TECHNICAL GUIDE | CONTENT REVIEW

# Rigid-Flex PCB Design & Manufacturing Guide

A practical guide to stackup, bending, fabrication and assembly — from the first mechanical concept to a production-ready enquiry.

## Introduction: design the connection and the enclosure together

A rigid-flex PCB combines rigid circuit areas and flexible interconnections in a single construction. The rigid areas support components and mounting features, while the flexible sections connect those areas and allow the assembly to fit into a three-dimensional enclosure.

The most useful design decisions begin before the flat board outline is complete. Identify where the assembly must bend, how it will be installed, which parts of the product need to be detachable, and how the board will be supported during assembly. Then develop the electrical stackup and fabrication data around those mechanical requirements.

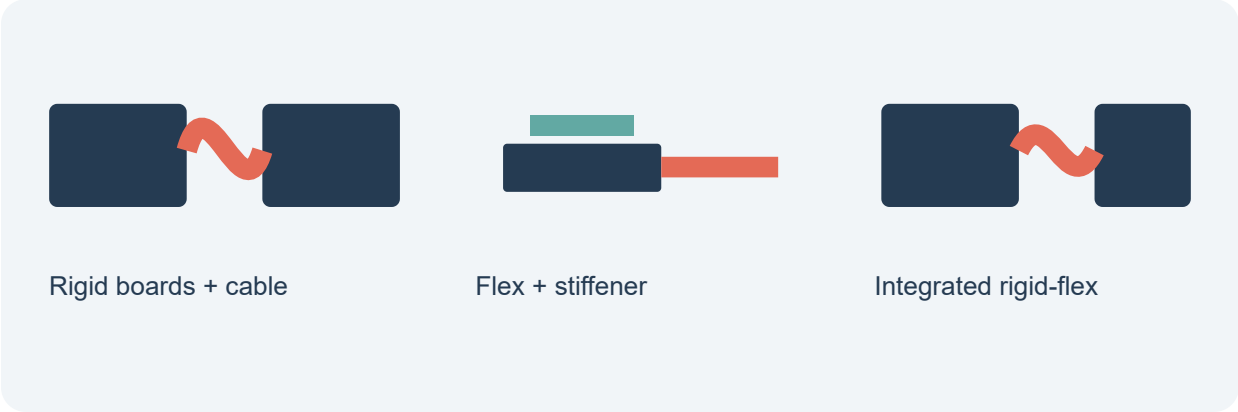
This guide follows that journey: selecting an interconnection approach, defining the stackup and bend, preparing the PCB for fabrication and assembly, and communicating the requirements needed for a useful quotation.

## 1. Choose the right interconnection approach

A rigid-flex board is one way to connect circuits inside a product. It can replace some separate cables and connectors, but it also combines the mechanical design and fabrication requirements of multiple regions into one PCB.

| Approach | Where it can fit | Main trade-off |
|---|---|---|
| Rigid boards with cables or connectors | Replaceable modules, long separations or designs needing detachable connections | More individual parts and connections; allow space for connectors and cable routing |
| Flex circuit with stiffeners | Flexible interconnection with local mechanical support for components or contacts | A stiffener reinforces the flex but is not necessarily an electrically interconnected rigid circuit section |
| Integrated rigid-flex PCB | Compact products with rigid component areas connected through a controlled flexible path | Fabrication, stackup and assembly planning are more involved; individual rigid sections are not normally separate replaceable boards |

Compare the complete product, not just the bare-board quote. Include connector and cable costs, assembly time, installation space, testing and the need to replace individual modules. Rigid-flex can simplify some of those items, but the result depends on the design and quantity.

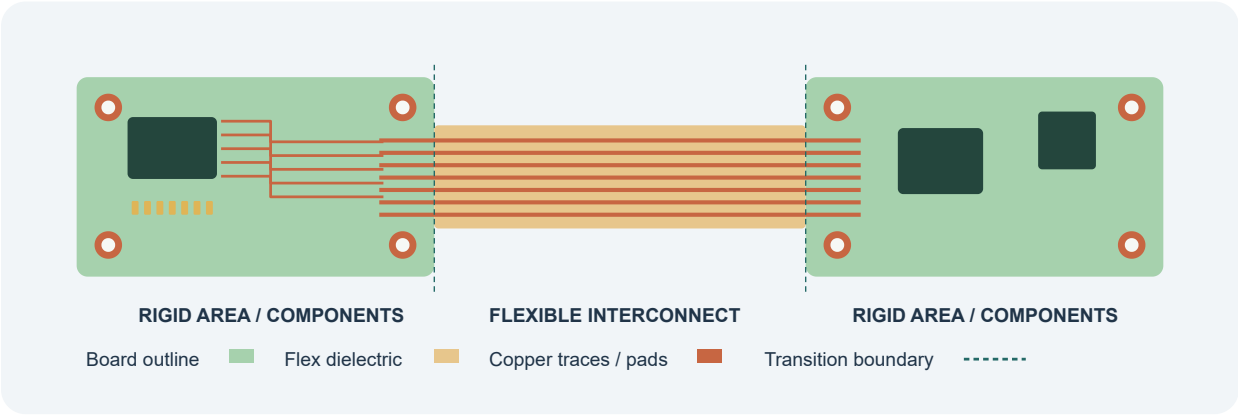



*Three interconnection approaches · Conceptual illustration, not to scale.*

## 2. Understand the rigid-flex construction

The **rigid areas** contain the more mechanically stable parts of the board. They commonly carry components, connectors and mounting holes. The **flexible areas** contain the conductive layers that connect rigid sections and accommodate the installed shape. The **transition** is where the construction changes from a rigid region to a flexible one; it deserves attention because the mechanical stiffness changes there.

Flexible copper layers continue into rigid regions and connect to other layers through the designed interconnections. A coverlay or other suitable protective system protects selected flexible-area circuitry while leaving required pads or contacts accessible. The exact materials and boundaries depend on the construction.




*Rigid-flex plan view: trace continuity and region boundaries · Conceptual illustration, not to scale.*

### Materials and their roles

| Element | Typical role | Design consideration |
|---|---|---|
| Rigid laminate and bonding layers | Support components and form rigid-region stackup | Layer count, thermal requirements, finished thickness and interface to flex |
| Polyimide flex dielectric | Supports copper in flexible sections | Thickness and construction influence flexibility and electrical geometry |
| Copper conductors | Carry signals and power | Copper thickness, foil type, routing and plating influence electrical and mechanical behaviour |
| Coverlay and adhesive, where used | Protect and insulate flex circuitry | Define openings, overlap and material placement around transitions and contacts |
| Surface finish | Protect exposed copper and support the intended assembly/contact | Select with the soldering process, contacts and storage requirements in mind |

The material name alone is not a complete specification. The grade, thickness, copper construction, bonding arrangement and intended use must be compatible with the full stackup.

## 3. Plan the stackup

Start by defining the rigid-region layer count and the number of conductive layers that must pass through each flex section. Decide which signals need controlled impedance, whether the flex must move repeatedly, and how much space is available for the installed bend. The stackup must satisfy these requirements together.

### Illustrative stackup A: two conductive flex layers

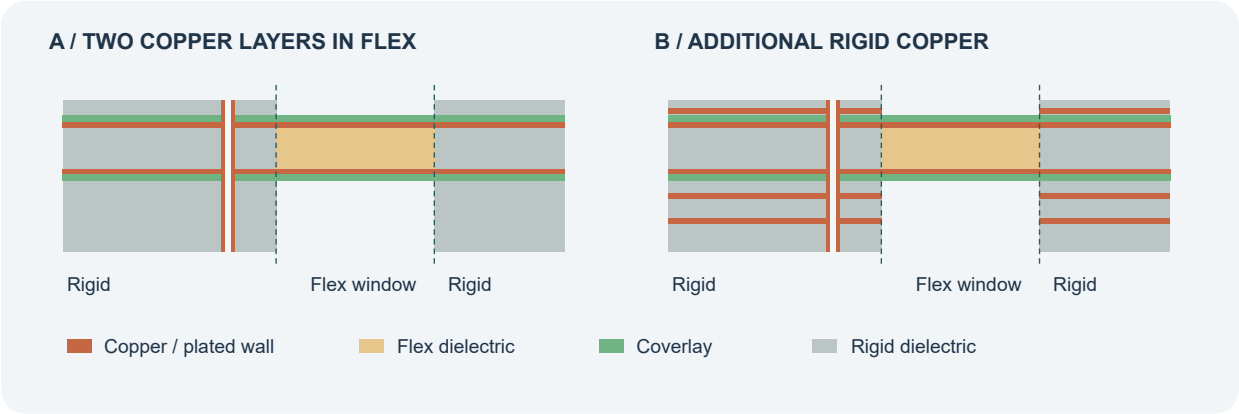
For a compact interconnection, a conceptual two-conductor-layer flex core can run between two rigid areas. From one outer face of the flex region to the other, the simplified sequence is: **protective coverlay / copper / polyimide dielectric / copper / protective coverlay**. The flexible circuit continues into the rigid regions, where rigid-region layers and bonding materials form the component-bearing board.

This example describes material relationships, not a released GreatPCB standard stackup. Copper thickness, dielectric thickness, protective layers and the total rigid-region construction depend on the circuit and the manufacturing review.

### Illustrative stackup B: multilayer rigid regions with internal flex

When the rigid regions need additional routing or reference layers, a flex subassembly can be integrated between rigid-region layers. Its copper layers connect through the defined plated structures in the rigid region. More layers can provide routing options, but their arrangement changes the thickness and mechanical behaviour of the bend region.

Do not assume that a rigid-area layer continues through the bend merely because it exists in the rigid stackup. Mark the start and end of each layer, bonding material and coverlay on the stackup drawing. Show the intended finished thickness separately for the rigid and flexible regions.




*Illustrative layer sections and plated interconnection · Conceptual illustration, not to scale.*

## Controlled impedance and HDI

For high-speed signals, review trace width, dielectric thickness and properties, copper geometry and the return path together. A change in the reference structure through a transition can affect the interconnect, so identify the required impedance and where it applies in the fabrication package.

HDI features may help route dense components in the rigid regions. Define microvia, buried-via and filling requirements in the context of the complete rigid-flex stackup; an HDI construction cannot simply be assumed compatible with every flexible-layer arrangement.

## Select copper and protective layers for the expected motion

Copper must carry the required current and meet signal requirements while surviving the intended bending. Rolled-annealed (RA) and electrodeposited (ED) copper can behave differently in repeated flexing. For a moving circuit, discuss foil type, grain orientation where applicable, finished copper thickness and the number of cycles with the fabricator. Thicker copper can improve current capacity but generally makes a bend region less compliant; increasing copper without reconsidering the mechanical design can move the problem from temperature rise to fatigue.

The protection over the bend also forms part of the flex construction. Polyimide coverlay typically combines a film with an adhesive and has openings for pads and contacts. Flexible solder mask is another possible protective system for suitable constructions. Their flexibility, opening registration, processing and resistance to repeated movement differ, so choose with the bend and assembly conditions rather than treating them as interchangeable names. Keep exposed surface finishes out of the active bend unless the specific finish and construction have been reviewed for bending.

| Selection | Benefit to assess | Trade-off to discuss |
|---|---|---|
| Fewer flex copper layers | Reduced bend-region construction thickness | Routing density and reference-path availability |
| Thinner copper at the bend | Greater mechanical compliance | Current carrying, voltage drop and manufacturing allowance |
| Coverlay | Flexible-region protection and insulation | Opening geometry, adhesive flow and registration |
| Flexible solder mask | May suit selected flexible constructions and finer openings | Suitability for the bend radius and number of cycles |
| RA copper for moving circuits | Often selected for demanding flexing | Cost, direction and availability depend on the construction |

### The return path through the flexible section

A signal does not travel independently of its return current. As a controlled-impedance route leaves the rigid area and enters the flexible portion, the dielectric thickness, reference plane and conductor geometry can change. Mark the impedance-controlled nets and their reference layers on the stackup; review both the rigid region and the flex region, including the transition. A hatched plane may improve flexibility in some constructions, but the hatch changes the reference geometry and therefore needs electrical review.

For a differential pair, retain the intended coupling and a suitable return structure through the fold, and coordinate any changes in layer, reference or width with the impedance design. Specify the required impedance and tolerance at the relevant structures rather than relying on a generic board-wide claim.

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## 4. Define the bend before completing the layout

### Flex-to-install and repeated motion

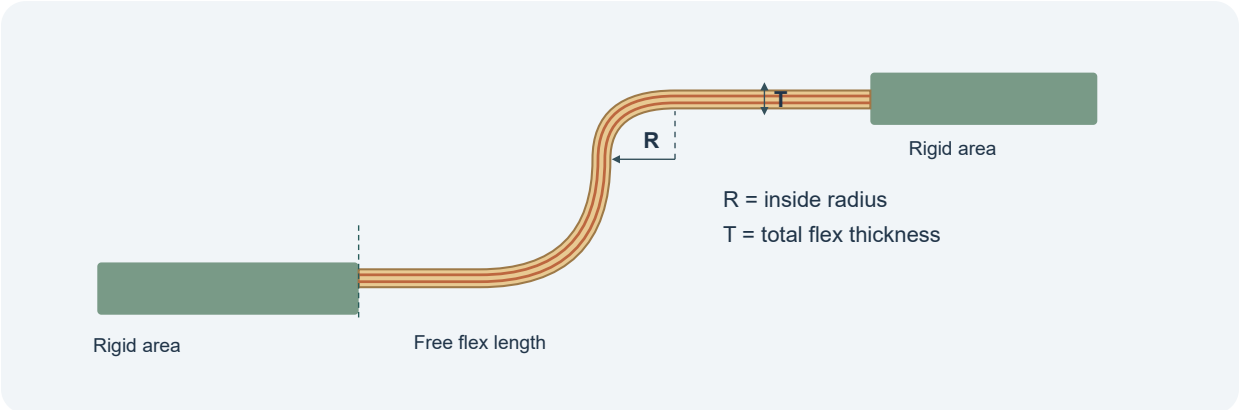
**Flex-to-install** describes a section that is shaped for installation and is not intended to move continuously in normal operation. Repeated or dynamic flexing has a different design objective: the circuit must withstand the specified movement over its service life. Vibration, servicing and installation can also introduce additional cycles, even where the final product appears stationary.

For either use, specify the bend location, inside bend radius, direction, final shape and clearance to surrounding parts. For repeated movement, also state expected cycles, motion range, temperature and any qualification test or acceptance criteria.

### Bend radius: a starting calculation, not a lifetime guarantee

The relevant thickness is the **complete flexible construction at the bend**, including the materials present there. A starting ratio can help check whether the available space is plausible, but it is not a universal acceptance limit: copper, number of layers, protective materials, construction and movement all matter.

For example, Würth's published rules for one specific two-copper-layer, flex-to-install construction use an inside radius of **10 × flex thickness**, for the conditions stated in that document. If the finished flexible section were hypothetically **0.20 mm** thick, that starting calculation would give an inside radius of **2.0 mm**. This is an illustrative calculation, not a GreatPCB blanket limit or a dynamic-flex recommendation. Other published guidance uses different starting ratios for different constructions. Confirm the actual radius with the complete stackup and intended use.




*Mechanical design: inside radius and full flex thickness · Conceptual illustration, not to scale.*

### Protect the transition and the bend

Give the flexible section enough free length to form the required radius without forcing the bend at a rigid edge. Avoid placing plated holes, component pads or abrupt copper changes in the active bend unless the specific design has been reviewed for that condition. Use smooth outlines and avoid notches that can concentrate mechanical stress.

Route the necessary conductors across the flexible region with a consistent geometry through the bend. Where copper is present on multiple layers, consider its distribution and the electrical return path together. Do not remove or hatch a reference plane solely for flexibility without considering impedance, shielding and signal integrity.

Provide both a **flat fabrication view** and a **formed or installed view**. The flat view defines the manufactured outline; the formed view shows the assembly's intended relationship to the enclosure, bend direction and clearance.

### Working design questions

| Design decision | Establish early | What changes if it is missed |
|---|---|---|
| Bend geometry | Inside radius, free flex length, bending direction and clearance | The fitted shape can force a tighter bend at the rigid edge |
| Movement | Installation cycles, service motion, vibration and temperature | A flex-to-install assumption may not match actual use |
| Layer transition | Layer terminations, adhesive and coverlay boundaries | Registration and local stiffness can change |
| Electrical path | Reference layers, impedance targets and power needs | A mechanically flexible route can still create an electrical discontinuity |
| Assembly support | Delivery panel, carrier access and component heights | Printing, placement and handling may be difficult |

### A worked project example

An illustrative handheld instrument has two rigid islands connected by a flex section and folded once into a housing. The engineering team defines an inside bend radius of 3 mm, the available free length and the installed clearance. It then asks for a two-conductor-layer flex stackup and identifies the impedance-controlled signals. The manufacturer checks the layer transition, panel support, copper and coverlay arrangement before the fabrication drawing is released. These are example requirements, not a standard construction or a guarantee of bend life.

### Compare bend allowance with the real installation

For a simple illustration, the inside arc length of a constant-radius 90° bend is πR/2. If the inside radius is 2 mm, the inside arc is about 3.14 mm. That is **only the curved inside arc**: it excludes straight sections, material thickness, transition offsets, tooling allowance and other details. It must not be used as the full finished flex length. A real folded section needs a formed drawing or mechanical model and a review of the construction.

Keep clearances to mounting hardware and enclosure walls in the installed model, not just in the flat PCB drawing. The flexible area should not be trapped against a sharp wall or forced to take the bend at a rigid edge. If a product will be opened for service, include the additional motion in the requirements. Where strain relief or a

support feature is proposed, define its material, contact area and assembly sequence so the support does not itself introduce a hard stress point.

### Routes, pads and transition zones

Use an EDA mechanical layer to show rigid boundaries, flex boundaries and the intended bend zone. Put vias and component pads in stable areas where practical. A via or soldered joint placed in a moving bend introduces a locally stiff feature and can concentrate strain. Use smooth conductor transitions; avoid abrupt changes in width or direction inside the active bend, and discuss the arrangement of copper on opposite sides of a thin flex with the fabricator.

| Region | Design information to identify | Review focus |
|---|---|---|
| Rigid component island | Components, mounting, plated holes and thickness | Stiffness, thermal exposure and enclosure fit |
| Rigid-to-flex transition | Layer ends, coverlay boundaries and nearest pads or vias | Registration, local stress and practical clearances |
| Active bend | Radius, angle, thickness, routing and movement | Fatigue, fit and required qualification |
| Contacts and stiffeners | Connector position, exposed surface, support and thickness | Mating tolerance and assembly handling |

Exact transition clearances are construction-specific. Record the required pad-to-transition, copper-to-edge and coverlay-opening distances on the drawing, then compare them with the fabrication rules for the selected stackup. Reference charts from another supplier are useful for identifying the features to check; their dimensions do not automatically apply to this build.

## 5. Manufacturing capability and design review

GreatPCB's published flex PCB capability table lists the following information. These are individual published figures, not a promise that every minimum and maximum can be combined in one stackup.

| Item | Published information | How to use it |
|---|---|---|
| Rigid-flex layer count | 2–18 layers | Identify total layers and separately identify which layers continue through each flexible section |
| Rigid-flex final thickness | 0.06–4.0 mm, as listed | Specify finished thickness and measurement location for rigid and flex regions; the online table does not distinguish regional limits |
| Materials listed | PI, PET, PEN and FR-4 among the listed materials | Identify the material grade and intended construction; listed materials are not necessarily interchangeable |
| Copper thickness in flex capability table | 1/3–2 oz | Define finished copper by layer and region; confirm the intended construction |
| Trace/space in flex capability table | At 0.5 oz, 4/4 mil listed; at 1 oz, 5/5 mil listed | The source groups flex and rigid-flex capabilities; applicability to the specific rigid-flex stackup needs review |
| Minimum hole in flex capability table | 8 mil (approximately 0.20 mm) | The source does not specify whether the figure is drill size or finished hole; clarify before using as a design limit |

The published table also lists other finishes and tolerances. Provide the stackup, drawings and critical features for review, especially when combining fine traces, higher copper weight, tight transitions, controlled impedance or special via structures. A table cannot capture every interaction among these features.

### Design features: what to define on the drawing

| Feature | Drawing reference | What the fabrication team needs | Why it matters |
|---|---|---|---|
| Flex-to-rigid transition | Transition line on outline and stackup | Material and coverlay terminations; tolerances and critical dimensions | Layer registration and stiffness change at the boundary |
| Active bend | Bend line and region | Inside radius, direction, free length, bend angle and required cycles | A drawing without the formed shape can hide tight bends |
| Copper across flex | Layer artwork and layer map | Copper thickness, track geometry and electrical reference path | Copper construction affects electrical performance and bending |
| Plated holes | Drill table and construction | Hole location, finished size, plating and relationship to transitions | Holes and rigid features affect local stress and manufacturing |
| Coverlay openings | Mask or coverlay data | Opening sizes, registration and exposed pads | Misalignment can affect exposed features and protective overlap |
| Delivery panel | Panel drawing | Rails, tooling holes, fiducials, support and depanelization | The board must remain supported through assembly and handling |

### Worked bend geometry: compare three design envelopes

This comparison applies the same **illustrative** flex-to-install starting ratio of 10 × total flex thickness to different hypothetical constructions. It is a geometry exercise, not a guaranteed minimum for all structures or a fatigue-life claim.

| Finished flexible section T | Example calculation | Inside radius R | Design implication |
|---|---|---|---|
| 0.10 mm | 10 × 0.10 mm | 1.0 mm | Check that the complete stackup and manufacturing tolerances support the required geometry |
| 0.20 mm | 10 × 0.20 mm | 2.0 mm | More thickness needs more available bend space under the same ratio |
| 0.30 mm | 10 × 0.30 mm | 3.0 mm | Review layer count and copper distribution if the enclosure is tight |

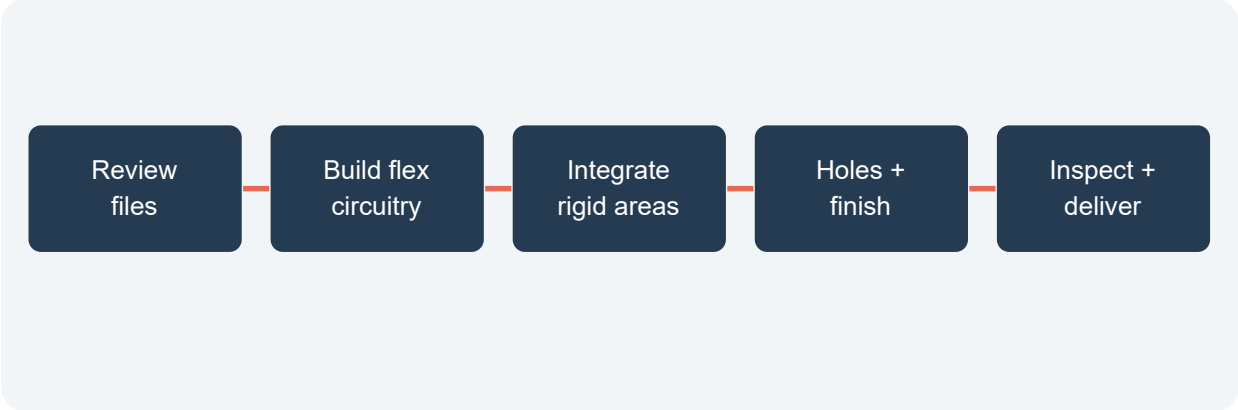
### Drawing conventions for a stackup

Number conductive layers from the same viewing direction as the fabrication data. Show each rigid and flex dielectric, conductor, bonding layer and coverlay in order. Distinguish **base copper** from **finished copper**, and indicate whether dimensions are nominal or finished. Identify the boundaries of layers that stop before the active bend. A cross-section is an explanation of construction; it is not a substitute for a complete, manufacturer-approved stackup.

## 6. From fabrication files to a finished rigid-flex board

The exact process sequence changes with the stackup, but the following stages explain the manufacturing questions that deserve attention.

1. **Review the fabrication package.** Align the layer data, rigid/flex boundaries, materials, formed shape and inspection requirements. Identify the active bend and the areas that must remain flat during handling.
2. **Prepare the flexible circuitry.** Form the required copper pattern and apply the protection specified for the flexible construction. The position of coverlay openings and edges matters around pads and transitions.
3. **Integrate the rigid areas.** Assemble and laminate the rigid-region materials with the flex construction. Registration matters because rigid layers, flex layers and their openings must align at the finished transition.
4. **Complete holes and outer features.** Produce the specified holes and interconnections, outer circuits and surface finish according to the construction. Hole preparation and metallization must suit the materials and required interconnections.
5. **Define the outline and inspect.** Release the intended rigid and flexible outlines, then inspect the completed construction against the agreed electrical, dimensional and visual requirements.




*From design to delivery · Conceptual illustration, not to scale.*

## 7. Plan PCB assembly and inspection

Rigid sections provide stable areas for most components, but the whole board still needs support through printing, placement, soldering, inspection and handling. Identify components on both sides, connector placement, the shape of the panel and any areas that must be protected from pressure or contamination.

A temporary carrier or other support may be appropriate when the geometry cannot move through assembly equipment reliably on its own. Agree the support and panel approach early; carrier openings, board thickness and component clearance can affect printing and assembly access.

| Check | What it helps establish | What it does not establish alone |
|---|---|---|
| Bare-board continuity and isolation | Electrical opens and shorts within the test coverage | Bend life or complete functional performance |
| Dimensional and visual inspection | Defined outlines, dimensions and visible features | Hidden interconnection integrity or all electrical behaviour |
| AOI or X-ray for an assembled board | Selected visible features or suitable hidden solder structures | Every circuit function or long-term mechanical endurance |
| Functional test | Specified behaviour under an agreed test procedure | Unspecified conditions or service-life qualification |
| Bend or environmental qualification, if specified | Performance under the agreed conditions and cycle count | Performance outside that test's defined conditions |

If component assembly is required, provide the BOM, placement data, assembly drawings and instructions along with the bare-board files. State any functional test procedure, fixture needs, required records and acceptance criteria.

### Moisture, thermal exposure and handling

Polyimide-based flex materials can absorb moisture. During soldering, rapid heating of a moisture-exposed assembly can create defects or damage if the material and process are not managed appropriately. Follow the board fabricator's packaging, storage, exposure and drying instructions for the actual construction. If drying is specified, coordinate temperature and time with the materials, surface finish, existing components and subsequent soldering schedule; do not apply one baking recipe to every assembled board.

Keep the flex section supported when loading and unloading panels. A carrier can support thin or irregular assemblies, but its openings, clearances, attachment and removal method must suit both sides of the board. Depanelization should avoid pulling, twisting or nicking the flexible span. Agree the support and removal method before the fixture is made.

### Plan test coverage before production

For bare boards, define continuity and isolation expectations and any impedance coupons or measurements. For assembled boards, decide whether optical inspection, X-ray and electrical or functional tests are required, and specify the locations or coverage and acceptance criteria. If the design requires repeated flexing, define the actual test fixture, inside radius, motion, cycle count, environmental conditions and pass/fail criteria; an electrical test on a flat board alone does not prove the required bend life.

## 8. Understand cost and lead time

Rigid-flex cost is affected by the whole construction: layer count, material selection, panel utilization, outline, number of rigid areas, hole and via structures, finish, quantities and inspection. More complex constructions can require additional processing and review. Material availability, file completeness and qualification requirements also influence scheduling.

For a practical comparison, request quotes for the same quantity and acceptance scope. Compare the bare board and the complete assembled system separately. A higher bare-board price may or may not be offset by fewer connectors, less wiring or simpler installation; the result is project-specific.

Early review is particularly useful when the enclosure is tight, the bend is small, the PCB contains HDI structures or a special material is specified. A proposed change to stackup or panel layout is easiest to evaluate before the manufacturing data are released.

### Release package: compare the two views

| Drawing or file | Show clearly | Review together |
|---|---|---|
| Flat fabrication view | Board outline, rigid and flex boundaries, drill and profile data | Layer data and fabrication drawing must identify the same revision |
| Formed view | Fold direction, inside radius, bend position and final orientation | Confirm interference and fit in the enclosure |
| Stackup drawing | Copper and dielectric sequence, layer continuation and rigid/flex thickness | Align material, bend and electrical requirements |
| Assembly drawing | Component side, polarity, mounting and handling limits | Review panel, support, test access and packaging |

### Typical design choices and their effects

| Choice | Potential benefit | What to check |
|---|---|---|
| Fewer flexible copper layers | Lower flex thickness and potentially easier bending | Routing density, current and return path |
| Additional rigid-region routing | More routing area around components | Interconnection, lamination sequence and transition |
| Filled or capped vias | Can support particular pad and routing arrangements | Stackup compatibility, process and inspection scope |
| Larger available bend radius | Reduces bend severity for a given construction | Housing space and installed geometry |
| PCB fabrication with assembly | One coordinated project scope | BOM availability, tooling, inspection and functional-test needs |

### Compare two quotes on the same basis

Suppose an enquiry compares an integrated rigid-flex assembly with two rigid boards joined by a cable. Use the same production quantity, quality criteria and delivery date. Add bare-board costs, purchased connectors and cable, assembly and handling, inspection, enclosure space and any rework or service requirements. A rigid-flex quotation can be higher at board level yet reduce some system costs; a connector-based design may be preferable when modules need independent replacement. Neither outcome can be decided from the board price alone.

| Quote component | Integrated rigid-flex | Rigid boards and cable |
|---|---|---|
| PCB fabrication | One combined rigid/flex construction | Separate board constructions |
| Connectors and cable | Reduced where integrated flex replaces them | Include connector and cable purchase |
| Assembly | Consider support, flex protection and handling | Include connector soldering and cable preparation |
| Final product assembly | Fold and secure the integrated board | Route, connect and secure the cable |
| Maintenance | Assess whether rigid sections need independent replacement | Assess connector access and replacement procedure |

These are comparison categories, not a price or performance prediction. Ask for comparable quotations and use the actual project costs.

## 9. Rigid-flex project and quotation checklist

| Area | Information to provide |
|---|---|
| Fabrication files | Gerber or agreed manufacturing data, drill data, board outline and fabrication drawing |
| Stackup | Rigid and flex layer counts, copper and dielectric requirements, layer transitions, target regional thicknesses |
| Mechanical design | Flat and formed views, bend locations and directions, inside radius, available clearance and mounting requirements |
| Movement | Flex-to-install or repeated motion, expected cycles, service environment and any test conditions |
| Electrical | Controlled impedance, target values and tolerances, reference layers, power and signal requirements |
| Materials and finish | Required material grades if specified, coverlay boundaries, surface finish and special contact requirements |
| Production | Quantity, desired delivery, panel or individual-board format, and any approved alternatives |
| Inspection | Electrical, dimensional and visual criteria; impedance reports, cross-sections or qualification tests if required |
| Assembly, if needed | BOM, placement data, assembly drawings, material-supply plan, programming and functional-test requirements |

## Discuss your rigid-flex project

Share your fabrication package and describe how the board fits and bends inside the product. GreatPCB can review rigid-flex fabrication and PCB assembly requirements together and discuss the construction, inspection and quotation for your project.

Contact GreatPCB · Rigid-Flex PCB Manufacturing · Flex PCB Capability

## Technical references and scope

The values in the GreatPCB capability table are taken from the published Flex PCB Capability page. The design examples are explanatory and should be reviewed with the actual stackup and manufacturing requirements.

The construction-specific 10× bend calculation is based on the stated conditions in Würth Elektronik's 2F-xRi design rules. See also All Flex Solutions' bend-radius considerations for a discussion of construction and movement. The broader design sequence draws on the engineering subjects discussed in the Flex Solutions Design Guide and Epec's manufacturing process overview. Diagrams in this review are original conceptual illustrations.