ETCHED THICK FILM CERAMICS

Offering innovative precision ceramics substrate solutions:

- Precision Thick Film
- Faster Turn TimesThan Conventional Thin Film
- Advanced Etching Technology (APECS)
- Cost Effective vs. Thin Film

Anaren®
What'll we think of next?®

www.anaren.com
800-411-6596

ABOUT THIS PRODUCT & DESIGN GUIDE

Anaren's Etched Thick Film Ceramics Product & Design Guide reflects a broad representation of etched thick film technology capabilities in Anaren's, Wireless Group. This guide is intended to assist you in the initial evaluation of your design's compatibility with the various thick film technologies provided by Anaren. The guide will also introduce you to methods, processes, and techniques that can minimize costs and cycle times. As a guide, the information provided does not represent the full range of possibilities of our fast-expanding and continually improving technologies and manufacturing capabilities, nor does it replace the interaction between customers and Anaren's ceramic, RF and Microwave engineers; this collaborative dialogue is required to provide the most robust and cost-effective design.

ABOUT US

ANAREN is a leading global designer and manufacturer of high-frequency RF and microwave microelectronics, components, and assemblies for the space, defense, and telecommunications sectors for over 50 years. Our engineering expertise and products are utilized by major manufacturers around the world, in everything from telecommunications networking products, fighter-jet jammers, base-station amplifiers, to communication satellite systems. Anaren products are the result of innovative engineering, design, materials processing, and world-class volume manufacturing. As a leading manufacturer of components, sub systems and innovative material solutions. Anaren Wireless Group also provides quality thick film circuits and a world class etched thick film process. This thick film capability allows for multilayer substrates that create lower cost microwave circuitry featuring high precision capability, including: etched conductors, chip resistors and attenuators, and more!

OUR SPECIALTIES INCLUDE:

- **Exclusive, ceramic-based thick film solutions.** Whatever your product requirements may be, we support a wide variety of the latest technologies and material, coupled with the engineering experience that optimize them efficiently and resourcefully. This enables us to provide solutions other suppliers simply can't.

  Anaren substrate capabilities include features such as filled substrate vias, edge wraps, integrated resistors, capacitors, and inductors. Throughout, we employ the latest thick film technology — and a variety of substrate materials such as alumina, aluminum nitride, beryllia, and ferrite for maximum design flexibility. Anaren's engineering and processing team are constantly adding additional material sets and capabilities to our portfolio.
- **Vertical integration.** Through Anaren's shared expertise across disciplines, we can help reduce costs and increase turn times. If thick film screening, etching, plating, laser trimming, design assistance, ceramic machining, and comprehensive testing are what you need, Anaren can accommodate.
- **Products for a diverse customer base.** We work with customers in medical, wireless, optical, automotive, aerospace, aviation, and other industries.

  The varied and exacting demands of these sectors have made us proficient in developing all kinds of low cost, quick-turn prototypes. They have also enabled us to compress our design-to-production cycle times, matching our capacity to your low or high-volume manufacturing needs, and develop a range of quality "standard" products, including microwave chip resistors and power terminations and the industry's smallest termination resistors, measuring 1mm square. exceeding our customers most stringent performance standards.
- **The added confidence of Anaren engineering.** In addition to ceramics design expertise, you can count on Anaren across manufacturing disciplines, including: integrated RF solutions, multi-chip modules, and printed circuit boards. Results can include reduced costs and time-to-market.

  Whether your current solution is LTCC, HTCC or Thin Film, Anaren world class team of Mechanical, RF and Microwave and production engineering experts would relish the opportunity to convert you to a lower cost and faster turns time, Thick Film user.

  If you are thinking of solutions never before possible, think Anaren! Start with this Product & Design Guide for data, specifications, and drawings — then call us at 315-432-8909 when you need the expertise, experience, and capabilities to make those solutions real.

PRODUCT QUALITY ASSURANCE

- ISO-9001:2008 registered
- Quality requirements MIL-Q-9858
- QPL listed chip resistors MIL-PRF-55342
- Test capabilities MIL-PRF-38534

CONTACT

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TABLE OF CONTENTS

HIGHLIGHTS

- Sequentially applied layers of alternating conductor and dielectric to build up the multilayer structure
- Typically used in four to six conductor layers per side (single or double sided)
- A selection of metals for wirebonding, soldering, brazing
- Integrated resistors, capacitors, inductors
- Alumina, ferrite, aluminum nitride, beryllia substrates, and more
- Wide range of resistor materials and values on a single substrate
- Wraps and metallized substrate vias
- Advanced substrate machining, including various shapes and cutouts
- For recommended materials selection, please contact Anaren for details

CONDUCTORS

Fritless golds are used for high-reliability conductors and for gold wire bonding. Fritted gold metallizations have higher adhesion to the substrate and, for that reason, are often substituted for fritless gold. Pt/Au and Pt/Pd/Au alloys have very high solder leach resistance and are used for critical solderable applications. Pure silvers have the lowest resistivity, and when alloyed with palladium and/or platinum, become increasingly leach resistant. Careful silver alloy selection will produce a high-reliability part in cost-sensitive applications. Special acid-resistant alloys of silver are used as the base metal for nickel barrier plating when the ultimate in solder leach resistance is required.

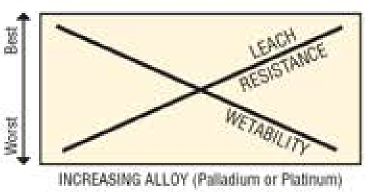


Table 1: Conductor Properties

	Gold	Platinum/ Gold	Silver	Palladium/ Silver
Relative Cost[1]	20-25	25-30	1	2-5
Sheet Resistivity (µΩ/sq)	3-7	60-100	1-2	10-50
Solderability (Sn/Pb)[2]	4	2	5	2-4
Leach Resistance[2]	1	5	1	3-4
Printed Typical Fired Thickness (microns/layer)	7-13	10-15	10-18	10-25
Typical Min. Line Width (width in mils)	5-7	7-10	7-10	7-10
Etched Thick Film Min. Line Width (width in mils)	1.3		2	
Typical Etched Fired Thickness (microns/layer)	6-12		10-14	

1 Relative Cost: 1 = Best
2 Relative Values: 5 = Best

DIELECTRIC

Thick film dielectrics are designed to be used as insulators between conductor layers in crossover and multilayer applications. Overglazes are used as protective coatings over printed resistors and capacitors. They also serve as solder stops in surface mount assemblies and provide protection from harsh chemicals in the plating process.

Table 2: Dielectric Properties

	Dielectric Constant	Dissipation Factor	Breakdown Voltage (V/mil)	Fired Thickness (microns)	Insulation Resistance (ohms)
Dielectric	6-12	< 0.5%	500	38-51	$>10^{11}$ @ 100 V
Low - K	3.9-4.5	<0.01% 0.04% @ 20 GHz	500	25-51	$>10^{11}$ @ 100 V

* Contact Anaren Ceramics for recommendations.

RESISTORS

Standard resistor materials are made from glasses and metal oxides of ruthenium metal. Sheet resistivities are available from milliohms to gigaohms and can be combined on a single substrate. Standard trim tolerances are 10% through 1%, and in some cases to 0.5%. Large numbers of minimum size resistors on a substrate may limit the tolerance to 5% to 10% due to yield considerations.

Table 3: Typical Resistor Characteristics

	Sheet Resistivities (ohms/square)							
	1	10	100	1K	10K	100K	1M	10M
TCR (PPM/C) Maximum	±300	±300	±300	±300	±300	±300	±300	±300
Typical	100±200	100±200	100±200	0±200	0±200	0±200	0±200	0±200
Maximum Rated Power Dissipation (mW)								
Alumina	500	575	750	500	400	275	100	10

Note: Laser trim will reduce resistor area by up to 50%, power based on 1306 metric size.

VCR

If VCR is important in your application, contact Anaren for design and material recommendations.

CAPACITORS

Capacitors are processed using standard screen printing techniques and fired directly onto any layer of the substrate. They may also be buried within or on top of multilayer structures. Electrodes must be of the same material. Typical dielectric thickness is 40 microns. Capacitor tolerance is typically ± 30%. Design options are available to reduce tolerances.

Table 4: Typical Printed Capacitor Dielectric Properties

Dielectric Constant (K)	20-50	100-300	500-750	750-1500
Dissipation Factor (1 kHz)	< 0.3%	< 1.0%	< 1.2%	< 3%
Dissipation Factor (1 MHz)	< 0.5%	< 1.6%	< 2.0%	–
Dielectric Strength (Volts/mil)	> 500	> 500	> 500	> 500
Insulation Resistance (@ 100 V, 1 kHz)	> 10^{11}	> 10^{11}	> 10^{11}	> 10^{9}
TCC (25°C-125°C)	< 3%	< 6%	< 15%	(Z5U)

Note: Typical properties based on 0.100" x 0.100" capacitor. Contact Anaren Ceramics for more details

SUBSTRATES

Standard substrate materials include alumina (Al_2O_3) in sizes to 6" x 4", aluminum nitride (AlN) in sizes to 4" x 4", and beryillia (BeO) in sizes to 2.3" x 2.9". Laser scribing 0.025"-thick rectangular alumina provides the most effective approach to meeting mechanical requirements. When necessary, substrates can be machined to produce virtually any outline. Other available substrate materials include barium titanate, ferrite, and quartz. Standard thicknesses 10 to 120 mils ±10%. Standard camber 3 mils/inch. Increased control of thickness, camber, and surface finish is available by lapping or polishing.

Table 5: Substrate Material Characteristics

	Unit	96% Alumina	99.5%/ 99.6% Alumina	Beryllia (BeO)	Aluminum Nitride (AlN)
Dielectric Constant (1MHz)		9.5	9.9	6.5	8.6
Dissipation Factor (1MHz)		0.0004	0.0001	0.0004	0.001
Thermal Conductivity (100°C)	W/m-K	20	27	270	170
Coeff. Thermal Expansion	ppm/°C	6.3-8.0	7.0-8.3	9.0	4.6

Table 6: Thicknesses and Sizes (BeO/AlN)

	Standard Thickness (mils)									
	10	15	20	25	40	50	60	80	100	120
Alumina	X	X	X	X	X	X	X	X	X	X
BeO	X	X	X	X	X		X			
AlN	X	X	X	X	X	X	X			

Table 7: Recommendation for attach methods

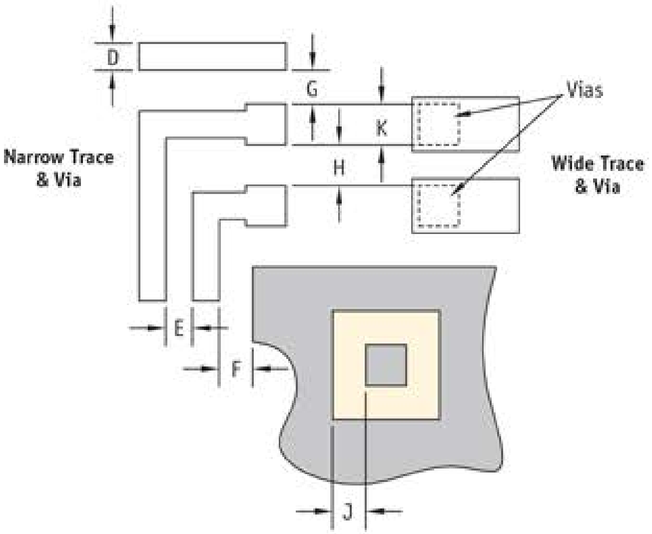
	SnPb Solder	Epoxy	RoHS (Pb Free)	SAC Solder	AuSn Solder	Au Wire-bond	Al Wire-bond
Au		X			X	X	X
Pt-Au	X	X	X	X	X	X	
Ag		X					X
Pt-Ag	X	X	X				
Electroless Nickel-Gold	X	X	X	X	X	X	X
SnPb Plate	X		X	X			
Matte Tin Plate	X		X				

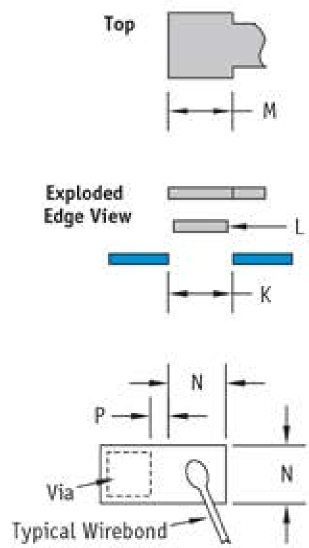
DESIGN FEATURES

Thick film multilayer design rules follow on the next several pages.

- Minimum and standard feature sizes are shown. All features can be of greater size unless otherwise indicated.
- Feature sizes greater than the minimum improve producibility.

CONDUCTORS & VIAS



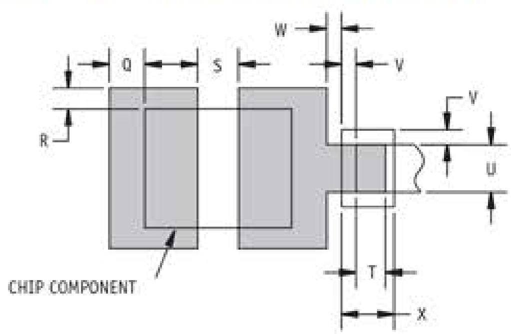


	Rule	Etched Gold Minimum (mils)	Etched Gold Standard (mils)	Standard Thick Film Minimum (mils)	Standard Thick Film Standard (mils)
D	Conductor Width	1.3	2.0	7	10
E	Conductor Spacing	1.3	2.0	7	10
F	Conductor Spacing Different Materials	6	12	6	12
G	Conductor to Via	5	10	10	12
H	Via to Via, Isolated	10	15	12	15
J	Conductor Isolation in Power/Ground Plane	2.0	2.5	10	12

	Rule	Etched Gold Minimum (mils)	Etched Gold Standard (mils)	Standard Thick Film Minimum (mils)	Standard Thick Film Standard (mils)
K	Via Diameter	4	6	8	10
L	Via Fill[1]	3.5	N/A	7	9
M	Conductor Over Via[2]		3.5 x 3.5	10 x 10	15 x 15
N	Wirebond Pad Size (for 1 mil Gold Wire)		5 x 5	10 x 10	10 x 15
P	Via to Wirebond Pad[3]	12	15	12	15

1 Via fill typically 1/2 mil smaller than via opening all around
2 Minimum size same as via size
3 This spacing improves planarity of wirebond site

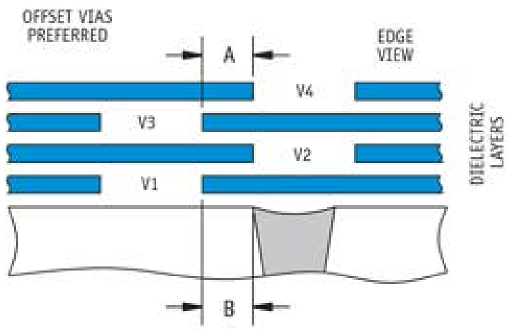
SOLDER PADS & GOLD/SILVER INTERFACE

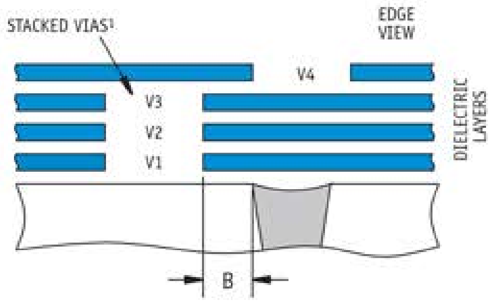


	Rule	Minimum (mils)	Standard (mils)
	Rules Q-S: Solder Pads[1]		
Q	Chip Pad Extension, Length	10	12
R	Chip Pad Extension, Width	5	7
S	Solder Pad Spacing	15	–
	Rules T-X: Au-Ag Interface where required[2]		
T	Overlap Length, Dissimilar Materials	8	12
U	Overlap Width, Dissimilar Materials	10	12
V	Solder Mask Overlap at Gold-Silver Interface	5	7
W	Glaze Solder Mask Stepback	2	5
X	Glaze Width	8	15

1 Suggested dimensions for typical components
2 Non-alloyed gold must be protected from the leaching effects of solder

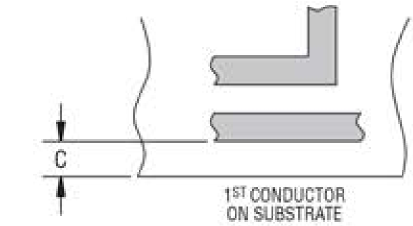
VIAS, DIELECTRICS & CROSSOVERS

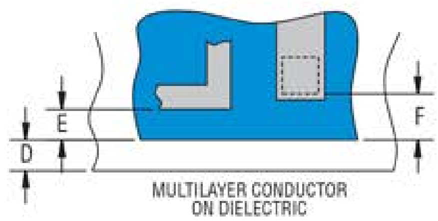




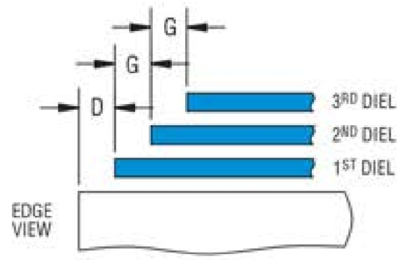
	Rule	Minimum (mils)	Standard (mils)
A	Offset Via Spacing	5	10
B	Via to Filled Substrate Hole	3	5

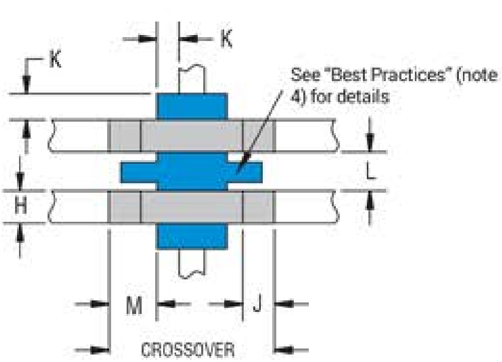
1 Limit stacked layers to 3 before offsetting





	Rule	Minimum (mils)	Standard (mils)
C	Conductor to Snapped Substrate Edge Conductor to Diced Substrate Edge	8 2	10 5
D	Dielectric to Snapped Substrate Edge Dielectric to Diced/Machined Substrate Edge	8 0	10 5
E	Multilayer Conductor to Dielectric Edge	7	10
F	Via to Dielectric Edge	10	15

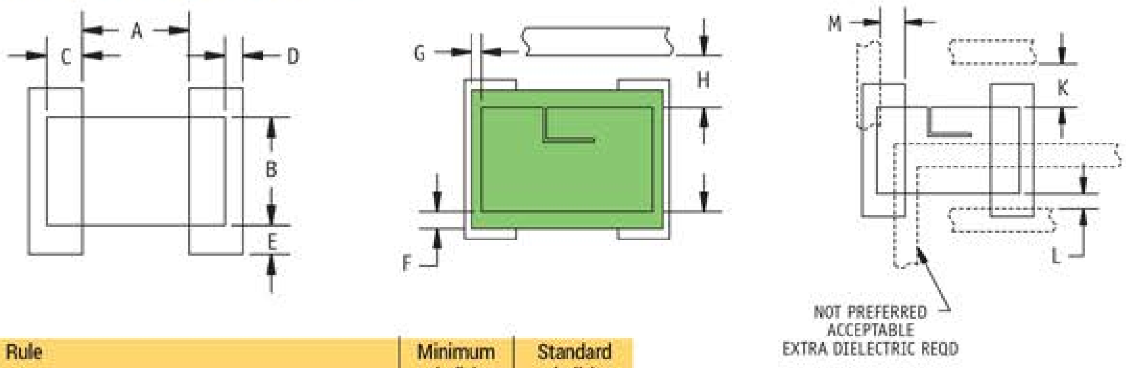


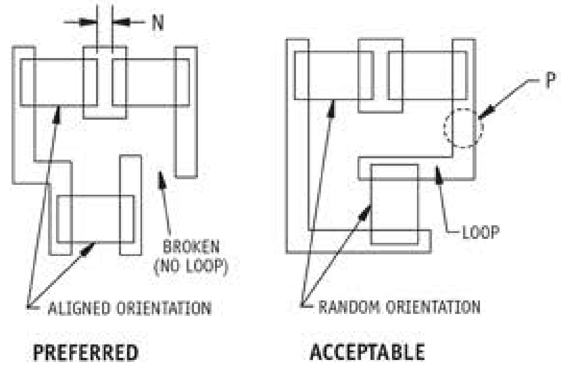


	Rule	Minimum (mils)	Standard (mils)
	Rules H-M also apply to conductors running off the edge of a dielectric		
G	Dielectric Stepback	0	2
H	Crossover Width	10	12
J	Crossover Overlap	8	12
K	Dielectric Overlap	7	10
L	Crossover Spacing	10	12
M	Crossover Length Beyond Dielectric	8	15

Note: A minimum of two layers of dielectric is needed for isolation between conductor traces. Dielectric layer counts greater than 4 may impact listed dimensions.

PRINTED RESISTORS





	Rule	Minimum (mils)	Standard (mils)
A	Resistor Length[1]	15	30
B	Resistor Width	15	30
C	Resistor/ Termination Overlap	7	10
D	Termination Extension (Length Direction)	3	5
E	Termination Extension (Width Direction)	5	8
F	Overglaze Coverage, Width[2]	5	8
G	Overglaze Coverage, Length	0	3
H	Conductor to Resistor Edge	10	15
	Rules K-N apply to 1ST layer below resistor		
K	Buried Conductor to Resistor Along Termination	15	20
L	Buried Conductor to Untrimmed Resistor Edge	0	5
M	Buried Conductor to Trimmed Resistor Edge	10	15
N	Resistor to Resistor on Common Termination[3]	0	10
P	Resistor Probe Pad[4]	8 x 10	15 x 15
–	Resistor Orientation[5]	Random	Aligned
–	Resistor Loops[6]	Loop	No Loops

1 Dimensions based on Au terminated resistors; Ag terminated add 10 mils
2 Overglaze used where environmental stability is required
3 Zero spacing allowed if both resistors use same paste
4 Probe pad not covered by glaze or dielectric; located anywhere on trace; not in area reserved for termination extension; see E for reference
5 Orienting resistors in the same direction is especially helpful for small-geometry ...... resistors
6 Identify resistor loops in drawing notes: contact Anaren for details.

TRIM

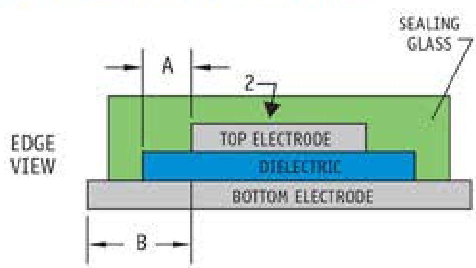
J-Cut
- Low Cost
- Improved Power performance
- Better RF performance

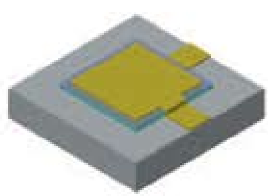
L-Predict Cut
- Best Tolerance performance
- Highest processing cost

Scan Cut
- Best Power performance
- Better Tolerance performance
- High processing cost

Note: Unless otherwise specified by customer, Mil STD 38534 and Mil STD 883 will be employed.

PRINTED CAPACITORS





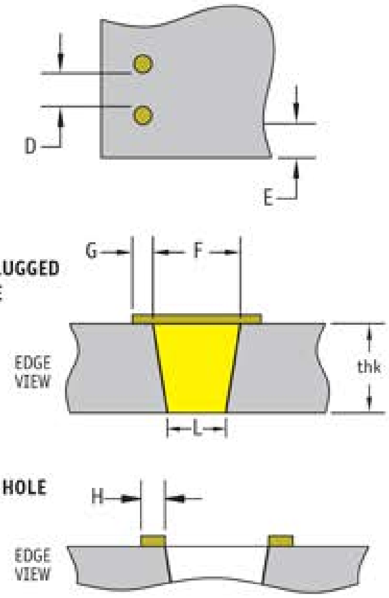
	Rule	Minimum (mils)	Standard (mils)
A	Dielectric Overlap Smaller Electrode	7	10
B	Larger to Smaller Electrode Overlap	2	5
	Value[1] 2pF to 500pF		
	Capacitor Tolerance	± 30%	± 50%

Note: Bottom and top electrode can be interchanged
1 Value depends on Dk and area of capacitor
2 Full encapsulation of sealing glass to prevent environmental exposure

HOLES AND EDGE WRAPS

FILLED / PLUGGED HOLE

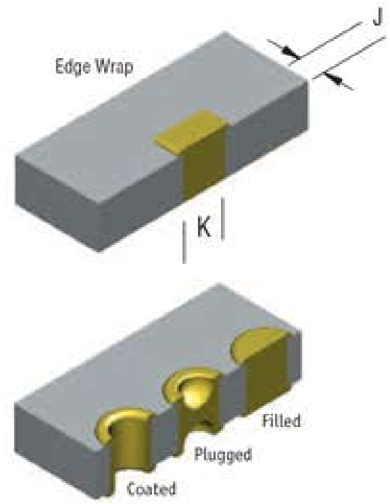
COATED HOLE



	Rule	Minimum	Standard
D	Hole Spacing (Edge to Edge)	Sub Thk	1.5 x Sub Thk
E	Hole Edge to Snapped Substrate Edge	1.0 x Sub Thk	
E	Hole Edge to Diced Substrate Edge	0.5 x Sub Thk	1.0 x Sub Thk
-	Substrate Length & Width Tolerance, Diced Edge	± 1 mil	± 2 mils
-	Substrate Length & Width Tolerance, Snapped Edge	± 5 mils	± 10 mils

Table 8: Hole Machining

	Rule	Minimum	Standard
L	Top Hole Diameter	10-25 mils thk	F-(thk x 10%)
L	Top Hole Diameter	30-40 mils thk	F-(thk x 10%)
L	Top Hole Diameter	50-60 mils thk	F-(thk x 10%)



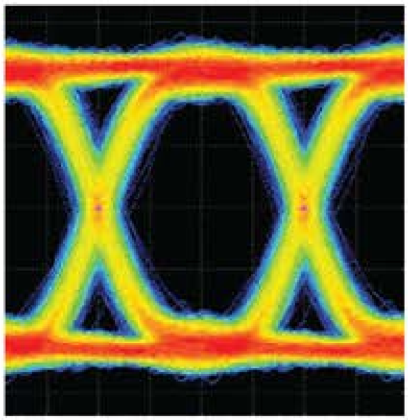
	Rule	Minimum (mils)	Standard (mils)
F	Plugged/Filled Hole Diam, 10-25 mil thk Substrate	7	
F	Plugged/Filled Hole Diam, 30-40 mil thk Substrate	8	
F	Plugged/Filled Hole Diam, 50-60 mil thk Substrate	10	
G	Conductor Pad Covering Filled Hole	5	7
H	Annular Ring around Coated Hole	7	10
J	Wrap onto Top or Bottom Surface	15	20
K	Width of Edge Wrap	10	15
L	Bottom Hole Diameter	F-(thk x 10%)	

Note: Plugged and filled hole diameters should not exceed the ceramic thickness

CUSTOMER DRAWINGS AND CAD FILES

- For any design work (thick film multilayer, thick film multilayer or etched thick film), customer CAD files are preferred in one of the following formats:
  – AutoCad .DWG
  – DXF
  – Gerber files
- High-density designs require a customer-furnished netlist:
  – IPC 356D preferred
- All specifications should be listed on drawing or supporting documentation.
- In all cases, an active dialogue between you and your Anaren team ensures that design requirements and applications intents are met!

FOR EXTREMELY TIGHT TOLERANCES AT HIGHLY AFFORDABLE PRICES... ENGAGE ANAREN: PRECISION ETCH CIRCUITS



Anaren Precision Etch Technology is your choice for RF/microwave circuits, filters, inductors and couplers.

- Thin Film performance at Thick Film cost – up to 40% savings over Thin Film
- Fine line capability: 1 mil lines, 1 mil spaces
- Excellent line edge definition
- Au and Ag etch capability
- Integrates with standard Thick Film resistors & capacitors
- Multiple substrates available: Alumina, AlN, BeO & more
- No Nickel barrier means less intermodulation distortion
- RoHS/REACH Compliant

The APECS process can be combined with standard thick film technology to create a highly integrated, more cost effective solution and improve overall substrate yield. Just use APECS precision lines and spacing in those distinct locations of your design where precision is needed most—leaving other, less precise areas on your substrate to be rendered using traditional thick film techniques. Want to integrate components? That's easy, too, because APECS substrates allow you to embed precision resistors, Lange couplers, and capacitors into the substrate itself — rather than applying discrete components using more labor-intensive, less consistent traditional component mounting approach.

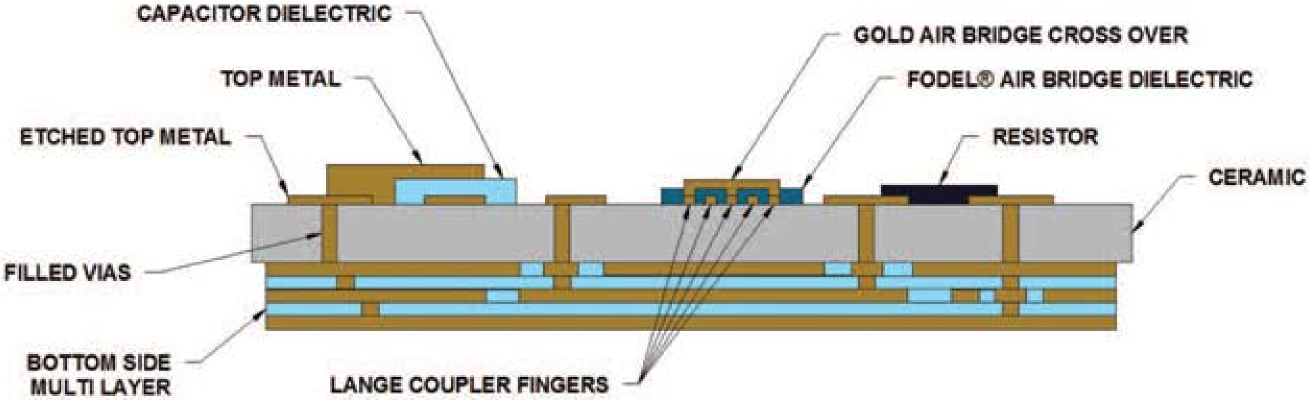


Figure 1: Cross-Section of APECS Circuit
Showing multilayer backside and integrated passives

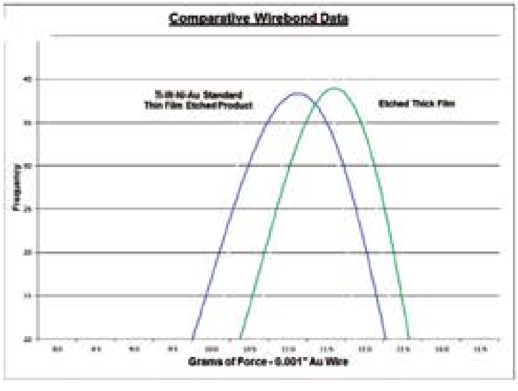


Figure 2: Comparative Wire Bond Data

ETCHED THICK FILM CAPABILITIES

- Capacitors, resistors, hole fill, wraps, solder- and braze-metallizations
- Alumina (96%, 99.5%, 99.6%), ferrite, aluminum nitride, Beryllium Oxide and Quartz substrates
- Standard and low-K dielectrics
- Air bridges
- Multilayer structures
- Wide range of resistive values (0 to Gohm)
- Glass encapsulations

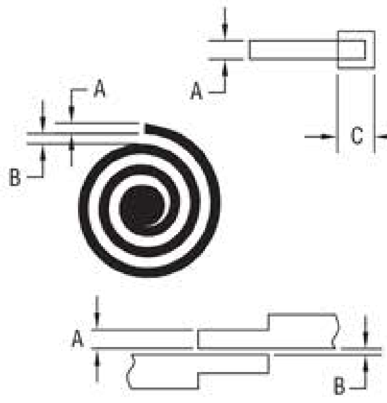


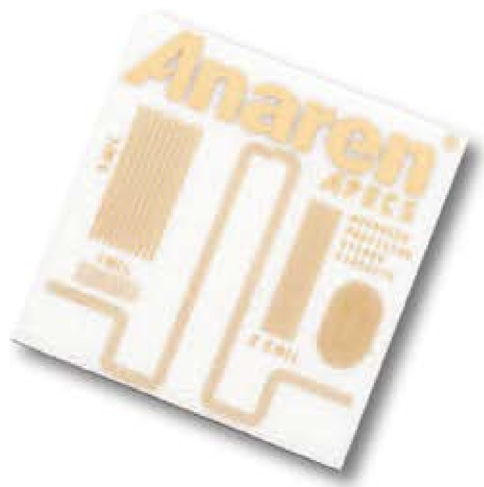
Figure 3: Etched Conductors

	Rule	Minimum (mils)	Standard (mils)
A	Conductor Width	1.3	2.0
t	Line Width Tolerance	± 0.1	± 0.2
B	Conductor Spacing Same Print Mask	1.3	2.0
C	Via Size Diameter	5.3	8.6

Note: For best tolerances, a lapped ceramic surface may be required.

THE APECS RF ADVANTAGE

Comparing line losses between an APECS Thick Film board and a typical Thin Film board the line loss is significant lower for the APECS Thick Film. As the frequency increases the lower loss becomes even more significant. Both boards were fabricated using a 96% Alumina ceramics and identical Gold trace thickness.



DIELECTRIC CONSTANT MEASUREMENTS

Ring Resonators are used to measure the dielectric constant of available material sets. A ring resonator is a simple structure that is a 50Ω transmission line, one wavelength long at a fundamental frequency. The single wavelength transmission line ring has no discontinuity effects resulting in a standing wave pattern that resonates at every harmonic of the fundamental frequency. There is no reflection characteristic on the ring structure resulting in full wavelength resonances only. Energy is coupled onto and off the ring through two identical transmission lines that are seperated from the ring by a 4 mil gap, resulting in a capacitive coupling effect. The dielectric constant information is extracted from the frequency of resonance at each harmonic allowing multiple D_K (dielectric constant) estimates per structure. This information is somewhat independent of the quality of the transmission line print allowing a very accurate estimate of the material D_K.

Microstrip and Stripline ring resonators have been designed, fabricated and measured yielding DK data for material sets. D_K is extracted from resonant frequency measurements using the following equations:

Table 9: DK and effective DK:

STRIPLINE RING RESONATORS Material $D_K = (c*n/(f_c*l))^2$
MICROSTRIP RING RESONATORS Effective $D_K = (c*n/(f_c*l))^2$
PARAMETERS
$c = 3.0*10^8$ (m/s)
n = Harmonic number
f_c = Measured harmonic resonant frequency (Hz)
l = Resonator length (m)

Dual ring resonator coupons designed to resonate at fundamental frequencies of 2, 3, 5, 7 and 11 GHz have been manufactured and RF tested at Anaren. The resonator coupon contains a microstrip structure and a stripline structure, forming two ring resonators in one block of ceramic. Figure 11.1.1 shows a single dual resonator coupon; figure 11.1.2 shows a typical broadband 5GHz ring resonator response.

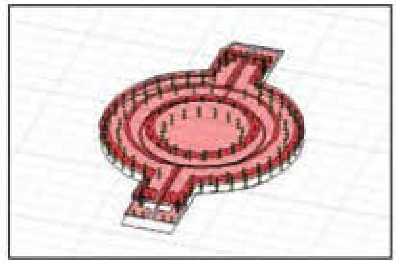


Figure 4: Dual Ring Resonator Structure

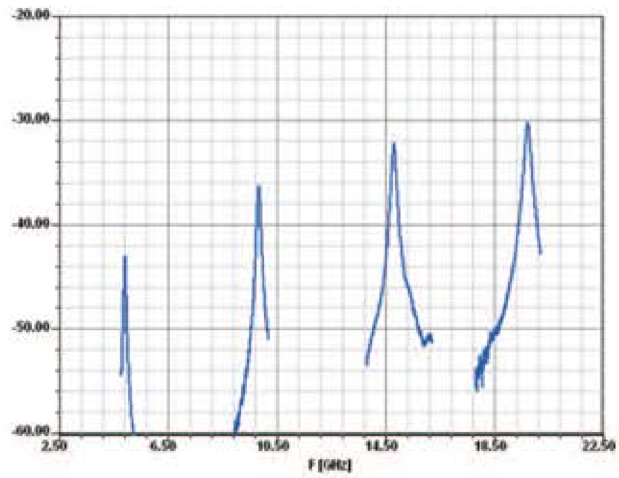


Figure 5: Typical Broadband 5GHz Ring Resonator Response showing resonances at the first/second/third and fourth harmonics.

BEST PRACTICES

1. In areas where there is a crossover, active conductor traces should be coated with solder mask.
2. Components less than .080" x .050" attached with conductive epoxy should have a solder mask between the attached pads.
3. For multilayer structures, we recommend a 2 mil pullback of dielectric layer for each consecutive dielectric print.
4. When creating a crossover dielectric, it is a good idea to put a barrier in between the 2 crossovers to prevent shorts between adjacent traces (see page 5).
5. Don't put silver material beneath gold conductors separated by dielectric, to avoid Kirkendall voiding.
6. Do not design resistors in close proximity to a multilayer structure such as a printed capacitor.
7. If possible, use similar layer-to-layer count on both sides of a substrate to minimize potential for bowing of substrate.
8. For cost reduction, keep resistors in same orientation on circuit board.
9. For cost reduction and maximum resistor value consistency, alter the aspect ratio to achieve different resistor values with the same paste.

NOTES

APECS HIGHLIGHTS:

- Single, double, or multi-layer thick film substrates
- Etched line width and spacing — controlled to an order of magnitude better than traditional screen printing for lower-loss, faster turn time, higher-density circuits
- Lines and spaces down to 37 µm
- Through via down to 175 µm with 175 µm spacing
- Blind via down to 75 µm with 150 µm spacing
- Edge wraps and fully metallized substrate vias
- Alumina base substrates 96%, 99.5%, and 99.6%
- Machining of substrates to any shape
- Specific metallizations for wire bonding, soldering, or brazing
- In-house plating: gold-tin, matte-tin, tin-lead, electroless nickel-gold
- Lower-cost than thin film for microwave circuitry, featuring advanced etching technology (APECS)
- Microwave modeling, design and test capability
- Circuit layout assistance
- Integrated laser marking and serialization
- Innovative method for creating structures with blind features such as open cavities and counterbores
- Net testing
- RoHS/Reach compliant material sets available
- ISO-9001:2008 registered facility
- Vertical integration: All processes from CAD to shipped product are performed in-house
- Extensive industry experience in materials, ceramics, microelectronics, and RF design
- Standard and custom chip resistors and attenuators, plus QPL-listed chips per DESC MIL-PRF-55342

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