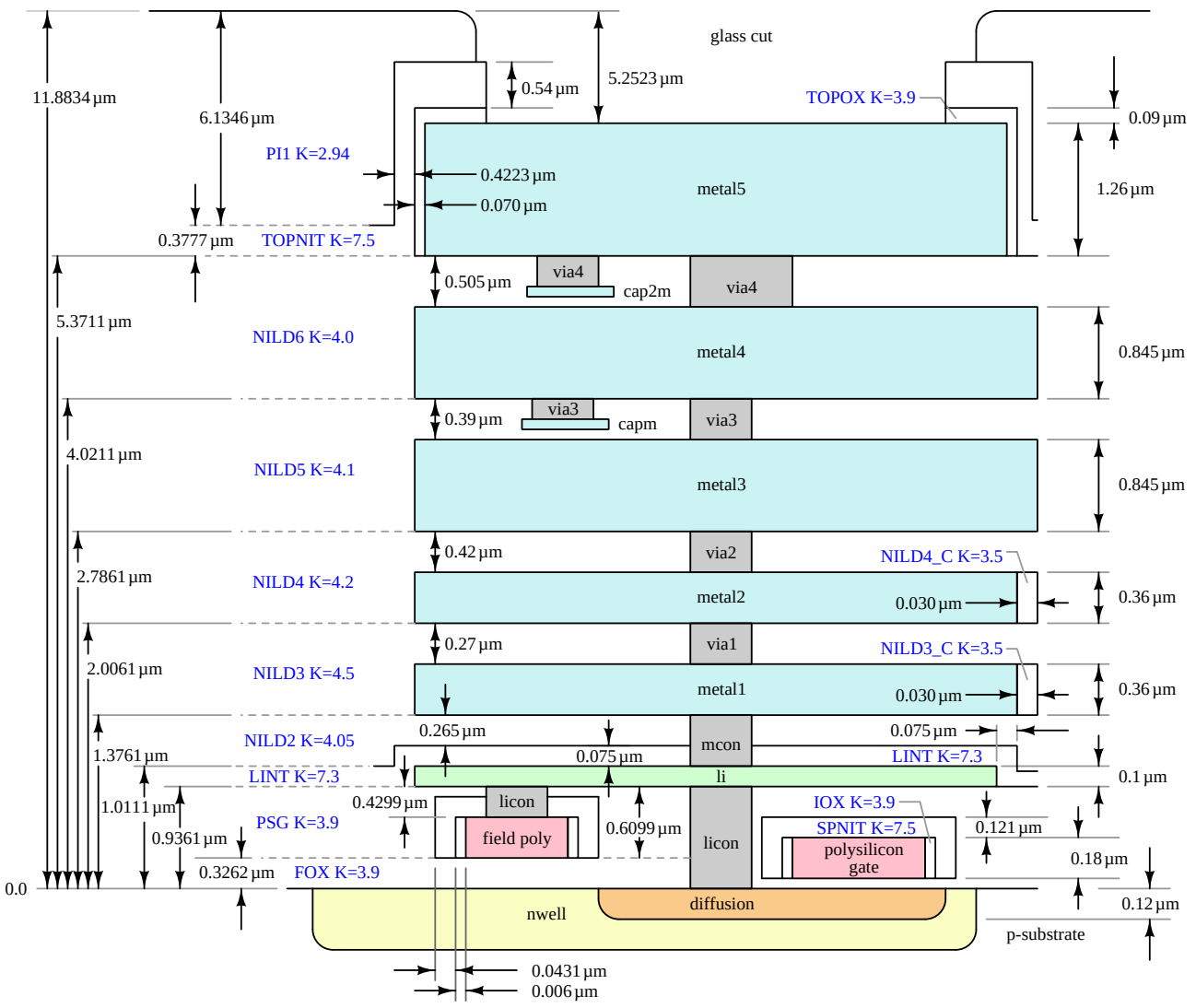
SkyWater Sky130A metal stack (not to scale!):



SkyWater sky130A capacitance tables

Inter-layer distances (microns)

	metal5	metal4	metal3	metal2	metal1	li	poly
metal4	0.505						
metal3	1.74	0.39					
metal2	3.005	1.655	0.42				
metal1	3.635	2.285	1.05	0.27			
li	4.335	2.985	1.75	0.97	0.34		
poly (field)	4.8649	3.5149	2.2799	1.4999	0.8699	0.4299	
diffusion n-well substrate	5.3711	4.0211	2.7861	2.0061	1.3761	0.9361	0.3262

Inter-layer capacitances (final values in aF/μm^2) Note: LEF CPERSQDIST is in pF/μm^2, so divide by 1.0e^{-6}

	metal5	metal4	metal3	metal2	metal1	li	poly
metal4	70.1307						
metal3	20.4659	93.0805					
metal2	11.9856	22.0677	88.5400				
metal1	10.0109	16.1884	36.0337	147.5667			
li	8.5302	12.640	22.177	41.466	116.96		
poly (field)	7.6460	10.791	17.051	26.544	45.235	92.872	
diffusion n-well substrate	6.7968	9.1734	13.335	18.514	26.009	36.8877	105.8571

Fringe capacitances (values in aF/μm) Note: LEF EDGECAPACITANCE is in pF/μm, so divide by 1.0e^{-6}

	metal5	metal4	metal3	metal2	metal1	li	poly
metal4	378.01						
metal3	168.89	351.52					
metal2	129.16	144.86	341.14				
metal1	119.67	125.83	191.73	273.21			
li	113.11	114.74	150.89	137.79	249.97		
poly (field)	109.36	109.04	135.42	115.79	152.95	120.86	
diffusion n-well substrate	102.25	99.483	116.62	94.529	106.39	72.763	141.68

Sidewall capacitances (values in aF/μm)

metal5	metal4	metal3	metal2	metal1	li	poly
77.267	29.9265	30.675	13.387	14.343	3.937	6.710

SkyWater sky130A capacitance tables

Inter-layer capacitances worksheet (series capacitors, top to bottom)

metal5 to metal4:

$4.0\,\varepsilon_0$ / 0.505

metal5 to metal3:

$4.0\,\varepsilon_0$ / 1.35
$4.1\,\varepsilon_0$ / 0.39

metal4 to metal3:

$4.1\,\varepsilon_0$ / 0.39

metal5 to metal2:

$4.0\,\varepsilon_0$ / 1.35
$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.42

metal4 to metal2:

$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.42

metal3 to metal2:

$4.2\,\varepsilon_0$ / 0.42

metal5 to metal1:

$4.0\,\varepsilon_0$ / 1.35
$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.27

metal4 to metal1:

$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.27

metal3 to metal1:

$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.27

metal2 to metal1:

$4.5\,\varepsilon_0$ / 0.27

metal5 to li:

$4.0\,\varepsilon_0$ / 1.35
$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.265
$7.3\,\varepsilon_0$ / 0.075

metal4 to li:

$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.265
$7.3\,\varepsilon_0$ / 0.075

metal3 to li:

$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.265
$7.3\,\varepsilon_0$ / 0.075

metal2 to li:

$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.265
$7.3\,\varepsilon_0$ / 0.075

metal1 to li:

$4.05\,\varepsilon_0$ / 0.265
$7.3\,\varepsilon_0$ / 0.075

metal5 to field poly:

$4.0\,\varepsilon_0$ / 1.35
$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.3089
$7.5\,\varepsilon_0$ / 0.1210

metal4 to field poly:

$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.3089
$7.5\,\varepsilon_0$ / 0.1210

metal3 to field poly:

$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.3089
$7.5\,\varepsilon_0$ / 0.1210

metal2 to field poly:

$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.3089
$7.5\,\varepsilon_0$ / 0.1210

metal1 to field poly:

$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.3089
$7.5\,\varepsilon_0$ / 0.1210

li to field poly:

$3.9\,\varepsilon_0$ / 0.3089
$7.5\,\varepsilon_0$ / 0.1210

metal5 to diff/well/sub:

$4.0\,\varepsilon_0$ / 1.35
$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.9361

metal4 to diff/well/sub:

$4.1\,\varepsilon_0$ / 1.235
$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.9361

metal3 to diff/well/sub:

$4.2\,\varepsilon_0$ / 0.78
$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.9361

metal2 to diff/well/sub:

$4.5\,\varepsilon_0$ / 0.63
$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.9361

metal1 to diff/well/sub:

$4.05\,\varepsilon_0$ / 0.365
$7.3\,\varepsilon_0$ / 0.075
$3.9\,\varepsilon_0$ / 0.9361

li to diff/well/sub:

$3.9\,\varepsilon_0$ / 0.9361

poly to diff/well/sub:

$3.9\,\varepsilon_0$ / 0.3262

Use $\varepsilon_0 = 8.854$ to get result in aF/μm^2 (used in magic tech file extract section)

SkyWater sky130A capacitance tables

Inter-layer capacitances worksheet (series capacitors, top to bottom)

metal5 to metal4:

70.1307

metal5 to metal3: metal4 to metal3:

26.2341	93.0805
93.0805	

metal5 to metal2: metal4 to metal2: metal3 to metal2:

26.2341	29.3938	88.5400
29.3938	88.5400	
88.5400		

metal5 to metal1: metal4 to metal1: metal3 to metal1: metal2 to metal1:

26.2341	29.3938	47.6754	147.5667
29.3938	47.6754	147.5667	
47.6754	147.5667		
147.5667			

metal5 to li: metal4 to li: metal3 to li: metal2 to li: metal1 to li:

26.2341	29.3938	47.6754	64.2429	135.320
29.3938	47.6754	64.2429	135.320	861.7893
47.6754	64.2429	135.320	861.7893	
64.2429	135.320	861.7893		
135.320	861.7893			
861.7893				

metal5 to field poly: metal4 to field poly: metal3 to field poly: metal2 to field poly: metal1 to field poly: li to field poly:

26.2341	29.3938	47.6754	64.2429	98.243	111.7900
29.3938	47.6754	64.2429	98.243	861.7893	548.8000
47.6754	64.2429	98.243	861.7893	111.7900	
64.2429	98.243	861.7893	111.7900	548.8000	
98.243	861.7893	111.7900	548.8000		
861.7893	111.7900	548.8000			
111.7900	548.8000				
548.8000					

metal5 to diff/well/sub: metal4 to diff/well/sub: metal3 to diff/well/sub: metal2 to diff/well/sub: metal1 to diff/well/sub: li to diff/well/sub: poly to diff/well/sub:

26.2341	29.3938	47.6754	64.2429	98.243	36.8877	105.8571
29.3938	47.6754	64.2429	98.243	861.7893		
47.6754	64.2429	98.243	861.7893	36.8877		
64.2429	98.243	861.7893	36.8877			
98.243	861.7893	36.8877				
861.7893	36.8877					
36.8877						

Add these in parallel combination ($1/C_{tot} = 1/C_0 + 1/C_1 + ... + 1/C_N$) to get final interlayer capacitor value.

Interlayer (fringe) capacitance worksheet:

Simple fringe capacitance equation used: $C_{fringe} = \frac{2\pi\varepsilon_0 K}{\log(h/t)}$ where h is the distance between layers and t is the sidewall thickness.

$2\pi\varepsilon_0 = 2(3.14159)(8.854) = 55.631$

Use geometric mean for K (instead of doing series capacitor additions).

K_{eff} (5-4) = 4.0

K_{eff} (5-3) = (1.35/1.74) * 4.0 + (0.39/1.74) * 4.1 = 4.0224

K_{eff} (5-2) = (1.35/3.005) * 4.0 + (1.235/3.005) * 4.1 + (0.42/3.005) * 4.2 = 4.0691

K_{eff} (5-1) = (1.35/3.635) * 4.0 + (1.235/3.635) * 4.1 + (0.78/3.635) * 4.2 + (0.27/3.635) * 4.5 = 4.114

K_{eff} (5-li) = (1.35/4.335) * 4.0 + (1.235/4.335) * 4.1 + (0.78/4.335) * 4.2 + (0.63/4.335) * 4.5 + (0.265/4.335) * 4.05 + (0.075/4.335) * 7.3 = 4.1973

K_{eff} (5-poly) = (1.35/4.8649) * 4.0 + (1.235/4.8649) * 4.1 + (0.78/4.8649) * 4.2 + (0.63/4.8649) * 4.5 + (0.365/4.8649) * 4.05
+ (0.075/4.8649) * 7.3 + (0.3089/4.8649) * 3.9 + (0.121/4.8649) * 7.5 = 4.2575

K_{eff} (5-sub) = (1.35/5.3711) * 4.0 + (1.235/5.3711) * 4.1 + (0.78/5.3711) * 4.2 + (0.63/5.3711) * 4.5 + (0.365/5.3711) * 4.05
+ (0.075/5.3711) * 7.3 + (0.9361/5.3711) * 3.9 = 4.1427

K_{eff} (4-3) = 4.1

K_{eff} (4-2) = (1.235/1.655) * 4.1 + (0.42/1.655) * 4.2 = 4.1254

K_{eff} (4-1) = (1.235/2.285) * 4.1 + (0.78/2.285) * 4.2 + (0.27/2.285) * 4.5 = 4.1814

K_{eff} (4-li) = (1.235/2.985) * 4.1 + (0.78/2.985) * 4.2 + (0.63/2.985) * 4.5 + (0.265/2.985) * 4.05 + (0.075/2.985) * 7.3 = 4.2865

K_{eff} (4-poly) = (1.235/3.5149) + (0.78/3.5149) * 4.2 + (0.63/3.5149) * 4.5 + (0.365/3.5149) * 4.05
+ (0.075/3.5149) * 7.3 + (0.3089/3.5149) * 3.9 + (0.121/3.5149) * 7.5 = 4.3564

K_{eff} (4-sub) = (1.235/4.0211) * 4.1 + (0.78/4.0211) * 4.2 + (0.63/4.0211) * 4.5 + (0.365/4.0211) * 4.05
+ (0.075/4.0211) * 7.3 + (0.9361/4.0211) * 3.9 = 4.1907

K_{eff} (3-2) = 4.2

K_{eff} (3-1) = (0.78/1.05) * 4.2 + (0.27/1.05) * 4.5 = 4.2771

K_{eff} (3-li) = (0.78/1.75) * 4.2 + (0.63/1.75) * 4.5 + (0.265/1.75) * 4.05 + (0.075/1.75) * 7.3 = 4.4181

K_{eff} (3-poly) = (0.78/2.2799) * 4.2 + (0.63/2.2799) * 4.5 + (0.365/2.2799) * 4.05
+ (0.075/2.2799) * 7.3 + (0.3089/2.2799) * 3.9 + (0.121/2.2799) * 7.5 = 4.4954

K_{eff} (3-sub) = (0.78/2.7861) * 4.2 + (0.63/2.7861) * 4.5 + (0.365/2.7861) * 4.05 + (0.075/2.7861) * 7.3 + (0.9361/2.7861) * 3.9 = 4.2308

K_{eff} (2-1) = 4.5

K_{eff} (2-li) = (0.63/0.97) * 4.5 + (0.265/0.97) * 4.05 + (0.075/0.97) * 7.3 = 4.5936

K_{eff} (2-poly) = (0.63/1.4999) * 4.5 + (0.365/1.4999) * 4.05 + (0.075/1.4999) * 7.3 + (0.3089/1.4999) * 3.9 + (0.121/1.4999) * 7.5 = 4.6489

K_{eff} (2-sub) = (0.63/2.0061) * 4.5 + (0.365/2.0061) * 4.05 + (0.075/2.0061) * 7.3 + (0.9361/2.0061) * 3.9 = 4.2428

K_{eff} (1-li) = (0.265/0.34) * 4.05 + (0.075/0.34) * 7.3 = 4.7669

K_{eff} (1-poly) = (0.265/0.7699) + (0.075/0.7699) * 7.3 + (0.3089/0.7699) * 3.9 + (0.121/0.7699) * 7.5 = 4.8486

K_{eff} (1-sub) = (0.365/1.3761) * 4.05 + (0.075/1.3761) * 7.3 + (0.9361/1.3761) * 3.9 = 4.1251

K_{eff} (li-poly) = (0.3089/0.4299) * 3.9 + (0.121/0.4299) * 7.5 = 4.9133

K_{eff} (li-sub) = 3.9

K_{eff} (poly-sub) = 3.9

Interlayer (fringe) capacitance worksheet (continued from last page):

Simple fringe capacitance equation used: $C_{fringe} = \frac{2\pi\varepsilon_0 K}{\log(1 + 2h/t)}$ where h is the distance between layers and t is the sidewall thickness.

$2\pi\varepsilon_0 = 2(3.14159)(8.854) = 55.631$

Note that all (?) texts seem to use "log(h/t)" which is entirely nonsensical as it implies negative fringe capacitance for h < t. The above expression is a better match, although there are also more complicated expressions (all are ultimately approximations to the exact field equation solutions).

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metal5 to metal4: (Note: K value of 4.0 is inaccurate due to TOPNIT and PI1 surrounding metal5)

$$\frac{55.631 * 4.0}{\log(1 + 2\cdot 0.505/1.26)}$$

metal5 to metal3:

$$\frac{55.631 * 4.0224}{\log(1 + 2\cdot 1.74/1.26)}$$

metal4 to metal3:

$$\frac{55.631 * 4.1}{\log(1 + 2\cdot 0.39/0.854)}$$

metal5 to metal2:

$$\frac{55.631 * 4.0691}{\log(1 + 2\cdot 3.005/1.26)}$$

metal4 to metal2:

$$\frac{55.631 * 4.1254}{\log(1 + 2\cdot 1.655/0.854)}$$

metal3 to metal2:

$$\frac{55.631 * 4.2}{\log(1 + 2\cdot 0.42/0.854)}$$

metal5 to metal1:

$$\frac{55.631 * 4.114}{\log(1 + 2\cdot 3.635/1.26)}$$

metal4 to metal1:

$$\frac{55.631 * 4.1814}{\log(1 + 2\cdot 2.285/0.854)}$$

metal3 to metal1:

$$\frac{55.631 * 4.2771}{\log(1 + 2\cdot 1.05/0.854)}$$

metal2 to metal1:

$$\frac{55.631 * 4.5}{\log(1 + 2\cdot 0.27/0.36)}$$

metal5 to li:

$$\frac{55.631 * 4.1973}{\log(1 + 2\cdot 4.335/1.26)}$$

metal4 to li:

$$\frac{55.631 * 4.2865}{\log(1 + 2\cdot 2.985/0.854)}$$

metal3 to li:

$$\frac{55.631 * 4.4181}{\log(1 + 2\cdot 1.75/0.854)}$$

metal2 to li:

$$\frac{55.631 * 4.5936}{\log(1 + 2\cdot 0.97/0.36)}$$

metal1 to li:

$$\frac{55.631 * 4.7669}{\log(1 + 2\cdot 0.34/0.36)}$$

metal5 to field poly:

$$\frac{55.631 * 4.2575}{\log(1 + 2\cdot 4.8649/1.26)}$$

metal4 to field poly:

$$\frac{55.631 * 4.3564}{\log(1 + 2\cdot 3.5149/0.854)}$$

metal3 to field poly:

$$\frac{55.631 * 4.4954}{\log(1 + 2\cdot 2.2799/0.854)}$$

metal2 to field poly:

$$\frac{55.631 * 4.6489}{\log(1 + 2\cdot 1.4999/0.36)}$$

metal1 to field poly:

$$\frac{55.631 * 4.8486}{\log(1 + 2\cdot 0.8699/0.36)}$$

li to field poly:

$$\frac{55.631 * 4.9133}{\log(1 + 2\cdot 0.4299/0.1)}$$

metal5 to diff/well/sub:

$$\frac{55.631 * 4.1427}{\log(1 + 2\cdot 5.3711/1.26)}$$

metal4 to diff/well/sub:

$$\frac{55.631 * 4.1907}{\log(1 + 2\cdot 4.0211/0.854)}$$

metal3 to diff/well/sub:

$$\frac{55.631 * 4.2308}{\log(1 + 2\cdot 2.7861/0.854)}$$

metal2 to diff/well/sub:

$$\frac{55.631 * 4.2428}{\log(1 + 2\cdot 2.0061/0.36)}$$

metal1 to diff/well/sub:

$$\frac{55.631 * 4.1251}{\log(1 + 2\cdot 1.3761/0.36)}$$

li to diff/well/sub:

$$\frac{55.631 * 3.9}{\log(1 + 2\cdot 0.9361/0.1)}$$

poly to diff/well/sub:

$$\frac{55.631 * 3.9}{\log(1 + 2\cdot 0.3262/0.18)}$$

---

metal5 to metal4: (Note: K value of 4.0 is inaccurate due to TOPNIT and PI1 surrounding metal5)

378.01

metal5 to metal3: 168.89

metal4 to metal3: 351.52

metal5 to metal2: 129.16

metal4 to metal2: 144.86

metal3 to metal2: 341.14

metal5 to metal1: 119.67

metal4 to metal1: 125.83

metal3 to metal1: 191.73

metal2 to metal1: 273.21

metal5 to li: 113.11

metal4 to li: 114.74

metal3 to li: 150.89

metal2 to li: 137.79

metal1 to li: 249.97

metal5 to field poly: 109.36

metal4 to field poly: 109.04

metal3 to field poly: 135.42

metal2 to field poly: 115.79

metal1 to field poly: 152.95

li to field poly: 120.86

metal5 to diff/well/sub: 102.25

metal4 to diff/well/sub: 99.483

metal3 to diff/well/sub: 116.62

metal2 to diff/well/sub: 94.529

metal1 to diff/well/sub: 106.39

li to diff/well/sub: 72.763

poly to diff/well/sub: 141.68

Sidewall capacitance worksheet:

Capacitance (in magic's tech file) is measured at 1µm separation. For an answer in units per micron, assume 1µm length as well.

Capacitance is then just the usual equation, $C_{ox} = K \varepsilon_0 h$ with $\varepsilon_0 = 8.854$ and where h is the layer thickness.

For side-extending dielectric, use a pro-rated K (values for horizontal thickness of these dielectrics not shown on the first page).

	K	ε_0	h	$C_{sidewall}$ (aF/µm)	
metal5:	6.926 *	8.854 *	1.26	= 77.267	$K_{eff} = (2 \cdot 0.07 \cdot 3.9) + (2 \cdot 0.4223 \cdot 7.5) + ((1 - 2(0.07 + 0.4223)) \cdot 2.94) = 6.926$
metal4:	4.0 *	8.854 *	0.845	= 29.9265	
metal3:	4.1 *	8.854 *	0.845	= 30.675	
metal2:	4.2 *	8.854 *	0.36	= 13.387	
metal1:	4.5 *	8.854 *	0.36	= 14.343	
li:	4.447 *	8.854 *	0.1	= 3.937	$K_{eff} = (2 \cdot 0.061 \cdot 7.3) + ((1 - 2(0.061)) \cdot 4.05) = 4.447$
poly:	4.21 *	8.854 *	0.18	= 6.710	$K_{eff} = (2 \cdot 0.006 \cdot 3.9) + (2 \cdot 0.0431 \cdot 7.5) + ((1 - 2(0.006 + 0.0431)) \cdot 3.9) = 4.210$