IEC PAS 63267-3-31

Edition 1.0 2020-02

PUBLICLY AVAILABLE SPECIFICATION

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Fibre optic interconnecting devices and passive components – Fibre optic connector optical interfaces – Part 3-31: End face geometry – Flat PC PPS rectangular ferrule multimode fibres

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
86B/4231/PAS	86B/4249/RVDPAS

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – FIBRE OPTIC CONNECTOR OPTICAL INTERFACES –

Part 3-31: End face geometry – Flat PC PPS rectangular ferrule multimode fibres

1 Scope

This part of IEC 63267 defines certain dimensional limits of a flat PC rectangular polyphenylene sulphide (PPS) ferrule optical interface in order to meet specific longitudinal offset requirements for fibre-to-fibre interconnection. Ferrules made from the material specified in this PAS are suitable for use in categories C, U, E, and O as defined in IEC 61753-1.

Ferrule interface dimensions and features are contained in IEC 61754 (all parts), which deals with fibre optic connector interfaces.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61300-3-30, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-30: Examinations and measurements – Polish angle and fibre position on single ferrule multifibre connectors*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Description

The performance of a multimode flat PC rectangular ferrule optical interface is determined by the accuracy with which the optical datum targets of two mating ferrules are aligned with each other. There are three conditions affecting the alignment of the optical datum targets: lateral offset, angular offset, and longitudinal offset.

Parameters influencing the lateral and angular offset of the optical fibre axes include the following:

– fibre hole deviation from designated location;
– fibre cladding diameter relative to fibre hole clearance;
– fibre hole angular misalignment;
– fibre core concentricity relative to the cladding diameter;
– alignment pin diameter relative to the guide hole clearance.

Parameters influencing the longitudinal offset of the optical fibre axes include the following:

– fibre protrusion;
– fibre array minus coplanarity;
– adjacent fibre height differential;
– end face angle in the x-axis;
– end face angle in the y-axis;
– end face radius in the x-axis;
– end face radius in the y-axis;
– fibre tip spherical radii;
– axial force on ferrule end face;
– ferrule and fibre material constants;
– frictional force of alignment pins in ferrule guide holes;
– core dip.

5 Interface parameters

This PAS defines the dimensional limits of flat PC rectangular ferrules with a single row of 12 fibres. The fibre centres are spaced with a nominal alignment pitch of 0,25 mm. Interface variant, which identify nominal ferrule cross-section, is given in Table 1. The fibre numbering conventions are illustrated in Figure 1.

End face geometry limits associated with longitudinal offset when < 50 % of the fibres have core dip are specified in Table 2. End face geometry limits associated with longitudinal offset when > 50 % of the fibres have core dip are specified in Table 3. In this case, geometry limit (GL) is not calculated and maximum minus coplanarity is reduced.

Table 1 – Optical interface variant information

Variant number[b, c]	Nominal ferrule cross-section[a] (mm x mm)	Number of fibres
1112	2,45 x 6,4	12

[a] Refer to the applicable IEC 61754 series fibre optic connector interface standard for dimensional requirements.

[b] The four digit variant code describes a combination of material type, nominal ferrule cross-section, and number of fibres. The first digit defines 1 for PPS ferrule materials; the second digit represents 2,45 mm x 4,4 mm with 0 and 2,45 mm x 6,4 mm with 1; and the last two digits designates the number of fibres.

[c] All ferrule materials for rectangular type ferrules are intended to be intermateable, in the lowest specified performance category as described within IEC 61755-1, provided that the last three digits of the variant number are the same. It is also possible to mate ferrules with different fibre counts, in which case all mating fibres shall meet the designated performance category.

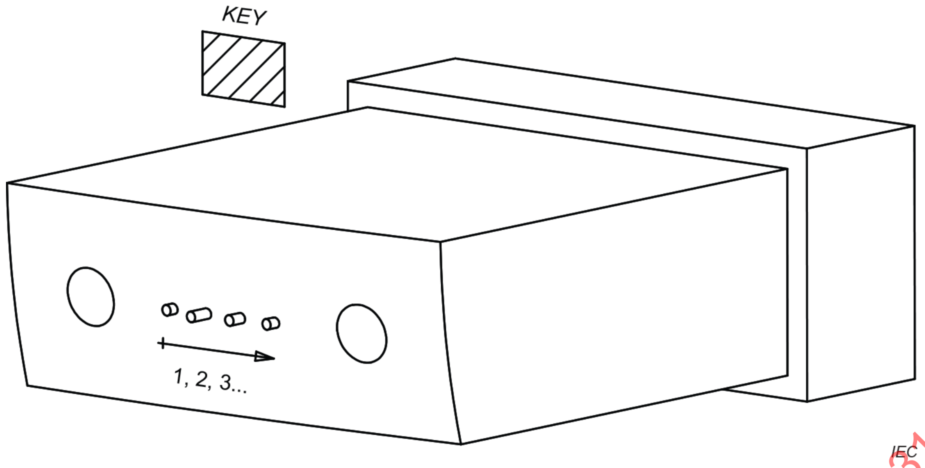

Figure 1 – Fibre numbering conventions

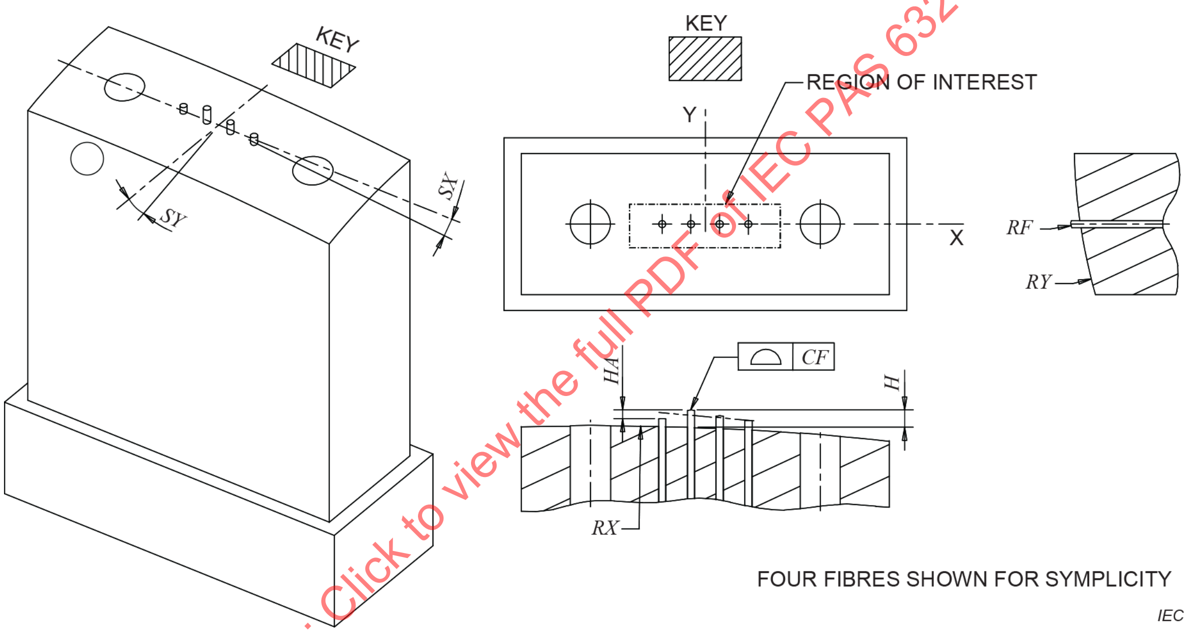

Figure 2 – Interface dimensions related to longitudinal offset

The optical interface coordinate system is established with an x-axis, which passes through the guide hole centres, a perpendicular y-axis that passes through the midpoint of the line connecting the guide hole centres, and an orthogonal z-axis pointing away from the ferrule. All parameters are illustrated as positive values with respect to the defined coordinate system. Concave ferrule radii are indicated by negative values.

Table 2 – Physical contact end face geometry dimensions having < 50 % fibres with core dip for optical interface variant 1112

Ref.	Parameter values		Units	Remarks
	Minimum	Maximum		
CF	-	0,4	µm	Minus coplanarity[a]
SX	−0,15	0,15	°	Ferrule surface x-angle[b]
SY	−0,2	0,2	°	Ferrule surface y-angle[c]
H	1	3,5	µm	Fibre height[d]
HA	0	0,3	µm	Adjacent fibre height differential
RF	1	-	mm	Fibre tip spherical radius[e]
RX	2 000 (convex) $\lvert -10\,000 \rvert$ (concave)	-	mm	Ferrule surface x-radius
RY	5	-	mm	Ferrule surface y-radius
GL	-	17,4		Geometry limit[f]
CD		120	nm	Core dip

The end face geometry shall be measured in accordance with IEC 61300-3-30.

The values in Table 2 shall be specified in the central surface region surrounding fibres of 2,900 mm wide and 0,675 mm high. Furthermore, the outside surface region is lower than the central surface region of interest.

NOTE 1 End face parameter requirements apply to performance grades B, C, and D.

NOTE 2 Refer to Figure 2 for dimensional references.

NOTE 3 The values in Table 2 shall be specified in the central surface region surrounding fibres of 2,900 mm wide and 0,675 mm high. Furthermore, the outside surface region is lower than the central surface region of interest.

NOTE 4 The values in Table 2 apply for polyphenylene sulphide (PPS) ferrules with a Young's modulus of 15 GPa to 20 GPa. Ferrule compression force: 7,8 N minimum and 11,8 N maximum.

[a] Refer to Annex A for a description of minus coplanarity.

[b] X-angle represents the slope of the ferrule surface as defined by a bi-parabolic fit in accordance with IEC 61300-3-30.

[c] Y-angle represents the slope of the ferrule surface as defined by a bi-parabolic fit in accordance with IEC 61300-3-30.

[d] A positive value indicates a fibre protrusion.

[e] Fibre tip spherical radii fitting region is defined within IEC 61300-3-30.

[f] Refer to Annex B for a description of parameter *GL*.

Table 3 – Physical contact end face geometry dimensions having > 50 % fibres with core dip for optical interface variant 1112

Ref.	Parameter values		Units	Remarks
	Minimum	Maximum		
CF	-	0,15	µm	Minus cplanarity[a]
SX	–0,15	0,15	°	Ferrule surface x-angle[b]
SY	–0,2	0,2	°	Ferrule surface y-angle[c]
H	1	3,5	µm	Fibre height[d]
HA	0	0,3	µm	Adjacent fibre height differential
RF	1	-	mm	Fibre tip spherical radius[e]
RX	2 000 (convex) |–10 000| (concave)	-	mm	Ferrule surface x-radius
RY	5	-	mm	Ferrule surface y-radius
CD		120	nm	Core dip

The end face geometry shall be measured in accordance with IEC 61300-3-30.

The values in Table 3 shall be specified in the central surface region surrounding fibres of 2,900 mm wide and 0,675 mm high. Furthermore, the outside surface region is lower than the central surface region of interest.

NOTE 1 End face parameter requirements apply to performance grades B, C, and D.

NOTE 2 Refer to Figure 2 for dimensional references.

NOTE 3 The values in Table 3 apply for polyphenylene sulphide (PPS) ferrules with a Young's modulus of 15 GPa to 20 GPa. Ferrule compression force: 7,8 N minimum and 11,8 N maximum.

[a] Refer to Annex A for a description of minus coplanarity.

[b] X-angle represents the slope of the ferrule surface as defined by a bi-parabolic fit in accordance with IEC 61300-3-30.

[c] Y-angle represents the slope of the ferrule surface as defined by a bi-parabolic fit in accordance with IEC 61300-3-30.

[d] A positive value indicates a fibre protrusion.

[e] Fibre tip spherical radii fitting region is defined within IEC 61300-3-30.

Annex A
(normative)

Minus coplanarity

The fibre protrusion distribution for rectangular ferrules is characterized by a parameter referred to as minus coplanarity. This metric represents the unilateral distance from a least squares fit line through the array of protrusions, known as the fibre line, to the minimum height fibre as illustrated in Figure A.1.

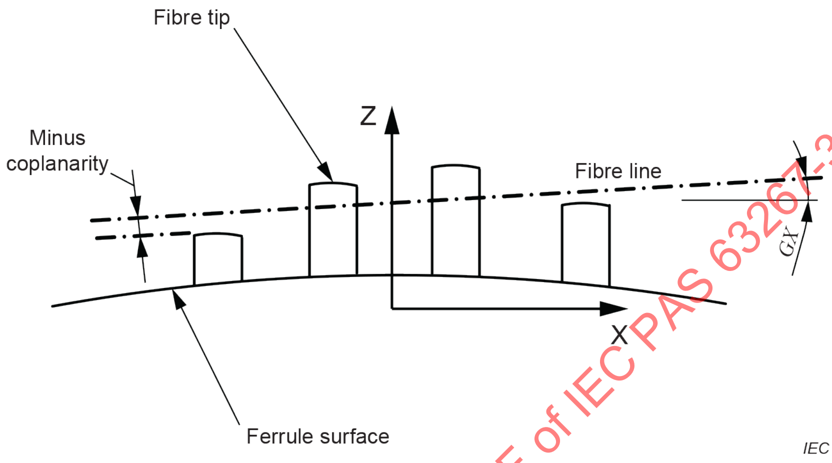

Figure A.1 – Illustration of fibre line and minus coplanarity parameters

The fibre line, which provides a single characterization of the height distribution, takes the form:

$$z(x) = \tan(GX) \cdot x + \beta \qquad \text{(A.1)}$$

The angle of the array, GX, denotes the x-slope angle. A measure of the average fibre height at the x-origin of the coordinate system is given by the intercept of the fit, β.

Minus coplanarity, CF, can be defined as:

$$CF = \max(z_i(x) - Z_i) \qquad \text{(A.2)}$$

where

$z_i(x) - Z_i$ represents the deviation of each fibre tip, i, from the fibre line.

The physical significance of minus coplanarity is that it indicates the requisite axial displacement of the fibre line needed to ensure physical contact across the fibre array under worst case mating conditions.

Annex B
(informative)

Minimum normal force required to achieve physical contact

To establish limits of acceptance on end face geometry, a mathematical system model was developed to estimate the minimum normal force required to achieve physical contact across an array of mated fibres. This model takes into account various factors including:

- fibre tip compression and axial stiffness;
- elastic, foundational deflection of the ferrule structure;
- rotational stiffness of the system;
- frictional resistance between the alignment pins and holes;
- variation in end face geometry dimensions.

For a ferrule with a single row of fibres, there are three dominant end face dimensions that influence the minimum mating force needed to assure physical contact:

- x-slope angle of the end face, SX;
- minus coplanarity of the fibre array, CF;
- fibre tip spherical radius of curvature, RF.

These parameters were systematically varied to determine their interrelationships with mating force. As a result of the analysis, a geometry limit, GL, can be used to quantitatively assess the acceptability of an end face. This term is a calculated merit function, which relates x-slope angle, coplanarity, and fibre tip radii in comparison to the defined ferrule compression force. For a specific end face condition, lower calculated values for GL indicate a better geometry. For instance, GL is zero for interfaces with perfectly coplanar fibres and null x-slope angle. A maximum allowable limit can therefore be placed on GL to serve as a bound for unacceptable geometries. Furthermore, the magnitude of the limit may be different depending on the number of fibres or the ferrule material type.

To develop the relationship between GL, CF, and SX, end faces with flat fibre tips ($RF = \infty$) were initially studied as summarized in Figure B.1.

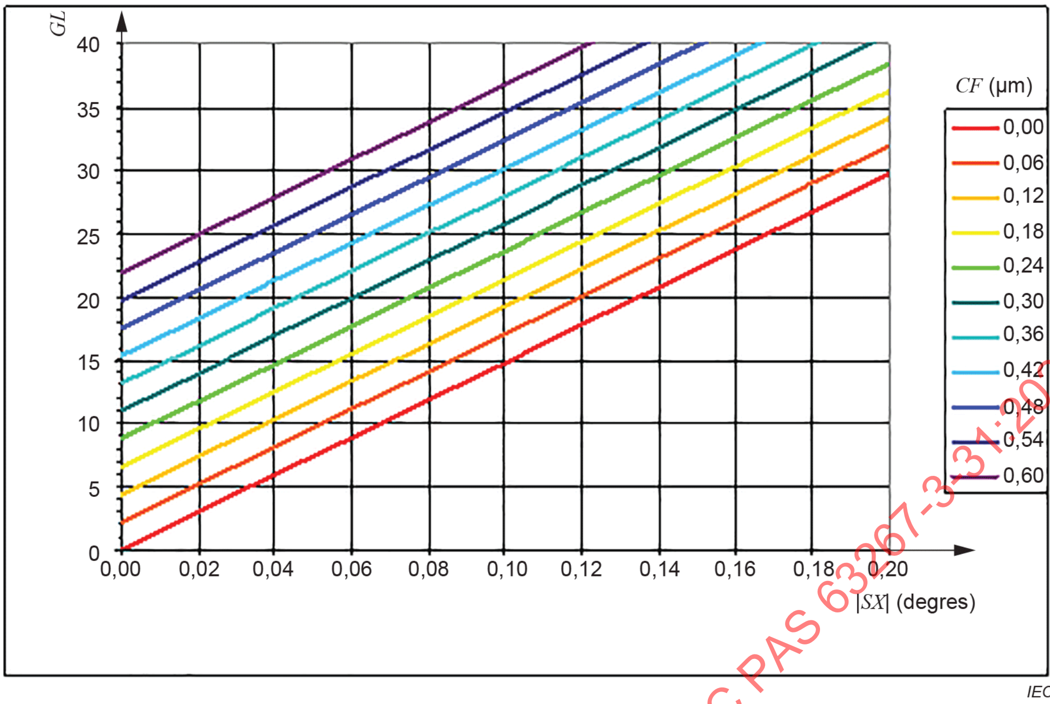

Figure B.1 – Geometry limit, GL, needed to mate 12 fibres, as a function of absolute X-angle, $|SX|$ for different magnitudes of minus coplanarity and flat fibre tips

Inspection of the results indicates that the family of curves are linear with equal slopes and constant offsets between their y-axis intercepts. This gives a functional relationship of the form

$$F_{\text{max}}(SX, CF, RF = \infty) = B \cdot |SX| + D \cdot CF \; GL(SX, CF, RF = \infty) = B \cdot |SX| + D \cdot CF \quad \text{(B.1)}$$

When the fibre tips have finite radii of curvature, there is a slight nonlinearity and the slopes of the curves steepen with increasing CF. Additionally, the value of GL when $|SX|$ = 0 is no longer directly proportional to CF as illustrated in Figure B.2.

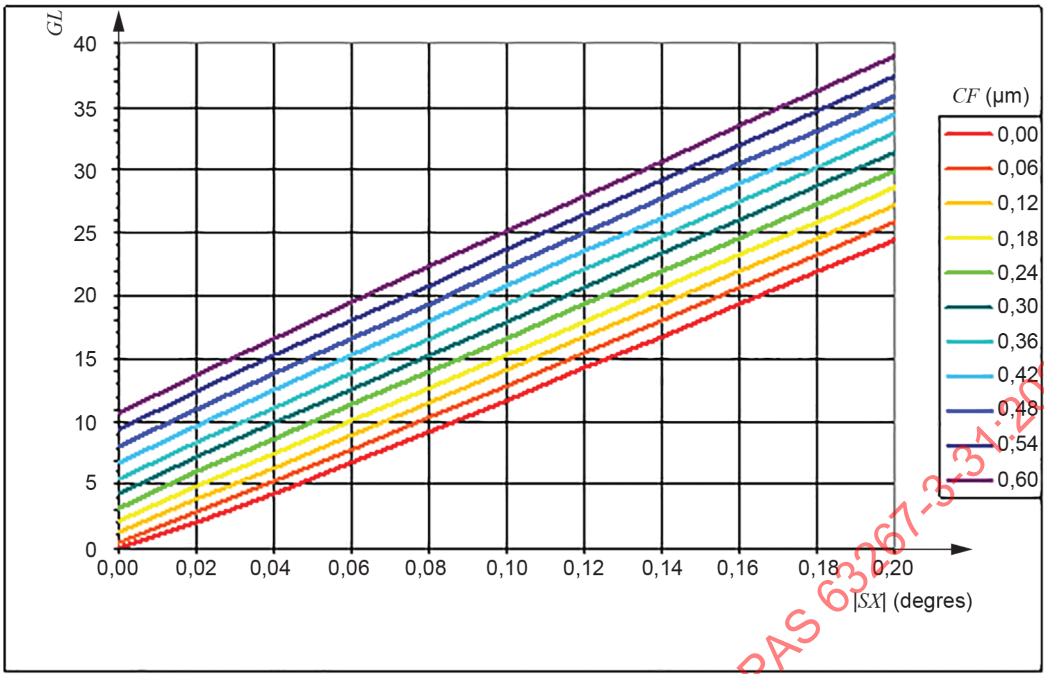

Figure B.2 – Geometry Limit, GL, needed to mate 12 fibres, as a function of absolute X-angle, $|SX|$ for different magnitudes of minus coplanarity and 1 mm fibre tips

A function that fits this behaviour can be expressed as

$$GL(SX,CF) = [(A_0 - A_1)\cdot e^{-A_q\cdot CF} + A_1]\cdot(e^{-n\cdot|SX|} - 1) + [(B_0 - B_1)\cdot e^{-B_q\cdot CF} + B_1]\cdot|SX| + C\cdot(e^{-p\cdot CF} - 1) + \ldots$$
$$D\cdot CF \qquad \text{(B.2)}$$

where the parameter constants, A_0, A_1, A_q, n, B_0, B_1, B_q, C, p, and D, are related to the fibre tip radius of curvature, RF, as defined by

$$f(RF) = (f_1 - f_0)\cdot e^{-\frac{f_q}{RF}} + f_0 \qquad \text{(B.3)}$$

The letter f given in Equation (B.3) represents any of the parameter constants. The resultant function, when Equation (B.2) and Equation (B.3) are combined, is constructed such that GL = 0 when CF = 0 and SX = 0. Furthermore, the function degenerates to the simple linear form given in Equation (B.1) when RF approaches infinity.

There are 30 constants that define the relationship among GL, SX, CF, and RF. When fully expanded the function takes the form of

$$GL(SX,CF,RF) = \Bigg[\Bigg(\Big(\big((A_{01}-A_{00})\cdot e^{-\frac{A_{0q}}{RF}}+A_{00}\big)-\big((A_{11}-A_{10})\cdot e^{-\frac{A_{1q}}{RF}}+A_{10}\big)\Big)\cdot e^{-\left((A_{q1}-A_{q0})\cdot e^{-\frac{A_{qq}}{RF}}+A_{q0}\right)\cdot CF}+(A_{11}-A_{10})\cdot e^{-\frac{A_{1q}}{RF}}+A_{10}\Bigg]\cdot\left(e^{-\left((n_1-n_0)\cdot e^{-\frac{n_q}{RF}}+n_0\right)\cdot|SX|}-1\right)+\Bigg[\Big(\big((B_{01}-B_{00})\cdot e^{-\frac{B_{0q}}{RF}}+B_{00}\big)-\big((B_{11}-B_{10})\cdot e^{-\frac{B_{1q}}{RF}}+B_{10}\big)\Big)\cdot e^{-\left((B_{q1}-B_{q0})\cdot e^{-\frac{B_{qq}}{RF}}+B_{q0}\right)\cdot CF}+(B_{11}-B_{10})\cdot e^{-\frac{B_{1q}}{RF}}+B_{10}\Bigg]\cdot|SX|+\left((C_1-C_0)\cdot e^{-\frac{C_q}{RF}}+C_0\right)\cdot\left(e^{-\left((p_1-p_0)\cdot e^{-\frac{p_q}{RF}}+p_0\right)\cdot CF}-1\right)+\left((D_1-D_0)\cdot e^{-\frac{D_q}{RF}}+D_0\right)\cdot CF \quad [B.4]$$

For incorporation with end face inspection algorithms, this function can also be expressed with Unicode text

$$GL(SX,CF,RF) = [(((A\_01-A\_00)\cdot e\hat{}(-A\_0q/RF)+A\_00)-((A\_11-A\_10)\cdot e\hat{}(-A\_1q/RF)+A\_10))\cdot e\hat{}(-((A\_q1-A\_q0)\cdot e\hat{}(-A\_qq/RF)+A\_q0)\cdot CF)+(A\_11-A\_10)\cdot e\hat{}(-A\_1q/RF)+A\_10]\cdot(e\hat{}(-((n\_1-n\_0)\cdot e\hat{}(-n\_q/RF)+n\_0)\cdot|SX|)-1)+[(((B\_01-B\_00)\cdot e\hat{}(-B\_0q/RF)+B\_00)-((B\_11-B\_10)\cdot e\hat{}(-B\_1q/RF)+B\_10))\cdot e\hat{}(-((B\_q1-B\_q0)\cdot e\hat{}(-B\_qq/RF)+B\_q0)\cdot CF)+(B\_11-B\_10)\cdot e\hat{}(-B\_1q/RF)+B\_10]\cdot|SX|+((C\_1-C\_0)\cdot e\hat{}(-C\_q/RF)+C\_0)\cdot(e\hat{}(-((p\_1-p\_0)\cdot e\hat{}(-p\_q/RF)+p\_0)\cdot CF)-1)+((D\_1-D\_0)\cdot e\hat{}(-D\_q/RF)+D\_0)\cdot CF$$