

Circuits, LLC is a quality-driven manufacturer of highly reliable, built-to-spec, flexible and rigid-flex printed circuit boards. Staffed with an experienced, customer-focused team, Circuits is committed to saving their customers time, money and the headaches commonly associated with PCB vendors.

Flex & Rigid-Flex PCB Capabilities	
Flex Materials	DuPont Pyralux AC, AP, FR & LF
Rigid Materials	FR4 & Polyimide, Rogers
Copper Weight	1/4 oz - 3oz
Core Thickness Min	0.5 mils
Board Thickness	2-125 mils
Layer Count Max	16
Max Board Size	22" x 16"
Premium delivery	3-10 business days available
Specifications	IPC-6013* MIL-PRF-31032, ITAR, UL94V-0
Trace/Space	2/2 mils
Via Structure	Through, Blind, Buried, Microvias
Hole Sizes	2-250 mils
Surface Finish	ENIG*, HAL, Hard & Soft Gold, Immersion Silver, OSP
Surface Coatings	Coverlay Pyralux LF*, FR, LPI
Special Processes	Controlled impedance, flying leads

\*Denotes standard processes

**Product Types**

Used in an ever-growing, wide variety of end applications, flexible circuit boards offer demanding industries such as military, medical, industrial controls, and aerospace numerous benefits.

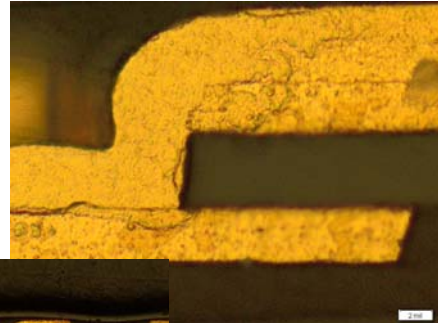
Circuits is committed to serving these markets with quality products on time at competitive costs. We build boards using IPC-6013 as the default performance specification and use a QMS designed to meet the rigorous requirements of MIL-PRF-31032.

- IPC Member
- UL 94V.0
- ITAR Registered
- ISO9001:2008 certified



**A Closer Look at Circuits, LLC**

Today's applications constantly demand smaller and lighter packaging which typically translates to increased circuit density. Circuits, LLC's microvia capabilities enable board designers to fit more connections in less space.



Microvia cross-section under 100 and 500X magnification

Through-hole interconnect integrity and plating thicknesses are verified through daily cross-sectioning at Circuits.

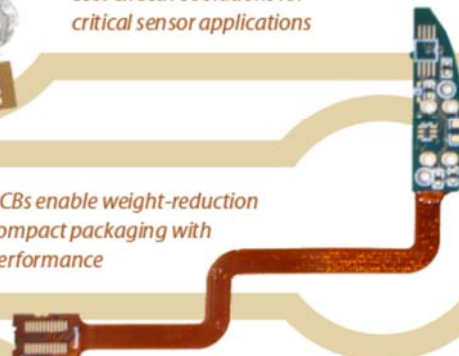
Test and measurement application built with 1/4 oz. copper and 1/2 mil adhesive coverlay to achieve a minimal bend radius



Flex circuits offer reliable and cost effective solutions for critical sensor applications



Rigid-flex PCBs enable weight-reduction and more compact packaging with improved performance



Produced on ultra thin substrates, this 4 mil flying lead frame is used in a medical ultrasound transducer.



## Clean Manufacturing

Creating an environmentally friendly manufacturing facility was a prominent consideration in planning our processes and choosing every piece of equipment. From our lead-free standard finishes to how we manage our waste, clean our air and water we have taken great strides to create a "Clean" operation.

- Exhaust and fume scrubbers reduce any pollutants leaving the facility
- Water treatment consists of an ion exchange technology to remove metallic and chemical contaminants ultimately eliminating generation of hazardous wastes
- Reclaim/recycle of valuable materials

Solar Energy –chemical rinses are heated with thermal solar power

- Warm water ensures a more effective rinse
- Reduces electrical and gas consumption



*Circuits' rooftop solar panels heat 10 gallons water per minute to 70°F with as little as 3 ½ hours average daily sunlight*

Efficient and environmentally-friendly process choices

- ENIG (cleanest, most reliable, assembly-friendly lead-free finish)
- Plasma etch – clean smear removal and etchback
- Cobra Bond™ - inner layer adhesion promotion

## Quality Across the Board

Operating under a Quality Management System (QMS) ensuring predictability, repeatability and the highest yields, the facility was designed specifically for flexible PCB manufacturing. Due to rigorous quality control requirements, the center of the operation is a self-contained Class 1000 clean room which houses all photo-sensitive and imaging processes. The mechanical and wet processes surround the clean room to create a highly efficient work flow.



Every customer order passes through our extensive design rule check prior to entering manufacturing and our panel of experts are readily accessible to every customer to provide guidance and design support as needed.

The hand-picked senior staff of Circuits rolls up more than 170 years PCB and electronics industry experience and is committed to ensuring customer satisfaction. The Circuits team works closely with each customer to meet their time-sensitive project schedules and budget constraints, offering the military, aerospace, and medical customers quality and consistent on-time delivery unsurpassed by our competitors.

## Circuits, LLC Facility

Our 50,000 square foot fabricating and testing facility houses a built-to-purpose, flow-optimized workspace specifically designed and equipped to produce reliable, high-quality flexible and rigid-flex PCBs with minimum handling and transport.

Count on us for consistent quality, competitive pricing and reliable on-time delivery. For more information or to submit an RFQ, email [sales@circuits-corp.com](mailto:sales@circuits-corp.com)



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The Circuits facility was designed for defect-free manufacturing of flex and rigid-flex printed circuit boards exclusively. The equipment and processes were chosen to minimize the handling and transport of thin core laminates and to ensure the highest reliability and quality while maintaining a cost-effective solution for our customers and environmental responsibility.

## Quality Management System (QMS)

Our QMS meets ISO9001:2008 and is designed to meet the requirements of MIL-PRF-31032 yielding a product that can comply with virtually any military or commercial standard at no extra cost to our customers.

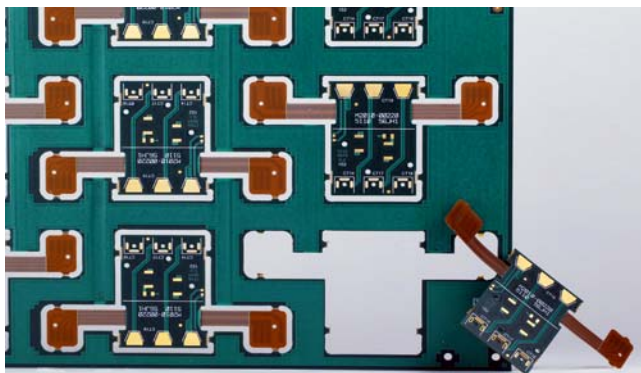


Circuits uses statistical process controls throughout production and conducts upfront contract and design for manufacturability reviews for every new customer order.

Daily cross-sections are performed to ensure plating integrity

## Computer-Aided Manufacturing

CAM is the process that provides the necessary tools and a verifiable reference for quality compliance at every step of the manufacturing chain. It guarantees the integrity of customer supplied data during manufacturing. CAM also enables conversion the customer's original Gerber data into the manufacturing tools needed on the production floor.



Circuits works closely with the customer to panelize the board for efficient assembly.

Design Rule Check (DRC) allows Circuits to identify and resolve manufacturability issues before manufacturing. All DRC discrepancies are reviewed and resolved with the customer prior to making any alterations to the artwork and before the manufacturing process can begin. Circuits takes extra steps to ensure the files received netlist is identical to the files produced data list.

## Imaging

All imaging processes are contained in our 16' X 20' modular Class 1000 clean room. The area is equipped with its own air-handling units, a HEPA air filtration system and UV light protection. A Class 10,000 gowning room and an interlocking pass-through ensure the integrity of the clean room environment. The structure consists of an insulated modular aluminum wall system with a double-plenum ceiling that hosts the forced-air HEPA filters and ground-level air returns designed to re-circulate the air several times every minute.

## Mechanical Processes

The mechanical processes are essential steps in building a reliable interconnection between layers. Work stations and tooling in our mechanical area were selected for their ability to deliver accuracy, repeatability and versatile process control.



From microvia to tight routing radii, fiducial based drilling to extremely critical dimensional features, our ESI 5150 and ESI 5200 laser driller/router allows us to take on challenging projects without reservations

With the increasing density and complexity of board designs, precision laser drilling and routing capabilities have become indispensable to the fabrication of flexible PCBs. Our drilling and routing machines, the workhorse EX200 and Uniline 2000, come equipped with air bearing spindles that turn at 80,000 RPM for the routing spindles and 125,000 RPM for the drillers. A sophisticated tool management system measures each tool before use, checks for spindle run-out at operating speed and can detect a broken drill bit at every drill stroke, all without operator intervention.

Vacuum is the key to ensuring the efficient removal of entrapped air before the pressing cycle begins. Our press has exceptional pressure uniformity across the platen surface and has fully programmable pressure and temperature capabilities.

## Process and Equipment Overview

### Quality Management System

- Upfront design for manufacturability review
- Statistical Process Control used throughout operations
- IPC-6013 default specification

### Computer-Aided Manufacturing (CAM)

- Data Integrity
- Extensive Design Rule Check
- Panelization and Manufacturing Tools

### Imaging and Optical Processes

- Class 1000 Clean Room central to operations
- Photoplotting fully integrated with front-end CAM
- High-res point source printing

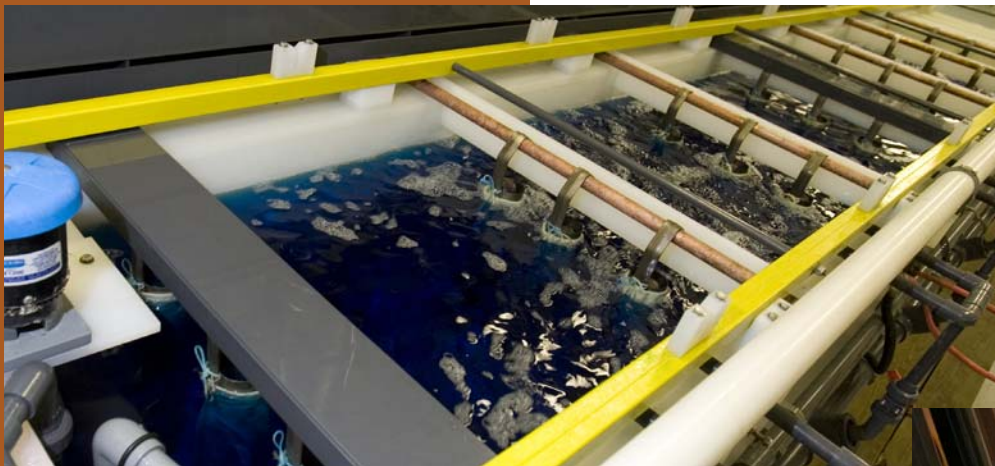
Superior technology, best practices and attention-to-detail in our chemical area are the foundation on which Circuits builds flexible and rigid-flex PCBs of exceptional quality and reliability.

## Chemical Processes

Employing a print-etch process for both inner and outer layers, we custom-designed our conveyerized Develop Etch Strip (DES) line. Delicate handling of thin core materials, efficient operation and ease of process control were the focal points in designing and procuring this critical system.

Copper plating is a vital keystone of a reliable finished product. For our process, we chose the combination of a low deposit of electroless copper immediately followed by a full-panel electroplating step, ensuring the best hole plating characteristics while allowing for a lean process that is efficient, reliable and controlled.

Circuits chose an innerlayer adhesion promotion system that combines micro-etching and surface adhesion promotion to influence the flow of the pre-preg resin. The process is designed to work with multiple types of foils, is scratch resistant and has lower overall processing costs.



Electroless Nickel Immersion Gold (ENIG) is the standard finish at Circuits. While other options are available at the customer's request, ENIG is the cleanest, most reliable and assembly-friendly finish presently available for flexible PCBs. For this proven technology, we focused on the handling issues of thin flex substrates to ensure that our customers get the only final finish that combines low operating costs with a safe and clean process.

### Chemical Processes

- Standard Electroless Nickel Immersion Gold (ENIG)
- Custom-engineered DES process line
- Plasma etchback
- Cobra-Bond inner layer adhesion promotion system for the manufacture of rigid-flex (black oxide alternative)

### Mechanical Processes

- Vacuum Lamination Press
- Mechanical Drill/Route
- Laser Drill and Route for microvias, tight radii and critical dimension features
- Controlled depth drilling

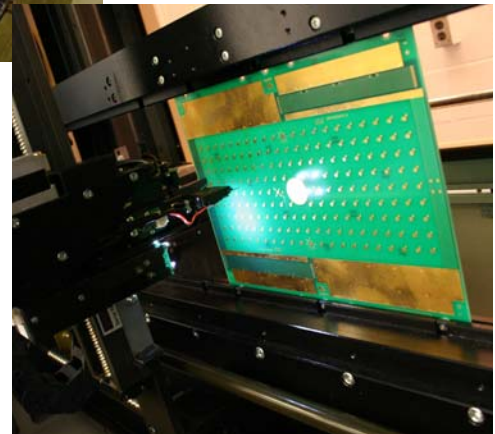
### Electrical Test & Final Inspection

- Fixtureless flying probe netlist test
- Comprehensive final inspection procedures
- Cross-section analysis
- In-house SEM/EDAX for in-depth analysis
- Controlled impedance TDR testing

PTH-electroless copper followed by full-panel electroplating

## Electrical Testing

Circuits employs a highly accurate, high-speed flying probe tester to give our clients the confidence that the integrity of each finished board is verified through continuity as well as isolation tests. Because the flying probe is fixtureless, our customers are not burdened with the cost of expensive test fixtures and can be fully confident that 100% of the flexible PCB has been tested. The 4 high-speed moving probes travel in X, Y and Z dimensions to test all critical pad locations. Every PCB is electrically tested prior to quality approval for shipment. Resistance and capacitance testing is available for buried passives as well as Controlled Impedance TDR testing for coupons.



Circuits high speed flying probe eliminates the need for costly test fixtures

## Final Inspection

Final inspection of products ensures compliance with customer specifications, including dimensional measurements of all mechanical features, finished hole sizes and annular ring, verification of through-hole interconnect integrity and plating thickness via cross section, and review of surface finishes. A final visual inspection for quality of workmanship is performed on 100% of our products.

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### Flexible PCB Benefits

Used in an ever-growing variety of end applications, flexible circuit boards offer demanding industries such as military, medical, aerospace, and industrial numerous benefits.

Flexible PCB properties:

- dissipate heat quickly
- highly resistant to shock/vibration
- ability to predict and control impedance and crosstalk
- versatile shape and formability enable 3D configurations

**Weight and Size:** Compared to rigid and round wire configurations, a flex design can save up to 75% in overall weight. Flex circuit boards can be as thin as four mils, enabling designers to solve intricate interconnection issues while reducing overall packaging size.

**Cost effective:** Flex circuits are typically designed to eliminate board to board interconnects or board to wire connections which are the most common failure point in electronic assemblies.

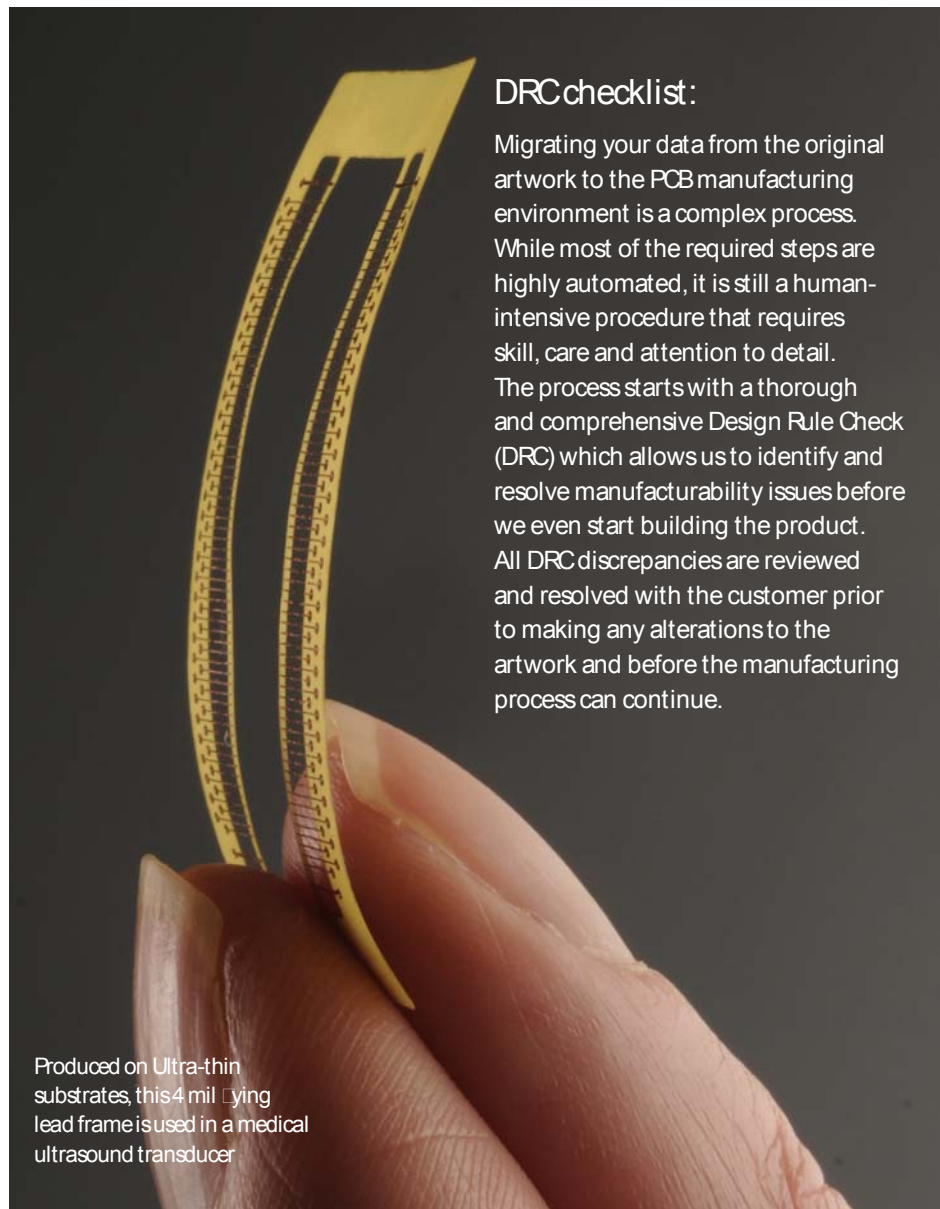
- BOM connector count reduction
- increase product reliability
- easy to install/replace

**Durability:** Able to bend and straighten up to 500 million times without a failure, flex circuits provide unmatched performance for applications with repetitive motion. Flexible circuit boards are also able to survive hostile environments due the characteristics of Polyimide KAPTON.

- dimensional stability
- dielectric strength

### Design for Manufacturability

Laminate, construction, finishes and design features can greatly affect price and delivery. Circuits works closely with each customer to understand their requirements and end applications so that the most cost-effective solution is available to them.



#### DRC checklist:

Migrating your data from the original artwork to the PCB manufacturing environment is a complex process. While most of the required steps are highly automated, it is still a human-intensive procedure that requires skill, care and attention to detail. The process starts with a thorough and comprehensive Design Rule Check (DRC) which allows us to identify and resolve manufacturability issues before we even start building the product. All DRC discrepancies are reviewed and resolved with the customer prior to making any alterations to the artwork and before the manufacturing process can continue.

Produced on Ultra-thin substrates, this 4 mil wiring lead frame is used in a medical ultrasound transducer

### Standard Flexible Circuit Materials

Circuits, LLC carries a broad range of adhesive based or adhesiveless copper clad constructions using a wide variety of base dielectrics. Dupont Pyralux materials stocked at Circuits are Certified to IPC4204/11.

Materials & Features	Polyimide Thickness (mils)	Adhesive Thickness (mils)	RA Cu (oz/sq ft)	ED Cu (oz/sq ft)
DuPont Pyralux APCopper-clad Laminate Ideal for use in high reliability rigid-flex and multilayer flex circuitry	0.5, 0.8, 1, 1.5, 2, 3, 4, 5, 6, 7		0.5, 1, 2, 3, 4	0.25, 0.75, 0.5, 1, 2
Pyralux LF Copper-clad Laminate Ideal for avionics for its consistency and dependability	0.5, 1, 2, 3, 4, 5	0.5, 1, 2, 3, 4	0.5, 1, 2, 3, 4	0.5, 1, 2
DuPont Pyralux FR Commercial grade product ideal for applications requiring flame retardancy	0.5, 1, 2, 3, 4, 5	0.5, 1, 2, 3, 4	0.5, 1, 2, 3, 4	0.5, 1, 2

## Design Considerations

Bend radius:

For single and double-sided flex the minimum bend radius should be six times the overall thickness. Example: if the overall thickness of the flex circuit is .012, the minimum bend radius should be .072.

For multilayer flex and rigid-flex, the minimum bend radius should be 12 times the overall thickness. Example: if the overall thickness is .03, the minimum bend radius should be .360.

### Stiffeners

**Rigid Stiffeners:** Non-conductive rigid FR4, Polyimide or G10 laminate is most commonly used to add selective rigidity to flexible circuits for component support, achieving required thickness values to mate with components and strain relief. GFN thickness range from .004-.125.

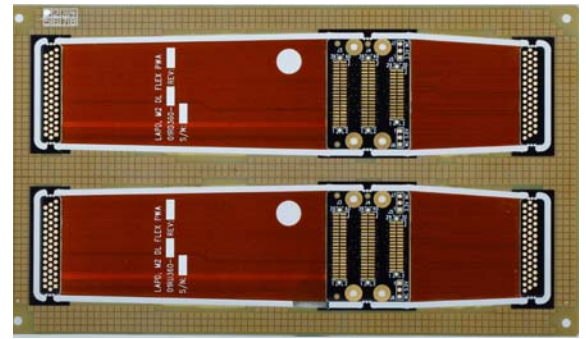
**Kapton Stiffeners:** Kapton stiffeners do not provide the rigidity found with a rigid stiffener, but can provide additional thickness to selected areas of the flexible circuit board to properly mate with flex connectors. Kapton stiffeners with their adhesive backing are available in .003-.007 thickness.



Contact our sales department at sales@circuits-corp.com for the complete Designing Flex and Rigid-Flex Application presentation.

## Panelization

Flex boards populated (assembled) using automated equipment typically require the board to be supplied in a panel form or with rigid cutting so that the circuit board can travel through conveyerized assembly equipment. Circuits works closely with customers and their assembly partners to ensure cost-effective panelization. Circuits' standard panel sizes are 18"X24" and 18"X12". The usable area is approximately two inches less across each dimension for tooling, coupons and processing. Multiple board images per panel may require cutting or specialized step and repeat patterns for assembly tooling and pick and place considerations.



Break-away panels gives flex rigidity during assembly pick and place operations

## Choosing the Right Surface Finish

**ENIG (Electroless Nickel Immersion Gold)** chemistries offers excellent wettability, coplanarity, surface oxidation and long shelf-life. Circuits, LLC offers ENIG as the standard surface finish.

**HASL (Hot air solder leveling)** (a tin lead finish) is not recommended for finer pitch and tight tolerances.

**Lead Free HASL** a good alternative to leaded HASL, however exhibits poor coplanarity and solder joints may appear darker, though this is just cosmetic and does not affect solderability.

**Hard Gold** a lead-free finish that is expensive and may crack over time.

**Soft Gold** used exclusively for wirebonding, does not perform well in other categories and overall cost is high.

**Immersion Silver** finished boards must be packed using sulphur-free paper to prevent tarnishing. Very reactive surface with handling issues.

**OSP (Organic Solderability Preservatives)** are lead-free and provide good surface oxidation, and are typically less expensive than other finishes, but have poor shelf life, handling issues and degrade with high temperatures.

**Immersion Tin** - good surface oxidation and excellent coplanarity properties, but known to have poor shelf life and handling issues.



Flex and rigid flex boards are panelized for efficient and cost-effective manufacturing.

Properties	HASL	Lead-free HASL	ENIG	Immersion Silver	OSP	Immersion Tin	Electrolytic NiAu
RoHS	No	Yes	Yes	Yes	Yes	Yes	Yes
Solder Wettability	Excellent	Good	Good	Very Good	Good	Good	Good
Coplanarity	Poor	Poor	Excellent	Excellent	Excellent	Excellent	Good
Solder Joint Integrity	Excellent	Good	Good	Good	Good	Good	Poor
Rework	Yes	Yes	No	Yes	Yes	Yes	No
Shelf Life	Very Good	Good	Very Good	Poor	Poor	Poor	Very Good
Fab Costs	Low	Medium	Low	Low	Low	Medium	High