but with an arbitrary function for the alternative space work.

```
\cs_new_protected:Npn \__color_backend_devicen_init:nnn #1#2#3
  {
    \pdf_object_unnamed_write:nx { stream }
      {
        {
          /FunctionType ~ 4 ~
          /Domain ~
            [ ~
              \prg_replicate:nn
                { 0 \__color_backend_devicen_init:w #1 ~ \s__color_stop }
                { 0 ~ 1 ~ } ~
            ] ~
          /Range ~
            [ ~
              \str_case:nn {#2}
                {
                  { /DeviceCMYK } { 0 ~ 1 ~ 0 ~ 1 ~ 0 ~ 1 ~ 0 ~ 1 }
                  { /DeviceGray } { 0 ~ 1 }
                  { /DeviceRGB }  { 0 ~ 1 ~ 0 ~ 1 ~ 0 ~ 1 }
                } ~
            ]
        }
        {#3}
     }
    \__color_backend_separation_init:n
      {
        /DeviceN ~
        [ ~ #1 ~ ] ~
        #2 ~
        \pdf_object_ref_last:
      }
    \cs_if_exist:NT \pdfmanagement_add:nnn
      {
        \use:x
          {
            \pdfmanagement_add:nnn
              { Page / Resources / ColorSpace }
              { color \int_use:N \g__color_model_int }
              { \pdf_object_ref_last: }
          }
      }
  }
\cs_new:Npn \__color_backend_devicen_init:w #1 ~ #2 \s__color_stop
  {
    + 1
    \tl_if_blank:nF {#2}
      { \__color_backend_devicen_init:w #2 \s__color_stop }
  }
\cs_new_eq:NN \__color_backend_devicen_init:n \__color_backend_separation_init:n
```

(*End definition for* `\__color_backend_devicen_init:nnn`*,* `\__color_backend_devicen_init:w`*, and* `\__color_backend_devicen_init:n`*.*)

```
⟨/dvipdfmx | luatex | pdftex | xetex⟩
⟨*dvipdfmx | xetex⟩
```

__color_backend_select_separation:nn
__color_backend_select_devicen:nn

For older `(x)dvipdfmx`, we *could* support separations using a dedicated mechanism, but it was not added that long before the color stacks. So instead of having two complex paths, just disable here.

```
\int_compare:nNnT \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
  {
    \cs_gset_protected:Npn \__color_backend_select_separation:nn #1#2 { }
    \cs_gset_eq:NN \__color_backend_select_devicen:nn
      \__color_backend_select_separation:nn
  }
```

(*End definition for* `\__color_backend_select_separation:nn` *and* `\__color_backend_select_devicen:nn`*.*)

```
⟨/dvipdfmx | xetex⟩
```

3.5 Fill and stroke color

Here, `dvipdfmx`/XƎTEX follows LuaTEX and pdfTEX, while for `dvips` we have to manage fill and stroke color ourselves. We also handle `dvisvgm` independently, as there we can create SVG directly.

```
⟨*dvipdfmx | luatex | pdftex | xetex⟩
```

__color_backend_fill_cmyk:n
__color_backend_fill_gray:n
__color_backend_fill_rgb:n
__color_backend_fill:n
__color_backend_stroke_cmyk:n
__color_backend_stroke_gray:n
__color_backend_stroke_rgb:n
__color_backend_stroke:n

Drawing (fill/stroke) color is handled in `dvipdfmx`/XƎTEX in the same way as LuaTEX/pdfTEX. We use the same approach as earlier, except the color stack is not involved so the generic direct PDF operation is used. There is no worry about the nature of strokes: everything is handled automatically.

```
\cs_new_protected:Npn \__color_backend_fill_cmyk:n #1
  { \__color_backend_fill:n { #1 ~ k } }
\cs_new_protected:Npn \__color_backend_fill_gray:n #1
  { \__color_backend_fill:n { #1 ~ g } }
\cs_new_protected:Npn \__color_backend_fill_rgb:n #1
  { \__color_backend_fill:n { #1 ~ rg } }
\cs_new_protected:Npn \__color_backend_fill:n #1
  {
    \tl_set:Nn \l__color_backend_fill_tl {#1}
    \__kernel_color_backend_stack_push:nn \l__color_backend_stack_int
      { #1 ~ \l__color_backend_stroke_tl }
      \group_insert_after:N \__color_backend_reset:
    }
\cs_new_protected:Npn \__color_backend_stroke_cmyk:n #1
  { \__color_backend_stroke:n { #1 ~ K } }
\cs_new_protected:Npn \__color_backend_stroke_gray:n #1
  { \__color_backend_stroke:n { #1 ~ G } }
\cs_new_protected:Npn \__color_backend_stroke_rgb:n #1
  { \__color_backend_stroke:n { #1 ~ RG } }
\cs_new_protected:Npn \__color_backend_stroke:n #1
  {
    \tl_set:Nn \l__color_backend_stroke_tl {#1}
    \__kernel_color_backend_stack_push:nn \l__color_backend_stack_int
      { \l__color_backend_fill_tl \c_space_tl #1 }
    \group_insert_after:N \__color_backend_reset:
  }
```

(*End definition for* `\__color_backend_fill_cmyk:n` *and others.*)

`\__color_backend_fill_separation:nn`
`\__color_backend_stroke_separation:nn`
`\__color_backend_fill_devicen:nn`
`\__color_backend_stroke_devicen:nn`

```
\cs_new_protected:Npn \__color_backend_fill_separation:nn #1#2
  { \__color_backend_fill:n { /#1 ~ cs ~ #2 ~ scn } }
\cs_new_protected:Npn \__color_backend_stroke_separation:nn #1#2
  { \__color_backend_stroke:n { /#1 ~ CS ~ #2 ~ SCN } }
\cs_new_eq:NN \__color_backend_fill_devicen:nn \__color_backend_fill_separation:nn
\cs_new_eq:NN \__color_backend_stroke_devicen:nn \__color_backend_stroke_separation:nn
```

(*End definition for* `\__color_backend_fill_separation:nn` *and others.*)

```
⟨/dvipdfmx | luatex | pdftex | xetex⟩
⟨*dvipdfmx | xetex⟩
```

`\__color_backend_fill_cmyk:n`
`\__color_backend_fill_gray:n`
`\__color_backend_fill_rgb:n`
`\__color_backend_reset:`
`\__color_backend_stroke:n`
`\__color_backend_fill_separation:nn`
`\__color_backend_stroke_separation:nn`

Deal with older `(x)dvipdfmx`.

```
\int_compare:nNnT \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
  {
    \cs_gset_protected:Npn \__color_backend_fill_cmyk:n #1
      {
        \__kernel_backend_literal:n { pdf: bc ~ [#1] }
        \group_insert_after:N \__color_backend_reset:
      }
    \cs_gset_eq:NN \__color_backend_fill_gray:n \__color_backend_fill_cmyk:n
    \cs_gset_eq:NN \__color_backend_fill_rgb:n \__color_backend_fill_cmyk:n
    \cs_gset_protected:Npn \__color_backend_reset:
      { \__kernel_backend_literal:n { pdf: ec } }
    \cs_gset_protected:Npn \__color_backend_stroke:n #1
      { \__kernel_backend_literal:n {#1} }
    \cs_gset_protected:Npn \__color_backend_fill_separation:nn #1#2 { }
    \cs_gset_eq:NN \__color_backend_fill_devicen:nn
      \__color_backend_fill_separation:nn
    \cs_gset_eq:NN \__color_backend_stroke_separation:nn
      \__color_backend_fill_separation:nn
    \cs_gset_eq:NN \__color_backend_stroke_devicen:nn
      \__color_backend_stroke_separation:nn
  }
```

(*End definition for* `\__color_backend_fill_cmyk:n` *and others.*)

```
⟨/dvipdfmx | xetex⟩
⟨*dvips⟩
```

`\__color_backend_fill_cmyk:n`
`\__color_backend_fill_gray:n`
`\__color_backend_fill_rgb:n`
`\__color_backend_fill:n`
`\__color_backend_stroke_cmyk:n`
`\__color_backend_stroke_gray:n`
`\__color_backend_stroke_rgb:n`

Fill color here is the same as general color *except* we skip the stroke part.

```
\cs_new_protected:Npn \__color_backend_fill_cmyk:n #1
  { \__color_backend_fill:n { cmyk ~ #1 } }
\cs_new_protected:Npn \__color_backend_fill_gray:n #1
  { \__color_backend_fill:n { gray ~ #1 } }
\cs_new_protected:Npn \__color_backend_fill_rgb:n #1
  { \__color_backend_fill:n { rgb ~ #1 } }
\cs_new_protected:Npn \__color_backend_fill:n #1
  {
    \__kernel_backend_literal:n { color~push~ #1 }
    \group_insert_after:N \__color_backend_reset:
  }
\cs_new_protected:Npn \__color_backend_stroke_cmyk:n #1
  { \__kernel_backend_postscript:n { /color.sc { #1 ~ setcmykcolor } def } }
\cs_new_protected:Npn \__color_backend_stroke_gray:n #1
  { \__kernel_backend_postscript:n { /color.sc { #1 ~ setgray } def } }
\cs_new_protected:Npn \__color_backend_stroke_rgb:n #1
  { \__kernel_backend_postscript:n { /color.sc { #1 ~ setrgbcolor } def } }
```

(*End definition for* `\__color_backend_fill_cmyk:n` *and others.*)

`\__color_backend_fill_separation:nn`
`\__color_backend_stroke_separation:nn`
`\__color_backend_fill_devicen:nn`
`\__color_backend_stroke_devicen:nn`

```
\cs_new_protected:Npn \__color_backend_fill_separation:nn #1#2
  { \__color_backend_fill:n { separation ~ #1 ~ #2 } }
\cs_new_protected:Npn \__color_backend_stroke_separation:nn #1#2
  { \__kernel_backend_postscript:n { /color.sc { separation ~ #1 ~ #2 } def } }
\cs_new_eq:NN \__color_backend_fill_devicen:nn \__color_backend_fill_separation:nn
\cs_new_eq:NN \__color_backend_stroke_devicen:nn \__color_backend_stroke_separation:nn
```

(*End definition for* `\__color_backend_fill_separation:nn` *and others.*)

```
⟨/dvips⟩
⟨*dvisvgm⟩
```

`\__color_backend_fill_cmyk:n`
`\__color_backend_fill_gray:n`
`\__color_backend_fill_rgb:n`
`\__color_backend_fill:n`

Fill color here is the same as general color *except* we skip the stroke part.

```
\cs_new_protected:Npn \__color_backend_fill_cmyk:n #1
  { \__color_backend_fill:n { cmyk ~ #1 } }
\cs_new_protected:Npn \__color_backend_fill_gray:n #1
  { \__color_backend_fill:n { gray ~ #1 } }
\cs_new_protected:Npn \__color_backend_fill_rgb:n #1
  { \__color_backend_fill:n { rgb ~ #1 } }
\cs_new_protected:Npn \__color_backend_fill:n #1
  {
    \__kernel_backend_literal:n { color~push~ #1 }
    \group_insert_after:N \__color_backend_reset:
  }
```

(*End definition for* `\__color_backend_fill_cmyk:n` *and others.*)

__color_backend_stroke_cmyk:n
__color_backend_stroke_cmyk:w
__color_backend_stroke_gray:n
__color_backend_stroke_gray_aux:n
__color_backend_stroke_rgb:n
__color_backend_stroke_rgb:w
__color_backend:nnn

For drawings in SVG, we use scopes for all stroke colors. That requires using `RGB` values, which luckily are easy to convert here (`cmyk` to `RGB` is a fixed function).

```
\cs_new_protected:Npn \__color_backend_stroke_cmyk:n #1
  { \__color_backend_cmyk:w #1 \s__color_stop }
\cs_new_protected:Npn \__color_backend_stroke_cmyk:w
  #1 ~ #2 ~ #3 ~ #4 \s__color_stop
  {
    \use:x
      {
        \__color_backend:nnn
          { \fp_eval:n { -100 * ( 1 - min ( 1 , #1 + #4 ) ) } }
          { \fp_eval:n { -100 * ( 1 - min ( 1 , #2 + #4 ) ) } }
          { \fp_eval:n { -100 * ( 1 - min ( 1 , #3 + #4 ) ) } }
      }
  }
\cs_new_protected:Npn \__color_backend_stroke_gray:n #1
  {
    \use:x
      {
        \__color_backend_stroke_gray_aux:n
          { \fp_eval:n { 100 * (#1) } }
      }
  }
\cs_new_protected:Npn \__color_backend_stroke_gray_aux:n #1
  { \__color_backend:nnn {#1} {#1} {#1} }
\cs_new_protected:Npn \__color_backend_stroke_rgb:n #1
  { \__color_backend_rgb:w #1 \s__color_stop }
\cs_new_protected:Npn \__color_backend_stroke_rgb:w
  #1 ~ #2 ~ #3 \s__color_stop
  {
    \use:x
      {
        \__color_backend:nnn
          { \fp_eval:n { 100 * (#1) } }
          { \fp_eval:n { 100 * (#2) } }
          { \fp_eval:n { 100 * (#3) } }
      }
  }
\cs_new_protected:Npx \__color_backend:nnn #1#2#3
  {
    \__kernel_backend_scope:n
      {
        stroke =
         "
           rgb
             (
               #1 \c_percent_str ,
               #2 \c_percent_str ,
               #3 \c_percent_str
             )
         "
      }
  }
```

(*End definition for* `\__color_backend_stroke_cmyk:n` *and others.*)

`\__color_backend_fill_separation:nn`
`\__color_backend_stroke_separation:nn`
`\__color_backend_fill_devicen:nn`
`\__color_backend_stroke_devicen:nn`

At present, these are no-ops.

```
\cs_new_protected:Npn \__color_backend_fill_separation:nn #1#2 { }
\cs_new_protected:Npn \__color_backend_stroke_separation:nn #1#2 { }
\cs_new_eq:NN \__color_backend_fill_devicen:nn \__color_backend_fill_separation:nn
\cs_new_eq:NN \__color_backend_stroke_devicen:nn \__color_backend_stroke_separation:nn
```

(*End definition for* `\__color_backend_fill_separation:nn` *and others.*)

```
⟨/dvisvgm⟩
⟨/package⟩
```

4 l3backend-draw Implementation

```
⟨*package⟩
⟨@@=draw⟩
```

4.1 dvips backend

```
⟨*dvips⟩
```

`\__draw_backend_literal:n`
`\__draw_backend_literal:x`

The same as literal PostScript: same arguments about positioning apply her.

```
\cs_new_eq:NN \__draw_backend_literal:n \__kernel_backend_literal_postscript:n
\cs_generate_variant:Nn \__draw_backend_literal:n { x }
```

(*End definition for* `\__draw_backend_literal:n`.)

`\__draw_backend_begin:`
`\__draw_backend_end:`

The `ps::[begin]` special here deals with positioning but allows us to continue on to a matching `ps::[end]`: contrast with `ps:`, which positions but where we can't split material between separate calls. The `@beginspecial`/`@endspecial` pair are from `special.pro` and correct the scale and y-axis direction. In contrast to `pgf`, we don't save the current point: discussion with Tom Rokici suggested a better way to handle the necessary translations (see `\__draw_backend_box_use:Nnnnn`). (Note that `@beginspecial`/`@endspecial` forms a backend scope.) The `[begin]`/`[end]` lines are handled differently from the rest as they are conceptually different: not really drawing literals but instructions to `dvips` itself.

```
\cs_new_protected:Npn \__draw_backend_begin:
  {
    \__kernel_backend_literal:n { ps::[begin] }
    \__draw_backend_literal:n { @beginspecial }
  }
\cs_new_protected:Npn \__draw_backend_end:
  {
    \__draw_backend_literal:n { @endspecial }
    \__kernel_backend_literal:n { ps::[end] }
  }
```

(*End definition for* `\__draw_backend_begin:` *and* `\__draw_backend_end:`.)

`\__draw_backend_scope_begin:`
`\__draw_backend_scope_end:`

Scope here may need to contain saved definitions, so the entire memory rather than just the graphic state has to be sent to the stack.

```
\cs_new_protected:Npn \__draw_backend_scope_begin:
  { \__draw_backend_literal:n { save } }
\cs_new_protected:Npn \__draw_backend_scope_end:
  { \__draw_backend_literal:n { restore } }
```

(*End definition for* `\__draw_backend_scope_begin:` *and* `\__draw_backend_scope_end:`.)

`\__draw_backend_moveto:nn`
`\__draw_backend_lineto:nn`
`\__draw_backend_rectangle:nnnn`
`\__draw_backend_curveto:nnnnnn`

Path creation operations mainly resolve directly to PostScript primitive steps, with only the need to convert to `bp`. Notice that `x`-type expansion is included here to ensure that any variable values are forced to literals before any possible caching. There is no native rectangular path command (without also clipping, filling or stroking), so that task is done using a small amount of PostScript.

```
\cs_new_protected:Npn \__draw_backend_moveto:nn #1#2
  {
    \__draw_backend_literal:x
      {
        \dim_to_decimal_in_bp:n {#1} ~
        \dim_to_decimal_in_bp:n {#2} ~ moveto
      }
  }
\cs_new_protected:Npn \__draw_backend_lineto:nn #1#2
  {
    \__draw_backend_literal:x
      {
        \dim_to_decimal_in_bp:n {#1} ~
        \dim_to_decimal_in_bp:n {#2} ~ lineto
      }
  }
\cs_new_protected:Npn \__draw_backend_rectangle:nnnn #1#2#3#4
  {
     \__draw_backend_literal:x
       {
         \dim_to_decimal_in_bp:n {#4} ~ \dim_to_decimal_in_bp:n {#3} ~
         \dim_to_decimal_in_bp:n {#1} ~ \dim_to_decimal_in_bp:n {#2} ~
         moveto~dup~0~rlineto~exch~0~exch~rlineto~neg~0~rlineto~closepath
      }
  }
\cs_new_protected:Npn \__draw_backend_curveto:nnnnnn #1#2#3#4#5#6
  {
    \__draw_backend_literal:x
      {
        \dim_to_decimal_in_bp:n {#1} ~ \dim_to_decimal_in_bp:n {#2} ~
        \dim_to_decimal_in_bp:n {#3} ~ \dim_to_decimal_in_bp:n {#4} ~
        \dim_to_decimal_in_bp:n {#5} ~ \dim_to_decimal_in_bp:n {#6} ~
        curveto
      }
 }
```

(*End definition for* `\__draw_backend_moveto:nn` *and others.*)

`\__draw_backend_evenodd_rule:`
`\__draw_backend_nonzero_rule:`
`\g__draw_draw_eor_bool`

The even-odd rule here can be implemented as a simply switch.

```
\cs_new_protected:Npn \__draw_backend_evenodd_rule:
  { \bool_gset_true:N \g__draw_draw_eor_bool }
\cs_new_protected:Npn \__draw_backend_nonzero_rule:
  { \bool_gset_false:N \g__draw_draw_eor_bool }
\bool_new:N \g__draw_draw_eor_bool
```

(*End definition for* `\__draw_backend_evenodd_rule:`, `\__draw_backend_nonzero_rule:`, *and* `\g__draw_draw_eor_bool`.)

__draw_backend_closepath:
__draw_backend_stroke:
__draw_backend_closestroke:
__draw_backend_fill:
__draw_backend_fillstroke:
__draw_backend_clip:
__draw_backend_discardpath:
\g__draw_draw_clip_bool

Unlike PDF, PostScript doesn't track separate colors for strokes and other elements. It is also desirable to have the `clip` keyword after a stroke or fill. To achieve those outcomes, there is some work to do. For color, the stoke color is simple but the fill one has to be inserted by hand. For clipping, the required ordering is achieved using a TeX switch. All of the operations end with a new path instruction as they do not terminate (again in contrast to PDF).

```
\cs_new_protected:Npn \__draw_backend_closepath:
  { \__draw_backend_literal:n { closepath } }
\cs_new_protected:Npn \__draw_backend_stroke:
  {
    \__draw_backend_literal:n { gsave }
    \__draw_backend_literal:n { color.sc }
    \__draw_backend_literal:n { stroke }
    \__draw_backend_literal:n { grestore }
    \bool_if:NT \g__draw_draw_clip_bool
      {
        \__draw_backend_literal:x
          {
            \bool_if:NT \g__draw_draw_eor_bool { eo }
            clip
          }
      }
    \__draw_backend_literal:n { newpath }
    \bool_gset_false:N \g__draw_draw_clip_bool
  }
\cs_new_protected:Npn \__draw_backend_closestroke:
  {
    \__draw_backend_closepath:
    \__draw_backend_stroke:
  }
\cs_new_protected:Npn \__draw_backend_fill:
  {
    \__draw_backend_literal:x
      {
        \bool_if:NT \g__draw_draw_eor_bool { eo }
        fill
      }
    \bool_if:NT \g__draw_draw_clip_bool
      {
        \__draw_backend_literal:x
          {
            \bool_if:NT \g__draw_draw_eor_bool { eo }
            clip
          }
      }
    \__draw_backend_literal:n { newpath }
    \bool_gset_false:N \g__draw_draw_clip_bool
  }
\cs_new_protected:Npn \__draw_backend_fillstroke:
  {
    \__draw_backend_literal:x
      {
        \bool_if:NT \g__draw_draw_eor_bool { eo }
        fill
      }
    \__draw_backend_literal:n { gsave }
    \__draw_backend_literal:n { color.sc }
    \__draw_backend_literal:n { stroke }
    \__draw_backend_literal:n { grestore }
    \bool_if:NT \g__draw_draw_clip_bool
      {
        \__draw_backend_literal:x
          {
            \bool_if:NT \g__draw_draw_eor_bool { eo }
            clip
          }
      }
    \__draw_backend_literal:n { newpath }
    \bool_gset_false:N \g__draw_draw_clip_bool
  }
\cs_new_protected:Npn \__draw_backend_clip:
  { \bool_gset_true:N \g__draw_draw_clip_bool }
\bool_new:N \g__draw_draw_clip_bool
\cs_new_protected:Npn \__draw_backend_discardpath:
  {
    \bool_if:NT \g__draw_draw_clip_bool
      {
        \__draw_backend_literal:x
          {
            \bool_if:NT \g__draw_draw_eor_bool { eo }
            clip
          }
      }
    \__draw_backend_literal:n { newpath }
    \bool_gset_false:N \g__draw_draw_clip_bool
  }
```

(*End definition for* `\__draw_backend_closepath:` *and others.*)

`\__draw_backend_dash_pattern:nn`
`\__draw_backend_dash:n`
`\__draw_backend_linewidth:n`
`\__draw_backend_miterlimit:n`
`\__draw_backend_cap_butt:`
`\__draw_backend_cap_round:`
`\__draw_backend_cap_rectangle:`
`\__draw_backend_join_miter:`
`\__draw_backend_join_round:`
`\__draw_backend_join_bevel:`

Converting paths to output is again a case of mapping directly to PostScript operations.

```
\cs_new_protected:Npn \__draw_backend_dash_pattern:nn #1#2
  {
    \__draw_backend_literal:x
      {
        [
          \exp_args:Nf \use:n
            { \clist_map_function:nN {#1} \__draw_backend_dash:n }
        ] ~
        \dim_to_decimal_in_bp:n {#2} ~ setdash
      }
  }
\cs_new:Npn \__draw_backend_dash:n #1
  { ~ \dim_to_decimal_in_bp:n {#1} }
\cs_new_protected:Npn \__draw_backend_linewidth:n #1
  {
    \__draw_backend_literal:x
      { \dim_to_decimal_in_bp:n {#1} ~ setlinewidth }
  }
\cs_new_protected:Npn \__draw_backend_miterlimit:n #1
  { \__draw_backend_literal:n { #1 ~ setmiterlimit } }
\cs_new_protected:Npn \__draw_backend_cap_butt:
  { \__draw_backend_literal:n { 0 ~ setlinecap } }
\cs_new_protected:Npn \__draw_backend_cap_round:
  { \__draw_backend_literal:n { 1 ~ setlinecap } }
\cs_new_protected:Npn \__draw_backend_cap_rectangle:
  { \__draw_backend_literal:n { 2 ~ setlinecap } }
\cs_new_protected:Npn \__draw_backend_join_miter:
  { \__draw_backend_literal:n { 0 ~ setlinejoin } }
\cs_new_protected:Npn \__draw_backend_join_round:
  { \__draw_backend_literal:n { 1 ~ setlinejoin } }
\cs_new_protected:Npn \__draw_backend_join_bevel:
  { \__draw_backend_literal:n { 2 ~ setlinejoin } }
```

(*End definition for* `\__draw_backend_dash_pattern:nn` *and others.*)

`\__draw_backend_cm:nnnn`

In `dvips`, keeping the transformations in line with the engine is unfortunately not possible for scaling and rotations: even if we decompose the matrix into those operations, there is still no backend tracking (*cf.* `dvipdfmx`/XƎTEX). Thus we take the shortest path available and simply dump the matrix as given.

```
\cs_new_protected:Npn \__draw_backend_cm:nnnn #1#2#3#4
  {
    \__draw_backend_literal:n
      { [ #1 ~ #2 ~ #3 ~ #4 ~ 0 ~ 0 ] ~ concat }
  }
```

(*End definition for* `\__draw_backend_cm:nnnn`*.*)

`\__draw_backend_box_use:Nnnnn`

Inside a picture `@beginspecial`/`@endspecial` are active, which is normally a good thing but means that the position and scaling would be off if the box was inserted directly. To deal with that, there are a number of possible approaches. The implementation here was suggested by Tom Rokici (author of `dvips`). We end the current special placement, then set the current point with a literal `[begin]`. As for general literals, we then use the stack to store the current point and move to it. To insert the required transformation, we have to flip the y-axis, once before and once after it. Then we get back to the TEX reference point to insert our content. The clean up has to happen in the right places, hence the `[begin]`/`[end]` pair around `restore`. Finally, we can return to "normal" drawing mode. Notice that the set up here is very similar to that in `\__draw_align_currentpoint_...`, but the ordering of saving and restoring is different (intermixed).

```
\cs_new_protected:Npn \__draw_backend_box_use:Nnnnn #1#2#3#4#5
  {
    \__draw_backend_literal:n { @endspecial }
    \__draw_backend_literal:n { [end] }
    \__draw_backend_literal:n { [begin] }
    \__draw_backend_literal:n { save }
    \__draw_backend_literal:n { currentpoint }
    \__draw_backend_literal:n { currentpoint~translate }
    \__draw_backend_cm:nnnn { 1 } { 0 } { 0 } { -1 }
    \__draw_backend_cm:nnnn {#2} {#3} {#4} {#5}
    \__draw_backend_cm:nnnn { 1 } { 0 } { 0 } { -1 }
    \__draw_backend_literal:n { neg~exch~neg~exch~translate }
    \__draw_backend_literal:n { [end] }
    \hbox_overlap_right:n { \box_use:N #1 }
    \__draw_backend_literal:n { [begin] }
    \__draw_backend_literal:n { restore }
    \__draw_backend_literal:n { [end] }
    \__draw_backend_literal:n { [begin] }
    \__draw_backend_literal:n { @beginspecial }
  }
```

(*End definition for* `\__draw_backend_box_use:Nnnnn`.)

```
⟨/dvips⟩
```

4.2 LuaTEX, pdfTEX, dvipdfmx and XƎTEX

LuaTEX, pdfTEX, `dvipdfmx` and XƎTEX directly produce PDF output and understand a shared set of specials for drawing commands.

```
⟨*dvipdfmx | luatex | pdftex | xetex⟩
```

4.2.1 Drawing

`\__draw_backend_literal:n`
`\__draw_backend_literal:x`

Pass data through using a dedicated interface.

```
\cs_new_eq:NN \__draw_backend_literal:n \__kernel_backend_literal_pdf:n
\cs_generate_variant:Nn \__draw_backend_literal:n { x }
```

(*End definition for* `\__draw_backend_literal:n`.)

`\__draw_backend_begin:`
`\__draw_backend_end:`

No special requirements here, so simply set up a drawing scope.

```
\cs_new_protected:Npn \__draw_backend_begin:
  { \__draw_backend_scope_begin: }
\cs_new_protected:Npn \__draw_backend_end:
  { \__draw_backend_scope_end: }
```

(*End definition for* `\__draw_backend_begin:` *and* `\__draw_backend_end:`.)

`\__draw_backend_scope_begin:`
`\__draw_backend_scope_end:`

Use the backend-level scope mechanisms.

```
\cs_new_eq:NN \__draw_backend_scope_begin: \__kernel_backend_scope_begin:
\cs_new_eq:NN \__draw_backend_scope_end: \__kernel_backend_scope_end:
```

(*End definition for* `\__draw_backend_scope_begin:` *and* `\__draw_backend_scope_end:`.)

`\__draw_backend_moveto:nn`
`\__draw_backend_lineto:nn`
`\__draw_backend_curveto:nnnnnn`
`\__draw_backend_rectangle:nnnn`

Path creation operations all resolve directly to PDF primitive steps, with only the need to convert to `bp`.

```
\cs_new_protected:Npn \__draw_backend_moveto:nn #1#2
  {
    \__draw_backend_literal:x
      { \dim_to_decimal_in_bp:n {#1} ~ \dim_to_decimal_in_bp:n {#2} ~ m }
  }
\cs_new_protected:Npn \__draw_backend_lineto:nn #1#2
  {
    \__draw_backend_literal:x
      { \dim_to_decimal_in_bp:n {#1} ~ \dim_to_decimal_in_bp:n {#2} ~ l }
  }
\cs_new_protected:Npn \__draw_backend_curveto:nnnnnn #1#2#3#4#5#6
  {
      \__draw_backend_literal:x
        {
          \dim_to_decimal_in_bp:n {#1} ~ \dim_to_decimal_in_bp:n {#2} ~
          \dim_to_decimal_in_bp:n {#3} ~ \dim_to_decimal_in_bp:n {#4} ~
          \dim_to_decimal_in_bp:n {#5} ~ \dim_to_decimal_in_bp:n {#6} ~
          c
        }
  }
\cs_new_protected:Npn \__draw_backend_rectangle:nnnn #1#2#3#4
  {
     \__draw_backend_literal:x
        {
          \dim_to_decimal_in_bp:n {#1} ~ \dim_to_decimal_in_bp:n {#2} ~
          \dim_to_decimal_in_bp:n {#3} ~ \dim_to_decimal_in_bp:n {#4} ~
          re
        }
  }
```

(*End definition for* `\__draw_backend_moveto:nn` *and others.*)

__draw_backend_evenodd_rule:
__draw_backend_nonzero_rule:
\g__draw_draw_eor_bool

The even-odd rule here can be implemented as a simply switch.

```
\cs_new_protected:Npn \__draw_backend_evenodd_rule:
  { \bool_gset_true:N \g__draw_draw_eor_bool }
\cs_new_protected:Npn \__draw_backend_nonzero_rule:
  { \bool_gset_false:N \g__draw_draw_eor_bool }
\bool_new:N \g__draw_draw_eor_bool
```

(*End definition for* `\__draw_backend_evenodd_rule:`, `\__draw_backend_nonzero_rule:`, *and* `\g__draw_draw_eor_bool`.)

__draw_backend_closepath:
__draw_backend_stroke:
__draw_backend_closestroke:
__draw_backend_fill:
__draw_backend_fillstroke:
__draw_backend_clip:
__draw_backend_discardpath:

Converting paths to output is again a case of mapping directly to PDF operations.

```
\cs_new_protected:Npn \__draw_backend_closepath:
  { \__draw_backend_literal:n { h } }
\cs_new_protected:Npn \__draw_backend_stroke:
  { \__draw_backend_literal:n { S } }
\cs_new_protected:Npn \__draw_backend_closestroke:
  { \__draw_backend_literal:n { s } }
\cs_new_protected:Npn \__draw_backend_fill:
  {
    \__draw_backend_literal:x
      { f \bool_if:NT \g__draw_draw_eor_bool * }
  }
\cs_new_protected:Npn \__draw_backend_fillstroke:
  {
    \__draw_backend_literal:x
      { B \bool_if:NT \g__draw_draw_eor_bool * }
  }
\cs_new_protected:Npn \__draw_backend_clip:
  {
    \__draw_backend_literal:x
      { W \bool_if:NT \g__draw_draw_eor_bool * }
  }
\cs_new_protected:Npn \__draw_backend_discardpath:
  { \__draw_backend_literal:n { n } }
```

(*End definition for* `\__draw_backend_closepath:` *and others.*)

`\__draw_backend_dash_pattern:nn`
`\__draw_backend_dash:n`
`\__draw_backend_linewidth:n`
`\__draw_backend_miterlimit:n`
`\__draw_backend_cap_butt:`
`\__draw_backend_cap_round:`
`\__draw_backend_cap_rectangle:`
`\__draw_backend_join_miter:`
`\__draw_backend_join_round:`
`\__draw_backend_join_bevel:`

Converting paths to output is again a case of mapping directly to PDF operations.

```
\cs_new_protected:Npn \__draw_backend_dash_pattern:nn #1#2
  {
    \__draw_backend_literal:x
      {
        [
          \exp_args:Nf \use:n
            { \clist_map_function:nN {#1} \__draw_backend_dash:n }
        ] ~
        \dim_to_decimal_in_bp:n {#2} ~ d
      }
  }
\cs_new:Npn \__draw_backend_dash:n #1
  { ~ \dim_to_decimal_in_bp:n {#1} }
\cs_new_protected:Npn \__draw_backend_linewidth:n #1
  {
    \__draw_backend_literal:x
      { \dim_to_decimal_in_bp:n {#1} ~ w }
  }
\cs_new_protected:Npn \__draw_backend_miterlimit:n #1
  { \__draw_backend_literal:x { #1 ~ M } }
\cs_new_protected:Npn \__draw_backend_cap_butt:
  { \__draw_backend_literal:n { 0 ~ J } }
\cs_new_protected:Npn \__draw_backend_cap_round:
  { \__draw_backend_literal:n { 1 ~ J } }
\cs_new_protected:Npn \__draw_backend_cap_rectangle:
  { \__draw_backend_literal:n { 2 ~ J } }
\cs_new_protected:Npn \__draw_backend_join_miter:
  { \__draw_backend_literal:n { 0 ~ j } }
\cs_new_protected:Npn \__draw_backend_join_round:
  { \__draw_backend_literal:n { 1 ~ j } }
\cs_new_protected:Npn \__draw_backend_join_bevel:
  { \__draw_backend_literal:n { 2 ~ j } }
```

(*End definition for* `\__draw_backend_dash_pattern:nn` *and others.*)

`\__draw_backend_cm:nnnn`
`\__draw_backend_cm_aux:nnnn`

Another split here between LuaTEX/pdfTeX and `dvipdfmx`/XƎTEX. In the former, we have a direct method to maintain alignment: the backend can use a matrix itself. For `dvipdfmx`/XƎTEX, we can to decompose the matrix into rotations and a scaling, then use those operations as they are handled by the backend. (There is backend support for matrix operations in `dvipdfmx`/XƎTEX, but as a matched pair so not suitable for the "stand alone" transformation set up here.) The specials used here are from `xdvipdfmx` originally: they are well-tested, but probably equivalent to the `pdf:` versions!

```
\cs_new_protected:Npn \__draw_backend_cm:nnnn #1#2#3#4
  {
⟨*luatex | pdftex⟩
    \__kernel_backend_matrix:n { #1 ~ #2 ~ #3 ~ #4 }
⟨/luatex | pdftex⟩
⟨*dvipdfmx | xetex⟩
    \__draw_backend_cm_decompose:nnnnN {#1} {#2} {#3} {#4}
      \__draw_backend_cm_aux:nnnn
⟨/dvipdfmx | xetex⟩
```

```
  }
⟨*dvipdfmx | xetex⟩
\cs_new_protected:Npn \__draw_backend_cm_aux:nnnn #1#2#3#4
  {
    \__kernel_backend_literal:x
      {
        x:rotate~
        \fp_compare:nNnTF {#1} = \c_zero_fp
          { 0 }
          { \fp_eval:n { round ( -#1 , 5 ) } }
      }
    \__kernel_backend_literal:x
      {
        x:scale~
        \fp_eval:n { round ( #2 , 5 ) } ~
        \fp_eval:n { round ( #3 , 5 ) }
      }
    \__kernel_backend_literal:x
      {
        x:rotate~
        \fp_compare:nNnTF {#4} = \c_zero_fp
          { 0 }
          { \fp_eval:n { round ( -#4 , 5 ) } }
      }
  }
⟨/dvipdfmx | xetex⟩
```

(*End definition for* `\__draw_backend_cm:nnnn` *and* `\__draw_backend_cm_aux:nnnn`.)

`\__draw_backend_cm_decompose:nnnnN`
`\__draw_backend_cm_decompose_auxi:nnnnN`
`\__draw_backend_cm_decompose_auxii:nnnnN`
`\__draw_backend_cm_decompose_auxiii:nnnnN`

Internally, transformations for drawing are tracked as a matrix. Not all engines provide a way of dealing with this: if we use a raw matrix, the engine looses track of positions (for example for hyperlinks), and this is not desirable. They do, however, allow us to track rotations and scalings. Luckily, we can decompose any (two-dimensional) matrix into two rotations and a single scaling:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cos\beta & \sin\beta \\ -\sin\beta & \cos\beta \end{bmatrix} \begin{bmatrix} w_1 & 0 \\ 0 & w_2 \end{bmatrix} \begin{bmatrix} \cos\gamma & \sin\gamma \\ -\sin\gamma & \cos\gamma \end{bmatrix}$$

The parent matrix can be converted to

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} E & H \\ -H & E \end{bmatrix} + \begin{bmatrix} F & G \\ G & -F \end{bmatrix}$$

From these, we can find that

$$\begin{aligned} \frac{w_1 + w_2}{2} &= \sqrt{E^2 + H^2} \\ \frac{w_1 - w_2}{2} &= \sqrt{F^2 + G^2} \\ \gamma - \beta &= \tan^{-1}(G/F) \\ \gamma + \beta &= \tan^{-1}(H/E) \end{aligned}$$

at which point we just have to do various pieces of re-arrangement to get all of the values. (See J. Blinn, *IEEE Comput. Graph. Appl.*, 1996, **16**, 82–88.) There is one wrinkle: the

PostScript (and PDF) way of specifying a transformation matrix exchanges where one would normally expect B and C to be.

```
⟨*dvipdfmx | xetex⟩
\cs_new_protected:Npn \__draw_backend_cm_decompose:nnnnN #1#2#3#4#5
  {
    \use:x
      {
        \__draw_backend_cm_decompose_auxi:nnnnN
          { \fp_eval:n { (#1 + #4) / 2 } }
          { \fp_eval:n { (#1 - #4) / 2 } }
          { \fp_eval:n { (#3 + #2) / 2 } }
          { \fp_eval:n { (#3 - #2) / 2 } }
      }
        #5
  }
\cs_new_protected:Npn \__draw_backend_cm_decompose_auxi:nnnnN #1#2#3#4#5
  {
    \use:x
      {
        \__draw_backend_cm_decompose_auxii:nnnnN
          { \fp_eval:n { 2 * sqrt ( #1 * #1 + #4 * #4 ) } }
          { \fp_eval:n { 2 * sqrt ( #2 * #2 + #3 * #3 ) } }
          { \fp_eval:n { atand ( #3 , #2 ) } }
          { \fp_eval:n { atand ( #4 , #1 ) } }
      }
         #5
  }
\cs_new_protected:Npn \__draw_backend_cm_decompose_auxii:nnnnN #1#2#3#4#5
  {
    \use:x
      {
        \__draw_backend_cm_decompose_auxiii:nnnnN
          { \fp_eval:n { ( #4 - #3 ) / 2 } }
          { \fp_eval:n { ( #1 + #2 ) / 2 } }
          { \fp_eval:n { ( #1 - #2 ) / 2 } }
          { \fp_eval:n { ( #4 + #3 ) / 2 } }
      }
        #5
  }
\cs_new_protected:Npn \__draw_backend_cm_decompose_auxiii:nnnnN #1#2#3#4#5
  {
    \fp_compare:nNnTF { abs( #2 ) } > { abs ( #3 ) }
      { #5 {#1} {#2} {#3} {#4} }
      { #5 {#1} {#3} {#2} {#4} }
  }
⟨/dvipdfmx | xetex⟩
```

(*End definition for* `\__draw_backend_cm_decompose:nnnnN` *and others.*)

`\__draw_backend_box_use:Nnnnn` Inserting a TeX box transformed to the requested position and using the current matrix is done using a mixture of TeX and low-level manipulation. The offset can be handled by TeX, so only any rotation/skew/scaling component needs to be done using the matrix operation. As this operation can never be cached, the scope is set directly not using the `draw` version.

```
\cs_new_protected:Npn \__draw_backend_box_use:Nnnnn #1#2#3#4#5
  {
    \__kernel_backend_scope_begin:
⟨*luatex | pdftex⟩
    \__draw_backend_cm:nnnn {#2} {#3} {#4} {#5}
⟨/luatex | pdftex⟩
⟨*dvipdfmx | xetex⟩
    \__kernel_backend_literal:n
      { pdf:btrans~matrix~ #2 ~ #3 ~ #4 ~ #5 ~ 0 ~ 0 }
⟨/dvipdfmx | xetex⟩
    \hbox_overlap_right:n { \box_use:N #1 }
⟨*dvipdfmx | xetex⟩
    \__kernel_backend_literal:n { pdf:etrans }
⟨/dvipdfmx | xetex⟩
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__draw_backend_box_use:Nnnnn`.)

```
⟨/dvipdfmx | luatex | pdftex | xetex⟩
```

4.3 `dvisvgm` backend

```
⟨*dvisvgm⟩
```

`\__draw_backend_literal:n`
`\__draw_backend_literal:x`

The same as the more general literal call.

```
\cs_new_eq:NN \__draw_backend_literal:n \__kernel_backend_literal_svg:n
\cs_generate_variant:Nn \__draw_backend_literal:n { x }
```

(*End definition for* `\__draw_backend_literal:n`.)

`\__draw_backend_begin:`
`\__draw_backend_end:`

A drawing needs to be set up such that the co-ordinate system is translated. That is done inside a scope, which as described below

```
\cs_new_protected:Npn \__draw_backend_begin:
  {
    \__kernel_backend_scope_begin:
    \__kernel_backend_scope:n { transform="translate({?x},{?y})~scale(1,-1)" }
  }
\cs_new_eq:NN \__draw_backend_end: \__kernel_backend_scope_end:
```

(*End definition for* `\__draw_backend_begin:` *and* `\__draw_backend_end:`.)

`\__draw_backend_moveto:nn`
`\__draw_backend_lineto:nn`
`\__draw_backend_rectangle:nnnn`
`\__draw_backend_curveto:nnnnnn`
`\__draw_backend_add_to_path:n`
`\g__draw_draw_path_tl`

Once again, some work is needed to get path constructs correct. Rather then write the values as they are given, the entire path needs to be collected up before being output in one go. For that we use a dedicated storage routine, which adds spaces as required. Since paths should be fully expanded there is no need to worry about the internal `x`-type expansion.

```
\cs_new_protected:Npn \__draw_backend_moveto:nn #1#2
  {
    \__draw_backend_add_to_path:n
      { M ~ \dim_to_decimal:n {#1} ~ \dim_to_decimal:n {#2} }
  }
\cs_new_protected:Npn \__draw_backend_lineto:nn #1#2
  {
    \__draw_backend_add_to_path:n
```

```
      { L ~ \dim_to_decimal:n {#1} ~ \dim_to_decimal:n {#2} }
  }
\cs_new_protected:Npn \__draw_backend_rectangle:nnnn #1#2#3#4
  {
    \__draw_backend_add_to_path:n
      {
        M ~ \dim_to_decimal:n {#1} ~ \dim_to_decimal:n {#2}
        h ~ \dim_to_decimal:n {#3} ~
        v ~ \dim_to_decimal:n {#4} ~
        h ~ \dim_to_decimal:n { -#3 } ~
        Z
      }
  }
\cs_new_protected:Npn \__draw_backend_curveto:nnnnnn #1#2#3#4#5#6
  {
    \__draw_backend_add_to_path:n
      {
        C ~
        \dim_to_decimal:n {#1} ~ \dim_to_decimal:n {#2} ~
        \dim_to_decimal:n {#3} ~ \dim_to_decimal:n {#4} ~
        \dim_to_decimal:n {#5} ~ \dim_to_decimal:n {#6}
      }
  }
\cs_new_protected:Npn \__draw_backend_add_to_path:n #1
  {
    \tl_gset:Nx \g__draw_draw_path_tl
      {
        \g__draw_draw_path_tl
        \tl_if_empty:NF \g__draw_draw_path_tl { \c_space_tl }
        #1
      }
  }
\tl_new:N \g__draw_draw_path_tl
```

(*End definition for* `\__draw_backend_moveto:nn` *and others.*)

`\__draw_backend_evenodd_rule:`
`\__draw_backend_nonzero_rule:`

The fill rules here have to be handled as scopes.

```
\cs_new_protected:Npn \__draw_backend_evenodd_rule:
  { \__draw_backend_scope:n { fill-rule="evenodd" } }
\cs_new_protected:Npn \__draw_backend_nonzero_rule:
  { \__draw_backend_scope:n { fill-rule="nonzero" } }
```

(*End definition for* `\__draw_backend_evenodd_rule:` *and* `\__draw_backend_nonzero_rule:`.)

`\__draw_backend_path:n`
`\__draw_backend_closepath:`
`\__draw_backend_stroke:`
`\__draw_backend_closestroke:`
`\__draw_backend_fill:`
`\__draw_backend_fillstroke:`
`\__draw_backend_clip:`
`\__draw_backend_discardpath:`
`\g__draw_draw_clip_bool`
`\g__draw_draw_path_int`

Setting fill and stroke effects and doing clipping all has to be done using scopes. This means setting up the various requirements in a shared auxiliary which deals with the bits and pieces. Clipping paths are reused for path drawing: not essential but avoids constructing them twice. Discarding a path needs a separate function as it's not quite the same.

```
\cs_new_protected:Npn \__draw_backend_closepath:
  { \__draw_backend_add_to_path:n { Z } }
\cs_new_protected:Npn \__draw_backend_path:n #1
  {
    \bool_if:NTF \g__draw_draw_clip_bool
```

```
      {
        \int_gincr:N \g__draw_clip_path_int
        \__draw_backend_literal:x
          {
            < clipPath~id = " l3cp \int_use:N \g__draw_clip_path_int " >
              { ?nl }
            <path~d=" \g__draw_draw_path_tl "/> { ?nl }
            < /clipPath > { ? nl }
            <
              use~xlink:href =
                "\c_hash_str l3path \int_use:N \g__draw_path_int " ~
                #1
            />
          }
        \__draw_backend_scope:x
          {
            clip-path =
              "url( \c_hash_str l3cp \int_use:N \g__draw_clip_path_int)"
          }
      }
      {
        \__draw_backend_literal:x
          { <path ~ d=" \g__draw_draw_path_tl " ~ #1 /> }
      }
    \tl_gclear:N \g__draw_draw_path_tl
    \bool_gset_false:N \g__draw_draw_clip_bool
  }
\int_new:N \g__draw_path_int
\cs_new_protected:Npn \__draw_backend_stroke:
  { \__draw_backend_path:n { style="fill:none" } }
\cs_new_protected:Npn \__draw_backend_closestroke:
  {
    \__draw_backend_closepath:
    \__draw_backend_stroke:
  }
\cs_new_protected:Npn \__draw_backend_fill:
  { \__draw_backend_path:n { style="stroke:none" } }
\cs_new_protected:Npn \__draw_backend_fillstroke:
  { \__draw_backend_path:n { } }
\cs_new_protected:Npn \__draw_backend_clip:
  { \bool_gset_true:N \g__draw_draw_clip_bool }
\bool_new:N \g__draw_draw_clip_bool
\cs_new_protected:Npn \__draw_backend_discardpath:
  {
    \bool_if:NT \g__draw_draw_clip_bool
      {
        \int_gincr:N \g__draw_clip_path_int
        \__draw_backend_literal:x
          {
            < clipPath~id = " l3cp \int_use:N \g__draw_clip_path_int " >
              { ?nl }
            <path~d=" \g__draw_draw_path_tl "/> { ?nl }
            < /clipPath >
          }
        \__draw_backend_scope:x
          {
            clip-path =
              "url( \c_hash_str l3cp \int_use:N \g__draw_clip_path_int)"
          }
      }
    \tl_gclear:N \g__draw_draw_path_tl
    \bool_gset_false:N \g__draw_draw_clip_bool
  }
```

(*End definition for* `\__draw_backend_path:n` *and others.*)

`\__draw_backend_dash_pattern:nn`
`\__draw_backend_dash:n`
`\__draw_backend_dash_aux:nn`
`\__draw_backend_linewidth:n`
`\__draw_backend_miterlimit:n`
`\__draw_backend_cap_butt:`
`\__draw_backend_cap_round:`
`\__draw_backend_cap_rectangle:`
`\__draw_backend_join_miter:`
`\__draw_backend_join_round:`
`\__draw_backend_join_bevel:`

All of these ideas are properties of scopes in SVG. The only slight complexity is converting the dash array properly (doing any required maths).

```
\cs_new_protected:Npn \__draw_backend_dash_pattern:nn #1#2
  {
    \use:x
      {
        \__draw_backend_dash_aux:nn
          { \clist_map_function:nn {#1} \__draw_backend_dash:n }
          { \dim_to_decimal:n {#2} }
      }
  }
\cs_new:Npn \__draw_backend_dash:n #1
  { , \dim_to_decimal_in_bp:n {#1} }
\cs_new_protected:Npn \__draw_backend_dash_aux:nn #1#2
  {
    \__draw_backend_scope:x
      {
        stroke-dasharray =
          "
            \tl_if_empty:oTF { \use_none:n #1 }
              { none }
              { \use_none:n #1 }
          " ~
          stroke-offset=" #2 "
      }
  }
\cs_new_protected:Npn \__draw_backend_linewidth:n #1
  { \__draw_backend_scope:x { stroke-width=" \dim_to_decimal:n {#1} " } }
\cs_new_protected:Npn \__draw_backend_miterlimit:n #1
  { \__draw_backend_scope:x { stroke-miterlimit=" #1 " } }
\cs_new_protected:Npn \__draw_backend_cap_butt:
  { \__draw_backend_scope:n { stroke-linecap="butt" } }
\cs_new_protected:Npn \__draw_backend_cap_round:
  { \__draw_backend_scope:n { stroke-linecap="round" } }
\cs_new_protected:Npn \__draw_backend_cap_rectangle:
  { \__draw_backend_scope:n { stroke-linecap="square" } }
\cs_new_protected:Npn \__draw_backend_join_miter:
  { \__draw_backend_scope:n { stroke-linejoin="miter" } }
\cs_new_protected:Npn \__draw_backend_join_round:
  { \__draw_backend_scope:n { stroke-linejoin="round" } }
\cs_new_protected:Npn \__draw_backend_join_bevel:
  { \__draw_backend_scope:n { stroke-linejoin="bevel" } }
```

(*End definition for* `\__draw_backend_dash_pattern:nn` *and others.*)

`\__draw_backend_cm:nnnn` The four arguments here are floats (the affine matrix), the last two are a displacement vector.

```
\cs_new_protected:Npn \__draw_backend_cm:nnnn #1#2#3#4
  {
    \__draw_backend_scope:n
      {
       transform =
         " matrix ( #1 , #2 , #3 , #4 , 0pt , 0pt ) "
      }
  }
```

(*End definition for* `\__draw_backend_cm:nnnn`.)

`\__draw_backend_box_use:Nnnnn` No special savings can be made here: simply displace the box inside a scope. As there is nothing to re-box, just make the box passed of zero size.

```
\cs_new_protected:Npn \__draw_backend_box_use:Nnnnn #1#2#3#4#5#6#7
  {
    \__kernel_backend_scope_begin:
    \__draw_backend_cm:nnnn {#2} {#3} {#4} {#5}
    \__kernel_backend_literal_svg:n
      {
        < g~
            stroke="none"~
            transform="scale(-1,1)~translate({?x},{?y})~scale(-1,-1)"
        >
      }
    \box_set_wd:Nn #1 { 0pt }
    \box_set_ht:Nn #1 { 0pt }
    \box_set_dp:Nn #1 { 0pt }
    \box_use:N #1
    \__kernel_backend_literal_svg:n { </g> }
    \__kernel_backend_scope_end:
  }
```

(*End definition for* `\__draw_backend_box_use:Nnnnn`.)

```
⟨/dvisvgm⟩
⟨/package⟩
```

5 l3backend-graphics Implementation

```
⟨*package⟩
⟨@@=graphics⟩
```

5.1 dvips backend

```
⟨*dvips⟩
```

`\__graphics_backend_getbb_eps:n` Simply use the generic function.

```
\cs_new_eq:NN \__graphics_backend_getbb_eps:n \graphics_read_bb:n
```

(*End definition for* `\__graphics_backend_getbb_eps:n`.)

__graphics_backend_include_eps:n

The special syntax is relatively clear here: remember we need PostScript sizes here.

```
\cs_new_protected:Npn \__graphics_backend_include_eps:n #1
  {
    \__kernel_backend_literal:x
      {
        PSfile = #1 \c_space_tl
        llx = \dim_to_decimal_in_bp:n \l_graphics_llx_dim \c_space_tl
        lly = \dim_to_decimal_in_bp:n \l_graphics_lly_dim \c_space_tl
        urx = \dim_to_decimal_in_bp:n \l_graphics_urx_dim \c_space_tl
        ury = \dim_to_decimal_in_bp:n \l_graphics_ury_dim
      }
  }
```

(*End definition for* `\__graphics_backend_include_eps:n`.)

```
⟨/dvips⟩
```

5.2 LuaTeX and pdfTeX backends

```
⟨*luatex | pdftex⟩
```

\l__graphics_graphics_attr_tl

In PDF mode, additional attributes of an graphic (such as page number) are needed both to obtain the bounding box and when inserting the graphic: this occurs as the graphic dictionary approach means they are read as part of the bounding box operation. As such, it is easier to track additional attributes using a dedicated `tl` rather than build up the same data twice.

```
\tl_new:N \l__graphics_graphics_attr_tl
```

(*End definition for* `\l__graphics_graphics_attr_tl`.)

__graphics_backend_getbb_jpg:n
__graphics_backend_getbb_pdf:n
__graphics_backend_getbb_png:n
__graphics_backend_getbb_auxi:n
__graphics_backend_getbb_auxii:n

Getting the bounding box here requires us to box up the graphic and measure it. To deal with the difference in feature support in bitmap and vector graphics but keeping the common parts, there is a little work to do in terms of auxiliaries. The key here is to notice that we need two forms of the attributes: a "short" set to allow us to track for caching, and the full form to pass to the primitive.

```
\cs_new_protected:Npn \__graphics_backend_getbb_jpg:n #1
  {
    \int_zero:N \l_graphics_page_int
    \tl_clear:N \l_graphics_pagebox_tl
    \tl_set:Nx \l__graphics_graphics_attr_tl
      {
        \tl_if_empty:NF \l_graphics_decodearray_tl
          { :D \l_graphics_decodearray_tl }
        \bool_if:NT \l_graphics_interpolate_bool
          { :I }
      }
    \tl_clear:N \l__graphics_graphics_attr_tl
    \__graphics_backend_getbb_auxi:n {#1}
  }
\cs_new_eq:NN \__graphics_backend_getbb_png:n \__graphics_backend_getbb_jpg:n
\cs_new_protected:Npn \__graphics_backend_getbb_pdf:n #1
  {
    \tl_clear:N \l_graphics_decodearray_tl
    \bool_set_false:N \l_graphics_interpolate_bool
    \tl_set:Nx \l__graphics_graphics_attr_tl
      {
        : \l_graphics_pagebox_tl
        \int_compare:nNnT \l_graphics_page_int > 1
          { :P \int_use:N \l_graphics_page_int }
      }
    \__graphics_backend_getbb_auxi:n {#1}
  }
\cs_new_protected:Npn \__graphics_backend_getbb_auxi:n #1
  {
    \graphics_bb_restore:xF { #1 \l__graphics_graphics_attr_tl }
      { \__graphics_backend_getbb_auxii:n {#1} }
  }
```

Measuring the graphic is done by boxing up: for PDF graphics we could use `\tex_pdfximagebbox:D`, but if doesn't work for other types. As the box always starts at $(0,0)$ there is no need to worry about the lower-left position.

```
\cs_new_protected:Npn \__graphics_backend_getbb_auxii:n #1
  {
    \tex_immediate:D \tex_pdfximage:D
      \bool_lazy_or:nnT
        { \l_graphics_interpolate_bool }
        { ! \tl_if_empty_p:N \l_graphics_decodearray_tl }
        {
          attr ~
            {
              \tl_if_empty:NF \l_graphics_decodearray_tl
                { /Decode~[ \l_graphics_decodearray_tl ] }
              \bool_if:NT \l_graphics_interpolate_bool
                { /Interpolate~true }
            }
        }
      \int_compare:nNnT \l_graphics_page_int > 0
        { page ~ \int_use:N \l_graphics_page_int }
      \tl_if_empty:NF \l_graphics_pagebox_tl
        { \l_graphics_pagebox_tl }
      {#1}
    \hbox_set:Nn \l__graphics_internal_box
      { \tex_pdfrefximage:D \tex_pdflastximage:D }
    \dim_set:Nn \l_graphics_urx_dim { \box_wd:N \l__graphics_internal_box }
    \dim_set:Nn \l_graphics_ury_dim { \box_ht:N \l__graphics_internal_box }
    \int_const:cn { c__graphics_graphics_ #1 \l__graphics_graphics_attr_tl _int }
      { \tex_the:D \tex_pdflastximage:D }
    \graphics_bb_save:x { #1 \l__graphics_graphics_attr_tl }
  }
```

(*End definition for* `\__graphics_backend_getbb_jpg:n` *and others.*)

__graphics_backend_include_jpg:n
__graphics_backend_include_pdf:n
__graphics_backend_include_png:n

Images are already loaded for the measurement part of the code, so inclusion is straightforward, with only any attributes to worry about. The latter carry through from determination of the bounding box.

```
\cs_new_protected:Npn \__graphics_backend_include_jpg:n #1
  {
    \tex_pdfrefximage:D
```

```
      \int_use:c { c__graphics_graphics_ #1 \l__graphics_graphics_attr_tl _int }
  }
\cs_new_eq:NN \__graphics_backend_include_pdf:n \__graphics_backend_include_jpg:n
\cs_new_eq:NN \__graphics_backend_include_png:n \__graphics_backend_include_jpg:n
```

(*End definition for* `\__graphics_backend_include_jpg:n`*,* `\__graphics_backend_include_pdf:n`*, and* `\__graphics_backend_include_png:n`*.*)

`\__graphics_backend_getbb_eps:n`
`\__graphics_backend_getbb_eps:nm`
`\__graphics_backend_include_eps:n`
`\l__graphics_backend_dir_str`
`\l__graphics_backend_name_str`
`\l__graphics_backend_ext_str`

EPS graphics may be included in LuaTEX/pdfTeX by conversion to PDF: this requires restricted shell escape. Modelled on the epstopdf LATEX 2$_\varepsilon$ package, but simplified, conversion takes place here if we have shell access.

```
\sys_if_shell:T
  {
    \str_new:N \l__graphics_backend_dir_str
    \str_new:N \l__graphics_backend_name_str
    \str_new:N \l__graphics_backend_ext_str
    \cs_new_protected:Npn \__graphics_backend_getbb_eps:n #1
      {
        \file_parse_full_name:nNNN {#1}
          \l__graphics_backend_dir_str
          \l__graphics_backend_name_str
          \l__graphics_backend_ext_str
        \exp_args:Nx \__graphics_backend_getbb_eps:nn
          {
            \l__graphics_backend_name_str - \str_tail:N \l__graphics_backend_ext_str
            -converted-to.pdf
          }
          {#1}
      }
    \cs_new_protected:Npn \__graphics_backend_getbb_eps:nn #1#2
      {
        \file_compare_timestamp:nNnT {#2} > {#1}
          {
            \sys_shell_now:n
              { repstopdf ~ #2 ~ #1 }
          }
        \tl_set:Nn \l_graphics_name_tl {#1}
        \__graphics_backend_getbb_pdf:n {#1}
      }
    \cs_new_protected:Npn \__graphics_backend_include_eps:n #1
      {
        \file_parse_full_name:nNNN {#1}
          \l__graphics_backend_dir_str \l__graphics_backend_name_str \l__graphics_backend_ex
        \exp_args:Nx \__graphics_backend_include_pdf:n
          {
            \l__graphics_backend_name_str - \str_tail:N \l__graphics_backend_ext_str
            -converted-to.pdf
          }
      }
  }
```

(*End definition for* `\__graphics_backend_getbb_eps:n` *and others.*)

```
⟨/luatex | pdftex⟩
```

5.3 dvipdfmx backend

```
⟨*dvipdfmx | xetex⟩
```

__graphics_backend_getbb_eps:n
__graphics_backend_getbb_jpg:n
__graphics_backend_getbb_pdf:n
__graphics_backend_getbb_png:n

Simply use the generic functions: only for dvipdfmx in the extraction cases.

```
\cs_new_eq:NN \__graphics_backend_getbb_eps:n \graphics_read_bb:n
⟨*dvipdfmx⟩
\cs_new_protected:Npn \__graphics_backend_getbb_jpg:n #1
  {
    \int_zero:N \l_graphics_page_int
    \tl_clear:N \l_graphics_pagebox_tl
    \graphics_extract_bb:n {#1}
  }
\cs_new_eq:NN \__graphics_backend_getbb_png:n \__graphics_backend_getbb_jpg:n
\cs_new_protected:Npn \__graphics_backend_getbb_pdf:n #1
  {
    \tl_clear:N \l_graphics_decodearray_tl
    \bool_set_false:N \l_graphics_interpolate_bool
    \graphics_extract_bb:n {#1}
  }
⟨/dvipdfmx⟩
```

(*End definition for* `\__graphics_backend_getbb_eps:n` *and others.*)

\g__graphics_track_int

Used to track the object number associated with each graphic.

```
\int_new:N \g__graphics_track_int
```

(*End definition for* `\g__graphics_track_int`.)

__graphics_backend_include_eps:n
__graphics_backend_include_jpg:n
__graphics_backend_include_pdf:n
__graphics_backend_include_png:n
__graphics_backend_include_auxi:nn
__graphics_backend_include_auxii:nnn
__graphics_backend_include_auxii:xnn
__graphics_backend_include_auxiii:nnn

The special syntax depends on the file type. There is a difference in how PDF graphics are best handled between dvipdfmx and XeTeX: for the latter it is better to use the primitive route. The relevant code for that is included later in this file.

```
\cs_new_protected:Npn \__graphics_backend_include_eps:n #1
  {
    \__kernel_backend_literal:x
      {
        PSfile = #1 \c_space_tl
        llx = \dim_to_decimal_in_bp:n \l_graphics_llx_dim \c_space_tl
        lly = \dim_to_decimal_in_bp:n \l_graphics_lly_dim \c_space_tl
        urx = \dim_to_decimal_in_bp:n \l_graphics_urx_dim \c_space_tl
        ury = \dim_to_decimal_in_bp:n \l_graphics_ury_dim
      }
  }
\cs_new_protected:Npn \__graphics_backend_include_jpg:n #1
  { \__graphics_backend_include_auxi:nn {#1} { image } }
\cs_new_eq:NN \__graphics_backend_include_png:n \__graphics_backend_include_jpg:n
⟨*dvipdfmx⟩
\cs_new_protected:Npn \__graphics_backend_include_pdf:n #1
  { \__graphics_backend_include_auxi:nn {#1} { epdf } }
⟨/dvipdfmx⟩
```

Graphic inclusion is set up to use the fact that each image is stored in the PDF as an XObject. This means that we can include repeated images only once and refer to them. To allow that, track the nature of each image: much the same as for the direct PDF mode case.

```
\cs_new_protected:Npn \__graphics_backend_include_auxi:nn #1#2
  {
    \__graphics_backend_include_auxii:xnn
      {
        \tl_if_empty:NF \l_graphics_pagebox_tl
          { : \l_graphics_pagebox_tl }
        \int_compare:nNnT \l_graphics_page_int > 1
          { :P \int_use:N \l_graphics_page_int }
        \tl_if_empty:NF \l_graphics_decodearray_tl
          { :D \l_graphics_decodearray_tl }
        \bool_if:NT \l_graphics_interpolate_bool
           { :I }
      }
      {#1} {#2}
  }
\cs_new_protected:Npn \__graphics_backend_include_auxii:nnn #1#2#3
  {
    \int_if_exist:cTF { c__graphics_graphics_ #2#1 _int }
      {
        \__kernel_backend_literal:x
          { pdf:usexobj~@graphic \int_use:c { c__graphics_graphics_ #2#1 _int } }
      }
      { \__graphics_backend_include_auxiii:nnn {#2} {#1} {#3} }
  }
\cs_generate_variant:Nn \__graphics_backend_include_auxii:nnn { x }
```

Inclusion using the specials is relatively straight-forward, but there is one wrinkle. To get the pagebox correct for PDF graphics in all cases, it is necessary to provide both that information and the bbox argument: odd things happen otherwise!

```
\cs_new_protected:Npn \__graphics_backend_include_auxiii:nnn #1#2#3
  {
    \int_gincr:N \g__graphics_track_int
    \int_const:cn { c__graphics_graphics_ #1#2 _int } { \g__graphics_track_int }
    \__kernel_backend_literal:x
      {
        pdf:#3~
        @graphic \int_use:c { c__graphics_graphics_ #1#2 _int } ~
        \int_compare:nNnT \l_graphics_page_int > 1
          { page ~ \int_use:N \l_graphics_page_int \c_space_tl }
        \tl_if_empty:NF \l_graphics_pagebox_tl
          {
            pagebox ~ \l_graphics_pagebox_tl \c_space_tl
            bbox ~
              \dim_to_decimal_in_bp:n \l_graphics_llx_dim \c_space_tl
              \dim_to_decimal_in_bp:n \l_graphics_lly_dim \c_space_tl
              \dim_to_decimal_in_bp:n \l_graphics_urx_dim \c_space_tl
              \dim_to_decimal_in_bp:n \l_graphics_ury_dim \c_space_tl
          }
        (#1)
        \bool_lazy_or:nnT
          { \l_graphics_interpolate_bool }
          { ! \tl_if_empty_p:N \l_graphics_decodearray_tl }
          {
            <<
```

```
              \tl_if_empty:NF \l_graphics_decodearray_tl
                { /Decode~[ \l_graphics_decodearray_tl ] }
              \bool_if:NT \l_graphics_interpolate_bool
                { /Interpolate~true> }
            >>
          }
      }
  }
```

(*End definition for* `\__graphics_backend_include_eps:n` *and others.*)

```
⟨/dvipdfmx | xetex⟩
```

5.4 XƎTEX backend

```
⟨*xetex⟩
```

5.4.1 Images

__graphics_backend_getbb_jpg:n
__graphics_backend_getbb_pdf:n
__graphics_backend_getbb_png:n
__graphics_backend_getbb_auxi:nN
__graphics_backend_getbb_auxii:nnN
__graphics_backend_getbb_auxii:VnN
__graphics_backend_getbb_auxiii:nNnn
__graphics_backend_getbb_auxiv:nnNnn
__graphics_backend_getbb_auxiv:VnNnn
__graphics_backend_getbb_auxv:nNnn
__graphics_backend_getbb_auxv:nNnn
__graphics_backend_getbb_pagebox:w

For XƎTEX, there are two primitives that allow us to obtain the bounding box without needing `extractbb`. The only complexity is passing the various minor variations to a common core process. The XƎTEX primitive omits the text `box` from the page box specification, so there is also some "trimming" to do here.

```
\cs_new_protected:Npn \__graphics_backend_getbb_jpg:n #1
  {
    \int_zero:N \l_graphics_page_int
    \tl_clear:N \l_graphics_pagebox_tl
    \__graphics_backend_getbb_auxi:nN {#1} \tex_XeTeXpicfile:D
  }
\cs_new_eq:NN \__graphics_backend_getbb_png:n \__graphics_backend_getbb_jpg:n
\cs_new_protected:Npn \__graphics_backend_getbb_pdf:n #1
  {
    \tl_clear:N \l_graphics_decodearray_tl
    \bool_set_false:N \l_graphics_interpolate_bool
    \__graphics_backend_getbb_auxi:nN {#1} \tex_XeTeXpdffile:D
  }
\cs_new_protected:Npn \__graphics_backend_getbb_auxi:nN #1#2
  {
    \int_compare:nNnTF \l_graphics_page_int > 1
      { \__graphics_backend_getbb_auxii:VnN \l_graphics_page_int {#1} #2  }
      { \__graphics_backend_getbb_auxiii:nNnn {#1} #2 { :P 1 } { page 1 } }
  }
\cs_new_protected:Npn \__graphics_backend_getbb_auxii:nnN #1#2#3
  { \__graphics_backend_getbb_auxiii:nNnn {#2} #3 { :P #1 } { page #1 } }
\cs_generate_variant:Nn \__graphics_backend_getbb_auxii:nnN { V }
\cs_new_protected:Npn \__graphics_backend_getbb_auxiii:nNnn #1#2#3#4
  {
    \tl_if_empty:NTF \l_graphics_pagebox_tl
      { \__graphics_backend_getbb_auxiv:VnNnn \l_graphics_pagebox_tl }
      { \__graphics_backend_getbb_auxv:nNnn }
      {#1} #2 {#3} {#4}
  }
\cs_new_protected:Npn \__graphics_backend_getbb_auxiv:nnNnn #1#2#3#4#5
  {
    \use:x
```

```
      {
        \__graphics_backend_getbb_auxv:nNnn {#2} #3 { : #1 #4 }
          { #5 ~ \__graphics_backend_getbb_pagebox:w #1 }
      }
  }
\cs_generate_variant:Nn \__graphics_backend_getbb_auxiv:nnNnn { V }
\cs_new_protected:Npn \__graphics_backend_getbb_auxv:nNnn #1#2#3#4
  {
    \graphics_bb_restore:nF {#1#3}
      { \__graphics_backend_getbb_auxvi:nNnn {#1} #2 {#3} {#4} }
  }
\cs_new_protected:Npn \__graphics_backend_getbb_auxvi:nNnn #1#2#3#4
  {
    \hbox_set:Nn \l__graphics_internal_box { #2 #1 ~ #4 }
    \dim_set:Nn \l_graphics_urx_dim { \box_wd:N \l__graphics_internal_box }
    \dim_set:Nn \l_graphics_ury_dim { \box_ht:N \l__graphics_internal_box }
    \graphics_bb_save:n {#1#3}
  }
\cs_new:Npn \__graphics_backend_getbb_pagebox:w #1 box {#1}
```

(*End definition for* `\__graphics_backend_getbb_jpg:n` *and others.*)

__graphics_backend_include_pdf:n
__graphics_backend_include_bitmap_quote:w

For PDF graphics, properly supporting the `pagebox` concept in XƎTEX is best done using the `\tex_XeTeXpdffile:D` primitive. The syntax here is the same as for the graphic measurement part, although we know at this stage that there must be some valid setting for `\l_graphics_pagebox_tl`.

```
\cs_new_protected:Npn \__graphics_backend_include_pdf:n #1
  {
    \tex_XeTeXpdffile:D
      \__graphics_backend_include_pdf_quote:w #1 "#1" \s__graphics_stop \c_space_tl
      \int_compare:nNnT \l_graphics_page_int > 0
        { page ~ \int_use:N \l_graphics_page_int \c_space_tl }
        \exp_after:wN \__graphics_backend_getbb_pagebox:w \l_graphics_pagebox_tl
  }
\cs_new:Npn \__graphics_backend_include_pdf_quote:w #1 " #2 " #3 \s__graphics_stop
  { " #2 " }
```

(*End definition for* `\__graphics_backend_include_pdf:n` *and* `\__graphics_backend_include_bitmap_-quote:w`.)

```
⟨/xetex⟩
```

5.5 `dvisvgm` backend

```
⟨*dvisvgm⟩
```

__graphics_backend_getbb_eps:n

Simply use the generic function.

```
\cs_new_eq:NN \__graphics_backend_getbb_eps:n \graphics_read_bb:n
```

(*End definition for* `\__graphics_backend_getbb_eps:n`.)

__graphics_backend_getbb_png:n
__graphics_backend_getbb_jpg:n

These can be included by extracting the bounding box data.

```
\cs_new_protected:Npn \__graphics_backend_getbb_jpg:n #1
  {
    \int_zero:N \l_graphics_page_int
    \tl_clear:N \l_graphics_pagebox_tl
    \graphics_extract_bb:n {#1}
  }
\cs_new_eq:NN \__graphics_backend_getbb_png:n \__graphics_backend_getbb_jpg:n
```

(*End definition for* `\__graphics_backend_getbb_png:n` *and* `\__graphics_backend_getbb_jpg:n`.)

`\__graphics_backend_getbb_pdf:n`

Same as for `dvipdfmx`: use the generic function

```
\cs_new_protected:Npn \__graphics_backend_getbb_pdf:n #1
  {
    \tl_clear:N \l_graphics_decodearray_tl
    \bool_set_false:N \l_graphics_interpolate_bool
    \graphics_extract_bb:n {#1}
  }
```

(*End definition for* `\__graphics_backend_getbb_pdf:n`.)

`\__graphics_backend_include_eps:n`
`\__graphics_backend_include_pdf:n`
`\__graphics_backend_include:nn`

The special syntax is relatively clear here: remember we need PostScript sizes here. (This is the same as the `dvips` code.)

```
\cs_new_protected:Npn \__graphics_backend_include_eps:n #1
  { __graphics_backend_include:nn { PSfile } {#1} }
\cs_new_protected:Npn \__graphics_backend_include_pdf:n #1
  { __graphics_backend_include:nn { pdffile } {#1} }
\cs_new_protected:Npn \__graphics_backend_include:nn #1#2
  {
    \__kernel_backend_literal:x
      {
        #1 = #2 \c_space_tl
        llx = \dim_to_decimal_in_bp:n \l_graphics_llx_dim \c_space_tl
        lly = \dim_to_decimal_in_bp:n \l_graphics_lly_dim \c_space_tl
        urx = \dim_to_decimal_in_bp:n \l_graphics_urx_dim \c_space_tl
        ury = \dim_to_decimal_in_bp:n \l_graphics_ury_dim
      }
  }
```

(*End definition for* `\__graphics_backend_include_eps:n`*,* `\__graphics_backend_include_pdf:n`*, and* `\__graphics_backend_include:nn`.)

`\__graphics_backend_include_png:n`
`\__graphics_backend_include_jpg:n`
`\__graphics_backend_include_bitmap_quote:w`

The backend here has built-in support for basic graphic inclusion (see `dvisvgm.def` for a more complex approach, needed if clipping, *etc.*, is covered at the graphic backend level). The only issue is that `#1` must be quote-corrected. The `dvisvgm:img` operation quotes the file name, but if it is already quoted (contains spaces) then we have an issue: we simply strip off any quotes as a result.

```
\cs_new_protected:Npn \__graphics_backend_include_png:n #1
  {
     \__kernel_backend_literal:x
       {
         dvisvgm:img~
         \dim_to_decimal:n { \l_graphics_ury_dim } ~
         \dim_to_decimal:n { \l_graphics_ury_dim } ~
         \__graphics_backend_include_bitmap_quote:w #1 " #1 " \s__graphics_stop
       }
  }
\cs_new_eq:NN \__graphics_backend_include_jpg:n \__graphics_backend_include_png:n
\cs_new:Npn \__graphics_backend_include_bitmap_quote:w #1 " #2 " #3 \s__graphics_stop
  { " #2 " }
```

(*End definition for* `\__graphics_backend_include_png:n`*,* `\__graphics_backend_include_jpg:n`*, and* `\__graphics_backend_include_bitmap_quote:w`*.*)

```
⟨/dvisvgm⟩
⟨/package⟩
```

6 l3backend-pdf Implementation

```
⟨*package⟩
⟨@@=pdf⟩
```

Setting up PDF resources is a complex area with only limited documentation in the engine manuals. The following code builds heavily on existing ideas from hyperref work by Sebastian Rahtz and Heiko Oberdiek, and significant contributions by Alexander Grahn, in addition to the specific code referenced a various points.

6.1 Shared code

A very small number of items that belong at the backend level but which are common to all backends.

`\l__pdf_internal_box`

```
\box_new:N \l__pdf_internal_box
```

(*End definition for* `\l__pdf_internal_box`*.*)

6.2 dvips backend

```
⟨*dvips⟩
```

`\__pdf_backend_pdfmark:n`
`\__pdf_backend_pdfmark:x`

Used often enough it should be a separate function.

```
\cs_new_protected:Npn \__pdf_backend_pdfmark:n #1
  { \__kernel_backend_postscript:n { mark #1 ~ pdfmark } }
\cs_generate_variant:Nn \__pdf_backend_pdfmark:n { x }
```

(*End definition for* `\__pdf_backend_pdfmark:n`*.*)

6.2.1 Catalogue entries

`\__pdf_backend_catalog_gput:nn`
`\__pdf_backend_info_gput:nn`

```
\cs_new_protected:Npn \__pdf_backend_catalog_gput:nn #1#2
  { \__pdf_backend_pdfmark:n { { Catalog } << /#1 ~ #2 >> /PUT } }
\cs_new_protected:Npn \__pdf_backend_info_gput:nn #1#2
  { \__pdf_backend_pdfmark:n { /#1 ~ #2 /DOCINFO } }
```

(*End definition for* `\__pdf_backend_catalog_gput:nn` *and* `\__pdf_backend_info_gput:nn`*.*)

6.2.2 Objects

\g__pdf_backend_object_int
\g__pdf_backend_object_prop

For tracking objects to allow finalisation.

```
\int_new:N \g__pdf_backend_object_int
\prop_new:N \g__pdf_backend_object_prop
```

(*End definition for* \g__pdf_backend_object_int *and* \g__pdf_backend_object_prop.)

__pdf_backend_object_new:nn
__pdf_backend_object_ref:n

Tracking objects is similar to dvipdfmx.

```
\cs_new_protected:Npn \__pdf_backend_object_new:nn #1#2
  {
    \int_gincr:N \g__pdf_backend_object_int
    \int_const:cn
      { c__pdf_backend_object_ \tl_to_str:n {#1} _int }
      { \g__pdf_backend_object_int }
    \prop_gput:Nnn \g__pdf_backend_object_prop {#1} {#2}
  }
\cs_new:Npn \__pdf_backend_object_ref:n #1
  { { pdf.obj \int_use:c { c__pdf_backend_object_ \tl_to_str:n {#1} _int } } }
```

(*End definition for* __pdf_backend_object_new:nn *and* __pdf_backend_object_ref:n.)

__pdf_backend_object_write:nn
__pdf_backend_object_write:nx
__pdf_backend_object_write_array:nn
__pdf_backend_object_write_dict:nn
__pdf_backend_object_write_fstream:nn
__pdf_backend_object_write_stream:nn
__pdf_backend_object_write_stream:nnn

This is where we choose the actual type: some work to get things right.

```
\cs_new_protected:Npn \__pdf_backend_object_write:nn #1#2
  {
    \__pdf_backend_pdfmark:x
      {
        /_objdef ~ \__pdf_backend_object_ref:n {#1}
        /type
        \str_case_e:nn
          { \prop_item:Nn \g__pdf_backend_object_prop {#1} }
          {
            { array }   { /array }
            { dict }    { /dict }
            { fstream } { /stream }
            { stream }  { /stream }
          }
        /OBJ
      }
    \use:c
      { __pdf_backend_object_write_ \prop_item:Nn \g__pdf_backend_object_prop {#1} :nn }
      { \__pdf_backend_object_ref:n {#1} } {#2}
  }
\cs_generate_variant:Nn \__pdf_backend_object_write:nn { nx }
\cs_new_protected:Npn \__pdf_backend_object_write_array:nn #1#2
  {
    \__pdf_backend_pdfmark:x
      { #1 ~0~ [ ~ \exp_not:n {#2} ~ ] ~ /PUTINTERVAL }
  }
\cs_new_protected:Npn \__pdf_backend_object_write_dict:nn #1#2
  {
    \__pdf_backend_pdfmark:x
      { #1 << \exp_not:n {#2} >> /PUT }
  }
\cs_new_protected:Npn \__pdf_backend_object_write_fstream:nn #1#2
```

```
  {
    \exp_args:Nx
      \__pdf_backend_object_write_fstream:nnn {#1} #2
  }
\cs_new_protected:Npn \__pdf_backend_object_write_fstream:nnn #1#2#3
  {
    \__kernel_backend_postscript:n
      {
        SDict ~ begin ~
        mark ~ #1 ~ << #2 >> /PUT ~ pdfmark ~
        mark ~ #1 ~ ( #3 )~ ( r )~ file ~ /PUT ~ pdfmark ~
        end
      }
  }
\cs_new_protected:Npn \__pdf_backend_object_write_stream:nn #1#2
  {
    \exp_args:Nx
      \__pdf_backend_object_write_stream:nnn {#1} #2
  }
\cs_new_protected:Npn \__pdf_backend_object_write_stream:nnn #1#2#3
  {
    \__kernel_backend_postscript:n
      {
        mark ~ #1 ~ ( #3 ) /PUT ~ pdfmark ~
        mark ~ #1 ~ << #2 >> /PUT ~ pdfmark
      }
  }
```

(*End definition for* `\__pdf_backend_object_write:nn` *and others.*)

`\__pdf_backend_object_now:nn`
`\__pdf_backend_object_now:nx`

No anonymous objects, so things are done manually.

```
\cs_new_protected:Npn \__pdf_backend_object_now:nn #1#2
  {
    \int_gincr:N \g__pdf_backend_object_int
    \__pdf_backend_pdfmark:x
      {
        /_objdef ~ { pdf.obj \int_use:N \g__pdf_backend_object_int }
        /type
        \str_case:nn
          {#1}
          {
            { array }   { /array }
            { dict }    { /dict }
            { fstream } { /stream }
            { stream }  { /stream }
          }
        /OBJ
      }
    \exp_args:Nnx \use:c { __pdf_backend_object_write_ #1 :nn }
      { { pdf.obj \int_use:N \g__pdf_backend_object_int } } {#2}
  }
\cs_generate_variant:Nn \__pdf_backend_object_now:nn { nx }
```

(*End definition for* `\__pdf_backend_object_now:nn`*.*)

__pdf_backend_object_last: Much like the annotation version.

```
\cs_new:Npn \__pdf_backend_object_last:
  { { pdf.obj \int_use:N \g__pdf_backend_object_int } }
```

(*End definition for* `\__pdf_backend_object_last:`.)

__pdf_backend_pageobject_ref:n Page references are easy in `dvips`.

```
\cs_new:Npn \__pdf_backend_pageobject_ref:n #1
  { { Page #1 } }
```

(*End definition for* `\__pdf_backend_pageobject_ref:n`.)

6.2.3 Annotations

In `dvips`, annotations have to be constructed manually. As such, we need the object code above for some definitions.

\l__pdf_backend_content_box The content of an annotation.

```
\box_new:N \l__pdf_backend_content_box
```

(*End definition for* `\l__pdf_backend_content_box`.)

\l__pdf_backend_model_box For creating model sizing for links.

```
\box_new:N \l__pdf_backend_model_box
```

(*End definition for* `\l__pdf_backend_model_box`.)

\g__pdf_backend_annotation_int Needed as objects which are not annotations could be created.

```
\int_new:N \g__pdf_backend_annotation_int
```

(*End definition for* `\g__pdf_backend_annotation_int`.)

__pdf_backend_annotation:nnnn Annotations are objects, but we track them separately. Notably, they are not in the object data lists. Here, to get the co-ordinates of the annotation, we need to have the data collected at the PostScript level. That requires a bit of box trickery (effectively a LaTeX 2$_\varepsilon$ `picture` of zero size). Once the data is collected, use it to set up the annotation border.

```
\cs_new_protected:Npn \__pdf_backend_annotation:nnnn #1#2#3#4
  {
    \exp_args:Nf \__pdf_backend_annotation_aux:nnnn
      { \dim_eval:n {#1} } {#2} {#3} {#4}
  }
\cs_new_protected:Npn \__pdf_backend_annotation_aux:nnnn #1#2#3#4
  {
    \box_move_down:nn {#3}
      { \hbox:n { \__kernel_backend_postscript:n { pdf.save.ll } } }
    \box_move_up:nn {#2}
      {
        \hbox:n
          {
            \__kernel_kern:n {#1}
            \__kernel_backend_postscript:n { pdf.save.ur }
            \__kernel_kern:n { -#1 }
          }
      }
    \int_gincr:N \g__pdf_backend_object_int
    \int_gset_eq:NN \g__pdf_backend_annotation_int \g__pdf_backend_object_int
    \__pdf_backend_pdfmark:x
      {
        /_objdef { pdf.obj \int_use:N \g__pdf_backend_object_int }
        pdf.rect
        #4 ~
        /ANN
      }
  }
```

(*End definition for* `\__pdf_backend_annotation:nnnn`.)

`\__pdf_backend_annotation_last:` Provide the last annotation we created: could get tricky of course if other packages are loaded.

```
\cs_new:Npn \__pdf_backend_annotation_last:
  { { pdf.obj \int_use:N \g__pdf_backend_annotation_int } }
```

(*End definition for* `\__pdf_backend_annotation_last:`.)

`\g__pdf_backend_link_int` To track annotations which are links.

```
\int_new:N \g__pdf_backend_link_int
```

(*End definition for* `\g__pdf_backend_link_int`.)

`\g__pdf_backend_link_dict_tl` To pass information to the end-of-link function.

```
\tl_new:N \g__pdf_backend_link_dict_tl
```

(*End definition for* `\g__pdf_backend_link_dict_tl`.)

`\g__pdf_backend_link_sf_int` Needed to save/restore space factor, which is needed to deal with the face we need a box.

```
\int_new:N \g__pdf_backend_link_sf_int
```

(*End definition for* `\g__pdf_backend_link_sf_int`.)

`\g__pdf_backend_link_math_bool` Needed to save/restore math mode.

```
\bool_new:N \g__pdf_backend_link_math_bool
```

(*End definition for* `\g__pdf_backend_link_math_bool`.)

`\g__pdf_backend_link_bool` Track link formation: we cannot nest at all.

```
\bool_new:N \g__pdf_backend_link_bool
```

(*End definition for* `\g__pdf_backend_link_bool`.)

`\l__pdf_breaklink_pdfmark_tl` Swappable content for link breaking.

```
\tl_new:N \l__pdf_breaklink_pdfmark_tl
\tl_set:Nn \l__pdf_breaklink_pdfmark_tl { pdfmark }
```

(*End definition for* `\l__pdf_breaklink_pdfmark_tl`.)

`\__pdf_breaklink_postscript:n` To allow dropping material unless link breaking is active.

```
\cs_new_protected:Npn \__pdf_breaklink_postscript:n #1 { }
```

(*End definition for* `\__pdf_breaklink_postscript:n`.)

__pdf_breaklink_usebox:N

Swappable box unpacking or use.

```
\cs_new_eq:NN \__pdf_breaklink_usebox:N \box_use:N
```

(*End definition for* __pdf_breaklink_usebox:N.)

__pdf_backend_link_begin_goto:nnw
__pdf_backend_link_begin_user:nnw
__pdf_backend_link:nw
__pdf_backend_link_aux:nw
__pdf_backend_link_end:
__pdf_backend_link_end_aux:
__pdf_backend_link_minima:
__pdf_backend_link_outerbox:n
__pdf_backend_link_sf_save:
__pdf_backend_link_sf_restore:
pdf.linkdp.pad
pdf.linkht.pad
pdf.llx
pdf.lly
pdf.ury
pdf.link.dict
pdf.outerbox
pdf.baselineskip

Links are crated like annotations but with dedicated code to allow for adjusting the size of the rectangle. In contrast to hyperref, we grab the link content as a box which can then unbox: this allows the same interface as for pdfTEX.

Taking the idea of evenboxes from hypdvips, we implement a minimum box height and depth for link placement. This means that "underlining" with a hyperlink will generally give an even appearance. However, to ensure that the full content is always above the link border, we do not allow this to be negative (contrast hypdvips approach). The result should be similar to pdfTEX in the vast majority of foreseeable cases.

The object number for a link is saved separately from the rest of the dictionary as this allows us to insert it just once, at either an unbroken link or only in the first line of a broken one. That makes the code clearer but also avoids a low-level PostScript error with the code as taken from hypdvips.

Getting the outer dimensions of the text area may be better using a two-pass approach and \tex_savepos:D. That plus format mode are still to re-examine.

```
\cs_new_protected:Npn \__pdf_backend_link_begin_goto:nnw #1#2
  { \__pdf_backend_link_begin:nw { #1 /Subtype /Link /A << /S /GoTo /D ( #2 ) >> } }
\cs_new_protected:Npn \__pdf_backend_link_begin_user:nnw #1#2
  { \__pdf_backend_link_begin:nw {#1#2} }
\cs_new_protected:Npn \__pdf_backend_link_begin:nw #1
  {
    \bool_if:NF \g__pdf_backend_link_bool
      { \__pdf_backend_link_begin_aux:nw {#1} }
  }
\cs_new_protected:Npn \__pdf_backend_link_begin_aux:nw #1
  {
    \bool_gset_true:N \g__pdf_backend_link_bool
    \__kernel_backend_postscript:n
      { /pdf.link.dict ( #1 ) def }
    \tl_gset:Nn \g__pdf_backend_link_dict_tl {#1}
    \__pdf_backend_link_sf_save:
    \mode_if_math:TF
      { \bool_gset_true:N \g__pdf_backend_link_math_bool }
      { \bool_gset_false:N \g__pdf_backend_link_math_bool }
    \hbox_set:Nw \l__pdf_backend_content_box
      \__pdf_backend_link_sf_restore:
      \bool_if:NT \g__pdf_backend_link_math_bool
        { \c_math_toggle_token }
  }
\cs_new_protected:Npn \__pdf_backend_link_end:
  {
    \bool_if:NT \g__pdf_backend_link_bool
      { \__pdf_backend_link_end_aux: }
  }
\cs_new_protected:Npn \__pdf_backend_link_end_aux:
  {
      \bool_if:NT \g__pdf_backend_link_math_bool
        { \c_math_toggle_token }
      \__pdf_backend_link_sf_save:
```

```
    \hbox_set_end:
    \__pdf_backend_link_minima:
    \hbox_set:Nn \l__pdf_backend_model_box { Gg }
    \exp_args:Nx \__pdf_backend_link_outerbox:n
      {
         \int_if_odd:nTF { \value { page } }
           { \oddsidemargin }
           { \evensidemargin }
      }
    \box_move_down:nn { \box_dp:N \l__pdf_backend_content_box }
      { \hbox:n { \__kernel_backend_postscript:n { pdf.save.linkll } } }
    \__pdf_breaklink_postscript:n { pdf.bordertracking.begin }
    \__pdf_breaklink_usebox:N \l__pdf_backend_content_box
    \__pdf_breaklink_postscript:n { pdf.bordertracking.end }
    \box_move_up:nn { \box_ht:N \l__pdf_backend_content_box }
      {
        \hbox:n
          { \__kernel_backend_postscript:n { pdf.save.linkur } }
      }
    \int_gincr:N \g__pdf_backend_object_int
    \int_gset_eq:NN \g__pdf_backend_link_int \g__pdf_backend_object_int
    \__kernel_backend_postscript:x
      {
        mark
        /_objdef { pdf.obj \int_use:N \g__pdf_backend_link_int }
        \g__pdf_backend_link_dict_tl \c_space_tl
        pdf.rect
        /ANN ~ \l__pdf_breaklink_pdfmark_tl
      }
    \__pdf_backend_link_sf_restore:
    \bool_gset_false:N \g__pdf_backend_link_bool
  }
\cs_new_protected:Npn \__pdf_backend_link_minima:
  {
    \hbox_set:Nn \l__pdf_backend_model_box { Gg }
    \__kernel_backend_postscript:x
      {
        /pdf.linkdp.pad ~
          \dim_to_decimal:n
            {
              \dim_max:nn
                {
                    \box_dp:N \l__pdf_backend_model_box
                  - \box_dp:N \l__pdf_backend_content_box
                }
                { 0pt }
            } ~
              pdf.pt.dvi ~ def
        /pdf.linkht.pad ~
          \dim_to_decimal:n
            {
              \dim_max:nn
                {
                    \box_ht:N \l__pdf_backend_model_box
                  - \box_ht:N \l__pdf_backend_content_box
                }
                { 0pt }
            } ~
              pdf.pt.dvi ~ def
        }
    }
\cs_new_protected:Npn \__pdf_backend_link_outerbox:n #1
  {
    \__kernel_backend_postscript:x
      {
        /pdf.outerbox
          [
            \dim_to_decimal:n {#1} ~
            \dim_to_decimal:n { -\box_dp:N \l__pdf_backend_model_box } ~
            \dim_to_decimal:n { #1 + \textwidth } ~
            \dim_to_decimal:n { \box_ht:N \l__pdf_backend_model_box }
          ]
          [ exch { pdf.pt.dvi } forall ] def
        /pdf.baselineskip ~
          \dim_to_decimal:n { \tex_baselineskip:D } ~ dup ~ 0 ~ gt
            { pdf.pt.dvi ~ def }
            { pop ~ pop }
          ifelse
      }
  }
\cs_new_protected:Npn \__pdf_backend_link_sf_save:
  {
    \int_gset:Nn \g__pdf_backend_link_sf_int
      {
        \mode_if_horizontal:TF
          { \tex_spacefactor:D }
          { 0 }
      }
  }
\cs_new_protected:Npn \__pdf_backend_link_sf_restore:
  {
    \mode_if_horizontal:T
      {
        \int_compare:nNnT \g__pdf_backend_link_sf_int > { 0 }
          { \int_set_eq:NN \tex_spacefactor:D \g__pdf_backend_link_sf_int }
      }
  }
```

(*End definition for* `\__pdf_backend_link_begin_goto:nnw` *and others. These functions are documented on page* **??**.)

`\@makecol@hook` Hooks to allow link breaking: something will be needed in format mode at some stage. At present this code is disabled as there is an open question about the name of the hook: to be resolved at the LaTeX 2$_\varepsilon$ end.

```
\use_none:n
  {
    \cs_if_exist:NT \@makecol@hook
      {
        \tl_put_right:Nn \@makecol@hook
          {
            \box_if_empty:NF \@cclv
              {
                \vbox_set:Nn \@cclv
                  {
                    \__kernel_backend_postscript:n
                      {
                        pdf.globaldict /pdf.brokenlink.rect ~ known
                          { pdf.bordertracking.continue }
                        if
                      }
                    \vbox_unpack_drop:N \@cclv
                    \__kernel_backend_postscript:n
                      { pdf.bordertracking.endpage }
                  }
              }
          }
        \tl_set:Nn \l__pdf_breaklink_pdfmark_tl { pdf.pdfmark }
        \cs_set_eq:NN \__pdf_breaklink_postscript:n \__kernel_backend_postscript:n
        \cs_set_eq:NN \__pdf_breaklink_usebox:N \hbox_unpack:N
      }
  }
```

(*End definition for* `\@makecol@hook`. *This function is documented on page* **??**.)

`\__pdf_backend_link_last:` The same as annotations, but with a custom integer.

```
\cs_new:Npn \__pdf_backend_link_last:
  { { pdf.obj \int_use:N \g__pdf_backend_link_int } }
```

(*End definition for* `\__pdf_backend_link_last:`.)

`\__pdf_backend_link_margin:n` Convert to big points and pass to PostScript.

```
\cs_new_protected:Npn \__pdf_backend_link_margin:n #1
  {
    \__kernel_backend_postscript:x
      {
        /pdf.linkmargin { \dim_to_decimal:n {#1} ~ pdf.pt.dvi } def
      }
  }
```

(*End definition for* `\__pdf_backend_link_margin:n`.)

`\__pdf_backend_destination:nn`
`\__pdf_backend_destination:nnnn`
`\__pdf_backend_destination_aux:nnnn`

Here, we need to turn the zoom into a scale. We also need to know where the current anchor point actually is: worked out in PostScript. For the rectangle version, we have a bit more PostScript: we need two points. fitr without rule spec doesn't work, so it falls back to `/Fit` here.

```
\cs_new_protected:Npn \__pdf_backend_destination:nn #1#2
  {
    \__kernel_backend_postscript:n { pdf.dest.anchor }
    \__pdf_backend_pdfmark:x
      {
        /View
        [
          \str_case:nnF {#2}
            {
              { xyz }   { /XYZ ~ pdf.dest.point ~ null }
              { fit }   { /Fit }
              { fitb }  { /FitB }
              { fitbh } { /FitBH ~ pdf.dest.y }
              { fitbv } { /FitBV ~ pdf.dest.x }
              { fith }  { /FitH ~ pdf.dest.y }
              { fitv }  { /FitV ~ pdf.dest.x }
              { fitr }  { /Fit }
            }
            {
              /XYZ ~ pdf.dest.point ~ \fp_eval:n { (#2) / 100 }
            }
        ]
        /Dest ( \exp_not:n {#1} ) cvn
        /DEST
      }
  }
\cs_new_protected:Npn \__pdf_backend_destination:nnnn #1#2#3#4
  {
    \exp_args:Ne \__pdf_backend_destination_aux:nnnn
      { \dim_eval:n {#2} } {#1} {#3} {#4}
  }
\cs_new_protected:Npn \__pdf_backend_destination_aux:nnnn #1#2#3#4
  {
    \vbox_to_zero:n
      {
        \__kernel_kern:n {#4}
        \hbox:n { \__kernel_backend_postscript:n { pdf.save.ll } }
        \tex_vss:D
      }
    \__kernel_kern:n {#1}
    \vbox_to_zero:n
      {
        \__kernel_kern:n { -#3 }
        \hbox:n { \__kernel_backend_postscript:n { pdf.save.ur } }
        \tex_vss:D
      }
    \__kernel_kern:n { -#1 }
    \__pdf_backend_pdfmark:n
      {
        /View
        [
          /FitR ~
            pdf.llx ~ pdf.lly ~ pdf.dest2device ~
            pdf.urx ~ pdf.ury ~ pdf.dest2device
        ]
        /Dest ( #2 ) cvn
        /DEST
      }
  }
```

(*End definition for* `\__pdf_backend_destination:nn`*,* `\__pdf_backend_destination:nnnn`*, and* `\__pdf_backend_destination_aux:nnnn`*.*)

6.2.4 Structure

__pdf_backend_compresslevel:n
__pdf_backend_compress_objects:n

Doable for the usual ps2pdf method.

```
\cs_new_protected:Npn \__pdf_backend_compresslevel:n #1
  {
    \int_compare:nNnT {#1} = 0
      {
        \__kernel_backend_literal_postscript:n
          {
            /setdistillerparams ~ where
              { pop << /CompressPages ~ false >> setdistillerparams }
            if
          }
      }
  }
\cs_new_protected:Npn \__pdf_backend_compress_objects:n #1
  {
    \bool_if:nF {#1}
      {
        \__kernel_backend_literal_postscript:n
          {
            /setdistillerparams ~ where
              { pop << /CompressStreams ~ false >> setdistillerparams }
            if
          }
      }
  }
```

(*End definition for* __pdf_backend_compresslevel:n *and* __pdf_backend_compress_objects:n.)

__pdf_backend_version_major_gset:n
__pdf_backend_version_minor_gset:n

Data not available!

```
\cs_new_protected:Npn \__pdf_backend_version_major_gset:n #1 { }
\cs_new_protected:Npn \__pdf_backend_version_minor_gset:n #1 { }
```

(*End definition for* __pdf_backend_version_major_gset:n *and* __pdf_backend_version_minor_gset:n.)

__pdf_backend_version_major:
__pdf_backend_version_minor:

Data not available!

```
\cs_new:Npn \__pdf_backend_version_major: { -1 }
\cs_new:Npn \__pdf_backend_version_minor: { -1 }
```

(*End definition for* __pdf_backend_version_major: *and* __pdf_backend_version_minor:.)

6.2.5 Marked content

__pdf_backend_bdc:nn
__pdf_backend_emc:

Simple wrappers.

```
\cs_new_protected:Npn \__pdf_backend_bdc:nn #1#2
  { \__pdf_backend_pdfmark:n { /#1 ~ #2 /BDC } }
\cs_new_protected:Npn \__pdf_backend_emc:
  { \__pdf_backend_pdfmark:n { /EMC } }
```

(*End definition for* __pdf_backend_bdc:nn *and* __pdf_backend_emc:.)

```
⟨/dvips⟩
```

6.3 LuaTEX and pdfTEX backend

```
⟨*luatex | pdftex⟩
```

6.3.1 Annotations

__pdf_backend_annotation:nnnn

Simply pass the raw data through, just dealing with evaluation of dimensions.

```
\cs_new_protected:Npn \__pdf_backend_annotation:nnnn #1#2#3#4
  {
⟨*luatex⟩
    \tex_pdfextension:D annot ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfannot:D
⟨/pdftex⟩
      width  ~ \dim_eval:n {#1} ~
      height ~ \dim_eval:n {#2} ~
      depth  ~ \dim_eval:n {#3} ~
      {#4}
  }
```

(*End definition for* `\__pdf_backend_annotation:nnnn`.)

__pdf_backend_annotation_last:

A tiny amount of extra data gets added here; we use `x`-type expansion to get the space in the right place and form. The "extra" space in the LuaTEX version is *required* as it is consumed in finding the end of the keyword.

```
\cs_new:Npx \__pdf_backend_annotation_last:
  {
    \exp_not:N \int_value:w
⟨*luatex⟩
      \exp_not:N \tex_pdffeedback:D lastannot ~
⟨/luatex⟩
⟨*pdftex⟩
      \exp_not:N \tex_pdflastannot:D
⟨/pdftex⟩
      \c_space_tl 0 ~ R
  }
```

(*End definition for* `\__pdf_backend_annotation_last:`.)

__pdf_backend_link_begin_goto:nnw
__pdf_backend_link_begin_user:nnw
__pdf_backend_link_begin:nnnw
__pdf_backend_link_end:

Links are all created using the same internals.

```
\cs_new_protected:Npn \__pdf_backend_link_begin_goto:nnw #1#2
  { \__pdf_backend_link_begin:nnnw {#1} { goto~name } {#2} }
\cs_new_protected:Npn \__pdf_backend_link_begin_user:nnw #1#2
  { \__pdf_backend_link_begin:nnnw {#1} { user } {#2} }
\cs_new_protected:Npn \__pdf_backend_link_begin:nnnw #1#2#3
  {
⟨*luatex⟩
    \tex_pdfextension:D startlink ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfstartlink:D
⟨/pdftex⟩
      attr {#1}
      #2 {#3}
  }
\cs_new_protected:Npn \__pdf_backend_link_end:
  {
⟨*luatex⟩
    \tex_pdfextension:D endlink \scan_stop:
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfendlink:D
⟨/pdftex⟩
  }
```

(*End definition for* `\__pdf_backend_link_begin_goto:nnw` *and others.*)

`\__pdf_backend_link_last:` Formatted for direct use.

```
\cs_new:Npx \__pdf_backend_link_last:
  {
    \exp_not:N \int_value:w
⟨*luatex⟩
      \exp_not:N \tex_pdffeedback:D lastlink ~
⟨/luatex⟩
⟨*pdftex⟩
      \exp_not:N \tex_pdflastlink:D
⟨/pdftex⟩
      \c_space_tl 0 ~ R
  }
```

(*End definition for* `\__pdf_backend_link_last:`.)

`\__pdf_backend_link_margin:n` A simple task: pass the data to the primitive.

```
\cs_new_protected:Npn \__pdf_backend_link_margin:n #1
  {
⟨*luatex⟩
    \tex_pdfvariable:D linkmargin
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdflinkmargin:D
⟨/pdftex⟩
      \dim_eval:n {#1} \scan_stop:
  }
```

(*End definition for* `\__pdf_backend_link_margin:n`.)

`\__pdf_backend_destination:nn`
`\__pdf_backend_destination:nnnn`
A simple task: pass the data to the primitive. The `\scan_stop:` deals with the danger of an unterminated keyword. The zoom given here is a percentage, but we need to pass it as *per mille*. The rectangle version is also easy as everything is build in.

```
\cs_new_protected:Npn \__pdf_backend_destination:nn #1#2
  {
⟨*luatex⟩
    \tex_pdfextension:D dest ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfdest:D
⟨/pdftex⟩
        name {#1}
        \str_case:nnF {#2}
```

```
          {
            { xyz }   { xyz }
            { fit }   { fit }
            { fitb }  { fitb }
            { fitbh } { fitbh }
            { fitbv } { fitbv }
            { fith }  { fith }
            { fitv }  { fitv }
            { fitr }  { fitr }
          }
          { xyz ~ zoom \fp_eval:n { #2 * 10 } }
        \scan_stop:
  }
\cs_new_protected:Npn \__pdf_backend_destination:nnnn #1#2#3#4
  {
⟨*luatex⟩
    \tex_pdfextension:D dest ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfdest:D
⟨/pdftex⟩
    name {#1}
    fitr ~
      width  \dim_eval:n {#2} ~
      height \dim_eval:n {#3} ~
      depth  \dim_eval:n {#4} \scan_stop:
  }
```

(*End definition for* `\__pdf_backend_destination:nn` *and* `\__pdf_backend_destination:nnnn`.)

6.3.2 Catalogue entries

`\__pdf_backend_catalog_gput:nn`
`\__pdf_backend_info_gput:nn`

```
\cs_new_protected:Npn \__pdf_backend_catalog_gput:nn #1#2
  {
⟨*luatex⟩
    \tex_pdfextension:D catalog
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfcatalog:D
⟨/pdftex⟩
      { / #1 ~ #2 }
  }
\cs_new_protected:Npn \__pdf_backend_info_gput:nn #1#2
  {
⟨*luatex⟩
    \tex_pdfextension:D info
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfinfo:D
⟨/pdftex⟩
      { / #1 ~ #2 }
  }
```

(*End definition for* `\__pdf_backend_catalog_gput:nn` *and* `\__pdf_backend_info_gput:nn`.)

6.3.3 Objects

\g__pdf_backend_object_prop

For tracking objects to allow finalisation.

```
\prop_new:N \g__pdf_backend_object_prop
```

(*End definition for* \g__pdf_backend_object_prop.)

__pdf_backend_object_new:nn
__pdf_backend_object_ref:n

Declaring objects means reserving at the PDF level plus starting tracking.

```
\cs_new_protected:Npn \__pdf_backend_object_new:nn #1#2
  {
⟨*luatex⟩
    \tex_pdfextension:D obj ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_pdfobj:D
⟨/pdftex⟩
      reserveobjnum ~
      \int_const:cn
        { c__pdf_backend_object_ \tl_to_str:n {#1} _int }
⟨*luatex⟩
        { \tex_pdffeedback:D lastobj }
⟨/luatex⟩
⟨*pdftex⟩
        { \tex_pdflastobj:D }
⟨/pdftex⟩
    \prop_gput:Nnn \g__pdf_backend_object_prop {#1} {#2}
  }
\cs_new:Npn \__pdf_backend_object_ref:n #1
  { \int_use:c { c__pdf_backend_object_ \tl_to_str:n {#1} _int } ~ 0 ~ R }
```

(*End definition for* __pdf_backend_object_new:nn *and* __pdf_backend_object_ref:n.)

__pdf_backend_object_write:nn
__pdf_backend_object_write:nx
__pdf_exp_not_i:nn
__pdf_exp_not_ii:nn

Writing the data needs a little information about the structure of the object.

```
\cs_new_protected:Npn \__pdf_backend_object_write:nn #1#2
  {
⟨*luatex⟩
    \tex_immediate:D \tex_pdfextension:D obj ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_immediate:D \tex_pdfobj:D
⟨/pdftex⟩
      useobjnum ~
      \int_use:c
        { c__pdf_backend_object_ \tl_to_str:n {#1} _int }
      \str_case_e:nn
        { \prop_item:Nn \g__pdf_backend_object_prop {#1} }
        {
          { array } { { [ ~ \exp_not:n {#2} ~ ] } }
          { dict }  { { << ~ \exp_not:n {#2} ~ >> } }
          { fstream }
            {
              stream ~ attr ~ { \__pdf_exp_not_i:nn #2 } ~
                file ~ { \__pdf_exp_not_ii:nn #2 }
            }
          { stream }
```

```
            {
              stream ~ attr ~ { \__pdf_exp_not_i:nn #2 } ~
                { \__pdf_exp_not_ii:nn #2 }
            }
        }
  }
\cs_generate_variant:Nn \__pdf_backend_object_write:nn { nx }
\cs_new:Npn \__pdf_exp_not_i:nn #1#2 { \exp_not:n {#1} }
\cs_new:Npn \__pdf_exp_not_ii:nn #1#2 { \exp_not:n {#2} }
```

(*End definition for* `\__pdf_backend_object_write:nn`*,* `\__pdf_exp_not_i:nn`*, and* `\__pdf_exp_not_ii:nn`*.*)

`\__pdf_backend_object_now:nn`
`\__pdf_backend_object_now:nx`

Much like writing, but direct creation.

```
\cs_new_protected:Npn \__pdf_backend_object_now:nn #1#2
  {
⟨*luatex⟩
    \tex_immediate:D \tex_pdfextension:D obj ~
⟨/luatex⟩
⟨*pdftex⟩
    \tex_immediate:D \tex_pdfobj:D
⟨/pdftex⟩
      \str_case:nn
        {#1}
        {
          { array } { { [ ~ \exp_not:n {#2} ~ ] } }
          { dict }  { { << ~ \exp_not:n {#2} ~ >> } }
          { fstream }
            {
              stream ~ attr ~ { \__pdf_exp_not_i:nn #2 } ~
                file ~ { \__pdf_exp_not_ii:nn #2 }
            }
          { stream }
            {
              stream ~ attr ~ { \__pdf_exp_not_i:nn #2 } ~
                { \__pdf_exp_not_ii:nn #2 }
            }
        }
  }
\cs_generate_variant:Nn \__pdf_backend_object_now:nn { nx }
```

(*End definition for* `\__pdf_backend_object_now:nn`*.*)

`\__pdf_backend_object_last:`

Much like annotation.

```
\cs_new:Npx \__pdf_backend_object_last:
  {
    \exp_not:N \int_value:w
⟨*luatex⟩
      \exp_not:N \tex_pdffeedback:D lastobj ~
⟨/luatex⟩
⟨*pdftex⟩
      \exp_not:N \tex_pdflastobj:D
⟨/pdftex⟩
      \c_space_tl 0 ~ R
  }
```

(*End definition for* `\__pdf_backend_object_last:`.)

`\__pdf_backend_pageobject_ref:n`

The usual wrapper situation; the three spaces here are essential.

```
\cs_new:Npx \__pdf_backend_pageobject_ref:n #1
  {
    \exp_not:N \int_value:w
⟨*luatex⟩
      \exp_not:N \tex_pdffeedback:D pageref
⟨/luatex⟩
⟨*pdftex⟩
      \exp_not:N \tex_pdfpageref:D
⟨/pdftex⟩
          \c_space_tl #1 \c_space_tl \c_space_tl \c_space_tl 0 ~ R
  }
```

(*End definition for* `\__pdf_backend_pageobject_ref:n`.)

6.3.4 Structure

`\__pdf_backend_compresslevel:n`
`\__pdf_backend_compress_objects:n`
`\__pdf_backend_objcompresslevel:n`

Simply pass data to the engine.

```
\cs_new_protected:Npn \__pdf_backend_compresslevel:n #1
  {
    \tex_global:D
⟨*luatex⟩
      \tex_pdfvariable:D compresslevel
⟨/luatex⟩
⟨*pdftex⟩
      \tex_pdfcompresslevel:D
⟨/pdftex⟩
        \int_value:w \int_eval:n {#1} \scan_stop:
  }
\cs_new_protected:Npn \__pdf_backend_compress_objects:n #1
  {
    \bool_if:nTF {#1}
      { \__pdf_backend_objcompresslevel:n { 2 } }
      { \__pdf_backend_objcompresslevel:n { 0 } }
  }
\cs_new_protected:Npn \__pdf_backend_objcompresslevel:n #1
  {
    \tex_global:D
⟨*luatex⟩
      \tex_pdfvariable:D objcompresslevel
⟨/luatex⟩
⟨*pdftex⟩
      \tex_pdfobjcompresslevel:D
⟨/pdftex⟩
        #1 \scan_stop:
  }
```

(*End definition for* `\__pdf_backend_compresslevel:n` , `\__pdf_backend_compress_objects:n` , *and* `\__pdf_backend_objcompresslevel:n`.)

`\__pdf_backend_version_major_gset:n`
`\__pdf_backend_version_minor_gset:n`

The availability of the primitive is not universal, so we have to test at load time.

```
\cs_new_protected:Npx \__pdf_backend_version_major_gset:n #1
```

```
  {
⟨*luatex⟩
    \int_compare:nNnT \tex_luatexversion:D > { 106 }
      {
        \exp_not:N \tex_global:D \tex_pdfvariable:D majorversion
          \exp_not:N \int_eval:n {#1} \scan_stop:
      }
⟨/luatex⟩
⟨*pdftex⟩
    \cs_if_exist:NT \tex_pdfmajorversion:D
      {
        \exp_not:N \tex_global:D \tex_pdfmajorversion:D
          \exp_not:N \int_eval:n {#1} \scan_stop:
      }
⟨/pdftex⟩
  }
\cs_new_protected:Npn \__pdf_backend_version_minor_gset:n #1
  {
    \tex_global:D
⟨*luatex⟩
      \tex_pdfvariable:D minorversion
⟨/luatex⟩
⟨*pdftex⟩
      \tex_pdfminorversion:D
⟨/pdftex⟩
        \int_eval:n {#1} \scan_stop:
  }
```

(*End definition for* `\__pdf_backend_version_major_gset:n` *and* `\__pdf_backend_version_minor_gset:n`.)

`\__pdf_backend_version_major:`
`\__pdf_backend_version_minor:`

As above.

```
\cs_new:Npx \__pdf_backend_version_major:
  {
⟨*luatex⟩
    \int_compare:nNnTF \tex_luatexversion:D > { 106 }
      { \exp_not:N \tex_the:D \tex_pdfvariable:D majorversion }
      { 1 }
⟨/luatex⟩
⟨*pdftex⟩
    \cs_if_exist:NTF \tex_pdfmajorversion:D
      { \exp_not:N \tex_the:D \tex_pdfmajorversion:D }
      { 1 }
⟨/pdftex⟩
  }
\cs_new:Npn \__pdf_backend_version_minor:
  {
    \tex_the:D
⟨*luatex⟩
      \tex_pdfvariable:D minorversion
⟨/luatex⟩
⟨*pdftex⟩
      \tex_pdfminorversion:D
⟨/pdftex⟩
  }
```

(*End definition for* `\__pdf_backend_version_major:` *and* `\__pdf_backend_version_minor:`.)

6.3.5 Marked content

`\__pdf_backend_bdc:nn`
`\__pdf_backend_emc:`

Simple wrappers. May need refinement: see https://chat.stackexchange.com/transcript/message/49970158#49970158.

```
\cs_new_protected:Npn \__pdf_backend_bdc:nn #1#2
  { \__kernel_backend_literal_page:n { /#1 ~ #2 ~ BDC } }
\cs_new_protected:Npn \__pdf_backend_emc:
  { \__kernel_backend_literal_page:n { EMC } }
```

(*End definition for* `\__pdf_backend_bdc:nn` *and* `\__pdf_backend_emc:`.)

```
⟨/luatex | pdftex⟩
```

6.4 dvipdfmx backend

```
⟨*dvipdfmx | xetex⟩
```

`\__pdf_backend:n`
`\__pdf_backend:x`

A generic function for the backend PDF specials: used where we can.

```
\cs_new_protected:Npx \__pdf_backend:n #1
  { \__kernel_backend_literal:n { pdf: #1 } }
\cs_generate_variant:Nn \__pdf_backend:n { x }
```

(*End definition for* `\__pdf_backend:n`.)

6.4.1 Catalogue entries

`\__pdf_backend_catalog_gput:nn`
`\__pdf_backend_info_gput:nn`

```
\cs_new_protected:Npn \__pdf_backend_catalog_gput:nn #1#2
  { \__pdf_backend:n { put ~ @catalog << /#1 ~ #2 >> } }
\cs_new_protected:Npn \__pdf_backend_info_gput:nn #1#2
  { \__pdf_backend:n { docinfo << /#1 ~ #2 >> } }
```

(*End definition for* `\__pdf_backend_catalog_gput:nn` *and* `\__pdf_backend_info_gput:nn`.)

6.4.2 Objects

`\g__pdf_backend_object_int`
`\g__pdf_backend_object_prop`

For tracking objects to allow finalisation.

```
\int_new:N \g__pdf_backend_object_int
\prop_new:N \g__pdf_backend_object_prop
```

(*End definition for* `\g__pdf_backend_object_int` *and* `\g__pdf_backend_object_prop`.)

`\__pdf_backend_object_new:nn`
`\__pdf_backend_object_ref:n`

Objects are tracked at the macro level, but we don't have to do anything at this stage.

```
\cs_new_protected:Npn \__pdf_backend_object_new:nn #1#2
  {
    \int_gincr:N \g__pdf_backend_object_int
    \int_const:cn
      { c__pdf_backend_object_ \tl_to_str:n {#1} _int }
      { \g__pdf_backend_object_int }
    \prop_gput:Nnn \g__pdf_backend_object_prop {#1} {#2}
  }
\cs_new:Npn \__pdf_backend_object_ref:n #1
  { @pdf.obj \int_use:c { c__pdf_backend_object_ \tl_to_str:n {#1} _int } }
```

(*End definition for* `\__pdf_backend_object_new:nn` *and* `\__pdf_backend_object_ref:n`.)

`\__pdf_backend_object_write:nn`
`\__pdf_backend_object_write:nx`
`\__pdf_backend_object_write:nnn`
`\__pdf_backend_object_write_array:nn`
`\__pdf_backend_object_write_dict:nn`
`\__pdf_backend_object_write_fstream:nn`
`\__pdf_backend_object_write_stream:nn`
`\__pdf_backend_object_write_stream:nnnn`

This is where we choose the actual type.

```
\cs_new_protected:Npn \__pdf_backend_object_write:nn #1#2
  {
    \exp_args:Nx \__pdf_backend_object_write:nnn
      { \prop_item:Nn \g__pdf_backend_object_prop {#1} } {#1} {#2}
  }
\cs_generate_variant:Nn \__pdf_backend_object_write:nn { nx }
\cs_new_protected:Npn \__pdf_backend_object_write:nnn #1#2#3
  {
    \use:c { __pdf_backend_object_write_ #1 :nn }
      { \__pdf_backend_object_ref:n {#2} } {#3}
  }
\cs_new_protected:Npn \__pdf_backend_object_write_array:nn #1#2
  {
    \__pdf_backend:x
      { obj ~ #1 ~ [ ~ \exp_not:n {#2} ~ ] }
  }
\cs_new_protected:Npn \__pdf_backend_object_write_dict:nn #1#2
  {
    \__pdf_backend:x
      { obj ~ #1 ~ << ~ \exp_not:n {#2} ~ >> }
  }
\cs_new_protected:Npn \__pdf_backend_object_write_fstream:nn #1#2
  { \__pdf_backend_object_write_stream:nnnn { f } {#1} #2 }
\cs_new_protected:Npn \__pdf_backend_object_write_stream:nn #1#2
  { \__pdf_backend_object_write_stream:nnnn { } {#1} #2 }
\cs_new_protected:Npn \__pdf_backend_object_write_stream:nnnn #1#2#3#4
  {
    \__pdf_backend:x
      {
        #1 stream ~ #2 ~
          ( \exp_not:n {#4} ) ~ << \exp_not:n {#3} >>
      }
  }
```

(*End definition for* `\__pdf_backend_object_write:nn` *and others.*)

`\__pdf_backend_object_now:nn`
`\__pdf_backend_object_now:nx`

No anonymous objects with `dvipdfmx` so we have to give an object name.

```
\cs_new_protected:Npn \__pdf_backend_object_now:nn #1#2
  {
    \int_gincr:N \g__pdf_backend_object_int
    \exp_args:Nnx \use:c { __pdf_backend_object_write_ #1 :nn }
      { @pdf.obj \int_use:N \g__pdf_backend_object_int }
      {#2}
  }
\cs_generate_variant:Nn \__pdf_backend_object_now:nn { nx }
```

(*End definition for* `\__pdf_backend_object_now:nn`.)

`\__pdf_backend_object_last:`

```
\cs_new:Npn \__pdf_backend_object_last:
 { @pdf.obj \int_use:N \g__pdf_backend_object_int }
```

(*End definition for* `\__pdf_backend_object_last:`.)

__pdf_backend_pageobject_ref:n

Page references are easy in `dvipdfmx`/XeTeX.

```
\cs_new:Npn \__pdf_backend_pageobject_ref:n #1
  { @page #1 }
```

(*End definition for* `\__pdf_backend_pageobject_ref:n`.)

6.4.3 Annotations

\g__pdf_landscape_bool

There is a bug in `dvipdfmx`/XeTeX which means annotations do not rotate. As such, we need to know if landscape is active.

```
\bool_new:N \g__pdf_landscape_bool
\cs_if_exist:NT \landscape
  {
    \tl_put_right:Nn \landscape
      { \bool_gset_true:N \g__pdf_landscape_bool }
    \tl_put_left:Nn \endlandscape
      { \bool_gset_false:N \g__pdf_landscape_bool }
  }
```

(*End definition for* `\g__pdf_landscape_bool`.)

\g__pdf_backend_annotation_int

Needed as objects which are not annotations could be created.

```
\int_new:N \g__pdf_backend_annotation_int
```

(*End definition for* `\g__pdf_backend_annotation_int`.)

__pdf_backend_annotation:nnnn
__pdf_backend_annotation_aux:nnnn

Simply pass the raw data through, just dealing with evaluation of dimensions. The only wrinkle is landscape: we have to adjust by hand.

```
\cs_new_protected:Npn \__pdf_backend_annotation:nnnn #1#2#3#4
  {
    \bool_if:NTF \g__pdf_landscape_bool
      {
         \box_move_up:nn {#2}
           {
             \vbox:n
               {
                 \__pdf_backend_annotation_aux:nnnn
                   { #2 + #3 } {#1} { 0pt } {#4}
               }
           }
      }
      { \__pdf_backend_annotation_aux:nnnn {#1} {#2} {#3} {#4} }
  }
\cs_new_protected:Npn \__pdf_backend_annotation_aux:nnnn #1#2#3#4
  {
    \int_gincr:N \g__pdf_backend_object_int
    \int_gset_eq:NN \g__pdf_backend_annotation_int \g__pdf_backend_object_int
    \__pdf_backend:x
      {
        ann ~ @pdf.obj \int_use:N \g__pdf_backend_object_int \c_space_tl
        width  ~ \dim_eval:n {#1} ~
        height ~ \dim_eval:n {#2} ~
        depth  ~ \dim_eval:n {#3} ~
        <</Type/Annot #4 >>
      }
  }
```

(*End definition for* `\__pdf_backend_annotation:nnnn` *and* `\__pdf_backend_annotation_aux:nnnn`*.*)

`\__pdf_backend_annotation_last:`

```
\cs_new:Npn \__pdf_backend_annotation_last:
 { @pdf.obj \int_use:N \g__pdf_backend_annotation_int }
```

(*End definition for* `\__pdf_backend_annotation_last:`*.*)

`\g__pdf_backend_link_int` To track annotations which are links.

```
\int_new:N \g__pdf_backend_link_int
```

(*End definition for* `\g__pdf_backend_link_int`*.*)

`\__pdf_backend_link_begin_goto:nnw`
`\__pdf_backend_link_begin_user:nnw`
`\__pdf_backend_link_begin:n`
`\__pdf_backend_link_end:`

All created using the same internals.

```
\cs_new_protected:Npn \__pdf_backend_link_begin_goto:nnw #1#2
  { \__pdf_backend_link_begin:n { #1 /Subtype /Link /A << /S /GoTo /D ( #2 ) >> } }
\cs_new_protected:Npn \__pdf_backend_link_begin_user:nnw #1#2
  { \__pdf_backend_link_begin:n {#1#2} }
\cs_new_protected:Npx \__pdf_backend_link_begin:n #1
  {
    \int_compare:nNnF \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
      {
        \exp_not:N \int_gincr:N \exp_not:N  \g__pdf_backend_link_int
      }
    \__pdf_backend:x
      {
         bann ~
         \int_compare:nNnF \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
           {
             @pdf.lnk
             \exp_not:N \int_use:N \exp_not:N  \g__pdf_backend_link_int
             \c_space_tl
           }
         <<
           /Type /Annot
           #1
         >>
      }
  }
\cs_new_protected:Npn \__pdf_backend_link_end:
  { \__pdf_backend:n { eann } }
```

(*End definition for* `\__pdf_backend_link_begin_goto:nnw` *and others.*)

`\__pdf_backend_link_last:` Available using the backend mechanism with a suitably-recent version.

```
\cs_new:Npx \__pdf_backend_link_last:
  {
    \int_compare:nNnF \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
      {
        @pdf.lnk
```

```
          \exp_not:N \int_use:N \exp_not:N \g__pdf_backend_link_int
        }
    }
```

(*End definition for* `\__pdf_backend_link_last:`.)

`\__pdf_backend_link_margin:n`

Pass to `dvipdfmx`.

```
\cs_new_protected:Npn \__pdf_backend_link_margin:n #1
  { \__kernel_backend_literal:x { dvipdfmx:config~g~ \dim_eval:n {#1} } }
```

(*End definition for* `\__pdf_backend_link_margin:n`.)

`\__pdf_backend_destination:nn`
`\__pdf_backend_destination:nnnn`
`\__pdf_backend_destination_aux:nnnn`

Here, we need to turn the zoom into a scale. The method for `FitR` is from Alexander Grahn: the idea is to avoid needing to do any calculations in TeX by using the backend data for `@xpos` and `@ypos`. `/FitR` without rule spec doesn't work, so it falls back to `/Fit` here.

```
\cs_new_protected:Npn \__pdf_backend_destination:nn #1#2
  {
    \__pdf_backend:x
      {
        dest ~ ( \exp_not:n {#1} )
        [
          @thispage
          \str_case:nnF {#2}
            {
              { xyz }   { /XYZ ~ @xpos ~ @ypos ~ null }
              { fit }   { /Fit }
              { fitb }  { /FitB }
              { fitbh } { /FitBH }
              { fitbv } { /FitBV ~ @xpos }
              { fith }  { /FitH ~ @ypos }
              { fitv }  { /FitV ~ @xpos }
              { fitr }  { /Fit }
            }
            { /XYZ ~ @xpos ~ @ypos ~ \fp_eval:n { (#2) / 100 } }
        ]
      }
  }
\cs_new_protected:Npn \__pdf_backend_destination:nnnn #1#2#3#4
  {
    \exp_args:Ne \__pdf_backend_destination_aux:nnnn
      { \dim_eval:n {#2} } {#1} {#3} {#4}
  }
\cs_new_protected:Npn \__pdf_backend_destination_aux:nnnn #1#2#3#4
  {
    \vbox_to_zero:n
      {
        \__kernel_kern:n {#4}
        \hbox:n
          {
            \__pdf_backend:n { obj ~ @pdf_ #2 _llx ~ @xpos }
            \__pdf_backend:n { obj ~ @pdf_ #2 _lly ~ @ypos }
          }
        \tex_vss:D
      }
    \__kernel_kern:n {#1}
    \vbox_to_zero:n
      {
        \__kernel_kern:n { -#3 }
        \hbox:n
          {
            \__pdf_backend:n
              {
                dest ~ (#2)
                [
                  @thispage
                  /FitR ~
                    @pdf_ #2 _llx ~ @pdf_ #2 _lly ~
                    @xpos ~ @ypos
                ]
              }
          }
        \tex_vss:D
      }
    \__kernel_kern:n { -#1 }
  }
```

(*End definition for* `\__pdf_backend_destination:nn`, `\__pdf_backend_destination:nnnn`, *and* `\__pdf_backend_destination_aux:nnnn`.)

6.4.4 Structure

`\__pdf_backend_compresslevel:n`
`\__pdf_backend_compress_objects:n`

Pass data to the backend: these are a one-shot.

```
\cs_new_protected:Npn \__pdf_backend_compresslevel:n #1
  { \__kernel_backend_literal:x { dvipdfmx:config~z~ \int_eval:n {#1} } }
\cs_new_protected:Npn \__pdf_backend_compress_objects:n #1
  {
    \bool_if:nF {#1}
      { \__kernel_backend_literal:n { dvipdfmx:config~C~0x40 } }
  }
```

(*End definition for* `\__pdf_backend_compresslevel:n` *and* `\__pdf_backend_compress_objects:n`.)

`\__pdf_backend_version_major_gset:n`
`\__pdf_backend_version_minor_gset:n`

We start with the assumption that the default is active.

```
\cs_new_protected:Npn \__pdf_backend_version_major_gset:n #1
  {
    \cs_gset:Npx \__pdf_backend_version_major: { \int_eval:n {#1} }
    \__kernel_backend_literal:x { pdf:majorversion~ \__pdf_backend_version_major: }
  }
\cs_new_protected:Npn \__pdf_backend_version_minor_gset:n #1
  {
    \cs_gset:Npx \__pdf_backend_version_minor: { \int_eval:n {#1} }
    \__kernel_backend_literal:x { pdf:minorversion~ \__pdf_backend_version_minor: }
  }
```

(*End definition for* `\__pdf_backend_version_major_gset:n` *and* `\__pdf_backend_version_minor_gset:n`.)

`\__pdf_backend_version_major:`
`\__pdf_backend_version_minor:`

We start with the assumption that the default is active.

```
\cs_new:Npn \__pdf_backend_version_major: { 1 }
\cs_new:Npn \__pdf_backend_version_minor: { 5 }
```

(*End definition for* `\__pdf_backend_version_major:` *and* `\__pdf_backend_version_minor:`.)

6.4.5 Marked content

`\__pdf_backend_bdc:nn`
`\__pdf_backend_emc:`

Simple wrappers. May need refinement: see https://chat.stackexchange.com/transcript/message/49970158#49970158.

```
\cs_new_protected:Npn \__pdf_backend_bdc:nn #1#2
  { \__kernel_backend_literal_page:n { /#1 ~ #2 ~ BDC } }
\cs_new_protected:Npn \__pdf_backend_emc:
  { \__kernel_backend_literal_page:n { EMC } }
```

(*End definition for* `\__pdf_backend_bdc:nn` *and* `\__pdf_backend_emc:`.)

```
⟨/dvipdfmx | xetex⟩
```

6.5 dvisvgm backend

```
⟨*dvisvgm⟩
```

6.5.1 Catalogue entries

`\__pdf_backend_catalog_gput:nn`
`\__pdf_backend_info_gput:nn`

No-op.

```
\cs_new_protected:Npn \__pdf_backend_catalog_gput:nn #1#2 { }
\cs_new_protected:Npn \__pdf_backend_info_gput:nn #1#2 { }
```

(*End definition for* `\__pdf_backend_catalog_gput:nn` *and* `\__pdf_backend_info_gput:nn`.)

6.5.2 Objects

`\__pdf_backend_object_new:nn`
`\__pdf_backend_object_ref:n`
`\__pdf_backend_object_write:nn`
`\__pdf_backend_object_write:nx`
`\__pdf_backend_object_now:nn`
`\__pdf_backend_object_now:nx`
`\__pdf_backend_object_last:`
`\__pdf_backend_pageobject_ref:n`

All no-ops here.

```
\cs_new_protected:Npn \__pdf_backend_object_new:nn #1#2 { }
\cs_new:Npn \__pdf_backend_object_ref:n #1 { }
\cs_new_protected:Npn \__pdf_backend_object_write:nn #1#2 { }
\cs_new_protected:Npn \__pdf_backend_object_write:nx #1#2 { }
\cs_new_protected:Npn \__pdf_backend_object_now:nn #1#2 { }
\cs_new_protected:Npn \__pdf_backend_object_now:nx #1#2 { }
\cs_new:Npn \__pdf_backend_object_last: { }
\cs_new:Npn \__pdf_backend_pageobject_ref:n #1 { }
```

(*End definition for* `\__pdf_backend_object_new:nn` *and others.*)

6.5.3 Structure

`\__pdf_backend_compresslevel:n`
`\__pdf_backend_compress_objects:n`

These are all no-ops.

```
\cs_new_protected:Npn \__pdf_backend_compresslevel:n #1 { }
\cs_new_protected:Npn \__pdf_backend_compress_objects:n #1 { }
```

(*End definition for* `\__pdf_backend_compresslevel:n` *and* `\__pdf_backend_compress_objects:n`.)

`\__pdf_backend_version_major_gset:n`
`\__pdf_backend_version_minor_gset:n`

Data not available!

```
\cs_new_protected:Npn \__pdf_backend_version_major_gset:n #1 { }
\cs_new_protected:Npn \__pdf_backend_version_minor_gset:n #1 { }
```

(*End definition for* `\__pdf_backend_version_major_gset:n` *and* `\__pdf_backend_version_minor_gset:n`.)

__pdf_backend_version_major:
__pdf_backend_version_minor:

Data not available!

```
\cs_new:Npn \__pdf_backend_version_major: { -1 }
\cs_new:Npn \__pdf_backend_version_minor: { -1 }
```

(*End definition for* `\__pdf_backend_version_major:` *and* `\__pdf_backend_version_minor:`.)

__pdf_backend_bdc:nn
__pdf_backend_emc:

More no-ops.

```
\cs_new_protected:Npn \__pdf_backend_bdc:nn #1#2 { }
\cs_new_protected:Npn \__pdf_backend_emc: { }
```

(*End definition for* `\__pdf_backend_bdc:nn` *and* `\__pdf_backend_emc:`.)

```
⟨/dvisvgm⟩
⟨/package⟩
```

7 l3backend-opacity Implementation

```
⟨*package⟩
⟨@@=opacity⟩
```

Although opacity is not color, it needs to be managed in a somewhat similar way: using a dedicated stack if possible. Depending on the backend, that may not be possible. There is also the need to cover fill/stroke setting as well as more general running opacity. It is easiest to describe the value used in terms of opacity, although commonly this is referred to as transparency.

```
⟨*dvips⟩
```

__opacity_backend_select:n
__opacity_backend_select_aux:n

No stack so set values directly.

```
\cs_new_protected:Npn \__opacity_backend_select:n #1
  {
    \exp_args:Nx \__opacity_backend_select_aux:n
      { \fp_eval:n { min(max(0,#1),1) } }
  }
\cs_new_protected:Npn \__opacity_backend_select_aux:n #1
  {
    \__kernel_backend_postscript:n
      { #1 ~ .setfillconstantalpha ~ #1 ~ .setstrokeconstantalpha }
  }
```

(*End definition for* `\__opacity_backend_select:n` *and* `\__opacity_backend_select_aux:n`.)

__opacity_backend_fill:n
__opacity_backend_stroke:n
__opacity_backend:nn
__opacity_backend:xn

Similar to the above but with no stack and only adding to one or other of the entries.

```
\cs_new_protected:Npn \__opacity_backend_fill:n #1
  { \__opacity_backend:xn { \fp_eval:n { min(max(0,#1),1) } } { fill } }
\cs_new_protected:Npn \__opacity_backend_stroke:n #1
  { \__opacity_backend:xn { \fp_eval:n { min(max(0,#1),1) } } { stroke } }
\cs_new_protected:Npn \__opacity_backend:nn #1#2
  {
    \__kernel_backend_postscript:n { #1 ~ .set #2 constantalpha  }
  }
\cs_generate_variant:Nn \__opacity_backend:nn { x }
```

(*End definition for* `\__opacity_backend_fill:n`, `\__opacity_backend_stroke:n`, *and* `\__opacity_backend:nn`.)

```
⟨/dvips⟩
```

```
⟨*dvipdfmx | luatex | pdftex | xetex⟩
```

\c__opacity_backend_stack_int

Set up a stack.

```
\cs_if_exist:NT \pdfmanagement_add:nnn
  {
    \__kernel_color_backend_stack_init:Nnn \c__opacity_backend_stack_int
      { page ~ direct } { /opacity 1 ~ gs }
    \pdfmanagement_add:nnn { Page / Resources / ExtGState }
      { opacity 1 } { << /ca ~ 1 /CA ~ 1 >> }
  }
```

(*End definition for* \c__opacity_backend_stack_int.)

\l__opacity_backend_fill_tl
\l__opacity_backend_stroke_tl

We use tl here for speed: at the backend, this should be reasonable.

```
\tl_new:N \l__opacity_backend_fill_tl
\tl_new:N \l__opacity_backend_stroke_tl
```

(*End definition for* \l__opacity_backend_fill_tl *and* \l__opacity_backend_stroke_tl.)

__opacity_backend_select:n
__opacity_backend_select_aux:n
__opacity_backend_reset:

Other than the need to evaluate the opacity as an fp, much the same as color.

```
\cs_new_protected:Npn \__opacity_backend_select:n #1
 {
   \exp_args:Nx \__opacity_backend_select_aux:n
     { \fp_eval:n { min(max(0,#1),1) } }
 }
\cs_new_protected:Npn \__opacity_backend_select_aux:n #1
  {
    \tl_set:Nn \l__opacity_backend_fill_tl {#1}
    \tl_set:Nn \l__opacity_backend_stroke_tl {#1}
    \pdfmanagement_add:nnn { Page / Resources / ExtGState }
      { opacity #1 }
      { << /ca ~ #1 /CA ~ #1 >> }
    \__kernel_color_backend_stack_push:nn \c__opacity_backend_stack_int
      { /opacity #1 ~ gs }
    \group_insert_after:N \__opacity_backend_reset:
  }
\cs_if_exist:NF \pdfmanagement_add:nnn
  {
    \cs_gset_protected:Npn \__opacity_backend_select_aux:n #1 { }
  }
\cs_new_protected:Npn \__opacity_backend_reset:
 { \__kernel_color_backend_stack_pop:n \c__opacity_backend_stack_int }
```

(*End definition for* __opacity_backend_select:n*,* __opacity_backend_select_aux:n*, and* __opacity_-backend_reset:.)

__opacity_backend_fill:n
__opacity_backend_stroke:n
__opacity_backend_fillstroke:nn
__opacity_backend_fillstroke:xx

For separate fill and stroke, we need to work out if we need to do more work or if we can stick to a single setting.

```
\cs_new_protected:Npn \__opacity_backend_fill:n #1
  {
    \__opacity_backend_fill_stroke:xx
      { \fp_eval:n { min(max(0,#1),1) } }
      \l__opacity_backend_stroke_tl
  }
\cs_new_protected:Npn \__opacity_backend_stroke:n #1
```

```
  {
    \__opacity_backend_fill_stroke:xx
      \l__opacity_backend_fill_tl
      { \fp_eval:n { min(max(0,#1),1) } }
  }
\cs_new_protected:Npn \__opacity_backend_fill_stroke:nn #1#2
  {
    \str_if_eq:nnTF {#1} {#2}
      { \__opacity_backend_select_aux:n {#1} }
      {
        \tl_set:Nn \l__opacity_backend_fill_tl {#1}
        \tl_set:Nn \l__opacity_backend_stroke_tl {#2}
        \pdfmanagement_add:nnn { Page / Resources / ExtGState }
          { opacity.fill #1 }
          { << /ca ~ #1 >> }
        \pdfmanagement_add:nnn { Page / Resources / ExtGState }
          { opacity.stroke #1 }
          { << /CA ~ #2 >> }
        \__kernel_color_backend_stack_push:nn \c__opacity_backend_stack_int
         { /opacity.fill #1 ~ gs /opacity.stroke #2 ~ gs }
        \group_insert_after:N \__opacity_backend_reset:
      }
  }
\cs_generate_variant:Nn \__opacity_backend_fill_stroke:nn { xx }
```

(*End definition for* `\__opacity_backend_fill:n`, `\__opacity_backend_stroke:n`, *and* `\__opacity_backend_fillstroke:nn`.)

```
⟨/dvipdfmx | luatex | pdftex | xetex⟩
```

```
⟨*dvipdfmx | xdvipdfmx⟩
```

`\__opacity_backend_select:n` Older backends have no stack support, so everything is done directly.

```
\int_compare:nNnT \c__kernel_sys_dvipdfmx_version_int < { 20201111 }
  {
    \cs_gset_protected:Npn \__opacity_backend_select_aux:n #1
      {
        \tl_set:Nn \l__opacity_backend_fill_tl {#1}
        \tl_set:Nn \l__opacity_backend_stroke_tl {#1}
        \pdfmanagement_add:nnn { Page / Resources / ExtGState }
          { opacity #1 }
          { << /ca ~ #1 /CA ~ #1 >> }
        \__kernel_backend_literal_pdf:n { /opacity #1 ~ gs }
      }
    \cs_gset_protected:Npn \__opacity_backend_fill_stroke:nn #1#2
      {
        \str_if_eq:nnTF {#1} {#2}
          { \__opacity_backend_select_aux:n {#1} }
          {
            \tl_set:Nn \l__opacity_backend_fill_tl {#1}
            \tl_set:Nn \l__opacity_backend_stroke_tl {#2}
            \pdfmanagement_add:nnn { Page / Resources / ExtGState }
              { opacity.fill #1 }
              { << /ca ~ #1 >> }
            \pdfmanagement_add:nnn { Page / Resources / ExtGState }
              { opacity.stroke #1 }
              { << /CA ~ #2 >> }
            \__kernel_backend_literal_pdf:n
              { /opacity.fill #1 ~ gs /opacity.stroke #2 ~ gs }
          }
      }
  }
```

(*End definition for* `\__opacity_backend_select:n`.)

⟨/dvipdfmx | xdvipdfmx⟩

⟨*dvisvgm⟩

`\__opacity_backend_select:n`
`\__opacity_backend_fill:n`
`\__opacity_backend_stroke:n`
`\__opacity_backend:nn`

Once again, we use a scope here. There is a general opacity function for SVG, but that is of course not set up using the stack.

```
\cs_new_protected:Npn \__opacity_backend_select:n #1
  { \__opacity_backend:nn {#1} { } }
\cs_new_protected:Npn \__opacity_backend_fill:n #1
  { \__opacity_backend:nn {#1} { fill- } }
\cs_new_protected:Npn \__opacity_backend_stroke:n #1
  { \__opacity_backend:nn { {#1} } { stroke- } }
\cs_new_protected:Npn \__opacity_backend:nn #1#2
  { \__kernel_backend_scope:x { #2 opacity = " \fp_eval:n { min(max(0,#1),1) } " } }
```

(*End definition for* `\__opacity_backend_select:n` *and others.*)

⟨/dvisvgm⟩

⟨/package⟩

8 l3backend-header Implementation

⟨*dvips & header⟩

`color.sc`

Empty definition for color at the top level.

```
/color.sc { } def
```

(*End definition for* `color.sc`*. This function is documented on page* **??***.*)

`TeXcolorseparation`
`separation`

Support for separation/spot colors: this strange naming is so things work with the color stack.

```
TeXDict begin
/TeXcolorseparation { setcolor } def
end
```

(*End definition for* `TeXcolorseparation` *and* `separation`*. These functions are documented on page* **??***.*)

`pdf.globaldict`

A small global dictionary for backend use.

```
true setglobal
/pdf.globaldict 4 dict def
false setglobal
```

(*End definition for* `pdf.globaldict`*. This function is documented on page* **??***.*)

pdf.cvs
pdf.dvi.pt
pdf.pt.dvi
pdf.rect.ht

Small utilities for PostScript manipulations. Conversion to DVI dimensions is done here to allow for `Resolution`. The total height of a rectangle (an array) needs a little maths, in contrast to simply extracting a value.

```
/pdf.cvs { 65534 string cvs } def
/pdf.dvi.pt { 72.27 mul Resolution div } def
/pdf.pt.dvi { 72.27 div Resolution mul } def
/pdf.rect.ht { dup 1 get neg exch 3 get add } def
```

(*End definition for* `pdf.cvs` *and others. These functions are documented on page* **??**.)

pdf.linkmargin
pdf.linkdp.pad
pdf.linkht.pad

Settings which are defined up-front in `SDict`.

```
/pdf.linkmargin { 1 pdf.pt.dvi } def
/pdf.linkdp.pad { 0 } def
/pdf.linkht.pad { 0 } def
```

(*End definition for* `pdf.linkmargin`*,* `pdf.linkdp.pad`*, and* `pdf.linkht.pad`*. These functions are documented on page* **??**.)

pdf.rect
pdf.save.ll
pdf.save.ur
pdf.save.linkll
pdf.save.linkur
pdf.llx
pdf.lly
pdf.urx
pdf.ury

Functions for marking the limits of an annotation/link, plus drawing the border. We separate links for generic annotations to support adding a margin and setting a minimal size.

```
/pdf.rect
  { /Rect [ pdf.llx pdf.lly pdf.urx pdf.ury ] } def
/pdf.save.ll
  {
    currentpoint
    /pdf.lly exch def
    /pdf.llx exch def
  }
    def
/pdf.save.ur
  {
    currentpoint
    /pdf.ury exch def
    /pdf.urx exch def
  }
    def
/pdf.save.linkll
  {
    currentpoint
    pdf.linkmargin add
    pdf.linkdp.pad add
    /pdf.lly exch def
    pdf.linkmargin sub
    /pdf.llx exch def
  }
    def
/pdf.save.linkur
  {
    currentpoint
    pdf.linkmargin sub
    pdf.linkht.pad sub
    /pdf.ury exch def
    pdf.linkmargin add
    /pdf.urx exch def
  }
    def
```

(*End definition for* `pdf.rect` *and others. These functions are documented on page* **??**.)

`pdf.dest.anchor`
`pdf.dest.x`
`pdf.dest.y`
`pdf.dest.point`
`pdf.dest2device`
`pdf.dev.x`
`pdf.dev.y`
`pdf.tmpa`
`pdf.tmpb`
`pdf.tmpc`
`pdf.tmpd`

For finding the anchor point of a destination link. We make the use case a separate function as it comes up a lot, and as this makes it easier to adjust if we need additional effects. We also need a more complex approach to convert a co-ordinate pair correctly when defining a rectangle: this can otherwise be out when using a landscape page. (Thanks to Alexander Grahn for the approach here.)

```
/pdf.dest.anchor
  {
    currentpoint exch
    pdf.dvi.pt 72 add
    /pdf.dest.x exch def
    pdf.dvi.pt
    vsize 72 sub exch sub
    /pdf.dest.y exch def
  }
    def
/pdf.dest.point
  { pdf.dest.x pdf.dest.y } def
/pdf.dest2device
  {
    /pdf.dest.y exch def
    /pdf.dest.x exch def
    matrix currentmatrix
    matrix defaultmatrix
    matrix invertmatrix
    matrix concatmatrix
    cvx exec
    /pdf.dev.y exch def
    /pdf.dev.x exch def
    /pdf.tmpd exch def
    /pdf.tmpc exch def
    /pdf.tmpb exch def
    /pdf.tmpa exch def
    pdf.dest.x pdf.tmpa mul
      pdf.dest.y pdf.tmpc mul add
      pdf.dev.x add
    pdf.dest.x pdf.tmpb mul
     pdf.dest.y pdf.tmpd mul add
     pdf.dev.y add
  }
    def
```

(*End definition for* `pdf.dest.anchor` *and others. These functions are documented on page* **??**.)

`pdf.bordertracking`
`pdf.bordertracking.begin`
`pdf.bordertracking.end`
`pdf.leftboundary`
`pdf.rightboundary`
`pdf.brokenlink.rect`
`pdf.brokenlink.skip`
`pdf.brokenlink.dict`
`pdf.bordertracking.endpage`
`pdf.bordertracking.continue`
`pdf.originx`
`pdf.originy`

To know where a breakable link can go, we need to track the boundary rectangle. That can be done by hooking into `a` and `x` operations: those names have to be retained. The boundary is stored at the end of the operation. Special effort is needed at the start and end of pages (or rather galleys), such that everything works properly.

```
/pdf.bordertracking false def
```

```
/pdf.bordertracking.begin
  {
    SDict /pdf.bordertracking true put
    SDict /pdf.leftboundary undef
    SDict /pdf.rightboundary undef
    /a where
      {
        /a
          {
            currentpoint pop
            SDict /pdf.rightboundary known dup
              {
                SDict /pdf.rightboundary get 2 index lt
                  { not }
                if
              }
            if
              { pop }
              { SDict exch /pdf.rightboundary exch put }
            ifelse
            moveto
            currentpoint pop
            SDict /pdf.leftboundary known dup
              {
                SDict /pdf.leftboundary get 2 index gt
                  { not }
                if
              }
            if
              { pop }
              { SDict exch /pdf.leftboundary exch put }
            ifelse
          }
        put
      }
    if
  }
    def
/pdf.bordertracking.end
  {
    /a where { /a { moveto } put } if
    /x where { /x { 0 exch rmoveto } put } if
    SDict /pdf.leftboundary known
      { pdf.outerbox 0 pdf.leftboundary put }
    if
    SDict /pdf.rightboundary known
      { pdf.outerbox 2 pdf.rightboundary put }
    if
    SDict /pdf.bordertracking false put
  }
    def
  /pdf.bordertracking.endpage
{
  pdf.bordertracking
```

```
    {
      pdf.bordertracking.end
      true setglobal
      pdf.globaldict
        /pdf.brokenlink.rect [ pdf.outerbox aload pop ] put
      pdf.globaldict
        /pdf.brokenlink.skip pdf.baselineskip put
      pdf.globaldict
        /pdf.brokenlink.dict
          pdf.link.dict pdf.cvs put
      false setglobal
      mark pdf.link.dict cvx exec /Rect
        [
          pdf.llx
          pdf.lly
          pdf.outerbox 2 get pdf.linkmargin add
          currentpoint exch pop
          pdf.outerbox pdf.rect.ht sub pdf.linkmargin sub
        ]
      /ANN pdf.pdfmark
    }
  if
}
  def
/pdf.bordertracking.continue
  {
    /pdf.link.dict pdf.globaldict
      /pdf.brokenlink.dict get def
    /pdf.outerbox pdf.globaldict
      /pdf.brokenlink.rect get def
    /pdf.baselineskip pdf.globaldict
      /pdf.brokenlink.skip get def
    pdf.globaldict dup dup
    /pdf.brokenlink.dict undef
    /pdf.brokenlink.skip undef
    /pdf.brokenlink.rect undef
    currentpoint
    /pdf.originy exch def
    /pdf.originx exch def
    /a where
      {
        /a
          {
            moveto
            SDict
            begin
            currentpoint pdf.originy ne exch
              pdf.originx ne or
              {
                pdf.save.linkll
                /pdf.lly
                  pdf.lly pdf.outerbox 1 get sub def
                pdf.bordertracking.begin
              }
            if
            end
          }
        put
      }
    if
    /x where
      {
        /x
          {
            0 exch rmoveto
            SDict
            begin
            currentpoint
            pdf.originy ne exch pdf.originx ne or
              {
                pdf.save.linkll
                /pdf.lly
                  pdf.lly pdf.outerbox 1 get sub def
                pdf.bordertracking.begin
              }
            if
            end
          }
        put
      }
    if
  }
    def
```

(*End definition for* `pdf.bordertracking` *and others. These functions are documented on page* **??**.)

`pdf.breaklink` `pdf.breaklink.write` `pdf.count` `pdf.currentrect`

Dealing with link breaking itself has multiple stage. The first step is to find the `Rect` entry in the dictionary, looping over key–value pairs. The first line is handled first, adjusting the rectangle to stay inside the text area. The second phase is a loop over the height of the bulk of the link area, done on the basis of a number of baselines. Finally, the end of the link area is tidied up, again from the boundary of the text area.

```
/pdf.breaklink
  {
    pop
    counttomark 2 mod 0 eq
      {
        counttomark /pdf.count exch def
          {
           pdf.count 0 eq { exit } if
           counttomark 2 roll
           1 index /Rect eq
             {
               dup 4 array copy
               dup dup
                 1 get
                 pdf.outerbox pdf.rect.ht
                 pdf.linkmargin 2 mul add sub
                 3 exch put
```

```
 dup
   pdf.outerbox 2 get
   pdf.linkmargin add
   2 exch put
 dup dup
   3 get
   pdf.outerbox pdf.rect.ht
   pdf.linkmargin 2 mul add add
   1 exch put
 /pdf.currentrect exch  def
 pdf.breaklink.write
   {
     pdf.currentrect
     dup
       pdf.outerbox 0 get
       pdf.linkmargin sub
       0 exch put
     dup
       pdf.outerbox 2 get
       pdf.linkmargin add
       2 exch put
     dup dup
       1 get
       pdf.baselineskip add
       1 exch put
     dup dup
       3 get
       pdf.baselineskip add
       3 exch put
     /pdf.currentrect exch def
     pdf.breaklink.write
    }
  1 index 3 get
  pdf.linkmargin 2 mul add
  pdf.outerbox pdf.rect.ht add
  2 index 1 get sub
  pdf.baselineskip div round cvi 1 sub
  exch
repeat
pdf.currentrect
dup
  pdf.outerbox 0 get
  pdf.linkmargin sub
  0 exch put
dup dup
  1 get
  pdf.baselineskip add
  1 exch put
dup dup
  3 get
  pdf.baselineskip add
  3 exch put
dup 2 index 2 get  2 exch put
/pdf.currentrect exch def
```

```
              pdf.breaklink.write
              SDict /pdf.pdfmark.good false put
              exit
            }
            { pdf.count 2 sub /pdf.count exch def }
          ifelse
        }
      loop
    }
  if
  /ANN
}
  def
/pdf.breaklink.write
  {
    counttomark 1 sub
    index /_objdef eq
      {
        counttomark -2 roll
        dup wcheck
          {
            readonly
            counttomark 2 roll
          }
          { pop pop }
        ifelse
      }
    if
    counttomark 1 add copy
    pop pdf.currentrect
    /ANN pdfmark
  }
    def
```

(*End definition for* `pdf.breaklink` *and others. These functions are documented on page* **??**.)

`pdf.pdfmark`
`pdf.pdfmark.good`
`pdf.outerbox`
`pdf.baselineskip`
`pdf.pdfmark.dict`

The business end of breaking links starts by hooking into `pdfmarks`. Unlike hypdvips, we avoid altering any links we have not created by using a copy of the core `pdfmarks` function. Only mark types which are known are altered. At present, this is purely `ANN` marks, which are measured relative to the size of the baseline skip. If they are more than one apparent line high, breaking is applied.

```
/pdf.pdfmark
  {
    SDict /pdf.pdfmark.good true put
    dup /ANN eq
      {
        pdf.pdfmark.store
        pdf.pdfmark.dict
          begin
            Subtype /Link eq
            currentdict /Rect known and
            SDict /pdf.outerbox known and
            SDict /pdf.baselineskip known and
              {
                Rect 3 get
                pdf.linkmargin 2 mul add
                pdf.outerbox pdf.rect.ht add
                Rect 1 get sub
                pdf.baselineskip div round cvi 0 gt
                  { pdf.breaklink }
                if
              }
            if
          end
        SDict /pdf.outerbox undef
        SDict /pdf.baselineskip undef
        currentdict /pdf.pdfmark.dict undef
      }
    if
    pdf.pdfmark.good
      { pdfmark }
      { cleartomark }
    ifelse
  }
    def
/pdf.pdfmark.store
  {
    /pdf.pdfmark.dict 65534 dict def
    counttomark 1 add copy
    pop
      {
        dup mark eq
          {
            pop
            exit
          }
          {
            pdf.pdfmark.dict
            begin def end
          }
        ifelse
      }
    loop
}
  def
```

(*End definition for* `pdf.pdfmark` *and others. These functions are documented on page* **??**.)

```
⟨/dvips & header⟩
```

Index

The italic numbers denote the pages where the corresponding entry is described, numbers underlined point to the definition, all others indicate the places where it is used.