

File I

Implementation

1 l3draw implementation

```
1 <*initex | package>
2 <@@=draw>
3 <*package>
4 \ProvidesExplPackage{l3draw}{2018/03/05}{}
5   {L3 Experimental core drawing support}
6 </package>
7 \RequirePackage { l3color }
8
9 Everything else is in the sub-files!
10 </initex | package>
```

2 l3draw-paths implementation

```
9 <*initex | package>
10 <@@=draw>
```

This sub-module covers more-or-less the same ideas as `pgfcorepathconstruct.code.tex`, though using the expandable FPU means that the implementation often varies. At present, equivalents of the following are currently absent:

- `\pgfpatharcto`, `\pgfpatharctoprecomputed`: These are extremely specialised and are very complex in implementation. If the functionality is required, it is likely that it will be set up from scratch here.
- `\pgfpathparabola`: Seems to be unused other than defining a *TikZ* interface, which itself is then not used further.
- `\pgfpathsine`, `\pgfpathcosine`: Need to see exactly how these need to work, in particular whether a wider input range is needed and what approximation to make.
- `\pgfpathcurvebetweentime`, `\pgfpathcurvebetweentimecontinue`: These don't seem to be used at all.

```
\l__draw_path_tmp_tl Scratch space.
\l__draw_path_tmpa_fp 11 \tl_new:N \l__draw_path_tmp_tl
\l__draw_path_tmpb_fp 12 \fp_new:N \l__draw_path_tmpa_fp
13 \fp_new:N \l__draw_path_tmpb_fp
```

(End definition for `\l__draw_path_tmp_tl`, `\l__draw_path_tmpa_fp`, and `\l__draw_path_tmpb_fp`.)

2.1 Tracking paths

`\g__draw_path_lastx_dim` The last point visited on a path.

```
\g__draw_path_lasty_dim 14 \dim_new:N \g__draw_path_lastx_dim
15 \dim_new:N \g__draw_path_lasty_dim
```

(End definition for `\g__draw_path_lastx_dim` and `\g__draw_path_lasty_dim`.)

`\g__draw_path_xmax_dim` The limiting size of a path.

```
\g__draw_path_xmin_dim 16 \dim_new:N \g__draw_path_xmax_dim
\g__draw_path_ymax_dim 17 \dim_new:N \g__draw_path_xmin_dim
\g__draw_path_ymin_dim 18 \dim_new:N \g__draw_path_ymax_dim
19 \dim_new:N \g__draw_path_ymin_dim
```

(End definition for `\g__draw_path_xmax_dim` and others.)

`_draw_path_update_limits:nn` Track the limits of a path and (perhaps) of the picture as a whole. (At present the latter is always true: that will change as more complex functionality is added.)

```
\_draw_path_reset_limits: 20 \cs_new_protected:Npn \_draw_path_update_limits:nn #1#2
21 {
22   \dim_gset:Nn \g__draw_path_xmax_dim
23     { \dim_max:nn \g__draw_path_xmax_dim {#1} }
24   \dim_gset:Nn \g__draw_path_xmin_dim
25     { \dim_min:nn \g__draw_path_xmin_dim {#1} }
26   \dim_gset:Nn \g__draw_path_ymax_dim
27     { \dim_max:nn \g__draw_path_ymax_dim {#2} }
28   \dim_gset:Nn \g__draw_path_ymin_dim
29     { \dim_min:nn \g__draw_path_ymin_dim {#2} }
30   \bool_if:NT \l_draw_bb_update_bool
31     {
32       \dim_gset:Nn \g__draw_xmax_dim
33         { \dim_max:nn \g__draw_xmax_dim {#1} }
34       \dim_gset:Nn \g__draw_xmin_dim
35         { \dim_min:nn \g__draw_xmin_dim {#1} }
36       \dim_gset:Nn \g__draw_ymax_dim
37         { \dim_max:nn \g__draw_ymax_dim {#2} }
38       \dim_gset:Nn \g__draw_ymin_dim
39         { \dim_min:nn \g__draw_ymin_dim {#2} }
40     }
41 }
42 \cs_new_protected:Npn \_draw_path_reset_limits:
43 {
44   \dim_gset:Nn \g__draw_path_xmax_dim { -\c_max_dim }
45   \dim_gset:Nn \g__draw_path_xmin_dim { \c_max_dim }
46   \dim_gset:Nn \g__draw_path_ymax_dim { -\c_max_dim }
47   \dim_gset:Nn \g__draw_path_ymin_dim { \c_max_dim }
48 }
```

(End definition for `_draw_path_update_limits:nn` and `_draw_path_reset_limits:.`)

`_draw_path_update_last:nn` A simple auxiliary to avoid repetition.

```
49 \cs_new_protected:Npn \_draw_path_update_last:nn #1#2
50 {
51   \dim_gset:Nn \g__draw_path_lastx_dim {#1}
52   \dim_gset:Nn \g__draw_path_lasty_dim {#2}
53 }
```

(End definition for `_draw_path_update_last:nn`.)

2.2 Corner arcs

At the level of path *construction*, rounded corners are handled by inserting a marker into the path: that is then picked up once the full path is constructed. Thus we need to set up the appropriate data structures here, such that this can be applied every time it is relevant.

`\l__draw_corner_xarc_dim` The two arcs in use.

```
\l__draw_corner_yarc_dim 54 \dim_new:N \l__draw_corner_xarc_dim
55 \dim_new:N \l__draw_corner_yarc_dim
```

(End definition for `\l__draw_corner_xarc_dim` and `\l__draw_corner_yarc_dim`.)

`\l__draw_corner_arc_bool` A flag to speed up the repeated checks.

```
56 \bool_new:N \l__draw_corner_arc_bool
```

(End definition for `\l__draw_corner_arc_bool`.)

`\draw_path_corner_arc:nn` Calculate the arcs, check they are non-zero.

```
57 \cs_new_protected:Npn \draw_path_corner_arc:nn #1#2
58 {
59   \dim_set:Nn \l__draw_corner_xarc_dim {#1}
60   \dim_set:Nn \l__draw_corner_yarc_dim {#2}
61   \bool_lazy_and:nnTF
62     { \dim_compare_p:nNn \l__draw_corner_xarc_dim = { 0pt } }
63     { \dim_compare_p:nNn \l__draw_corner_yarc_dim = { 0pt } }
64     { \bool_set_false:N \l__draw_corner_arc_bool }
65     { \bool_set_true:N \l__draw_corner_arc_bool }
66 }
```

(End definition for `\draw_path_corner_arc:nn`. This function is documented on page ??.)

`__draw_path_mark_corner:` Mark up corners for arc post-processing.

```
67 \cs_new_protected:Npn \__draw_path_mark_corner:
68 {
69   \bool_if:NT \l__draw_corner_arc_bool
70     {
71       \__draw_softpath_roundpoint:VV
72         \l__draw_corner_xarc_dim
73         \l__draw_corner_yarc_dim
74     }
75 }
```

(End definition for `__draw_path_mark_corner:.`)

2.3 Basic path constructions

`\draw_path_moveto:n` At present, stick to purely linear transformation support and skip the soft path business:
`\draw_path_lineto:n` that will likely need to be revisited later.

```

76 \cs_new_protected:Npn \draw_path_moveto:n #1
77 {
78   \__draw_point_process:nn
79   { \__draw_path_moveto:nn }
80   { \draw_point_transform:n {#1} }
81 }
82 \cs_new_protected:Npn \__draw_path_moveto:nn #1#2
83 {
84   \__draw_path_update_limits:nn {#1} {#2}
85   \__draw_softpath_moveto:nn {#1} {#2}
86   \__draw_path_update_last:nn {#1} {#2}
87 }
88 \cs_new_protected:Npn \draw_path_lineto:n #1
89 {
90   \__draw_point_process:nn
91   { \__draw_path_lineto:nn }
92   { \draw_point_transform:n {#1} }
93 }
94 \cs_new_protected:Npn \__draw_path_lineto:nn #1#2
95 {
96   \__draw_path_mark_corner:
97   \__draw_path_update_limits:nn {#1} {#2}
98   \__draw_softpath_lineto:nn {#1} {#2}
99   \__draw_path_update_last:nn {#1} {#2}
100 }
101 \cs_new_protected:Npn \draw_path_curveto:nnn #1#2#3
102 {
103   \__draw_point_process:nnn
104   {
105     \__draw_point_process:nn
106     {
107       \__draw_path_mark_corner:
108       \__draw_path_curveto:nnnnn
109     }
110     { \draw_point_transform:n {#1} }
111   }
112   { \draw_point_transform:n {#2} }
113   { \draw_point_transform:n {#3} }
114 }
115 \cs_new_protected:Npn \__draw_path_curveto:nnnnn #1#2#3#4#5#6
116 {
117   \__draw_path_update_limits:nn {#1} {#2}
118   \__draw_path_update_limits:nn {#3} {#4}
119   \__draw_path_update_limits:nn {#5} {#6}
120   \__draw_softpath_curveto:nnnnn {#1} {#2} {#3} {#4} {#5} {#6}
121   \__draw_path_update_last:nn {#5} {#6}
122 }

```

(End definition for `\draw_path_moveto:n` and others. These functions are documented on page ??.)

`\draw_path_close:` A simple wrapper.

```

123 \cs_new_protected:Npn \draw_path_close:
124 {
125   \__draw_path_mark_corner:
126   \__draw_softpath_closepath:
127 }

```

(End definition for `\draw_path_close:`. This function is documented on page ??.)

2.4 Canvas path constructions

`\draw_path_canvas_moveto:n` Operations with no application of the transformation matrix.

```

\draw_path_canvas_lineto:n
\draw_path_canvas_curveto:nnn
128 \cs_new_protected:Npn \draw_path_canvas_moveto:n #1
129 { \__draw_point_process:nn { \__draw_path_moveto:nn } {#1} }
130 \cs_new_protected:Npn \draw_path_canvas_lineto:n #1
131 { \__draw_point_process:nn { \__draw_path_lineto:nn } {#1} }
132 \cs_new_protected:Npn \draw_path_canvas_curveto:nnn #1#2#3
133 {
134   \__draw_point_process:nnn
135   {
136     \__draw_point_process:nn
137     {
138       \__draw_path_mark_corner:
139       \__draw_path_curveto:nnnnnn
140     }
141     {#1}
142   }
143   {#2} {#3}
144 }

```

(End definition for `\draw_path_canvas_moveto:n`, `\draw_path_canvas_lineto:n`, and `\draw_path_canvas_curveto:nnn`. These functions are documented on page ??.)

2.5 Computed curves

More complex operations need some calculations. To assist with those, various constants are pre-defined.

`\draw_path_curveto:nn` A quadratic curve with one control point (x_c, y_c) . The two required control points are then

$$x_1 = \frac{1}{3}x_s + \frac{2}{3}x_c \quad y_1 = \frac{1}{3}y_s + \frac{2}{3}y_c$$

`__draw_path_curveto:nnnn`
`\c__draw_path_curveto_a_fp`
`\c__draw_path_curveto_b_fp`

and

$$x_2 = \frac{1}{3}x_e + \frac{2}{3}x_c \quad x_2 = \frac{1}{3}y_e + \frac{2}{3}y_c$$

using the start (last) point (x_s, y_s) and the end point (x_e, y_e) .

```

145 \cs_new_protected:Npn \draw_path_curveto:nn #1#2
146 {
147   \__draw_point_process:nnn
148   { \__draw_path_curveto:nnnn }
149   { \draw_point_transform:n {#1} }
150   { \draw_point_transform:n {#2} }
151 }

```

```

152 \cs_new_protected:Npn \__draw_path_curveto:nnnn #1#2#3#4
153 {
154   \fp_set:Nn \l__draw_path_tmpa_fp { \c__draw_path_curveto_b_fp * #1 }
155   \fp_set:Nn \l__draw_path_tmpb_fp { \c__draw_path_curveto_b_fp * #2 }
156   \use:x
157   {
158     \__draw_path_mark_corner:
159     \__draw_path_curveto:nnnnnn
160     {
161       \fp_to_dim:n
162       {
163         \c__draw_path_curveto_a_fp * \g__draw_path_lastx_dim
164         + \l__draw_path_tmpa_fp
165       }
166     }
167     {
168       \fp_to_dim:n
169       {
170         \c__draw_path_curveto_a_fp * \g__draw_path_lasty_dim
171         + \l__draw_path_tmpb_fp
172       }
173     }
174     {
175       \fp_to_dim:n
176       { \c__draw_path_curveto_a_fp * #3 + \l__draw_path_tmpa_fp }
177     }
178     {
179       \fp_to_dim:n
180       { \c__draw_path_curveto_a_fp * #4 + \l__draw_path_tmpb_fp }
181     }
182     {#3}
183     {#4}
184   }
185 }
186 \fp_const:Nn \c__draw_path_curveto_a_fp { 1 / 3 }
187 \fp_const:Nn \c__draw_path_curveto_b_fp { 2 / 3 }

```

(End definition for \draw_path_curveto:nn and others. This function is documented on page ??.)

<pre> \draw_path_arc:nnn \draw_path_arc:nnnn __draw_path_arc:nnnn __draw_path_arc:nnNnn __draw_path_arc_auxi:nnnnNnn __draw_path_arc_auxi:fnnnNnn __draw_path_arc_auxi:fnfnNnn __draw_path_arc_auxii:nnnNnnnn __draw_path_arc_auxiii:nn __draw_path_arc_auxiv:nnnn __draw_path_arc_auxv:nn __draw_path_arc_auxvi:nn __draw_path_arc_add:nnnn \l__draw_path_arc_delta_fp \l__draw_path_arc_start_fp \c__draw_path_arc_90_fp \c__draw_path_arc_60_fp </pre>	<p>Drawing an arc means dividing the total curve required into sections: using Bzier curves we can cover at most 90° at once. To allow for later manipulations, we aim to have roughly equal last segments to the line, with the split set at a final part of 115°.</p> <pre> 188 \cs_new_protected:Npn \draw_path_arc:nnn #1#2#3 189 { \draw_path_arc:nnnn {#1} {#2} {#3} {#3} } 190 \cs_new_protected:Npn \draw_path_arc:nnnn #1#2#3#4 191 { 192 \use:x 193 { 194 __draw_path_arc:nnnn 195 { \fp_eval:n {#1} } 196 { \fp_eval:n {#2} } 197 { \fp_to_dim:n {#3} } 198 { \fp_to_dim:n {#4} } 199 } </pre>
--	---

```

200 }
201 \cs_new_protected:Npn \__draw_path_arc:nnnn #1#2#3#4
202 {
203   \fp_compare:nNnTF {#1} > {#2}
204     { \__draw_path_arc:nnNnn {#1} {#2} - {#3} {#4} }
205     { \__draw_path_arc:nnNnn {#1} {#2} + {#3} {#4} }
206 }
207 \cs_new_protected:Npn \__draw_path_arc:nnNnn #1#2#3#4#5
208 {
209   \fp_set:Nn \l__draw_path_arc_start_fp {#1}
210   \fp_set:Nn \l__draw_path_arc_delta_fp { abs( #1 - #2 ) }
211   \fp_while_do:nNnn { \l__draw_path_arc_delta_fp } > { 90 }
212   {
213     \fp_compare:nNnTF \l__draw_path_arc_delta_fp > { 115 }
214     {
215       \__draw_path_arc_auxi:ffnnNnn
216       { \fp_to_decimal:N \l__draw_path_arc_start_fp }
217       { \fp_eval:n { \l__draw_path_arc_start_fp #3 90 } }
218       { 90 } {#2}
219       #3 {#4} {#5}
220     }
221     {
222       \__draw_path_arc_auxi:ffnnNnn
223       { \fp_to_decimal:N \l__draw_path_arc_start_fp }
224       { \fp_eval:n { \l__draw_path_arc_start_fp #3 60 } }
225       { 60 } {#2}
226       #3 {#4} {#5}
227     }
228   }
229   \__draw_path_mark_corner:
230   \__draw_path_arc_auxi:fnfnNnn
231   { \fp_to_decimal:N \l__draw_path_arc_start_fp }
232   {#2}
233   { \fp_eval:n { abs( \l__draw_path_arc_start_fp - #2 ) } }
234   {#2}
235   #3 {#4} {#5}
236 }

```

The auxiliary is responsible for calculating the required points. The “magic” number required to determine the length of the control vectors is well-established for a right-angle: $\frac{4}{3}(\sqrt{2} - 1) = 0.55228475$. For other cases, we follow the calculation used by `pgf` but with the second common case of 60° pre-calculated for speed.

```

237 \cs_new_protected:Npn \__draw_path_arc_auxi:nnnnNnn #1#2#3#4#5#6#7
238 {
239   \use:x
240   {
241     \__draw_path_arc_auxii:nnnNnnnn
242     {#1} {#2} {#4} #5 {#6} {#7}
243     {
244       \fp_to_dim:n
245       {
246         \cs_if_exist_use:cF
247         { c__draw_path_arc_ #3 _fp }
248         { 4/3 * tand( 0.25 * #3 ) }

```

```

249         * #6
250     }
251 }
252 {
253     \fp_to_dim:n
254     {
255         \cs_if_exist_use:cF
256         { c__draw_path_arc_ #3 _fp }
257         { 4/3 * tand( 0.25 * #3 ) }
258         * #7
259     }
260 }
261 }
262 }
263 \cs_generate_variant:Nn \__draw_path_arc_auxi:nnnnNnn { fnf , ff }

```

We can now calculate the required points. As everything here is non-expandable, that is best done by using x-type expansion to build up the tokens. The three points are calculated out-of-order, since finding the second control point needs the position of the end point. Once the points are found, fire-off the fundamental path operation and update the record of where we are up to. The final point has to be

```

264 \cs_new_protected:Npn \__draw_path_arc_auxii:nnNnnnn #1#2#3#4#5#6#7#8
265 {
266     \tl_clear:N \l__draw_path_tmp_tl
267     \__draw_point_process:nn
268     { \__draw_path_arc_auxiii:nn }
269     {
270         \__draw_point_transform_noshift:n
271         { \draw_point_polar:nnn { #1 #4 90 } {#7} {#8} }
272     }
273     \__draw_point_process:nn
274     {
275         \__draw_point_process:nn
276         { \__draw_path_arc_auxiv:nnnn }
277         {
278             \draw_point_transform:n
279             { \draw_point_polar:nnn {#1} {#5} {#6} }
280         }
281     }
282     {
283         \draw_point_transform:n
284         { \draw_point_polar:nnn {#2} {#5} {#6} }
285     }
286     \__draw_point_process:nn
287     { \__draw_path_arc_auxv:mn }
288     {
289         \__draw_point_transform_noshift:n
290         { \draw_point_polar:nnn { #2 #4 -90 } {#7} {#8} }
291     }
292     \exp_after:wN \__draw_path_curveto:nnnnnn \l__draw_path_tmp_tl
293     \fp_set:Nn \l__draw_path_arc_delta_fp { abs ( #2 - #3 ) }
294     \fp_set:Nn \l__draw_path_arc_start_fp {#2}
295 }

```

The first control point.

```

296 \cs_new_protected:Npn \__draw_path_arc_auxiii:nn #1#2
297 {
298   \__draw_path_arc_aux_add:nn
299   { \g__draw_path_lastx_dim + #1 }
300   { \g__draw_path_lasty_dim + #2 }
301 }

```

The end point: simple arithmetic.

```

302 \cs_new_protected:Npn \__draw_path_arc_auxiv:nnnn #1#2#3#4
303 {
304   \__draw_path_arc_aux_add:nn
305   { \g__draw_path_lastx_dim - #1 + #3 }
306   { \g__draw_path_lasty_dim - #2 + #4 }
307 }

```

The second control point: extract the last point, do some rearrangement and record.

```

308 \cs_new_protected:Npn \__draw_path_arc_auxv:nn #1#2
309 {
310   \exp_after:wN \__draw_path_arc_auxvi:nn
311   \l__draw_path_tmp_tl {#1} {#2}
312 }
313 \cs_new_protected:Npn \__draw_path_arc_auxvi:nn #1#2#3#4#5#6
314 {
315   \tl_set:Nn \l__draw_path_tmp_tl { {#1} {#2} }
316   \__draw_path_arc_aux_add:nn
317   { #5 + #3 }
318   { #6 + #4 }
319   \tl_put_right:Nn \l__draw_path_tmp_tl { {#3} {#4} }
320 }
321 \cs_new_protected:Npn \__draw_path_arc_aux_add:nn #1#2
322 {
323   \tl_put_right:Nx \l__draw_path_tmp_tl
324   { { \fp_to_dim:n {#1} } { \fp_to_dim:n {#2} } }
325 }
326 \fp_new:N \l__draw_path_arc_delta_fp
327 \fp_new:N \l__draw_path_arc_start_fp
328 \fp_const:cn { c__draw_path_arc_90_fp } { 4/3 * (sqrt(2) - 1) }
329 \fp_const:cn { c__draw_path_arc_60_fp } { 4/3 * tand(15) }

```

(End definition for \draw_path_arc:nnn and others. These functions are documented on page ??.)

`\draw_path_arc_axes:nnnn` A simple wrapper.

```

330 \cs_new_protected:Npn \draw_path_arc_axes:nnnn #1#2#3#4
331 {
332   \draw_transform_triangle:nnn { 0cm , 0cm } {#3} {#4}
333   \draw_path_arc:nnn {#1} {#2} { 1pt }
334 }

```

(End definition for \draw_path_arc_axes:nnnn. This function is documented on page ??.)

`\draw_path_ellipse:nnn` Drawing an ellipse is an optimised version of drawing an arc, in particular reusing the same constant. We need to deal with the ellipse in four parts and also deal with moving to the right place, closing it and ending up back at the center. That is handled on a per-arc basis, each in a separate auxiliary for readability.

```

\__draw_path_ellipse:nnnnnn
  \__draw_path_ellipse_arci:nnnnnn
  \__draw_path_ellipse_arci:nnnnnn
  \__draw_path_ellipse_arci:nnnnnn
  \__draw_path_ellipse_arci:nnnnnn
335 \cs_new_protected:Npn \draw_path_ellipse:nnn #1#2#3
  \__draw_path_ellipse_arci:nnnnnn
\c__draw_path_ellipse_fp

```

```

336 {
337   \__draw_point_process:nnn
338   {
339     \__draw_point_process:nn
340     { \__draw_path_ellipse:nnnnnn }
341     { \draw_point_transform:n {#1} }
342   }
343   { \__draw_point_transform_noshift:n {#2} }
344   { \__draw_point_transform_noshift:n {#3} }
345 }
346 \cs_new_protected:Npn \__draw_path_ellipse:nnnnnn #1#2#3#4#5#6
347 {
348   \use:x
349   {
350     \__draw_path_moveto:nn
351     { \fp_to_dim:n { #1 + #3 } } { \fp_to_dim:n { #2 + #4 } }
352     \__draw_path_ellipse_arci:nnnnnn {#1} {#2} {#3} {#4} {#5} {#6}
353     \__draw_path_ellipse_arcii:nnnnnn {#1} {#2} {#3} {#4} {#5} {#6}
354     \__draw_path_ellipse_arciiii:nnnnnn {#1} {#2} {#3} {#4} {#5} {#6}
355     \__draw_path_ellipse_arciv:nnnnnn {#1} {#2} {#3} {#4} {#5} {#6}
356   }
357   \__draw_softpath_closepath:
358   \__draw_path_moveto:nn {#1} {#2}
359 }
360 \cs_new:Npn \__draw_path_ellipse_arci:nnnnnn #1#2#3#4#5#6
361 {
362   \__draw_path_curveto:nnnnnn
363   { \fp_to_dim:n { #1 + #3 + #5 * \c__draw_path_ellipse_fp } }
364   { \fp_to_dim:n { #2 + #4 + #6 * \c__draw_path_ellipse_fp } }
365   { \fp_to_dim:n { #1 + #3 * \c__draw_path_ellipse_fp + #5 } }
366   { \fp_to_dim:n { #2 + #4 * \c__draw_path_ellipse_fp + #6 } }
367   { \fp_to_dim:n { #1 + #5 } }
368   { \fp_to_dim:n { #2 + #6 } }
369 }
370 \cs_new:Npn \__draw_path_ellipse_arcii:nnnnnn #1#2#3#4#5#6
371 {
372   \__draw_path_curveto:nnnnnn
373   { \fp_to_dim:n { #1 - #3 * \c__draw_path_ellipse_fp + #5 } }
374   { \fp_to_dim:n { #2 - #4 * \c__draw_path_ellipse_fp + #6 } }
375   { \fp_to_dim:n { #1 - #3 + #5 * \c__draw_path_ellipse_fp } }
376   { \fp_to_dim:n { #2 - #4 + #6 * \c__draw_path_ellipse_fp } }
377   { \fp_to_dim:n { #1 - #3 } }
378   { \fp_to_dim:n { #2 - #4 } }
379 }
380 \cs_new:Npn \__draw_path_ellipse_arciiii:nnnnnn #1#2#3#4#5#6
381 {
382   \__draw_path_curveto:nnnnnn
383   { \fp_to_dim:n { #1 - #3 - #5 * \c__draw_path_ellipse_fp } }
384   { \fp_to_dim:n { #2 - #4 - #6 * \c__draw_path_ellipse_fp } }
385   { \fp_to_dim:n { #1 - #3 * \c__draw_path_ellipse_fp - #5 } }
386   { \fp_to_dim:n { #2 - #4 * \c__draw_path_ellipse_fp - #6 } }
387   { \fp_to_dim:n { #1 - #5 } }
388   { \fp_to_dim:n { #2 - #6 } }
389 }

```

```

390 \cs_new:Npn \__draw_path_ellipse_arciv:nnnnnn #1#2#3#4#5#6
391 {
392   \__draw_path_curveto:nnnnnn
393   { \fp_to_dim:n { #1 + #3 * \c__draw_path_ellipse_fp - #5 } }
394   { \fp_to_dim:n { #2 + #4 * \c__draw_path_ellipse_fp - #6 } }
395   { \fp_to_dim:n { #1 + #3 - #5 * \c__draw_path_ellipse_fp } }
396   { \fp_to_dim:n { #2 + #4 - #6 * \c__draw_path_ellipse_fp } }
397   { \fp_to_dim:n { #1 + #3 } }
398   { \fp_to_dim:n { #2 + #4 } }
399 }
400 \fp_const:Nn \c__draw_path_ellipse_fp { \fp_use:c { c__draw_path_arc_90_fp } }

```

(End definition for `\draw_path_ellipse:nnn` and others. This function is documented on page ??.)

`\draw_path_circle:nn` A shortcut.

```

401 \cs_new_protected:Npn \draw_path_circle:nn #1#2
402 { \draw_path_ellipse:nnn {#1} { #2 , Opt } { Opt , #2 } }

```

(End definition for `\draw_path_circle:nn`. This function is documented on page ??.)

2.6 Rectangles

`\draw_path_rectangle:nn` Building a rectangle can be a single operation, or for rounded versions will involve step-by-step construction.

`__draw_path_rectangle:nnnn`

`__draw_path_rectangle_rounded:nnnn`

```

403 \cs_new_protected:Npn \draw_path_rectangle:nn #1#2
404 {
405   \__draw_point_process:nnn
406   {
407     \bool_lazy_or:nnTF
408     { \l__draw_corner_arc_bool }
409     { \l__draw_matrix_active_bool }
410     { \__draw_path_rectangle_rounded:nnnn }
411     { \__draw_path_rectangle:nnnn }
412   }
413   { \draw_point_transform:n {#1} }
414   {#2}
415 }
416 \cs_new_protected:Npn \__draw_path_rectangle:nnnn #1#2#3#4
417 {
418   \__draw_path_update_limits:nn {#1} {#2}
419   \__draw_path_update_limits:nn { #1 + #3 } { #2 + #4 }
420   \__draw_softpath_rectangle:nnnn {#1} {#2} {#3} {#4}
421   \__draw_path_update_last:nn {#1} {#2}
422 }
423 \cs_new_protected:Npn \__draw_path_rectangle_rounded:nnnn #1#2#3#4
424 {
425   \draw_path_moveto:n { #1 + #3 , #2 + #4 }
426   \draw_path_lineto:n { #1 , #2 + #4 }
427   \draw_path_lineto:n { #1 , #2 }
428   \draw_path_lineto:n { #1 + #3 , #2 }
429   \draw_path_close:
430   \draw_path_moveto:n { #1 , #2 }
431 }

```

(End definition for `\draw_path_rectangle:nn`, `_draw_path_rectangle:nnnn`, and `_draw_path_rectangle_rounded:nnnn`. This function is documented on page ??.)

```

\draw_path_rectangle_corners:mn Another shortcut wrapper.
\_draw_path_rectangle_corners:nnnn 432 \cs_new_protected:Npn \draw_path_rectangle_corners:nn #1#2
                                     433 {
                                     434   \_draw_point_process:nnn
                                     435   { \_draw_path_rectangle_corners:nnnnn {#1} }
                                     436   {#1} {#2}
                                     437 }
                                     438 \cs_new_protected:Npn \_draw_path_rectangle_corners:nnnnn #1#2#3#4#5
                                     439 { \draw_path_rectangle:nn {#1} { #4 - #2 , #5 - #3 } }

```

(End definition for `\draw_path_rectangle_corners:nn` and `_draw_path_rectangle_corners:nnnnn`. This function is documented on page ??.)

2.7 Grids

`\draw_path_grid:nnnn` The main complexity here is lining up the grid correctly. To keep it simple, we tidy up the argument ordering first.

```

\_draw_path_grid_auxi:nnnnnn 440 \cs_new_protected:Npn \draw_path_grid:nnnn #1#2#3#4
\_draw_path_grid_auxi:ffnnnn 441 {
\_draw_path_grid_auxii:nnnnnn 442   \_draw_point_process:nnn
\_draw_path_grid_auxiii:nnnnnn 443   {
\_draw_path_grid_auxiiii:ffnnnn 444     \_draw_path_grid_auxi:ffnnnnn
\_draw_path_grid_auxiv:nnnnnnnn 445     { \dim_eval:n { \dim_abs:n {#1} } }
\_draw_path_grid_auxiv:ffnnnnnn 446     { \dim_eval:n { \dim_abs:n {#2} } }
                                     447   }
                                     448   {#3} {#4}
                                     449 }
450 \cs_new_protected:Npn \_draw_path_grid_auxi:nnnnnn #1#2#3#4#5#6
451 {
452   \dim_compare:nNnTF {#3} > {#5}
453   { \_draw_path_grid_auxii:nnnnnn {#1} {#2} {#5} {#4} {#3} {#6} }
454   { \_draw_path_grid_auxii:nnnnnn {#1} {#2} {#3} {#4} {#5} {#6} }
455 }
456 \cs_generate_variant:Nn \_draw_path_grid_auxi:nnnnnn { ff }
457 \cs_new_protected:Npn \_draw_path_grid_auxii:nnnnnn #1#2#3#4#5#6
458 {
459   \dim_compare:nNnTF {#4} > {#6}
460   { \_draw_path_grid_auxiii:nnnnnn {#1} {#2} {#3} {#6} {#5} {#4} }
461   { \_draw_path_grid_auxiii:nnnnnn {#1} {#2} {#3} {#4} {#5} {#6} }
462 }
463 \cs_new_protected:Npn \_draw_path_grid_auxiii:nnnnnn #1#2#3#4#5#6
464 {
465   \_draw_path_grid_auxiv:ffnnnnnn
466   { \fp_to_dim:n { #1 * trunc(#3/(#1)) } }
467   { \fp_to_dim:n { #2 * trunc(#4/(#2)) } }
468   {#1} {#2} {#3} {#4} {#5} {#6}
469 }
470 \cs_new_protected:Npn \_draw_path_grid_auxiv:nnnnnnnn #1#2#3#4#5#6#7#8
471 {
472   \dim_step_inline:nnnn
473   {#1}

```

```

474     {#3}
475     {#7}
476     {
477         \draw_path_moveto:n { ##1 , #6 }
478         \draw_path_lineto:n { ##1 , #8 }
479     }
480     \dim_step_inline:nnnn
481     {#2}
482     {#4}
483     {#8}
484     {
485         \draw_path_moveto:n { #5 , ##1 }
486         \draw_path_lineto:n { #7 , ##1 }
487     }
488 }
489 \cs_generate_variant:Nn \__draw_path_grid_auxiv:nnnnnnnn { ff }

```

(End definition for `\draw_path_grid:nnnn` and others. This function is documented on page ??.)

2.8 Using paths

```

\l__draw_path_use_clip_bool
\l__draw_path_use_fill_bool
  \l__draw_path_use_stroke_bool

```

Actions to pass to the driver.

```

490 \bool_new:N \l__draw_path_use_clip_bool
491 \bool_new:N \l__draw_path_use_fill_bool
492 \bool_new:N \l__draw_path_use_stroke_bool

```

(End definition for `\l__draw_path_use_clip_bool`, `\l__draw_path_use_fill_bool`, and `\l__draw_path_use_stroke_bool`.)

```

\l__draw_path_use_bb_bool
\l__draw_path_use_clear_bool

```

Actions handled at the macro layer.

```

493 \bool_new:N \l__draw_path_use_bb_bool
494 \bool_new:N \l__draw_path_use_clear_bool

```

(End definition for `\l__draw_path_use_bb_bool` and `\l__draw_path_use_clear_bool`.)

```

\draw_path_use:n
\draw_path_use_clear:n
  \__draw_path_use:n
    \__draw_path_use_action_draw:
  \__draw_path_use_action_fillstroke:
\__draw_path_use_stroke_bb:
  \__draw_path_use_stroke_bb_aux:NnN

```

There are a range of actions which can apply to a path: they are handled in a single function which can carry out several of them. The first step is to deal with the special case of clearing the path.

```

495 \cs_new_protected:Npn \draw_path_use:n #1
496 {
497     \tl_if_blank:nF {#1}
498     { \__draw_path_use:n {#1} }
499 }
500 \cs_new_protected:Npn \draw_path_use_clear:n #1
501 {
502     \bool_lazy_or:nnTF
503     { \tl_if_blank_p:n {#1} }
504     { \str_if_eq_p:nn {#1} { clear } }
505     {
506         \__draw_softpath_clear:
507         \__draw_path_reset_limits:
508     }
509     { \__draw_path_use:n { #1 , clear } }
510 }

```

Map over the actions and set up the data: mainly just booleans, but with the possibility to cover more complex cases. The business end of the function is a series of checks on the various flags, then taking the appropriate action(s).

```

511 \cs_new_protected:Npn \__draw_path_use:n #1
512 {
513   \bool_set_false:N \l__draw_path_use_clip_bool
514   \bool_set_false:N \l__draw_path_use_fill_bool
515   \bool_set_false:N \l__draw_path_use_stroke_bool
516   \clist_map_inline:nn {#1}
517   {
518     \cs_if_exist:ctf { l__draw_path_use_ ##1 _ bool }
519     { \bool_set_true:c { l__draw_path_use_ ##1 _ bool } }
520     {
521       \cs_if_exist_use:cF { __draw_path_use_action_ ##1 : }
522       { \ERROR }
523     }
524   }
525   \__draw_softpath_round_corners:
526   \bool_lazy_and:nnT
527   { \l_draw_bb_update_bool }
528   { \l__draw_path_use_stroke_bool }
529   { \__draw_path_use_stroke_bb: }
530   \bool_if:NTF \l__draw_path_use_clear_bool
531   { \__draw_softpath_use_clear: }
532   { \__draw_softpath_use: }
533   \bool_if:NT \l__draw_path_use_clip_bool
534   { \driver_draw_clip: }
535   \bool_lazy_or:nnT
536   { \l__draw_path_use_fill_bool }
537   { \l__draw_path_use_stroke_bool }
538   {
539     \use:c
540     {
541       driver_draw_
542       \bool_if:NT \l__draw_path_use_fill_bool { fill }
543       \bool_if:NT \l__draw_path_use_stroke_bool { stroke }
544       :
545     }
546   }
547 }
548 \cs_new_protected:Npn \__draw_path_use_action_draw:
549 {
550   \bool_set_true:N \l__draw_path_use_stroke_bool
551 }
552 \cs_new_protected:Npn \__draw_path_use_action_fillstroke:
553 {
554   \bool_set_true:N \l__draw_path_use_fill_bool
555   \bool_set_true:N \l__draw_path_use_stroke_bool
556 }

```

Where the path is relevant to size and is stroked, we need to allow for the part which overlaps the edge of the bounding box.

```

557 \cs_new_protected:Npn \__draw_path_use_stroke_bb:
558 {

```

```

559     \__draw_path_use_stroke_bb_aux:NnN x { max } +
560     \__draw_path_use_stroke_bb_aux:NnN y { max } +
561     \__draw_path_use_stroke_bb_aux:NnN x { min } -
562     \__draw_path_use_stroke_bb_aux:NnN y { min } -
563   }
564 \cs_new_protected:Npn \__draw_path_use_stroke_bb_aux:NnN #1#2#3
565 {
566   \dim_compare:nNnF { \dim_use:c { g__draw_ #1#2 _dim } } = { #3 -\c_max_dim }
567   {
568     \dim_gset:cn { g__draw_ #1#2 _dim }
569     {
570       \use:c { dim_ #2 :nn }
571       { \dim_use:c { g__draw_ #1#2 _dim } }
572       {
573         \dim_use:c { g__draw_path_ #1#2 _dim }
574         #3 0.5 \g__draw_linewidth_dim
575       }
576     }
577   }
578 }

```

(End definition for `\draw_path_use:n` and others. These functions are documented on page ??.)

2.9 Scoping paths

`\l__draw_path_lastx_dim` Local storage for global data. There is already a `\l__draw_softpath_main_tl` for path manipulation, so we can reuse that (it is always grouped when the path is being reconstructed).

```

\l__draw_path_xmax_dim
\l__draw_path_xmin_dim
\l__draw_path_ymax_dim
\l__draw_path_ymin_dim
\l__draw_softpath_corners_bool
579 \dim_new:N \l__draw_path_lastx_dim
580 \dim_new:N \l__draw_path_lasty_dim
581 \dim_new:N \l__draw_path_xmax_dim
582 \dim_new:N \l__draw_path_xmin_dim
583 \dim_new:N \l__draw_path_ymax_dim
584 \dim_new:N \l__draw_path_ymin_dim
585 \dim_new:N \l__draw_softpath_lastx_dim
586 \dim_new:N \l__draw_softpath_lasty_dim
587 \bool_new:N \l__draw_softpath_corners_bool

```

(End definition for `\l__draw_path_lastx_dim` and others.)

`\draw_path_scope_begin:` Scoping a path is a bit more involved, largely as there are a number of variables to keep hold of.

```

\draw_path_scope_end:
588 \cs_new_protected:Npn \draw_path_scope_begin:
589 {
590   \group_begin:
591   \dim_set_eq:NN \l__draw_path_lastx_dim \g__draw_path_lastx_dim
592   \dim_set_eq:NN \l__draw_path_lasty_dim \g__draw_path_lasty_dim
593   \dim_set_eq:NN \l__draw_path_xmax_dim \g__draw_path_xmax_dim
594   \dim_set_eq:NN \l__draw_path_xmin_dim \g__draw_path_xmin_dim
595   \dim_set_eq:NN \l__draw_path_ymax_dim \g__draw_path_ymax_dim
596   \dim_set_eq:NN \l__draw_path_ymin_dim \g__draw_path_ymin_dim
597   \dim_set_eq:NN \l__draw_softpath_lastx_dim \g__draw_softpath_lastx_dim
598   \dim_set_eq:NN \l__draw_softpath_lasty_dim \g__draw_softpath_lasty_dim
599   \__draw_path_reset_limits:

```

```

600     \__draw_softpath_concat:n { }
601     \tl_set_eq:NN \l__draw_softpath_main_tl \g__draw_softpath_main_tl
602     \bool_set_eq:NN
603         \l__draw_softpath_corners_bool
604         \g__draw_softpath_corners_bool
605     \__draw_softpath_clear:
606 }
607 \cs_new_protected:Npn \draw_path_scope_end:
608 {
609     \bool_gset_eq:NN
610         \g__draw_softpath_corners_bool
611         \l__draw_softpath_corners_bool
612     \__draw_softpath_clear:
613     \tl_gset_eq:NN \g__draw_softpath_main_tl \l__draw_softpath_main_tl
614     \dim_gset_eq:NN \g__draw_softpath_lastx_dim \l__draw_softpath_lastx_dim
615     \dim_gset_eq:NN \g__draw_softpath_lasty_dim \l__draw_softpath_lasty_dim
616     \dim_gset_eq:NN \g__draw_path_xmax_dim \l__draw_path_xmax_dim
617     \dim_gset_eq:NN \g__draw_path_xmin_dim \l__draw_path_xmin_dim
618     \dim_gset_eq:NN \g__draw_path_ymax_dim \l__draw_path_ymax_dim
619     \dim_gset_eq:NN \g__draw_path_ymin_dim \l__draw_path_ymin_dim
620     \dim_gset_eq:NN \g__draw_path_lastx_dim \l__draw_path_lastx_dim
621     \dim_gset_eq:NN \g__draw_path_lasty_dim \l__draw_path_lasty_dim
622     \group_end:
623 }

```

(End definition for `\draw_path_scope_begin:` and `\draw_path_scope_end:`. These functions are documented on page ??.)

```
624 \</initex | package>
```

3 I3draw-points implementation

```
625 <*initex | package>
```

```
626 <@@=draw>
```

This sub-module covers more-or-less the same ideas as `pgfcorepoints.code.tex`, though the approach taken to returning values is different: point expressions here are processed by expansion and return a co-ordinate pair in the form $\langle x \rangle \langle y \rangle$. Equivalents of following `pgf` functions are deliberately omitted:

- `\pgfpointorigin:` Can be given explicitly as `{0pt}{0pt}`.
- `\pgfextractx`, `\pgfextracty:` Available by applying `\use_i:nn/\use_ii:nn` or similar to the `x`-type expansion of a point expression.
- `\pgfgetlastxy:` Unused in the entire `pgf` core, may be emulated by `x`-type expansion of a point expression, then using the result.

In addition, equivalents of the following *may* be added in future but are currently absent:

- `\pgfpointcylindrical`, `\pgfpointspherical:` The usefulness of these commands is not currently clear.
- `\pgfpointborderrectangle`, `\pgfpointborderellipse:` To be revisited once the semantics and use cases are clear.

- `\pgfqpoint`, `\pgfqpointscale`, `\pgfqpointpolar`, `\pgfqpointxy`, `\pgfqpointxyz`: The expandable approach taken in the code here, along with the absolute requirement for ε -TeX, means it is likely many use cases for these commands may be covered in other ways. This may be revisited as higher-level structures are constructed.

3.1 Support functions

Execute whatever code is passed to extract the x and y co-ordinates. The first argument here should itself absorb two arguments. There is also a version to deal with two co-ordinates: common enough to justify a separate function.

```

\__draw_point_process:nn
  \__draw_point_process_auxi:nn
  \__draw_point_process_auxi:fn
  \__draw_point_process_auxii:nw
\__draw_point_process:nnn
  \__draw_point_process_auxiii:nnn
  \__draw_point_process_auxiii:ffn
  \__draw_point_process_auxiv:nw
627 \cs_new:Npn \__draw_point_process:nn #1#2
628   {
629     \__draw_point_process_auxi:fn
630     { \__draw_point_to_dim:n {#2} }
631     {#1}
632   }
633 \cs_new:Npn \__draw_point_process_auxi:nn #1#2
634   { \__draw_point_process_auxii:nw {#2} #1 \q_stop }
635 \cs_generate_variant:Nn \__draw_point_process_auxi:nn { f }
636 \cs_new:Npn \__draw_point_process_auxii:nw #1 #2 , #3 \q_stop
637   { #1 {#2} {#3} }
638 \cs_new:Npn \__draw_point_process:nnn #1#2#3
639   {
640     \__draw_point_process_auxiii:ffn
641     { \__draw_point_to_dim:n {#2} }
642     { \__draw_point_to_dim:n {#3} }
643     {#1}
644   }
645 \cs_new:Npn \__draw_point_process_auxiii:nnn #1#2#3
646   { \__draw_point_process_auxiv:nw {#3} #1 \q_mark #2 \q_stop }
647 \cs_generate_variant:Nn \__draw_point_process_auxiii:nnn { ff }
648 \cs_new:Npn \__draw_point_process_auxiv:nw #1 #2 , #3 \q_mark #4 , #5 \q_stop
649   { #1 {#2} {#3} {#4} {#5} }

```

(End definition for `__draw_point_process:nn` and others.)

```

\__draw_point_to_dim:n
\__draw_point_to_dim_aux:n
\__draw_point_to_dim_aux:f
\__draw_point_to_dim_aux:w
650 \cs_new:Npn \__draw_point_to_dim:n #1
651   { \__draw_point_to_dim_aux:f { \fp_eval:n {#1} } }
652 \cs_new:Npn \__draw_point_to_dim_aux:n #1
653   { \__draw_point_to_dim_aux:w #1 }
654 \cs_generate_variant:Nn \__draw_point_to_dim_aux:n { f }
655 \cs_new:Npn \__draw_point_to_dim_aux:w ( #1 , ~ #2 ) { #1pt , #2pt }

```

3.2 Co-ordinates

The most basic way of giving points is as simple (x, y) co-ordinates.

Simply turn the given values into dimensions.

```

\draw_point:nn
656 \cs_new:Npn \draw_point:nn #1#2
657   { \__draw_point_to_dim:n { #1 , #2 } }

```

3.3 Polar co-ordinates

Polar co-ordinates may have either one or two lengths, so there is a need to do a simple split before the calculation. As the angle gets used twice, save on any expression evaluation there and force expansion.

```

\draw_point_polar:nn
\draw_point_polar:nnn
\__draw_draw_polar:nnn
\__draw_draw_polar:fnn
658 \cs_new:Npn \draw_point_polar:nn #1#2
659   { \draw_point_polar:nnn {#1} {#2} {#2} }
660 \cs_new:Npn \draw_point_polar:nnn #1#2#3
661   { \__draw_draw_polar:fnn { \fp_eval:n {#1} } {#2} {#3} }
662 \cs_new:Npn \__draw_draw_polar:nnn #1#2#3
663   { \__draw_point_to_dim:n { cosd(#1) * (#2) , sind(#1) * (#3) } }
664 \cs_generate_variant:Nn \__draw_draw_polar:nnn { f }

```

3.4 Point expression arithmetic

These functions all take point expressions as arguments.

Simple mathematics.

```

\draw_point_add:nn
\draw_point_diff:nn
\draw_point_scale:nn
665 \cs_new:Npn \draw_point_add:nn #1#2
666   { \__draw_point_to_dim:n { (#1) + (#2) } }
667 \cs_new:Npn \draw_point_diff:nn #1#2
668   { \__draw_point_to_dim:n { (#2) - (#1) } }
669 \cs_new:Npn \draw_point_scale:nn #1#2
670   { \__draw_point_to_dim:n { #1 * (#2) } }

```

Only a single point expression so the expansion is done here. The outcome is the normalised vector from (0,0) in the direction of the point, *i.e.*

```

\draw_point_unit_vector:nn
\__draw_point_unit_vector:nn

```

$$P_x = \frac{x}{\sqrt{x^2 + y^2}} \quad P_y = \frac{y}{\sqrt{x^2 + y^2}}$$

```

671 \cs_new:Npn \draw_point_unit_vector:n #1
672   { \__draw_point_process:nn { \__draw_point_unit_vector:nn } {#1} }
673 \cs_new:Npn \__draw_point_unit_vector:nn #1#2
674   {
675     \__draw_point_to_dim:n
676     { ( #1 , #2 ) / (sqrt(#1 * #1 + #2 * #2)) }
677   }

```

3.5 Intersection calculations

The intersection point P between a line joining points (x_1, y_1) and (x_2, y_2) with a second line joining points (x_3, y_3) and (x_4, y_4) can be calculated using the formulae

$$P_x = \frac{(x_1 y_2 - y_1 x_2)(x_3 - x_4) - (x_3 y_4 - y_3 x_4)(x_1 - x_2)}{(x_1 - x_2)(y_3 - y_4) - (y_1 - y_2)(x_3 - x_4)}$$

and

$$P_y = \frac{(x_1 y_2 - y_1 x_2)(y_3 - y_4) - (x_3 y_4 - y_3 x_4)(y_1 - y_2)}{(x_1 - x_2)(y_3 - y_4) - (y_1 - y_2)(x_3 - x_4)}$$

The work therefore comes down to expanding the incoming data, then pre-calculating as many parts as possible before the final work to find the intersection. (Expansion and argument re-ordering is much less work than additional floating point calculations.)

use the intermediate values

$$\begin{aligned} e &= c - a \\ f &= d - b \\ p &= \sqrt{e^2 + f^2} \\ k &= \frac{p^2 + r^2 - s^2}{2p} \end{aligned}$$

in either

$$\begin{aligned} P_x &= a + \frac{ek}{p} + \frac{f}{p}\sqrt{r^2 - k^2} \\ P_y &= b + \frac{fk}{p} - \frac{e}{p}\sqrt{r^2 - k^2} \end{aligned}$$

or

$$\begin{aligned} P_x &= a + \frac{ek}{p} - \frac{f}{p}\sqrt{r^2 - k^2} \\ P_y &= b + \frac{fk}{p} + \frac{e}{p}\sqrt{r^2 - k^2} \end{aligned}$$

depending on which solution is required. The rest of the work is simply forcing the appropriate expansion and shuffling arguments.

```

706 \cs_new:Npn \draw_point_intersect_circles:nnnnn #1#2#3#4#5
707 {
708   \__draw_point_process:nnn
709     { \__draw_point_intersect_circles_auxi:nnnnnnn {#2} {#4} {#5} }
710     {#1} {#3}
711 }
712 \cs_new:Npn \__draw_point_intersect_circles_auxi:nnnnnnn #1#2#3#4#5#6#7
713 {
714   \__draw_point_intersect_circles_auxii:ffnnnnn
715     { \fp_eval:n {#1} } { \fp_eval:n {#2} } {#4} {#5} {#6} {#7} {#3}
716 }

```

At this stage we have all of the information we need, fully expanded:

```

#1 r
#2 s
#3 a
#4 b
#5 c
#6 d
#7 n

```

Once we evaluate e and f , the co-ordinate (c, d) is no longer required: handy as we will need various intermediate values in the following.

```

717 \cs_new:Npn \__draw_point_intersect_circles_auxii:nnnnnnn #1#2#3#4#5#6#7

```

```

718 {
719   \_draw_point_intersect_circles_auxiii:ffnnnnnn
720   { \fp_eval:n { #5 - #3 } }
721   { \fp_eval:n { #6 - #4 } }
722   {#1} {#2} {#3} {#4} {#7}
723 }
724 \cs_generate_variant:Nn \_draw_point_intersect_circles_auxii:nnnnnnnn { ff }
725 \cs_new:Npn \_draw_point_intersect_circles_auxiii:nnnnnnnn #1#2#3#4#5#6#7
726 {
727   \_draw_point_intersect_circles_auxiv:fnnnnnnnn
728   { \fp_eval:n { sqrt( #1 * #1 + #2 * #2 ) } }
729   {#1} {#2} {#3} {#4} {#5} {#6} {#7}
730 }
731 \cs_generate_variant:Nn \_draw_point_intersect_circles_auxiii:nnnnnnnn { ff }

```

We now have p : we pre-calculate $1/p$ as it is needed a few times and is relatively expensive. We also need r^2 twice so deal with that here too.

```

732 \cs_new:Npn \_draw_point_intersect_circles_auxiv:nnnnnnnn #1#2#3#4#5#6#7#8
733 {
734   \_draw_point_intersect_circles_auxv:ffnnnnnnnn
735   { \fp_eval:n { 1 / #1 } }
736   { \fp_eval:n { #4 * #4 } }
737   {#1} {#2} {#3} {#5} {#6} {#7} {#8}
738 }
739 \cs_generate_variant:Nn \_draw_point_intersect_circles_auxiv:nnnnnnnn { f }
740 \cs_new:Npn \_draw_point_intersect_circles_auxv:nnnnnnnnnn #1#2#3#4#5#6#7#8#9
741 {
742   \_draw_point_intersect_circles_auxvi:fnnnnnnnn
743   { \fp_eval:n { 0.5 * #1 * ( #2 + #3 * #3 - #6 * #6 ) } }
744   {#1} {#2} {#4} {#5} {#7} {#8} {#9}
745 }
746 \cs_generate_variant:Nn \_draw_point_intersect_circles_auxv:nnnnnnnnnn { ff }

```

We now have all of the intermediate values we require, with one division carried out up-front to avoid doing this expensive step twice:

```

#1  $k$ 
#2  $1/p$ 
#3  $r^2$ 
#4  $e$ 
#5  $f$ 
#6  $a$ 
#7  $b$ 
#8  $n$ 

```

There are some final pre-calculations, k/p , $\frac{\sqrt{r^2-k^2}}{p}$ and the usage of n , then we can yield a result.

```

747 \cs_new:Npn \_draw_point_intersect_circles_auxvi:nnnnnnnn #1#2#3#4#5#6#7#8
748 {

```

```

749 \draw_point_intersect_circles_auxvii:fffnmnn
750 { \fp_eval:n { #1 * #2 } }
751 { \int_if_odd:nTF {#8} { 1 } { -1 } }
752 { \fp_eval:n { sqrt ( #3 - #1 * #1 ) * #2 } }
753 {#4} {#5} {#6} {#7}
754 }
755 \cs_generate_variant:Nn \draw_point_intersect_circles_auxvi:nnnnnnnn { f }
756 \cs_new:Npn \draw_point_intersect_circles_auxvii:nnnnnnn #1#2#3#4#5#6#7
757 {
758 \draw_point_to_dim:n
759 { #6 + #4 * #1 + #2 * #3 * #5 , #7 + #5 * #1 + -1 * #2 * #3 * #4 }
760 }
761 \cs_generate_variant:Nn \draw_point_intersect_circles_auxvii:nnnnnnn { fff }

```

3.6 Interpolation on a line (vector) or arc

Simple maths after expansion.

```

\draw_point_interpolate_line:nmn
\draw_point_interpolate_line_aux:nnnnn
\draw_point_interpolate_line_aux:fnnnn
\draw_point_interpolate_line_aux:nnnnnn
\draw_point_interpolate_line_aux:fnnnnn
762 \cs_new:Npn \draw_point_interpolate_line:nnn #1#2#3
763 {
764 \draw_point_process:nnn
765 { \draw_point_interpolate_line_aux:fnnnn { \fp_eval:n {#1} } }
766 {#2} {#3}
767 }
768 \cs_new:Npn \draw_point_interpolate_line_aux:nnnn #1#2#3#4#5
769 {
770 \draw_point_interpolate_line_aux:fnnnnn { \fp_eval:n { 1 - #1 } }
771 {#1} {#2} {#3} {#4} {#5}
772 }
773 \cs_generate_variant:Nn \draw_point_interpolate_line_aux:nnnnn { f }
774 \cs_new:Npn \draw_point_interpolate_line_aux:nnnnnn #1#2#3#4#5#6
775 { \draw_point_to_dim:n { #2 * #3 + #1 * #5 , #2 * #4 + #1 * #6 } }
776 \cs_generate_variant:Nn \draw_point_interpolate_line_aux:nnnnnn { f }

```

Same idea but using the normalised length to obtain the scale factor. The start point is needed twice, so we force evaluation, but the end point is needed only the once.

```

\draw_point_interpolate_distance:nmn
\draw_point_interpolate_distance:nnnnn
\draw_point_interpolate_distance:nnnnnn
\draw_point_interpolate_distance:fnnnnn
777 \cs_new:Npn \draw_point_interpolate_distance:nnn #1#2#3
778 {
779 \draw_point_process:nn
780 { \draw_point_interpolate_distance:nnnn {#1} {#3} }
781 {#2}
782 }
783 \cs_new:Npn \draw_point_interpolate_distance:nnnn #1#2#3#4
784 {
785 \draw_point_process:nn
786 {
787 \draw_point_interpolate_distance:fnnnn
788 { \fp_eval:n {#1} } {#3} {#4}
789 }
790 { \draw_point_unit_vector:n { ( #2 ) - ( #3 , #4 ) } }
791 }
792 \cs_new:Npn \draw_point_interpolate_distance:nnnnn #1#2#3#4#5
793 { \draw_point_to_dim:n { #2 + #1 * #4 , #3 + #1 * #5 } }
794 \cs_generate_variant:Nn \draw_point_interpolate_distance:nnnnn { f }

```

(End definition for `_draw_point_to_dim:n` and others. These functions are documented on page ??.)

```
\draw_point_interpolate_arcaxes:nmnnnnn
raw_point_interpolate_arcaxes_auxi:nnnnnnnnn
raw_point_interpolate_arcaxes_auxii:nnnnnnnnn
raw_point_interpolate_arcaxes_auxiii:nnnnnnnnn
raw_point_interpolate_arcaxes_auxiv:nnnnnnnnn
raw_point_interpolate_arcaxes_auxv:ffnnnnnnn
```

Finding a point on an ellipse arc is relatively easy: find the correct angle between the two given, use the sine and cosine of that angle, apply to the axes. We just have to work a bit with the co-ordinate expansion.

```
795 \cs_new:Npn \draw_point_interpolate_arcaxes:nmnnnnn #1#2#3#4#5#6
796 {
797   \_draw_point_process:nnn
798   {
799     \_draw_point_process:nn
800     { \fp_eval:n {#1} } {#5} {#6} }
801     {#4}
802   }
803   {#2} {#3}
804 }
805 \cs_new:Npn \_draw_point_interpolate_arcaxes_auxi:nnnnnnnnn #1#2#3#4#5#6#7#8#9
806 {
807   \_draw_point_interpolate_arcaxes_auxii:ffnnnnnnnn
808   { \fp_eval:n {#1} } {#2} {#3} {#6} {#7} {#8} {#9} {#4} {#5}
809 }
```

At this stage, the three co-ordinate pairs are fully expanded but somewhat re-ordered:

- #1 p
- #2 θ_1
- #3 θ_2
- #4 x_c
- #5 y_c
- #6 x_{a1}
- #7 y_{a1}
- #8 x_{a2}
- #9 y_{a2}

We are now in a position to find the target angle, and from that the sine and cosine required.

```
810 \cs_new:Npn \_draw_point_interpolate_arcaxes_auxii:nnnnnnnnn #1#2#3#4#5#6#7#8#9
811 {
812   \_draw_point_interpolate_arcaxes_auxiii:ffnnnnnnn
813   { \fp_eval:n { #1 * (#3) + ( 1 - #1 ) * (#2) } }
814   {#4} {#5} {#6} {#7} {#8} {#9}
815 }
816 \cs_generate_variant:Nn \_draw_point_interpolate_arcaxes_auxii:nnnnnnnnn { f }
817 \cs_new:Npn \_draw_point_interpolate_arcaxes_auxiii:nnnnnnn #1#2#3#4#5#6#7
818 {
819   \_draw_point_interpolate_arcaxes_auxiv:ffnnnnnnn
820   { \fp_eval:n { cosd (#1) } }
821   { \fp_eval:n { sind (#1) } }
822   {#2} {#3} {#4} {#5} {#6} {#7}
```

```

823 }
824 \cs_generate_variant:Nn \__draw_point_interpolate_arcaxes_auxiii:nnnnnnn { f }
825 \cs_new:Npn \__draw_point_interpolate_arcaxes_auxiv:nnnnnnnn #1#2#3#4#5#6#7#8
826 {
827   \__draw_point_to_dim:n
828     { #3 + #1 * #5 + #2 * #7 , #4 + #1 * #6 + #2 * #8 }
829 }
830 \cs_generate_variant:Nn \__draw_point_interpolate_arcaxes_auxiv:nnnnnnnn { ff }

```

(End definition for `\draw_point_interpolate_arcaxes:nnnnnn` and others. This function is documented on page ??.)

```

\draw_point_interpolate_curve:nnnnn
\draw_point_interpolate_curve_auxi:nnnnnnnnn
\draw_point_interpolate_curve_auxii:nnnnnnnnn
\draw_point_interpolate_curve_auxiii:fnnnnnnnn
\draw_point_interpolate_curve_auxiiii:nnnnnnn
\draw_point_interpolate_curve_auxiii:fnnnnn
\draw_point_interpolate_curve_auxiv:nnnnnnn
\draw_point_interpolate_curve_auxv:nnw
\draw_point_interpolate_curve_auxv:ffw
\draw_point_interpolate_curve_auxvi:n
\draw_point_interpolate_curve_auxvii:nnnnnnnnn
\draw_point_interpolate_curve_auxviii:nnnnnnn
\draw_point_interpolate_curve_auxviii:ffnnnnn

```

Here we start with a proportion of the curve (p) and four points

1. The initial point (x_1, y_1)
2. The first control point (x_2, y_2)
3. The second control point (x_3, y_3)
4. The final point (x_4, y_4)

The first phase is to expand out all of these values.

```

831 \cs_new:Npn \draw_point_interpolate_curve:nnnnnn #1#2#3#4#5
832 {
833   \__draw_point_process:nnn
834   {
835     \__draw_point_process:nnn
836     { \__draw_point_interpolate_curve_auxi:nnnnnnnnn {#1} }
837     {#4} {#5}
838   }
839   {#2} {#3}
840 }
841 \cs_new:Npn \__draw_point_interpolate_curve_auxi:nnnnnnnnn #1#2#3#4#5#6#7#8#9
842 {
843   \__draw_point_interpolate_curve_auxii:fnnnnnnnn
844   { \fp_eval:n {#1} }
845   {#6} {#7} {#8} {#9} {#2} {#3} {#4} {#5}
846 }

```

At this stage, everything is fully expanded and back in the input order. The approach to finding the required point is iterative. We carry out three phases. In phase one, we need all of the input co-ordinates

$$\begin{aligned}
 x'_1 &= (1-p)x_1 + px_2 \\
 y'_1 &= (1-p)y_1 + py_2 \\
 x'_2 &= (1-p)x_2 + px_3 \\
 y'_2 &= (1-p)y_2 + py_3 \\
 x'_3 &= (1-p)x_3 + px_4 \\
 y'_3 &= (1-p)y_3 + py_4
 \end{aligned}$$

In the second stage, we can drop the final point

$$\begin{aligned}x_1'' &= (1-p)x_1' + px_2' \\y_1'' &= (1-p)y_1' + py_2' \\x_2'' &= (1-p)x_2' + px_3' \\y_2'' &= (1-p)y_2' + py_3'\end{aligned}$$

and for the final stage only need one set of calculations

$$\begin{aligned}P_x &= (1-p)x_1'' + px_2'' \\P_y &= (1-p)y_1'' + py_2''\end{aligned}$$

Of course, this does mean a lot of calculations and expansion!

```

847 \cs_new:Npn \__draw_point_interpolate_curve_auxii:nnnnnnnnn
848   #1#2#3#4#5#6#7#8#9
849   {
850     \__draw_point_interpolate_curve_auxiii:fnnnnn
851     { \fp_eval:n { 1 - #1 } }
852     {#1}
853     { {#2} {#3} } { {#4} {#5} } { {#6} {#7} } { {#8} {#9} }
854   }
855 \cs_generate_variant:Nn \__draw_point_interpolate_curve_auxii:nnnnnnnnn { f }
856 % \begin{macrocode}
857 % We need to do the first cycle, but haven't got enough arguments to keep
858 % everything in play at once. So here we use a bit of argument re-ordering
859 % and a single auxiliary to get the job done.
860 % \begin{macrocode}
861 \cs_new:Npn \__draw_point_interpolate_curve_auxiii:nnnnnn #1#2#3#4#5#6
862   {
863     \__draw_point_interpolate_curve_auxiv:nnnnnn {#1} {#2} #3 #4
864     \__draw_point_interpolate_curve_auxiv:nnnnnn {#1} {#2} #4 #5
865     \__draw_point_interpolate_curve_auxiv:nnnnnn {#1} {#2} #5 #6
866     \prg_do_nothing:
867     \__draw_point_interpolate_curve_auxvi:n { {#1} {#2} }
868   }
869 \cs_generate_variant:Nn \__draw_point_interpolate_curve_auxiii:nnnnnn { f }
870 \cs_new:Npn \__draw_point_interpolate_curve_auxiv:nnnnnn #1#2#3#4#5#6
871   {
872     \__draw_point_interpolate_curve_auxv:ffw
873     { \fp_eval:n { #1 * #3 + #2 * #5 } }
874     { \fp_eval:n { #1 * #4 + #2 * #6 } }
875   }
876 \cs_new:Npn \__draw_point_interpolate_curve_auxv:nnw
877   #1#2#3 \prg_do_nothing: #4#5
878   {
879     #3
880     \prg_do_nothing:
881     #4 { #5 {#1} {#2} }
882   }
883 \cs_generate_variant:Nn \__draw_point_interpolate_curve_auxv:nnw { ff }
884 % \begin{macrocode}
885 % Get the arguments back into the right places and to the second and
886 % third cycles directly.

```

```

887 % \begin{macrocode}
888 \cs_new:Npn \__draw_point_interpolate_curve_auxvi:n #1
889 { \__draw_point_interpolate_curve_auxvii:nnnnnnn #1 }
890 \cs_new:Npn \__draw_point_interpolate_curve_auxvii:nnnnnnn #1#2#3#4#5#6#7#8
891 {
892   \__draw_point_interpolate_curve_auxviii:ffffnn
893   { \fp_eval:n { #1 * #5 + #2 * #3 } }
894   { \fp_eval:n { #1 * #6 + #2 * #4 } }
895   { \fp_eval:n { #1 * #7 + #2 * #5 } }
896   { \fp_eval:n { #1 * #8 + #2 * #6 } }
897   {#1} {#2}
898 }
899 \cs_new:Npn \__draw_point_interpolate_curve_auxviii:nnnnnn #1#2#3#4#5#6
900 {
901   \__draw_point_to_dim:n
902   { #5 * #3 + #6 * #1 , #5 * #4 + #6 * #2 }
903 }
904 \cs_generate_variant:Nn \__draw_point_interpolate_curve_auxviii:nnnnnn { ffff }

```

(End definition for `\draw_point_interpolate_curve:nnnn` and others. These functions are documented on page ??.)

3.7 Vector support

As well as co-ordinates relative to the drawing

```

\l__draw_xvec_x_dim Base vectors to map to the underlying two-dimensional drawing space.
\l__draw_xvec_y_dim
\l__draw_yvec_x_dim
\l__draw_yvec_y_dim
\l__draw_zvec_x_dim
\l__draw_zvec_y_dim
905 \dim_new:N \l__draw_xvec_x_dim
906 \dim_new:N \l__draw_xvec_y_dim
907 \dim_new:N \l__draw_yvec_x_dim
908 \dim_new:N \l__draw_yvec_y_dim
909 \dim_new:N \l__draw_zvec_x_dim
910 \dim_new:N \l__draw_zvec_y_dim

```

(End definition for `\l__draw_xvec_x_dim` and others.)

```

\draw_xvec:n Calculate the underlying position and store it.
\draw_yvec:n
\draw_zvec:n
__draw_vec:nn
__draw_vec:nnn
911 \cs_new_protected:Npn \draw_xvec:n #1
912 { \__draw_vec:nn { x } {#1} }
913 \cs_new_protected:Npn \draw_yvec:n #1
914 { \__draw_vec:nn { y } {#1} }
915 \cs_new_protected:Npn \draw_zvec:n #1
916 { \__draw_vec:nn { z } {#1} }
917 \cs_new_protected:Npn \__draw_vec:nn #1#2
918 {
919   \__draw_point_process:nn { \__draw_vec:nnn {#1} } {#2}
920 }
921 \cs_new_protected:Npn \__draw_vec:nnn #1#2#3
922 {
923   \dim_set:cn { l__draw_ #1 vec_x_dim } {#2}
924   \dim_set:cn { l__draw_ #1 vec_y_dim } {#3}
925 }

```

(End definition for `\draw_xvec:n` and others. These functions are documented on page ??.)

Initialise the vectors.

```
926 \draw_xvec:n { 1cm , 0cm }
927 \draw_yvec:n { 0cm , 1cm }
928 \draw_zvec:n { -0.385cm , -0.385cm }
```

```
\draw_point_vec:nn Force a single evaluation of each factor, then use these to work out the underlying point.
__draw_point_vec:nn 929 \cs_new:Npn \draw_point_vec:nn #1#2
__draw_point_vec:ff 930 { \__draw_point_vec:ff { \fp_eval:n {#1} } { \fp_eval:n {#2} } }
\draw_point_vec:nnn 931 \cs_new:Npn \__draw_point_vec:nn #1#2
__draw_point_vec:nnn 932 {
__draw_point_vec:fff 933   \__draw_point_to_dim:n
934   {
935     #1 * \l__draw_xvec_x_dim + #2 * \l__draw_yvec_x_dim ,
936     #1 * \l__draw_xvec_y_dim + #2 * \l__draw_yvec_y_dim
937   }
938 }
939 \cs_generate_variant:Nn \__draw_point_vec:nn { ff }
940 \cs_new:Npn \draw_point_vec:nnn #1#2#3
941 {
942   \__draw_point_vec:fff
943   { \fp_eval:n {#1} } { \fp_eval:n {#2} } { \fp_eval:n {#3} }
944 }
945 \cs_new:Npn \__draw_point_vec:nnn #1#2#3
946 {
947   \__draw_point_to_dim:n
948   {
949     #1 * \l__draw_xvec_x_dim
950     + #2 * \l__draw_yvec_x_dim
951     + #3 * \l__draw_zvec_x_dim
952   ,
953     #1 * \l__draw_xvec_y_dim
954     + #2 * \l__draw_yvec_y_dim
955     + #3 * \l__draw_zvec_y_dim
956   }
957 }
958 \cs_generate_variant:Nn \__draw_point_vec:nnn { fff }
```

(End definition for `\draw_point_vec:nn` and others. These functions are documented on page ??.)

```
\draw_point_vec_polar:nn Much the same as the core polar approach.
\draw_point_vec_polar:nnn 959 \cs_new:Npn \draw_point_vec_polar:nn #1#2
__draw_point_vec_polar:nnn 960 { \draw_point_vec_polar:nnn {#1} {#2} {#2} }
__draw_point_vec_polar:fnn 961 \cs_new:Npn \draw_point_vec_polar:nnn #1#2#3
962 { \__draw_draw_vec_polar:fnn { \fp_eval:n {#1} } {#2} {#3} }
963 \cs_new:Npn \__draw_draw_vec_polar:nnn #1#2#3
964 {
965   \__draw_point_to_dim:n
966   {
967     cosd(#1) * (#2) * \l__draw_xvec_x_dim ,
968     sind(#1) * (#3) * \l__draw_yvec_y_dim
969   }
970 }
971 \cs_generate_variant:Nn \__draw_draw_vec_polar:nnn { f }
```

(End definition for `\draw_point_vec_polar:nn`, `\draw_point_vec_polar:nnn`, and `__draw_point_vec_polar:nnn`. These functions are documented on page ??.)

3.8 Transformations

`\draw_point_transform:n` Applies a transformation matrix to a point: see `l3draw-transforms` for the business end. Where possible, we avoid the relatively expensive multiplication step.

```

972 \cs_new:Npn \draw_point_transform:n #1
973   {
974     \__draw_point_process:nn
975     { \__draw_point_transform:nn } {#1}
976   }
977 \cs_new:Npn \__draw_point_transform:nn #1#2
978   {
979     \bool_if:NTF \l__draw_matrix_active_bool
980     {
981       \__draw_point_to_dim:n
982       {
983         (
984           \l__draw_matrix_a_fp * #1
985           + \l__draw_matrix_c_fp * #2
986           + \l__draw_xshift_dim
987         )
988         ,
989         (
990           \l__draw_matrix_b_fp * #1
991           + \l__draw_matrix_d_fp * #2
992           + \l__draw_yshift_dim
993         )
994       }
995     }
996     {
997       \__draw_point_to_dim:n
998       {
999         (#1, #2)
1000         + ( \l__draw_xshift_dim , \l__draw_yshift_dim )
1001       }
1002     }
1003   }

```

(End definition for `\draw_point_transform:n` and `__draw_point_transform:nn`. This function is documented on page ??.)

`__draw_point_transform_noshift:n` A version with no shift: used for internal purposes.

```

1004 \cs_new:Npn \__draw_point_transform_noshift:n #1
1005   {
1006     \__draw_point_process:nn
1007     { \__draw_point_transform_noshift:nn } {#1}
1008   }
1009 \cs_new:Npn \__draw_point_transform_noshift:nn #1#2
1010   {
1011     \bool_if:NTF \l__draw_matrix_active_bool
1012     {
1013       \__draw_point_to_dim:n

```

```

1014     {
1015     (
1016         \l__draw_matrix_a_fp * #1
1017     + \l__draw_matrix_c_fp * #2
1018     )
1019     ,
1020     (
1021         \l__draw_matrix_b_fp * #1
1022     + \l__draw_matrix_d_fp * #2
1023     )
1024     }
1025     }
1026     { \__draw_point_to_dim:n { (#1, #2) } }
1027     }

```

(End definition for `__draw_point_transform_noshift:n` and `__draw_point_transform_noshift:nn`.)

```
1028 </initex | package>
```

4 I3draw-scopes implementation

```
1029 <*initex | package>
```

```
1030 <@@=draw>
```

4.1 Drawing environment

`\g__draw_xmax_dim` Used to track the overall (official) size of the image created: may not actually be the natural size of the content.

```

\g__draw_xmin_dim
\g__draw_ymax_dim
\g__draw_ymin_dim
1031 \dim_new:N \g__draw_xmax_dim
1032 \dim_new:N \g__draw_xmin_dim
1033 \dim_new:N \g__draw_ymax_dim
1034 \dim_new:N \g__draw_ymin_dim

```

(End definition for `\g__draw_xmax_dim` and others.)

`\l_draw_bb_update_bool` Flag to indicate that a path (or similar) should update the bounding box of the drawing.

```
1035 \bool_new:N \l_draw_bb_update_bool
```

(End definition for `\l_draw_bb_update_bool`. This variable is documented on page ??.)

`\l__draw_main_box` Box for setting the drawing.

```
1036 \box_new:N \l__draw_main_box
```

(End definition for `\l__draw_main_box`.)

`\g__draw_id_int` The drawing number.

```
1037 \int_new:N \g__draw_id_int
```

(End definition for `\g__draw_id_int`.)

`__draw_reset_bb:` A simple auxiliary.

```
1038 \cs_new_protected:Npn \__draw_reset_bb:
1039 {
1040   \dim_gset:Nn \g__draw_xmax_dim { -\c_max_dim }
1041   \dim_gset:Nn \g__draw_xmin_dim { \c_max_dim }
1042   \dim_gset:Nn \g__draw_ymax_dim { -\c_max_dim }
1043   \dim_gset:Nn \g__draw_ymin_dim { \c_max_dim }
1044 }
```

(End definition for `__draw_reset_bb:`.)

`\draw_begin:` Drawings are created by setting them into a box, then adjusting the box before inserting into the surroundings. Color is set here using the drawing mechanism largely as it then sets up the internal data structures. It may be that a coffin construct is better here in the longer term: that may become clearer as the code is completed. As we need to avoid any insertion of baseline skips, the outer box here has to be an `hbox`.

`\draw_end:`

```
1045 \cs_new_protected:Npn \draw_begin:
1046 {
1047   \group_begin:
1048   \int_gincr:N \g__draw_id_int
1049   \hbox_set:Nw \l__draw_main_box
1050   \driver_draw_begin:
1051   \__draw_reset_bb:
1052   \__draw_path_reset_limits:
1053   \bool_set_true:N \l_draw_bb_update_bool
1054   \draw_transform_matrix_reset:
1055   \draw_transform_shift_reset:
1056   \__draw_softpath_clear:
1057   \draw_linewidth:n { \l_draw_default_linewidth_dim }
1058   \draw_color:n { . }
1059 }
1060 \cs_new_protected:Npn \draw_end:
1061 {
1062   \driver_draw_end:
1063   \hbox_set_end:
1064   \dim_compare:nNnT \g__draw_xmin_dim = \c_max_dim
1065   {
1066     \dim_gzero:N \g__draw_xmax_dim
1067     \dim_gzero:N \g__draw_xmin_dim
1068     \dim_gzero:N \g__draw_ymax_dim
1069     \dim_gzero:N \g__draw_ymin_dim
1070   }
1071   \hbox_set:Nn \l__draw_main_box
1072   {
1073     \skip_horizontal:n { -\g__draw_xmin_dim }
1074     \box_move_down:nn { \g__draw_ymin_dim }
1075     { \box_use_drop:N \l__draw_main_box }
1076   }
1077   \box_set_ht:Nn \l__draw_main_box
1078   { \g__draw_ymax_dim - \g__draw_ymin_dim }
1079   \box_set_dp:Nn \l__draw_main_box { Opt }
1080   \box_set_wd:Nn \l__draw_main_box
1081   { \g__draw_xmax_dim - \g__draw_xmin_dim }
1082   \mode_leave_vertical:
```

```

1083     \box_use_drop:N \l__draw_main_box
1084     \group_end:
1085 }

```

(End definition for `\draw_begin:` and `\draw_end:`. These functions are documented on page ??.)

4.2 Scopes

```

\l__draw_linewidth_dim Storage for local variables.
\l__draw_fill_color_tl 1086 \dim_new:N \l__draw_linewidth_dim
\l__draw_stroke_color_tl 1087 \tl_new:N \l__draw_fill_color_tl
1088 \tl_new:N \l__draw_stroke_color_tl

```

(End definition for `\l__draw_linewidth_dim`, `\l__draw_fill_color_tl`, and `\l__draw_stroke_color_tl`.)

`\draw_scope_begin:` As well as the graphics (and T_EX) scope, also deal with global data structures.

```

\draw_scope_begin: 1089 \cs_new_protected:Npn \draw_scope_begin:
1090 {
1091     \driver_draw_scope_begin:
1092     \group_begin:
1093         \dim_set_eq:NN \l__draw_linewidth_dim \g__draw_linewidth_dim
1094         \draw_path_scope_begin:
1095     }
1096 \cs_new_protected:Npn \draw_scope_end:
1097 {
1098     \draw_path_scope_end:
1099     \dim_gset_eq:NN \g__draw_linewidth_dim \l__draw_linewidth_dim
1100     \group_end:
1101     \driver_draw_scope_end:
1102 }

```

(End definition for `\draw_scope_begin:`. This function is documented on page ??.)

```

\l__draw_xmax_dim Storage for the bounding box.
\l__draw_xmin_dim 1103 \dim_new:N \l__draw_xmax_dim
\l__draw_ymax_dim 1104 \dim_new:N \l__draw_xmin_dim
\l__draw_ymin_dim 1105 \dim_new:N \l__draw_ymax_dim
1106 \dim_new:N \l__draw_ymin_dim

```

(End definition for `\l__draw_xmax_dim` and others.)

`__draw_scope_bb_begin:` The bounding box is simple: a straight group-based save and restore approach.

```

\__draw_scope_bb_end: 1107 \cs_new_protected:Npn \__draw_scope_bb_begin:
1108 {
1109     \group_begin:
1110         \dim_set_eq:NN \l__draw_xmax_dim \g__draw_xmax_dim
1111         \dim_set_eq:NN \l__draw_xmin_dim \g__draw_xmin_dim
1112         \dim_set_eq:NN \l__draw_ymax_dim \g__draw_ymax_dim
1113         \dim_set_eq:NN \l__draw_ymin_dim \g__draw_ymin_dim
1114         \__draw_reset_bb:
1115     }
1116 \cs_new_protected:Npn \__draw_scope_bb_end:
1117 {
1118     \dim_gset_eq:NN \g__draw_xmax_dim \l__draw_xmax_dim

```

```

1119     \dim_gset_eq:NN \g__draw_xmin_dim \l__draw_xmin_dim
1120     \dim_gset_eq:NN \g__draw_ymax_dim \l__draw_ymax_dim
1121     \dim_gset_eq:NN \g__draw_ymin_dim \l__draw_ymin_dim
1122   \group_end:
1123 }

```

(End definition for `__draw_scope_bb_begin:` and `__draw_scope_bb_end:.`)

`\draw_suspend_begin:` Suspend all parts of a drawing.

```

\draw_suspend_end:
1124 \cs_new_protected:Npn \draw_suspend_begin:
1125 {
1126   \__draw_scope_bb_begin:
1127   \draw_path_scope_begin:
1128   \draw_transform_matrix_reset:
1129   \draw_transform_shift_reset:
1130 }
1131 \cs_new_protected:Npn \draw_suspend_end:
1132 {
1133   \draw_path_scope_end:
1134   \__draw_scope_bb_end:
1135 }

```

(End definition for `\draw_suspend_begin:` and `\draw_suspend_end:.` These functions are documented on page ??.)

```

1136 </initex | package>

```

5 l3draw-softpath implementation

```

1137 <*initex | package>

```

```

1138 <@@=draw>

```

5.1 Managing soft paths

There are two linked aims in the code here. The most significant is to provide a way to modify paths, for example to shorten the ends or round the corners. This means that the path cannot be written piecemeal as specials, but rather needs to be held in macros. The second aspect that follows from this is performance: simply adding to a single macro a piece at a time will have poor performance as the list gets long. Paths need to be global (as specials are), so we cannot use `l3tl-build` or a similar approach. Instead, we use the same idea as `pgf`: use a series of buffer macros such that in most cases we don't add tokens to the main list. This will get slow only for *enormous* paths.

Each marker (operation) token takes two arguments, which makes processing more straight-forward. As such, some operations have dummy arguments, whilst others have to be split over several tokens. As the code here is at a low level, all dimension arguments are assumed to be explicit and fully-expanded.

`\g__draw_softpath_main_tl` The soft path itself.

```

\g__draw_softpath_main_tl
\g__draw_softpath_buffer_a_tl
\g__draw_softpath_buffer_b_tl
1139 \tl_new:N \g__draw_softpath_main_tl
1140 \tl_new:N \g__draw_softpath_buffer_a_tl
1141 \tl_new:N \g__draw_softpath_buffer_b_tl

```

(End definition for `\g__draw_softpath_main_tl`, `\g__draw_softpath_buffer_a_tl`, and `\g__draw_softpath_buffer_b_tl`.)

```

\g__draw_softpath_buffer_a_int Tracking data.
\g__draw_softpath_buffer_b_int 1142 \int_new:N \g__draw_softpath_buffer_a_int
1143 \int_new:N \g__draw_softpath_buffer_b_int

(End definition for \g__draw_softpath_buffer_a_int and \g__draw_softpath_buffer_b_int.)

\g__draw_softpath_corners_bool Allow for optimised path use.
1144 \bool_new:N \g__draw_softpath_corners_bool

(End definition for \g__draw_softpath_corners_bool.)

\__draw_softpath_add:n The softpath itself is quite simple. We use three token lists to hold the data: two buffers
\__draw_softpath_add:x of limited length, and the main list of arbitrary size. Most of the time this will mean
\__draw_softpath_concat:n that we don't add to the full list, so performance will be acceptable.
\__draw_softpath_reset_buffers: 1145 \cs_new_protected:Npn \__draw_softpath_add:n #1
1146 {
1147   \int_compare:nNnTF \g__draw_softpath_buffer_a_int < { 40 }
1148   {
1149     \int_gincr:N \g__draw_softpath_buffer_a_int
1150     \tl_gput_right:Nn \g__draw_softpath_buffer_a_tl {#1}
1151   }
1152   {
1153     \int_compare:nNnTF \g__draw_softpath_buffer_b_int < { 40 }
1154     {
1155       \int_gincr:N \g__draw_softpath_buffer_b_int
1156       \tl_gset:Nx \g__draw_softpath_buffer_b_tl
1157       {
1158         \exp_not:V \g__draw_softpath_buffer_b_tl
1159         \exp_not:V \g__draw_softpath_buffer_a_tl
1160         \exp_not:n {#1}
1161       }
1162       \int_gzero:N \g__draw_softpath_buffer_a_int
1163       \tl_gclear:N \g__draw_softpath_buffer_a_tl
1164     }
1165     { \__draw_softpath_concat:n {#1} }
1166   }
1167 }
1168 \cs_generate_variant:Nn \__draw_softpath_add:n { x }
1169 \cs_new_protected:Npn \__draw_softpath_concat:n #1
1170 {
1171   \tl_gset:Nx \g__draw_softpath_main_tl
1172   {
1173     \exp_not:V \g__draw_softpath_main_tl
1174     \exp_not:V \g__draw_softpath_buffer_b_tl
1175     \exp_not:V \g__draw_softpath_buffer_a_tl
1176     \exp_not:n {#1}
1177   }
1178   \__draw_softpath_reset_buffers:
1179 }
1180 \cs_new_protected:Npn \__draw_softpath_reset_buffers:
1181 {
1182   \int_gzero:N \g__draw_softpath_buffer_a_int
1183   \tl_gclear:N \g__draw_softpath_buffer_a_tl
1184   \int_gzero:N \g__draw_softpath_buffer_b_int

```

```

1185 \tl_gclear:N \g__draw_softpath_buffer_b_tl
1186 }

```

(End definition for `__draw_softpath_add:n`, `__draw_softpath_concat:n`, and `__draw_softpath_reset_buffers:.`)

`__draw_softpath_use:` Using and clearing is trivial.

```

\__draw_softpath_clear: 1187 \cs_new_protected:Npn \__draw_softpath_use:
\__draw_softpath_use_clear: 1188 {
1189   \g__draw_softpath_main_tl
1190   \g__draw_softpath_buffer_b_tl
1191   \g__draw_softpath_buffer_a_tl
1192 }
1193 \cs_new_protected:Npn \__draw_softpath_clear:
1194 {
1195   \tl_gclear:N \g__draw_softpath_main_tl
1196   \tl_gclear:N \g__draw_softpath_buffer_a_tl
1197   \tl_gclear:N \g__draw_softpath_buffer_b_tl
1198   \bool_gset_false:N \g__draw_softpath_corners_bool
1199 }
1200 \cs_new_protected:Npn \__draw_softpath_use_clear:
1201 {
1202   \__draw_softpath_use:
1203   \__draw_softpath_clear:
1204 }

```

(End definition for `__draw_softpath_use:`, `__draw_softpath_clear:`, and `__draw_softpath_use_clear:.`)

`\g__draw_softpath_lastx_dim` For tracking the end of the path (to close it).

```

\g__draw_softpath_lasty_dim 1205 \dim_new:N \g__draw_softpath_lastx_dim
1206 \dim_new:N \g__draw_softpath_lasty_dim

```

(End definition for `\g__draw_softpath_lastx_dim` and `\g__draw_softpath_lasty_dim`.)

`\g__draw_softpath_move_bool` Track if moving a point should update the close position.

```

1207 \bool_new:N \g__draw_softpath_move_bool
1208 \bool_gset_true:N \g__draw_softpath_move_bool

```

(End definition for `\g__draw_softpath_move_bool`.)

`__draw_softpath_curveto:nmnnnn` The various parts of a path expressed as the appropriate soft path functions.

```

\__draw_softpath_lineto:nn 1209 \cs_new_protected:Npn \__draw_softpath_closepath:
\__draw_softpath_moveto:nn 1210 {
  \__draw_softpath_add:x
  \__draw_softpath_roundpoint:nn 1211 {
  \__draw_softpath_roundpoint:VV 1212   \__draw_softpath_close_op:nn
1213   { \dim_use:N \g__draw_softpath_lastx_dim }
1214   { \dim_use:N \g__draw_softpath_lasty_dim }
1215   }
1216 }
1217 }
1218 \cs_new_protected:Npn \__draw_softpath_curveto:nmnnnn #1#2#3#4#5#6
1219 {
1220   \__draw_softpath_add:n
1221   {

```

```

1222     \_draw_softpath_curveto_opi:nn {#1} {#2}
1223     \_draw_softpath_curveto_opii:nn {#3} {#4}
1224     \_draw_softpath_curveto_opiii:nn {#5} {#6}
1225   }
1226 }
1227 \cs_new_protected:Npn \_draw_softpath_lineto:nn #1#2
1228 {
1229   \_draw_softpath_add:n
1230   { \_draw_softpath_lineto_op:nn {#1} {#2} }
1231 }
1232 \cs_new_protected:Npn \_draw_softpath_moveto:nn #1#2
1233 {
1234   \_draw_softpath_add:n
1235   { \_draw_softpath_moveto_op:nn {#1} {#2} }
1236   \bool_if:NT \g__draw_softpath_move_bool
1237   {
1238     \dim_gset:Nn \g__draw_softpath_lastx_dim {#1}
1239     \dim_gset:Nn \g__draw_softpath_lasty_dim {#2}
1240   }
1241 }
1242 \cs_new_protected:Npn \_draw_softpath_rectangle:nmmm #1#2#3#4
1243 {
1244   \_draw_softpath_add:n
1245   {
1246     \_draw_softpath_rectangle_opi:nn {#1} {#2}
1247     \_draw_softpath_rectangle_opii:nn {#3} {#4}
1248   }
1249 }
1250 \cs_new_protected:Npn \_draw_softpath_roundpoint:nn #1#2
1251 {
1252   \_draw_softpath_add:n
1253   { \_draw_softpath_roundpoint_op:nn {#1} {#2} }
1254   \bool_gset_true:N \g__draw_softpath_corners_bool
1255 }
1256 \cs_generate_variant:Nn \_draw_softpath_roundpoint:nn { VV }

```

(End definition for _draw_softpath_curveto:nmmmm and others.)

_draw_softpath_close_op:nn The markers for operations: all the top-level ones take two arguments. The support tokens for curves have to be different in meaning to a round point, hence being quark-like.

```

\_draw_softpath_curveto_opi:nn
\_draw_softpath_curveto_opii:nn
\_draw_softpath_curveto_opiii:nn 1257 \cs_new_protected:Npn \_draw_softpath_close_op:nn #1#2
\_draw_softpath_lineto_op:nn 1258 { \driver_draw_closepath: }
\_draw_softpath_moveto_op:nn 1259 \cs_new_protected:Npn \_draw_softpath_curveto_opi:nn #1#2
\_draw_softpath_roundpoint_op:nn 1260 { \_draw_softpath_curveto_opi:nnNnnNnn {#1} {#2} }
\_draw_softpath_rectangle_opi:nn 1261 \cs_new_protected:Npn \_draw_softpath_curveto_opi:nnNnnNnn #1#2#3#4#5#6#7#8
\_draw_softpath_rectangle_opii:nn 1262 { \driver_draw_curveto:nmmmm {#1} {#2} {#4} {#5} {#7} {#8} }
\_draw_softpath_curveto_opi:nnNnnNnn 1263 \cs_new_protected:Npn \_draw_softpath_curveto_opii:nn #1#2
\_draw_softpath_rectangle_opi:nnNnn 1264 { \_draw_softpath_curveto_opii:nn }
1265 \cs_new_protected:Npn \_draw_softpath_curveto_opiii:nn #1#2
1266 { \_draw_softpath_curveto_opiii:nn }
1267 \cs_new_protected:Npn \_draw_softpath_lineto_op:nn #1#2
1268 { \driver_draw_lineto:nn {#1} {#2} }
1269 \cs_new_protected:Npn \_draw_softpath_moveto_op:nn #1#2

```

```

1270 { \driver_draw_moveto:nn {#1} {#2} }
1271 \cs_new_protected:Npn \__draw_softpath_roundpoint_op:nn #1#2 { }
1272 \cs_new_protected:Npn \__draw_softpath_rectangle_opi:nn #1#2
1273 { \__draw_softpath_rectangle_opi:nnNnn {#1} {#2} }
1274 \cs_new_protected:Npn \__draw_softpath_rectangle_opi:nnNnn #1#2#3#4#5
1275 { \driver_draw_rectangle:nnnn {#1} {#2} {#4} {#5} }
1276 \cs_new_protected:Npn \__draw_softpath_rectangle_opii:nn #1#2 { }

```

(End definition for `__draw_softpath_close_op:nn` and others.)

5.2 Rounding soft path corners

The aim here is to find corner rounding points and to replace them with arcs of appropriate length. The approach is exactly that in `pgf`: step through, find the corners, find the supporting data, do the rounding.

`\l__draw_softpath_main_tl` For constructing the updated path.

```
1277 \tl_new:N \l__draw_softpath_main_tl
```

(End definition for `\l__draw_softpath_main_tl`.)

`\l__draw_softpath_part_tl` Data structures.

```
1278 \tl_new:N \l__draw_softpath_part_tl
1279 \tl_new:N \l__draw_softpath_curve_end_tl
```

(End definition for `\l__draw_softpath_part_tl`.)

`\l__draw_softpath_lastx_fp` Position tracking: the token list data may be entirely empty or set to a co-ordinate.

```

\l__draw_softpath_lasty_fp 1280 \fp_new:N \l__draw_softpath_lastx_fp
\l__draw_softpath_corneri_dim 1281 \fp_new:N \l__draw_softpath_lasty_fp
\l__draw_softpath_cornerii_dim 1282 \dim_new:N \l__draw_softpath_corneri_dim
\l__draw_softpath_first_tl 1283 \dim_new:N \l__draw_softpath_cornerii_dim
\l__draw_softpath_move_tl 1284 \tl_new:N \l__draw_softpath_first_tl
1285 \tl_new:N \l__draw_softpath_move_tl

```

(End definition for `\l__draw_softpath_lastx_fp` and others.)

`\c__draw_softpath_arc_fp` The magic constant.

```
1286 \fp_const:Nn \c__draw_softpath_arc_fp { 4/3 * (sqrt(2) - 1) }
```

(End definition for `\c__draw_softpath_arc_fp`.)

`__draw_softpath_round_corners:` Rounding corners on a path means going through the entire path and adjusting it. As such, we avoid this entirely if we know there are no corners to deal with. Assuming there is work to do, we recover the existing path and start a loop.

```

\__draw_softpath_round_loop:Nnn 1287 \cs_new_protected:Npn \__draw_softpath_round_corners:
\__draw_softpath_round_action:nn 1288 {
\__draw_softpath_round_action:Nnn 1289   \bool_if:NT \g__draw_softpath_corners_bool
\__draw_softpath_round_action_curveto:NnnNnn 1290   {
\__draw_softpath_round_action_close: 1291     \group_begin:
\__draw_softpath_round_lookahead:NnnNnn 1292     \tl_clear:N \l__draw_softpath_main_tl
\__draw_softpath_round_roundpoint:NnnNnnNnn 1293     \tl_clear:N \l__draw_softpath_part_tl
\__draw_softpath_round_calc:nnnNnn 1294     \fp_zero:N \l__draw_softpath_lastx_fp
\__draw_softpath_round_calc:nnnnnn 1295     \fp_zero:N \l__draw_softpath_lasty_fp
\__draw_softpath_round_calc:fVnnnn 1296     \tl_clear:N \l__draw_softpath_first_tl
\__draw_softpath_round_calc:nnnnw
\__draw_softpath_round_close:nn
\__draw_softpath_round_close:w

```

`__draw_softpath_round_end:`

```

1297         \tl_clear:N \l__draw_softpath_move_tl
1298         \__draw_softpath_concat:n { }
1299         \exp_after:wN \__draw_softpath_round_loop:Nnn
1300         \g__draw_softpath_main_tl
1301         \q_recursion_tail ? ?
1302         \q_recursion_stop
1303     \group_end:
1304 }
1305 \bool_gset_false:N \g__draw_softpath_corners_bool
1306 }

```

The loop can take advantage of the fact that all soft path operations are made up of a token followed by two arguments. At this stage, there is a simple split: have we round a round point. If so, is there any actual rounding to be done: if the arcs have come through zero, just ignore it. In cases where we are not at a corner, we simply move along the path, allowing for any new part starting due to a moveto.

```

1307 \cs_new_protected:Npn \__draw_softpath_round_loop:Nnn #1#2#3
1308 {
1309     \quark_if_recursion_tail_stop_do:Nn #1 { \__draw_softpath_round_end: }
1310     \token_if_eq_meaning:NNTF #1 \__draw_softpath_roundpoint_op:nn
1311     { \__draw_softpath_round_action:nn {#2} {#3} }
1312     {
1313         \tl_if_empty:NT \l__draw_softpath_first_tl
1314         { \tl_set:Nn \l__draw_softpath_first_tl { {#2} {#3} } }
1315         \fp_set:Nn \l__draw_softpath_lastx_fp {#2}
1316         \fp_set:Nn \l__draw_softpath_lasty_fp {#3}
1317         \token_if_eq_meaning:NNTF #1 \__draw_softpath_moveto_op:nn
1318         {
1319             \tl_put_right:No \l__draw_softpath_main_tl
1320             \l__draw_softpath_move_tl
1321             \tl_put_right:No \l__draw_softpath_main_tl
1322             \l__draw_softpath_part_tl
1323             \tl_set:Nn \l__draw_softpath_move_tl { #1 {#2} {#3} }
1324             \tl_clear:N \l__draw_softpath_first_tl
1325             \tl_clear:N \l__draw_softpath_part_tl
1326         }
1327         { \tl_put_right:Nn \l__draw_softpath_part_tl { #1 {#2} {#3} } }
1328         \__draw_softpath_round_loop:Nnn
1329     }
1330 }
1331 \cs_new_protected:Npn \__draw_softpath_round_action:nn #1#2
1332 {
1333     \dim_set:Nn \l__draw_softpath_corneri_dim {#1}
1334     \dim_set:Nn \l__draw_softpath_cornerii_dim {#2}
1335     \bool_lazy_and:nnTF
1336     { \dim_compare_p:nNn \l__draw_softpath_corneri_dim = { Opt } }
1337     { \dim_compare_p:nNn \l__draw_softpath_cornerii_dim = { Opt } }
1338     { \__draw_softpath_round_loop:Nnn }
1339     { \__draw_softpath_round_action:Nnn }
1340 }

```

We now have a round point to work on and have grabbed the next item in the path. There are only a few cases where we have to do anything. Each of them is picked up by looking for the appropriate action.

```

1341 \cs_new_protected:Npn \__draw_softpath_round_action:Nnn #1#2#3
1342 {
1343   \tl_if_empty:NT \l__draw_softpath_first_tl
1344   { \tl_set:Nn \l__draw_softpath_first_tl { {#2} {#3} } }
1345   \token_if_eq_meaning:NNTF #1 \__draw_softpath_curveto_opi:nn
1346   { \__draw_softpath_round_action_curveto:NnnNnn }
1347   {
1348     \token_if_eq_meaning:NNTF #1 \__draw_softpath_close_op:nn
1349     { \__draw_softpath_round_action_close: }
1350     {
1351       \token_if_eq_meaning:NNTF #1 \__draw_softpath_lineto_op:nn
1352       { \__draw_softpath_round_lookahead:NnnNnn }
1353       { \__draw_softpath_round_loop:Nnn }
1354     }
1355   }
1356   #1 {#2} {#3}
1357 }

```

For a curve, we collect the two control points then move on to grab the end point and add the curve there: the second control point becomes our starter.

```

1358 \cs_new_protected:Npn \__draw_softpath_round_action_curveto:NnnNnn
1359   #1#2#3#4#5#6
1360 {
1361   \tl_put_right:Nn \l__draw_softpath_part_tl
1362   { #1 {#2} {#3} #4 {#5} {#6} }
1363   \fp_set:Nn \l__draw_softpath_lastx_fp {#5}
1364   \fp_set:Nn \l__draw_softpath_lasty_fp {#6}
1365   \__draw_softpath_round_lookahead:NnnNnn
1366 }
1367 \cs_new_protected:Npn \__draw_softpath_round_action_close:
1368 {
1369   \bool_lazy_and:nnTF
1370   { ! \tl_if_empty_p:N \l__draw_softpath_first_tl }
1371   { ! \tl_if_empty_p:N \l__draw_softpath_move_tl }
1372   {
1373     \exp_after:wN \__draw_softpath_round_close:nn
1374     \l__draw_softpath_first_tl
1375   }
1376   { \__draw_softpath_round_loop:Nnn }
1377 }

```

At this stage we have a current (sub)operation (#1) and the next operation (#4), and can therefore decide whether to round or not. In the case of yet another rounding marker, we have to look a bit further ahead.

```

1378 \cs_new_protected:Npn \__draw_softpath_round_lookahead:NnnNnn #1#2#3#4#5#6
1379 {
1380   \bool_lazy_any:nTF
1381   {
1382     { \token_if_eq_meaning_p:NN #4 \__draw_softpath_lineto_op:nn }
1383     { \token_if_eq_meaning_p:NN #4 \__draw_softpath_curveto_opi:nn }
1384     { \token_if_eq_meaning_p:NN #4 \__draw_softpath_close_op:nn }
1385   }
1386   {
1387     \__draw_softpath_round_calc:nnnNnn
1388     \__draw_softpath_round_loop:Nnn {#5} {#6}

```

```

1389     }
1390     {
1391     \token_if_eq_meaning:NNTF #4 \__draw_softpath_roundpoint_op:nn
1392     { \__draw_softpath_round_roundpoint:NnnNnnNnn }
1393     { \__draw_softpath_round_loop:Nnn }
1394     }
1395     #1 {#2} {#3}
1396     #4 {#5} {#6}
1397   }
1398 \cs_new_protected:Npn \__draw_softpath_round_roundpoint:NnnNnnNnn
1399 #1#2#3#4#5#6#7#8#9
1400 {
1401   \__draw_softpath_round_calc:nnnNnn
1402   \__draw_softpath_round_loop:Nnn
1403   {#8} {#9} #1 {#2} {#3}
1404   #4 {#5} {#6} #7 {#8} {#9}
1405 }

```

We now have all of the data needed to construct a rounded corner: all that is left to do is to work out the detail! At this stage, we have details of where the corner itself is (#4, #5), and where the next point is (#1, #2). There are two types of calculations to do. First, we need to interpolate from those two points in the direction of the corner, in order to work out where the curve we are adding will start and end. From those, plus the points we already have, we work out where the control points will lie. All of this is done in an expansion to avoid multiple calls to `\tl_put_right:Nx`. The end point of the line is worked out up-front and saved: we need that if dealing with a close-path operation.

```

1406 \cs_new_protected:Npn \__draw_softpath_round_calc:nnnNnn #1#2#3#4#5#6
1407 {
1408   \tl_set:Nx \l__draw_softpath_curve_end_tl
1409   {
1410     \draw_point_interpolate_distance:nnn
1411     \l__draw_softpath_cornerii_dim
1412     { #5 , #6 } { #2 , #3 }
1413   }
1414   \tl_put_right:Nx \l__draw_softpath_part_tl
1415   {
1416     \exp_not:N #4
1417     \__draw_softpath_round_calc:fVnnnn
1418     {
1419       \draw_point_interpolate_distance:nnn
1420       \l__draw_softpath_corneri_dim
1421       { #5 , #6 }
1422       {
1423         \l__draw_softpath_lastx_fp ,
1424         \l__draw_softpath_lasty_fp
1425       }
1426     }
1427     \l__draw_softpath_curve_end_tl
1428     {#5} {#6} {#2} {#3}
1429   }
1430   \fp_set:Nn \l__draw_softpath_lastx_fp {#5}
1431   \fp_set:Nn \l__draw_softpath_lasty_fp {#6}
1432   #1
1433 }

```

At this stage we have the two curve end points, but they are in co-ordinate form. So we split them up (with some more reordering).

```

1434 \cs_new:Npn \__draw_softpath_round_calc:nnnnn #1#2#3#4#5#6
1435 {
1436   \__draw_softpath_round_calc:nnnw {#3} {#4} {#5} {#6}
1437   #1 \q_mark #2 \q_stop
1438 }
1439 \cs_generate_variant:Nn \__draw_softpath_round_calc:nnnnn { fV }

```

The calculations themselves are relatively straight-forward, as we use a quadratic BÄzier curve.

```

1440 \cs_new:Npn \__draw_softpath_round_calc:nnnw
1441 #1#2#3#4 #5 , #6 \q_mark #7 , #8 \q_stop
1442 {
1443   {#5} {#6}
1444   \exp_not:N \__draw_softpath_curveto_opi:nn
1445   {
1446     \fp_to_dim:n
1447     { #5 + \c__draw_softpath_arc_fp * ( #1 - #5 ) }
1448   }
1449   {
1450     \fp_to_dim:n
1451     { #6 + \c__draw_softpath_arc_fp * ( #2 - #6 ) }
1452   }
1453   \exp_not:N \__draw_softpath_curveto_opii:nn
1454   {
1455     \fp_to_dim:n
1456     { #7 + \c__draw_softpath_arc_fp * ( #1 - #7 ) }
1457   }
1458   {
1459     \fp_to_dim:n
1460     { #8 + \c__draw_softpath_arc_fp * ( #2 - #8 ) }
1461   }
1462   \exp_not:N \__draw_softpath_curveto_opiii:nn
1463   {#7} {#8}
1464 }

```

To deal with a close-path operation, we need to do some manipulation. It needs to be treated as a line operation for rounding, and then have the close path operation re-added at the point where the curve ends. That means saving the end point in the calculation step (see earlier), and shuffling a lot.

```

1465 \cs_new_protected:Npn \__draw_softpath_round_close:nn #1#2
1466 {
1467   \use:x
1468   {
1469     \__draw_softpath_round_calc:nnnNnn
1470     {
1471       \tl_set:Nx \exp_not:N \l__draw_softpath_move_tl
1472       {
1473         \__draw_softpath_moveto_op:nn
1474         \exp_not:N \exp_after:wN
1475         \exp_not:N \__draw_softpath_round_close:w
1476         \exp_not:N \l__draw_softpath_curve_end_tl
1477         \exp_not:N \q_stop

```

```

1478     }
1479     \use:x
1480     {
1481         \exp_not:N \exp_not:N \exp_not:N \use_i:nmmn
1482         {
1483             \__draw_softpath_round_loop:Nnn
1484             \__draw_softpath_close_op:nn
1485             \exp_not:N \exp_after:wN
1486             \exp_not:N \__draw_softpath_round_close:w
1487             \exp_not:N \l__draw_softpath_curve_end_tl
1488             \exp_not:N \q_stop
1489         }
1490     }
1491     }
1492     {#1} {#2}
1493     \__draw_softpath_lineto_op:nn
1494     \exp_after:wN \use_none:n \l__draw_softpath_move_tl
1495 }
1496 }
1497 \cs_new:Npn \__draw_softpath_round_close:w #1 , #2 \q_stop { {#1} {#2} }

```

Tidy up the parts of the path, complete the built token list and put it back into action.

```

1498 \cs_new_protected:Npn \__draw_softpath_round_end:
1499 {
1500     \tl_put_right:No \l__draw_softpath_main_tl
1501     \l__draw_softpath_move_tl
1502     \tl_put_right:No \l__draw_softpath_main_tl
1503     \l__draw_softpath_part_tl
1504     \tl_gset_eq:NN \g__draw_softpath_main_tl \l__draw_softpath_main_tl
1505 }

```

(End definition for `__draw_softpath_round_corners:` and others.)

```
1506 </initex | package>
```

6 l3draw-state implementation

```
1507 <*initex | package>
```

```
1508 <@@=draw>
```

`\g__draw_linewidth_dim` Linewidth for strokes: global as the scope for this relies on the graphics state. The inner
`\g__draw_inner_linewidth_dim` line width is used for places where two lines are used.

```

1509 \dim_new:N \g__draw_linewidth_dim
1510 \dim_new:N \g__draw_inner_linewidth_dim

```

(End definition for `\g__draw_linewidth_dim` and `\g__draw_inner_linewidth_dim`.)

`\l_draw_default_linewidth_dim` A default: this is used at the start of every drawing.

```

1511 \dim_new:N \l_draw_default_linewidth_dim
1512 \dim_set:Nn \l_draw_default_linewidth_dim { 0.4pt }

```

(End definition for `\l_draw_default_linewidth_dim`. This variable is documented on page ??.)

`\draw_linewidth:n` Set the linewidth: we need a wrapper as this has to pass to the driver layer. The inner
`\draw_inner_linewidth:n` version is handled at the macro layer but is given a consistent interface here.

```
1513 \cs_new_protected:Npn \draw_linewidth:n #1
1514 {
1515     \dim_gset:Nn \g__draw_linewidth_dim { \fp_to_dim:n {#1} }
1516     \driver_draw_linewidth:n \g__draw_linewidth_dim
1517 }
1518 \cs_new_protected:Npn \draw_inner_linewidth:n #1
1519 { \dim_gset:Nn \g__draw_inner_linewidth_dim { \fp_to_dim:n {#1} } }
```

(End definition for `\draw_linewidth:n` and `\draw_inner_linewidth:n`. These functions are documented on page ??.)

`\draw_miterlimit:n` Pass through to the driver layer.

```
1520 \cs_new_protected:Npn \draw_miterlimit:n #1
1521 { \driver_draw_miterlimit:n { \fp_eval:n {#1} } }
```

(End definition for `\draw_miterlimit:n`. This function is documented on page ??.)

`\draw_cap_but`: All straight wrappers.

```
\draw_cap_rectangle: 1522 \cs_new_protected:Npn \draw_cap_but: { \driver_draw_cap_but: }
\draw_cap_round:     1523 \cs_new_protected:Npn \draw_cap_rectangle: { \driver_draw_cap_rectangle: }
\draw_evenodd_rule:  1524 \cs_new_protected:Npn \draw_cap_round: { \driver_draw_cap_round: }
\draw_nonzero_rule:  1525 \cs_new_protected:Npn \draw_evenodd_rule: { \driver_draw_evenodd_rule: }
\draw_join_bevel:    1526 \cs_new_protected:Npn \draw_nonzero_rule: { \driver_draw_nonzero_rule: }
\draw_join_miter:    1527 \cs_new_protected:Npn \draw_join_bevel: { \driver_draw_join_bevel: }
\draw_join_round:    1528 \cs_new_protected:Npn \draw_join_miter: { \driver_draw_join_miter: }
1529 \cs_new_protected:Npn \draw_join_round: { \driver_draw_join_round: }
```

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

`\l__draw_color_tmp_tl` Scratch space.

```
1530 \tl_new:N \l__draw_color_tmp_tl
```

(End definition for `\l__draw_color_tmp_tl`.)

`\draw_color:n` Much the same as for core color support but calling the relevant driver-level function.

```
\draw_color_fill:n 1531 \cs_new_eq:NN \draw_color:n \color_select:n
\draw_color_stroke:n 1532 \cs_new_protected:Npn \draw_color_fill:n #1
  \__draw_color:nn 1533 { \__draw_color:nn { fill } {#1} }
\__draw_color_aux:nn 1534 \cs_new_protected:Npn \draw_color_stroke:n #1
  \__draw_color_aux:Vn 1535 { \__draw_color:nn { stroke } {#1} }
  \__draw_color:nw 1536 \cs_new_protected:Npn \__draw_color:nn #1#2
1537 {
1538     \color_parse:nN {#2} \l__draw_color_tmp_tl
1539     \__draw_color_aux:Vn \l__draw_color_tmp_tl {#1}
1540 }
1541 \cs_new_protected:Npn \__draw_color_aux:nn #1#2
1542 { \__draw_color:nw {#2} #1 \q_stop }
1543 \cs_generate_variant:Nn \__draw_color_aux:nn { V }
1544 \cs_new_protected:Npn \__draw_color:nw #1#2 ~ #3 \q_stop
1545 { \use:c { \__draw_color_ #2 :nw } {#1} #3 \q_stop }
1546 \cs_new_protected:Npn \__draw_color_cmyk:nw #1#2 ~ #3 ~ #4 ~ #5 \q_stop
1547 { \use:c { driver_draw_color_ #1 _cmyk:nnnn } {#2} {#3} {#4} {#5} }
1548 \cs_new_protected:Npn \__draw_color_gray:nw #1#2 \q_stop
```

```

1549 { \use:c { driver_draw_color_ #1 _gray:n } {#2} }
1550 \cs_new_protected:Npn \__draw_color_rgb:nw #1#2 ~ #3 ~ #4 \q_stop
1551 { \use:c { driver_draw_color_ #1 _rgb:nnn } {#2} {#3} {#4} }
1552 \cs_new_protected:Npn \__draw_color_spot:nw #1#2 ~ #3 \q_stop
1553 { \use:c { driver_draw_color_ #1 _spot:nn } {#2} {#3} }

```

(End definition for `\draw_color:n` and others. These functions are documented on page ??.)

```
1554 \</initex | package>
```

7 l3draw-transforms implementation

```
1555 <*initex | package>
```

```
1556 <@@=draw>
```

This sub-module covers more-or-less the same ideas as `pgfcoretransformations.code.tex`. At present, equivalents of the following are currently absent:

- `\pgfgettransform`, `\pgfgettransformentries`: Awaiting use cases.
- `\pgftransformlineattime`, `\pgftransformarcaxesattime`, `\pgftransformcurveattime`: Need to look at the use cases for these to fully understand them.
- `\pgftransformarrow`: Likely to be done when other arrow functions are added.
- `\pgfflowlevelsynccm`, `\pgflevel`: Likely to be added when use cases are encountered in other parts of the code.

`\l__draw_matrix_active_bool` An internal flag to avoid redundant calculations.

```
1557 \bool_new:N \l__draw_matrix_active_bool
```

(End definition for `\l__draw_matrix_active_bool`.)

`\l__draw_matrix_a_fp` The active matrix and shifts.

```
\l__draw_matrix_b_fp 1558 \fp_new:N \l__draw_matrix_a_fp
```

```
\l__draw_matrix_c_fp 1559 \fp_new:N \l__draw_matrix_b_fp
```

```
\l__draw_xshift_dim 1560 \fp_new:N \l__draw_matrix_c_fp
```

```
\l__draw_yshift_dim 1561 \fp_new:N \l__draw_matrix_d_fp
```

```
1562 \dim_new:N \l__draw_xshift_dim
```

```
1563 \dim_new:N \l__draw_yshift_dim
```

(End definition for `\l__draw_matrix_a_fp` and others.)

`\draw_transform_matrix_reset:` Fast resetting.

```
\draw_transform_shift_reset: 1564 \cs_new_protected:Npn \draw_transform_matrix_reset:
```

```
1565 {
```

```
1566   \fp_set:Nn \l__draw_matrix_a_fp { 1 }
```

```
1567   \fp_zero:N \l__draw_matrix_b_fp
```

```
1568   \fp_zero:N \l__draw_matrix_c_fp
```

```
1569   \fp_set:Nn \l__draw_matrix_d_fp { 1 }
```

```
1570 }
```

```
1571 \cs_new_protected:Npn \draw_transform_shift_reset:
```

```
1572 {
```

```
1573   \dim_zero:N \l__draw_xshift_dim
```

```
1574   \dim_zero:N \l__draw_yshift_dim
```

```
1575 }
```

```
1576 \draw_transform_matrix_reset:
```

```
1577 \draw_transform_shift_reset:
```

(End definition for `\draw_transform_matrix_reset:` and `\draw_transform_shift_reset:`. These functions are documented on page ??.)

`\draw_transform_matrix:nnnn` Setting the transform matrix is straight-forward, with just a bit of expansion to sort out.
`\draw_transform_shift:n` With the mechanism active, the identity matrix is set.

```

\__draw_transform_shift:nn 1578 \cs_new_protected:Npn \draw_transform_matrix:nnnn #1#2#3#4
1579 {
1580   \fp_set:Nn \l__draw_matrix_a_fp {#1}
1581   \fp_set:Nn \l__draw_matrix_b_fp {#2}
1582   \fp_set:Nn \l__draw_matrix_c_fp {#3}
1583   \fp_set:Nn \l__draw_matrix_d_fp {#4}
1584   \bool_lazy_all:nTF
1585     {
1586       { \fp_compare_p:nNn \l__draw_matrix_a_fp = \c_one_fp }
1587       { \fp_compare_p:nNn \l__draw_matrix_b_fp = \c_zero_fp }
1588       { \fp_compare_p:nNn \l__draw_matrix_c_fp = \c_zero_fp }
1589       { \fp_compare_p:nNn \l__draw_matrix_d_fp = \c_one_fp }
1590     }
1591     { \bool_set_false:N \l__draw_matrix_active_bool }
1592     { \bool_set_true:N \l__draw_matrix_active_bool }
1593   }
1594 \cs_new_protected:Npn \draw_transform_shift:n #1
1595 {
1596   \__draw_point_process:nn
1597   { \__draw_transform_shift:nn } {#1}
1598 }
1599 \cs_new_protected:Npn \__draw_transform_shift:nn #1#2
1600 {
1601   \dim_set:Nn \l__draw_xshift_dim {#1}
1602   \dim_set:Nn \l__draw_yshift_dim {#2}
1603 }

```

(End definition for `\draw_transform_matrix:nnnn`, `\draw_transform_shift:n`, and `__draw_transform_shift:nn`. These functions are documented on page ??.)

`\draw_transform_matrix_concat:nnnn` Much the same story for adding to an existing matrix, with a bit of pre-expansion so
`__draw_transform_concat:nnnn` that the calculation uses “frozen” values.

```

\draw_transform_shift_concat:n 1604 \cs_new_protected:Npn \draw_transform_matrix_concat:nnnn #1#2#3#4
\__draw_transform_shift_concat:nn 1605 {
1606   \use:x
1607   {
1608     \__draw_transform_concat:nnnn
1609     { \fp_eval:n {#1} }
1610     { \fp_eval:n {#2} }
1611     { \fp_eval:n {#3} }
1612     { \fp_eval:n {#4} }
1613   }
1614 }
1615 \cs_new_protected:Npn \__draw_transform_concat:nnnn #1#2#3#4
1616 {
1617   \use:x
1618   {
1619     \draw_transform_matrix:nnnn
1620     { #1 * \l__draw_matrix_a_fp + #2 * \l__draw_matrix_c_fp }

```

```

1621         { #1 * \l__draw_matrix_b_fp + #2 * \l__draw_matrix_d_fp }
1622         { #3 * \l__draw_matrix_a_fp + #4 * \l__draw_matrix_c_fp }
1623         { #3 * \l__draw_matrix_b_fp + #4 * \l__draw_matrix_d_fp }
1624     }
1625 }
1626 \cs_new_protected:Npn \draw_transform_shift_concat:n #1
1627 {
1628     \__draw_point_process:nn
1629     { \__draw_transform_shift_concat:nn } {#1}
1630 }
1631 \cs_new_protected:Npn \__draw_transform_shift_concat:nn #1#2
1632 {
1633     \dim_set:Nn \l__draw_xshift_dim { \l__draw_xshift_dim + #1 }
1634     \dim_set:Nn \l__draw_yshift_dim { \l__draw_yshift_dim + #2 }
1635 }

```

(End definition for `\draw_transform_matrix_concat:nnnn` and others. These functions are documented on page ??.)

```

\draw_transform_matrix_invert: Standard mathematics: calculate the inverse matrix and use that, then undo the shifts.
\__draw_transform_invert:n
\__draw_transform_invert:f
\draw_transform_shift_invert:
1636 \cs_new_protected:Npn \draw_transform_matrix_invert:
1637 {
1638     \bool_if:NT \l__draw_matrix_active_bool
1639     {
1640         \__draw_transform_invert:f
1641         {
1642             \fp_eval:n
1643             {
1644                 1 /
1645                 (
1646                     \l__draw_matrix_a_fp * \l__draw_matrix_d_fp
1647                     - \l__draw_matrix_b_fp * \l__draw_matrix_c_fp
1648                 )
1649             }
1650         }
1651     }
1652 }
1653 \cs_new_protected:Npn \__draw_transform_invert:n #1
1654 {
1655     \fp_set:Nn \l__draw_matrix_a_fp
1656     { \l__draw_matrix_d_fp * #1 }
1657     \fp_set:Nn \l__draw_matrix_b_fp
1658     { -\l__draw_matrix_b_fp * #1 }
1659     \fp_set:Nn \l__draw_matrix_c_fp
1660     { -\l__draw_matrix_c_fp * #1 }
1661     \fp_set:Nn \l__draw_matrix_d_fp
1662     { \l__draw_matrix_a_fp * #1 }
1663 }
1664 \cs_generate_variant:Nn \__draw_transform_invert:n { f }
1665 \cs_new_protected:Npn \draw_transform_shift_invert:
1666 {
1667     \dim_set:Nn \l__draw_xshift_dim { -\l__draw_xshift_dim }
1668     \dim_set:Nn \l__draw_yshift_dim { -\l__draw_yshift_dim }
1669 }

```

(End definition for `\draw_transform_matrix_invert:`, `_draw_transform_invert:n`, and `\draw_transform_shift_invert:`. These functions are documented on page ??.)

`\draw_transform_triangle:nnn` Simple maths to move the canvas origin to #1 and the two axes to #2 and #3.

```

1670 \cs_new_protected:Npn \draw_transform_triangle:nnn #1#2#3
1671 {
1672   \__draw_point_process:nnn
1673   {
1674     \__draw_point_process:nn
1675     { \__draw_tranform_triangle:nnnnnn }
1676     {#1}
1677   }
1678   {#2} {#3}
1679 }
1680 \cs_new_protected:Npn \__draw_tranform_triangle:nnnnnn #1#2#3#4#5#6
1681 {
1682   \use:x
1683   {
1684     \draw_transform_matrix:nnnn
1685     { #3 - #1 }
1686     { #4 - #2 }
1687     { #5 - #1 }
1688     { #6 - #2 }
1689     \draw_transform_shift:n { #1 , #2 }
1690   }
1691 }

```

(End definition for `\draw_transform_triangle:nnn`. This function is documented on page ??.)

`\draw_transform_scale:n` Lots of shortcuts.

```

\draw_transform_xscale:n 1692 \cs_new_protected:Npn \draw_transform_scale:n #1
\draw_transform_yscale:n 1693 { \draw_transform_matrix_concat:nnnn { #1 } { 0 } { 0 } { #1 } }
\draw_transform_xshift:n 1694 \cs_new_protected:Npn \draw_transform_xscale:n #1
\draw_transform_yshift:n 1695 { \draw_transform_matrix_concat:nnnn { #1 } { 0 } { 0 } { 1 } }
\draw_transform_xslant:n 1696 \cs_new_protected:Npn \draw_transform_yscale:n #1
\draw_transform_yslant:n 1697 { \draw_transform_matrix_concat:nnnn { 1 } { 0 } { 0 } { #1 } }
1698 \cs_new_protected:Npn \draw_transform_xshift:n #1
1699 { \draw_transform_shift_concat:n { #1 , 0 } }
1700 \cs_new_protected:Npn \draw_transform_yshift:n #1
1701 { \draw_transform_shift_concat:n { 0 , #1 } }
1702 \cs_new_protected:Npn \draw_transform_xslant:n #1
1703 { \draw_transform_matrix_concat:nnnn { 1 } { 0 } { #1 } { 1 } }
1704 \cs_new_protected:Npn \draw_transform_yslant:n #1
1705 { \draw_transform_matrix_concat:nnnn { 1 } { #1 } { 0 } { 1 } }

```

(End definition for `\draw_transform_scale:n` and others. These functions are documented on page ??.)

`\draw_transform_rotate:n` Slightly more involved: evaluate the angle only once, and the sine and cosine only once.

```

\__draw_transform_rotate:n 1706 \cs_new_protected:Npn \draw_transform_rotate:n #1
\__draw_transform_rotate:f 1707 { \__draw_transform_rotate:f { \fp_eval:n {#1} } }
\__draw_transform_rotate:nn 1708 \cs_new_protected:Npn \__draw_transform_rotate:n #1
\__draw_transform_rotate:ff 1709 {
1710   \__draw_transform_rotate:ff
1711   { \fp_eval:n { cosd(#1) } } }

```

```

1712     { \fp_eval:n { sind(#1) } }
1713   }
1714 \cs_generate_variant:Nn \_draw_transform_rotate:n { f }
1715 \cs_new_protected:Npn \_draw_transform_rotate:nn #1#2
1716   { \draw_transform_matrix_concat:nmmm {#1} {#2} { -#2 } { #1 } }
1717 \cs_generate_variant:Nn \_draw_transform_rotate:nn { ff }

```

(End definition for \draw_transform_rotate:n, _draw_transform_rotate:n, and _draw_transform_rotate:nn. This function is documented on page ??.)

```

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```

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