

Applications Note
Capacitance of Test Probes and Sockets
Theoretical Estimate Calculations for Parallel
Conductors

Document# ANQ074 Rev A ECN# 3232 Page 1 of 2

Capacitance Overview:

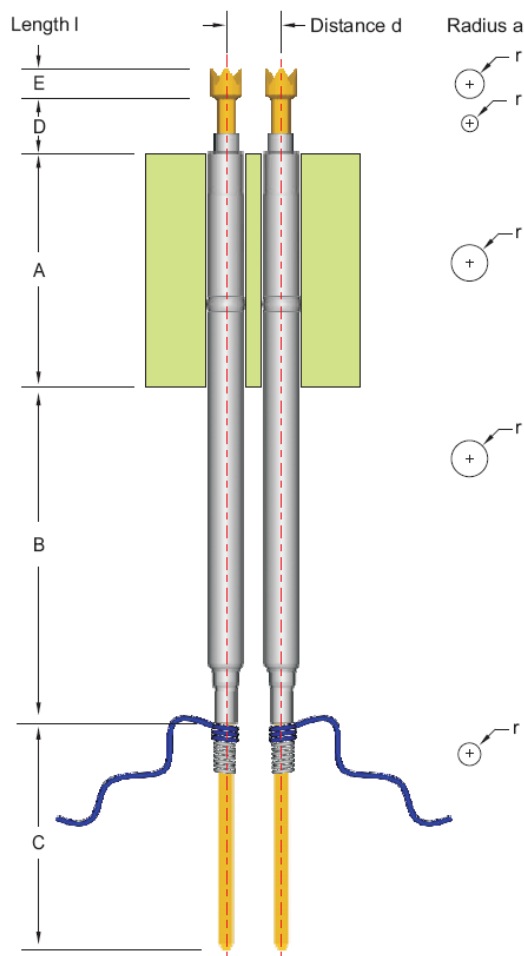
In electromagnetism and electronics, capacitance is the ability of a body to hold an electrical charge. Capacitance is also a measure of the amount of electric charge stored (or separated) for a given electric potential. Any pair of conductors (probe and socket) separated by an insulating medium or dielectric (air, vacuum, G10/FR4, plastic) creates capacitance between those conductors. As the two parallel conductors are moved away from each other, the capacitance will decrease. Capacitance and resistance should not be confused because while a conductor (probe and socket) will have a constant known resistance, that same conductor will not have a constant stable capacitance. This is due to the interaction of the other conductors around it and the dielectric constants of the medium through which they pass.

Capacitance Formulas for Parallel Conductors:

Two probes mounted next to each other with a known center spacing can utilize the capacitance formulas for Parallel Conductors adapted from Electromagnetic Compatibility Handbook by Kenneth L. Kaiser, page 8-28. The probe and socket assembly can be broken down into sections with the capacitance from each section added together to get a total capacitance for the complete assembly. These calculations ignore the boundary conditions between the different geometries through which they pass so the capacitance values given are only an approximation. The following page details the calculations performed to derive the final capacitance value for a pair of probes when mounted on the recommended centers.

Capacitance equation for two parallel conductors from Electromagnetic Compatibility Handbook:

$$C = \frac{\pi \cdot \epsilon_r \cdot \epsilon_0 \cdot l}{\ln \left(\frac{d}{2a} \left(1 + \sqrt{1 - \left(\frac{2a}{d} \right)^2} \right) \right)}$$



Applications Note

Capacitance of Test Probes and Sockets

Theoretical Estimate Calculations for Parallel Conductors

Document# ANQ074 Rev A ECN# 3232 Page 2 of 2

Results Summary:

The probe and socket are broken up into sections. Each section of the probe and socket assembly have a radius (a), distance (d), length (l) and a Relative Static Permittivity or Dielectric Constant (ϵ_r) that separates them associated with it (Data). The Electric Constant (ϵ_0) is 8.854E-12 Farads/Meter. The diameters and lengths were taken from the QA Catalog and then converted to meters (Conversions) to facilitate the calculations. Note that the length of the plunger shank is calculated when the plunger is compressed at it's test position (2/3 stroke). The capacitance formula is broken down into Intermediate Calculations which are used to calculate the Results. The Results from each section are then added together to arrive at the Total Capacitance values listed below. As stated previously, these Results for the Theoretical Estimate Calculations for Parallel Conductors do not take into account the boundary conditions that exist between the different geometry sections. Approximately 70% of the capacitance of a test probe and socket is contributed to through the G10/FR4 material through which it passes.

Table B: Results Summary (total)

Probe Series	Capacitance (picofarads)
039-16/25	3.4
050-T25/40	3.1
050-R25	3.5
075-25/40	2.9
100-25/40	2.7

Table A: Capacitance Calculations

Section Dimension	Conventional 100-mil, 280° stroke probe section descriptions:	Enter Data for "Parallel Conductors"				Calculations								
		Radius - a	Distance - d	Length - l	ϵ_r	Radius - a	Distance - d	Length - l	TR- ϵ_r -l	d/2a	Intermediate Calculations	Cap Results		
												Cap (pF)	Cap (pF)	
075-25 Series with Wire Wipe														
Conventional 75-mil, 280° stroke probe section descriptions:														
A	75-mil socket body, 75-mil pin, 5° G10	25.5	75	500	5.2	0.0005	0.00191	0.01270	1.837E-12	1.471	1.163	1.079	2.0E-12	1.89
B	75-mil socket body, 75-mil pin, 5° Air	25.5	75	500	1.0006	0.0005	0.00191	0.01270	3.635E-13	1.471	1.163	1.079	3.8E-13	0.38
C	75-mil probe plunger shank, 75-mil pin, 5° wire wipe with AWG 28 wire	30.3	75	600	1.0006	0.00077	0.00191	0.01270	3.635E-13	1.295	0.932	0.728	6.2E-13	0.52
D	75-mil probe plunger shank, 75-mil pin, 1° Air	12.5	75	100	1.0006	0.00032	0.00191	0.00254	7.095E-14	3.000	8.000	2.828	4.0E-14	0.04
E	75-mil probe plunger head, 75-mil pin, 0.6° Air	23.5	75	50	1.0006	0.00030	0.00191	0.00127	3.635E-14	1.969	1.244	1.244	3.4E-14	0.03
075-25 Series with Plug Housing														
Conventional 75-mil, 280° stroke probe section descriptions:														
A	50-mil socket body, 50-mil pin, 5° G10	19	50	600	5.2	0.0004	0.00127	0.01270	1.837E-12	1.316	0.731	0.855	2.4E-12	2.37
B	50-mil socket body, 50-mil pin, 5° Air	19	50	750	1.0006	0.0004	0.00127	0.01646	5.302E-13	1.316	0.731	0.855	6.8E-13	0.68
D	50-mil probe plunger shank, 50-mil pin, 13° Air	11.5	50	20	1.0006	0.00026	0.00127	0.00330	9.192E-14	2.174	3.729	1.920	9.2E-14	0.07
E	50-mil probe plunger head, 50-mil pin, 0.2° Air	17.5	50	20	1.0006	0.00044	0.00127	0.00051	1.414E-14	1.459	1.041	1.020	3.0E-14	0.02
050-R25 Series with Plug Housing														
Conventional 50-mil, 280° stroke probe section descriptions:														
A	50-mil socket body, 50-mil pin, 5° G10	19	50	600	5.2	0.0004	0.00127	0.01270	1.837E-12	1.316	0.731	0.855	2.4E-12	2.37
B	50-mil socket body, 50-mil pin, 1° Air (includes plug housing)	19	50	1100	1.0006	0.0004	0.00127	0.02794	7.776E-13	1.316	0.731	0.855	1.0E-12	1.00
C	50-mil probe plunger shank, 50-mil pin, 13° Air	11.5	50	130	1.0006	0.00026	0.00127	0.00330	9.192E-14	2.174	3.729	1.920	9.2E-14	0.07
E	50-mil probe plunger head, 50-mil pin, 0.2° Air	17.5	50	20	1.0006	0.00044	0.00127	0.00051	1.414E-14	1.459	1.041	1.020	3.0E-14	0.02
039-16 Series with Wire Jack														
Conventional 39-mil, 280° stroke probe section descriptions:														
A	39-mil socket body, 39-mil pin, 5° G10	15	39	600	5.2	0.0003	0.00099	0.01270	1.837E-12	1.300	0.690	0.831	2.4E-12	2.43
B	39-mil socket body, 39-mil pin, 1° Air (includes WJ)	15	39	1000	1.0006	0.0003	0.00099	0.02540	7.095E-13	1.300	0.690	0.831	9.2E-13	0.93
D	39-mil probe plunger shank, 39-mil pin, 15° Air (includes head E)	7.5	39	160	1.0006	0.00019	0.00099	0.00498	1.131E-13	2.600	5.790	2.400	7.0E-14	0.07
Total														
												3.4E-12	3.4	

$$C = \frac{\pi \cdot \epsilon_r \cdot \epsilon_0 \cdot l}{\ln \left(\frac{d}{2a} \left[1 + \sqrt{1 - \left(\frac{2a}{d} \right)^2} \right] \right)}$$

Parallel wire capacitance equation from Electromagnetic Compatibility Handbook by Kenneth L. Kaiser, page 528.

Relative Static Permittivity - Dielectric Constant (ϵ_r)	Electric Constant (ϵ_0)
Vacuum	8.854E-12
Air	1.0006
G10 (FR4)	5.2