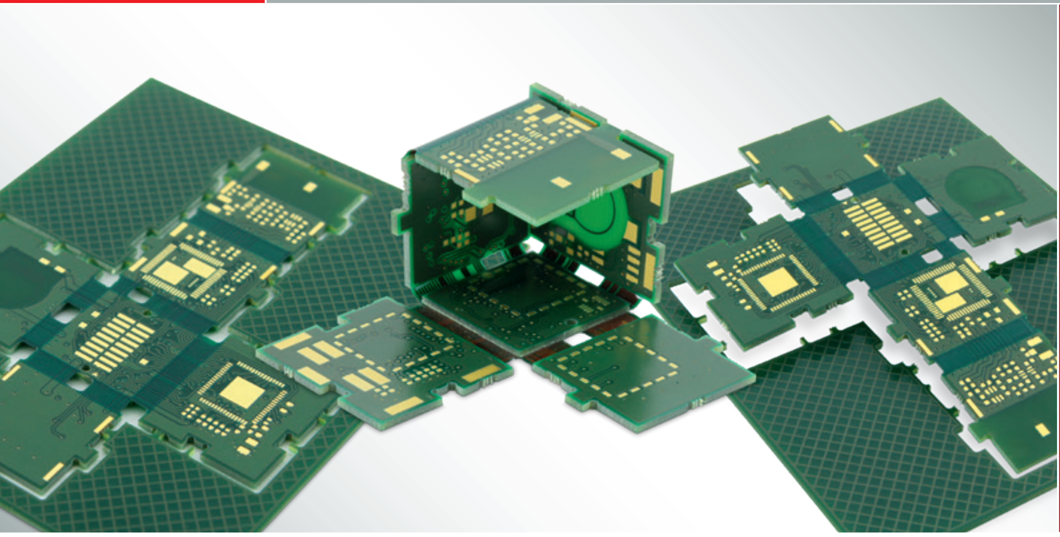
DESIGN GUIDE
Version 1.2 / March 2018

Flex-Rigid Design Guide



The trend to miniaturization in electronics continues. Integrated circuit board solutions are becoming more and more popular as a means of efficiently utilizing the even smaller casing volume in all three dimensions.

Flexible foils of polyimide with a typical thickness of 50 µm are materials that withstand high temperatures and can be used with copper-cladding as base material for pure flex circuit boards or in combination with rigid base materials for flex-rigid circuit boards with all the prevalent soldering methods. Thin FR4 layers in FR4 Semiflex circuit boards are also bendable.

In recent years, Würth Elektronik has accumulated extensive expertise in costumer projects and commissions of the widest variety of designs and applications, from Aerospace to Medical devices and currently it supplies more than 600 customers. With the broad range of technology we offer, you can make the best possible selection for any requirements in terms of performance and costs.

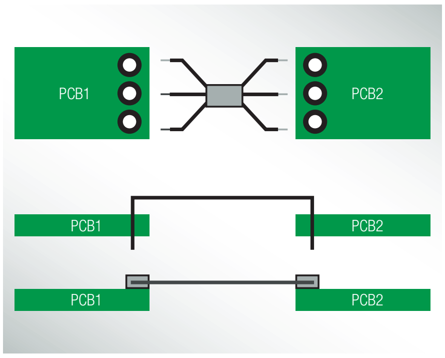
In the following, you will find information about systems that explain the different variants of flex-rigid circuit boards as well as practical tips on design:

! **Basically, standards must be regarded such as IPC-2223, IPC-6013, the Basic Design Guide from Würth Elektronik, as well as variant-specific design rules and our drying recommendations.**

1. Systematic view of flex-rigid circuit boards

There are basically different ways to create a system:

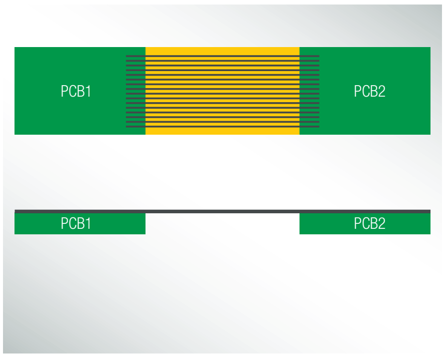
Heterogeneous system



Rigid circuit board + wiring harness/ flex soldered in or plugged (detachable)

- Only few connections
- Non-critical applications
- Wiring errors possible
- Many single parts
- High expenses for test and assembly

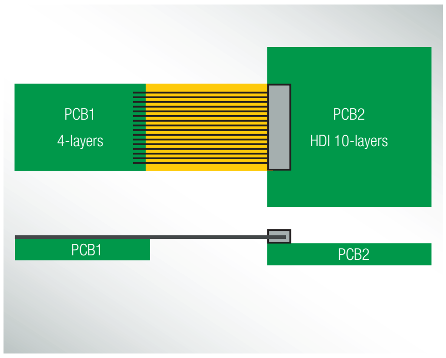
Homogeneous system



Circuit boards with identical stack-up in all rigid areas

- Integrated flex layer(s) throughout
- Considerably greater wiring density
- Saves valuable space by eliminating connecting points (solder pads or footprint of connectors)

Partially homogeneous system

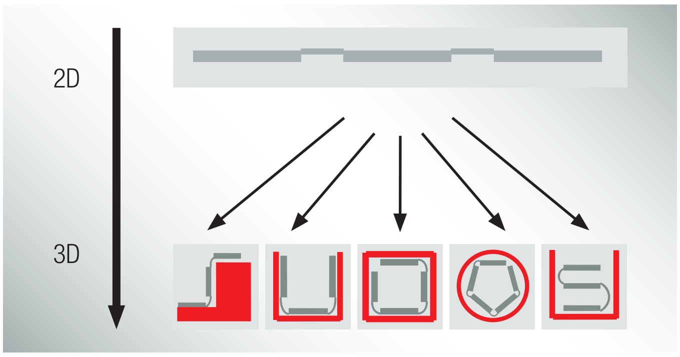


Sub-systems vary considerably in terms of technology and size: e.g. flex-rigid/ connector combination

- Separable
- Modular systems possible

TIPS:
- **Integrated wiring should be provided for the smaller and simpler PCB1.**
- **For pitch ≤ 0.5 mm or shielding a Board-to-Board connector is recommended.**

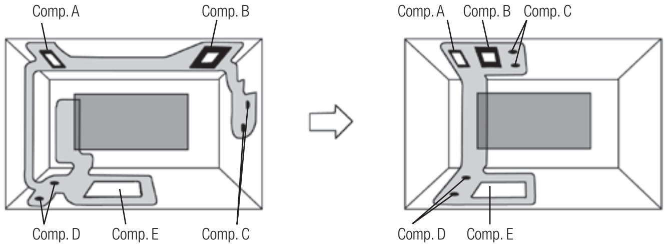
Flex-rigid circuit boards are mechatronic components. In addition to their electronic function, very careful consideration must also be given to mechanical factors:



- Component assembly, soldering and testing in flat condition in the delivery panel
- Separating, configuring and installing

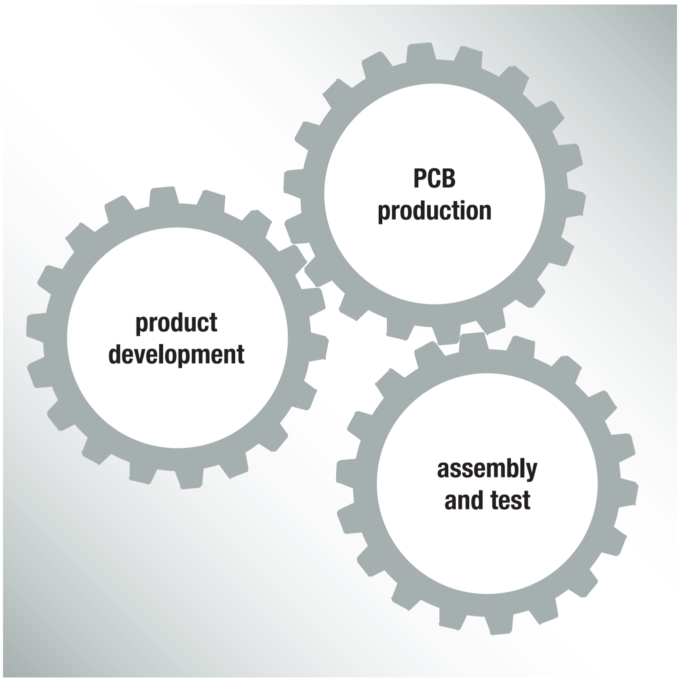
Advantages:
- Significantly less space required due to three-dimensional wiring
- Elimination of additional components such as connectors and connecting cables
- Improved signal transmission through elimination of cross-sectional changes to conductors (connectors, cable, solder connections)
- Weight reduction
- More valuable component assembly and wiring space
- Reduced logistical complexity
- Solution of difficult contacts is possible, simplification of assembly
- Considerably improved reliability of the entire system (a homogeneous unit is considerably more reliable than one with connectors and cable)
- Combination with HDI Microvia technologies (microvia, buried via, finest conductor width) is possible
- Combination with heatsink technology is possible
- Remarkable improvement of testability. Complete system could be tested prior to system assembly. All components and test points are still accessable.

The design phase decides the later cost structure, so all electrical and mechanical interfaces must be taken into consideration during the conceptual phase.



An exact selection of the best components and substrate technology is also necessary in order to be able to fulfill reliably the required operating conditions. Product development also includes getting a precise picture of component assembly, the soldering process, the test and the device assembly.

Cooperation of all participants of the value-added chain



„The benefits come from the system not through purchasing!“

Andreas Schilpp

! Flex/flex-rigid projects: Interdisciplinary cooperation in development is indispensable!

2. Project checklist for system requirements:

a) Technical requirements for the final product: target market, key functions, any unique features, service life, size, appearance

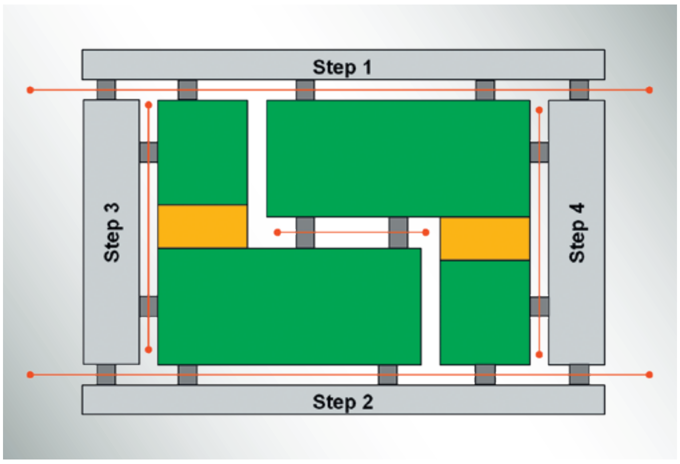
b) Commercial requirements: quantities, cost goals, prototype schedule, pre-series, series release, ramp-up, second source, possible audit planning

c) Legal requirements: listings and permits, regulated medical technology market, relevance for German Federal Office of Economics and Export (BAFA), UL

d) Reliability requirements: For example classification to IPC 1/2/3, failure risk analysis, product liability, quality management agreement, branch specific requirements e.g. APQP (Advanced Product Quality Planning) or PPAP (Production Parts Approval Process), traceability

e) Product operating conditions: ambient conditions such as temperature, temperature change, cooling, humidity, shock and vibration, non-flammability, component assembly/soldering/repairs, test procedures for environmental and reliability tests

f) Casing size, material and shape: analysis of all mechanical and electrical interfaces, displays, switches, connectors, interfaces with other devices or modules. Design of a three-dimensional model (paper + scissors / mCAD+eCAD) in order to find minimum area for flat projection of the circuitry



! Circuit board form „L" is better than „T" **Würth Elektronik will offer you the best delivery panel (best price!)**

g) Mechanical requirements of circuit board: static or dynamic application, circuit board thickness, stability, aspect ratio of drill hole diameter/board thickness, bending radii, bending radius/flex thickness ratio, bending form, number of bending cycles, bending frequency

h) Electrical requirements of circuit board: power, dielectric strength, amperage, insulation and shielding, EMC, number of signals across the flexible area, number of flex layers, signal integrity, impedance requirements, surface resistance

Number of flex layers	1	2	4	6	8	10	12
Flex/TWINflex							
Flex-rigid flex outside							
Flex-rigid flex inside							
FR4 Semiflex							

i) Type and positioning of components, design and connection technology: components such as BGA requiring advanced via technology, stackup, bare chip technology, soldering surface, delivery panel, legend print, press-fit technology, embedded components

j) Testing and Packaging: electrical and mechanical test of the circuit board, product testing documentation (detailed initial sample test report is recommended for complex stack-up, specify test criteria), packaging

k) Further processing of flex and flex-rigid PCBs: possibilities of drying prior to soldering, logistics, dry storage, panel separation, casing assembly, installation tolerances and fastening possibilities

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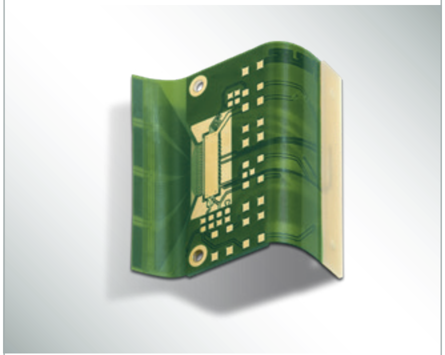
3. Selection of the right technology

Possible variants:

Flex / TWIN*flex*®



2F (Flex)

2F-Ri (TWINflex)

4F with microvias 1-2/2-3/3-4

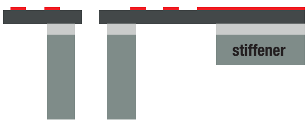
- Very thin flexible foil PI /LCP
- 1 to 6 copper layers
- Partially reinforced with stiffener
- Photosensitive solder mask foil or Polyimide coverlay
- Delivered individually or as panel

NOTE:

Flex-rigid 1F-0Ri design can be more affordable than a TWINflex 1F-Ri

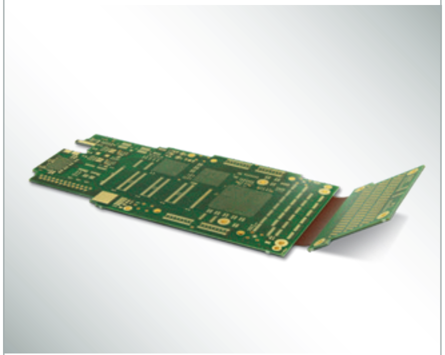
In comparison:

1F-Ri (TWINflex)

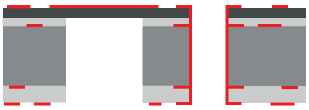


1F-0Ri (flex-rigid)

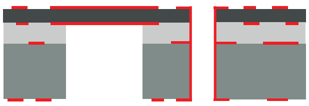
Flex-rigid



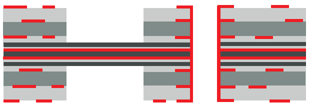
1F-3Ri



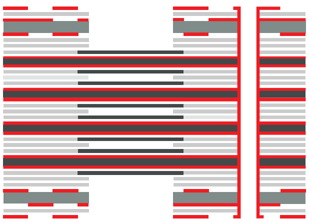
2F-2Ri



3Ri-2F-3Ri

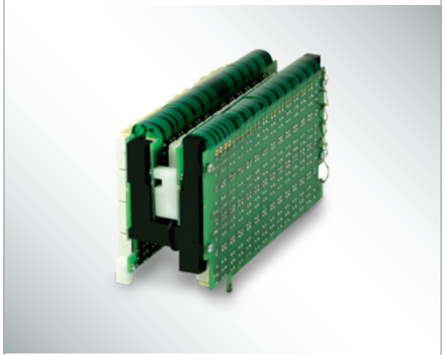


3Ri-8F-3Ri

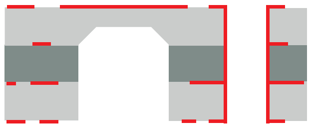


- Components on stable rigid section
- Flexible area 1 to 12 layers bonded/ unbonded (airgap)
- Flexible Polyimide layers out-side or symmetrically inside
- Rigid areas: standard soldermask
- Flexible area: highly flexible soldermask or Polyimide coverlay

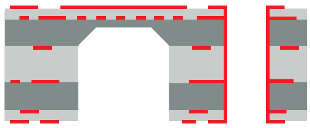
FR4 Semiflex



Semiflex 1Ri-3Ri



Semiflex 2Ri-4Ri



- Rigid FR4 circuit boards with deep milling process
- Affordable
- Clearly defined installation situation and large bending radius
- Bending area: 1 or 2 copper layers, flex soldermask or Polyimide coverlay

NOTE:

- Often more affordable than a connector-cable-connector solution
- Definitely better and cheaper compared to shielded connector and cables
- Usage of bending tools recommended

Indicators for preferential use of individual variants:

Variant	Indicators for	Comments
Flex xF	Very small, dense circuits	Microvias and contour possible with laser
	Very limited installation space	Flexible foil 50 µm thick
	Use in vacuum	Practically no gas emission
	Use at high temperatures	PI can be used up to 200°C (without solder mask)
	High frequency applications	Good thickness tolerance, copper treatment flat, small loss factor
	Vias in flexible area	But NOT permitted in bending area!
TWINflex xF-Ri	Cooling problem	Metal reinforcement (heatsink)
FR4 Semiflex	Flex-to-install with large bending radii	Affordable solution, miniaturization
	Large board with angled connector	Only bendability is necessary
	Flex material not permitted	Only rigid base materials
Flex-rigid 1F-xRi	Large portion of flex surface	Laser-cut panel very stable
	1:1 wiring across flexible area	More affordable than xRi-2F-xRi
	Small bending radii	Thin flexible area, highly flexible soldermask or cover foil
	Short drying times	Flex layer on outside
Flex-rigid 2F-xRi	High-frequency component-to-connector connection across flexible area with reference layer	No vias necessary for transfers WARNING: complex (see table below)
Flex-rigid xRi-1F-xRi	Highly-dynamic prolonged bending	Copper in neutral phase ideal
	High-level reliability requirements	-
Flex-rigid xRi-2F-xRi	Reference layer in flex area due to signal integrity	Polyimide with 75 or 100 µm for impedance control
	High-level reliability requirements	Rugged technology, mechanical stability

Indicators against the use of individual variants:

Variant	Indicators against	Comments
Flex xF	Wired components or connectors	Low mechanical stability
TWINflex xF-Ri	Many individual reinforcements	Better to use flex-rigid 1F-xRi
FR4 Semiflex	S-shaped bending in one surface	Do not subject glass mat to tension
	Multi-section casing	Assembly tolerances have effect on Semiflex area
Flex-rigid 1F-xRi	-	-
Flex-rigid 2F-xRi	Large circuit boards	Design tends to bow and twist
	Large quantities	limited area, tends to be expensive
Flex-rigid xRi-2F-xRi	-	-

! Please look at the *Basic Design Guide* of Würth Elektronik for design rules regarding structures, via sizes and soldermask.

! The requirements in the checklist should be analyzed in detail in a discussion of the project with our specialists.

4. Materials and design parameters - standards

IPC class 2, use A (flex-to-install)

Flexible material	Polyimide core 50 µm, up to 70 µm copper, epoxy glue or adhesiveles, coverlay 25 µm partially or flexible solder mask
Rigid material	TG 150 FR4 filled, halogen-free: IPC-4101C /128 (92,94,127)
Copper thicknesses	Inner layers 18(standard)/35/70 µm base copper, outer layers 12(standard)/18/35 µm + plating (with 1F-xRi flex layer is outside)
Circuit board thickness	Depends on number of layers: flex > 100 µm, flex-rigid/FR4 Semiflex ≥ 0.8 mm
Solder surface	ENIG

Enhanced specifications, e.g. regarding material, stack up, application case Use B, on request!

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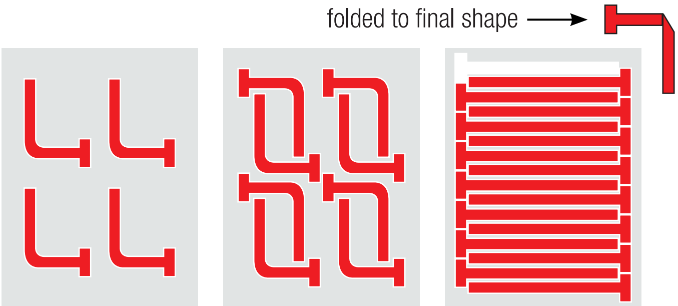
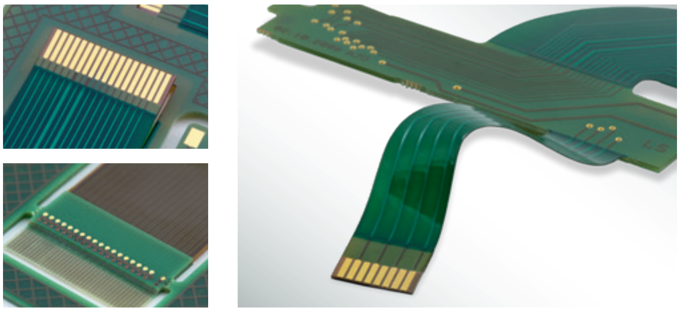
5. The mechanical design

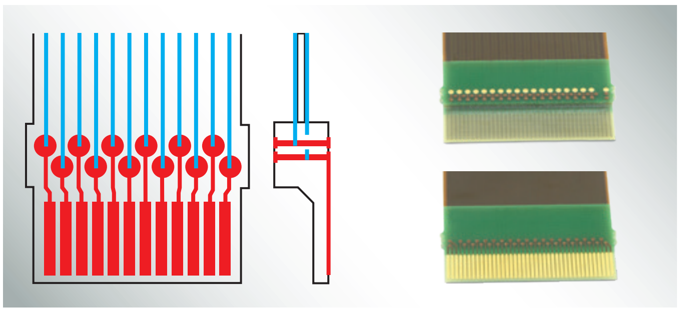
- Always provide large contour radii (inner and outer radii) in the flexible areas (design suitable for plastic)
- Provide registration drill holes for bonding reinforcements or heatsinks, if necessary
- Arrange flex extensions to save space, if necessary combine multiple extensions, use fold technology



- Flex-rigid: components and connectors always on rigid areas
- Contacts for ZIF connectors: standard thickness 0.3 mm ± 0.05 mm, handling aids/precise laser contour possible



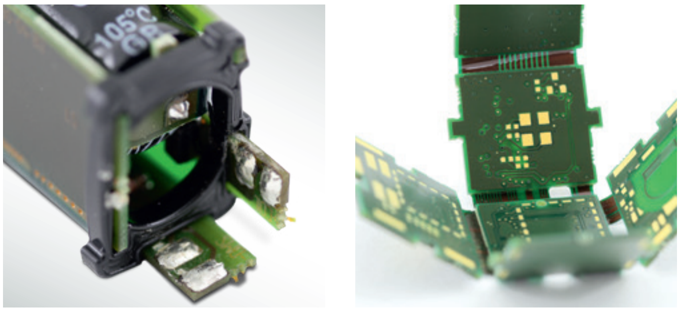
- With flex-rigid and inner layer is flex, changing to outer layer by means of vias near to the ZIF area is recommended



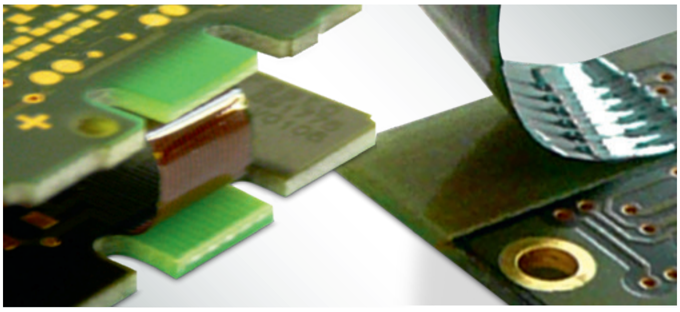
- Design bending radii based on flex thickness

Bending radius [mm]	1	2	3	4	5	6	7	
Flex area 1-layer				thickness x 10				IPC-2223: Use A
Flex area 2-layers				thickness x 10				Flex-to-install
Flex area 4-layers				thickness x 10				
FR4 Semiflex								

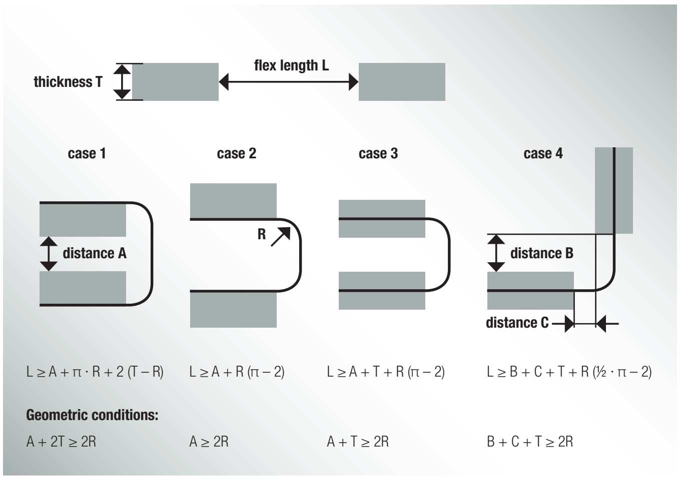
- Flex-rigid: Use „key and slot designs" or plastic retaining frame



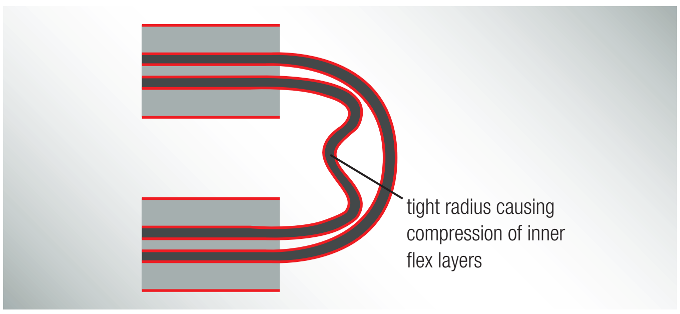
- Flex lift-off technique



- Calculation of flex length



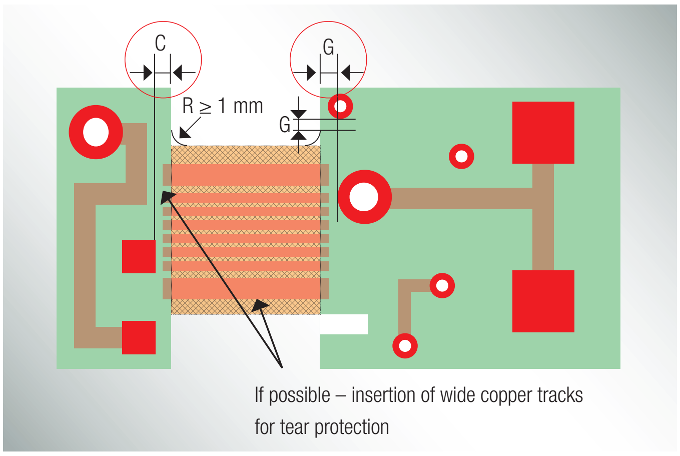
- With short flexible areas, four bonded flex layers are easier to bend than 2+2 flex layers with airgap



6. Layout & Routing

Features and recommendations for flex-rigid circuit boards

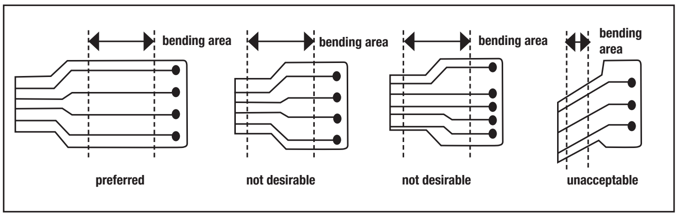
- Extra layer is necessary for defining flexible and rigid areas



- No vias in flexible area with flex-rigid
- Use teardrops
- Round routing in flexible area
- Preserve NFP (Non Functional Pads) on flexible layers

! **Regard distances of drill holes and SMD pads to flex-rigid transition, see Würth Elektronik design rules**

Layout / routing in the bending area:



(Source IPC-2223)

- Routing parallel and vertical to the bending line
- No through contacting in the bending area with flex circuit boards
- Do not change width or direction of conductors in the bending area
- Distribute conductors evenly
- If possible provide wide conductors outside near the flex contour as protection against tear propagation
- Offset conductors on top/bottom with two-sided routing
- Always apply copper removal to large copper areas in rigid and flexible areas to improve flexibility and to enable drying

! **For IPC-2223 „Use B“ (continous flexing) and Use D (UL recognition), be sure to consult with our specialists!**

7. Documents for the flex-rigid circuit board

- Include all applicable points from the checklist.
- Define what is more important: drawing or data. Electrical data (Gerber/ODB++, CAD data) already contain all geometric dimensions.
- No overspecification: a good drawing shows flat projection of the circuit (2D), a 3D view of the installation situation and critical dimensions only. Any redundant measurement on the drawing must be compared with electronic data, and any discrepancies will inevitably result in clarification, delays and additional costs.
- Specify materials in terms that are as general as possible, e.g. according to IPC specification sheets. Do not stipulate any material descriptions of supplier X with material Y.
- Adhesive layers basically should not be dimensioned, only the total thickness, copper thicknesses and necessary dielectric thicknesses (e.g. due to impedance or insulation requirements).
- General specifications for creating an optimal delivery panel and possible positions for posts (especially in the flexible area / alternative to laser cut). A delivery panel specified in the request for quotation can be replaced by a more affordable one, and due to better capacity utilization it has a more affordable price.

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