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Microelectronic Test Patterns NBS-12 and NBS-24

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
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Microelectronic test patterns NBS-12 and NBS-24 are modular developmental patterns for experimentally evaluating improved designs of certain test structures. NBS-12 addresses geometric design considerations for the cross-bridge sheet resistor test structure. NBS-24 contains a variety of preliminary designs for the integrated gated-diode electrometer and a series of variations on the design of the MOSFET dc profiler. Both patterns also include assorted process parameter test structures. Tables of design parameters, functional descriptions of the test structures in each pattern, and computer-composed outline drawings showing all of the test structures are included.

Key Words: Cross-bridge sheet resistor; integrated gated-diode electrometer; microelectronic test pattern; microelectronic test structure; MOSFET dc profiler.

1. INTRODUCTION

This report provides design information for the various microelectronic test structures contained in test patterns NBS-12 and NBS-24. Both of these test patterns are developmental in nature. Each was assembled primarily for verification of the design of one or more types of test structures. Neither contains all the relevant structures necessary to assess a process or to evaluate material quality [1]. Thus, these test patterns are not expected to find widespread application. However, it is desirable to document both patterns to facilitate the interpretation of experimental work using these test structures without repetition of the descriptions of the particular test structures used in each case. The design information in this report is presented in tables which list the geometrical parameters of each test structure and in outline drawings of the pattern quadrants.

Test pattern NBS-12 was designed primarily for experimental evaluation of designs and models for the cross-bridge sheet resistor test structure [2,3]. This test pattern contains several groups of cross and cross-bridge sheet resistors with incrementally different linewidths. Sheet resistor designs are repeated in the various conducting layers of the fabrication process. In addition, there are specialized bridge sheet resistors which contain bridge voltage taps with incrementally different tap widths, and there are sequences of bridge sheet resistors which have different distances between one current contact and the adjacent voltage tap [3]. In addition, certain other test structures and devices unrelated to the primary purpose of the test pattern were included in order to enable preliminary design evaluation data to be obtained.

Test pattern NBS-24 was designed for evaluation of designs for the integrated gated-diode electrometer [4,5] and for investigation of short-channel effects and other limitations on the usable accuracy of the MOSFET dc profiler [6,7,8]. Integrated gated-diode electrometer test structures are present with a variety of gated-diode shapes. Each shape is repeated four times, fabricated using either polysilicon or metal for the diode gate and either with or without a channel stop diffusion. The four-terminal MOSFET profilers have different channel width-to-length ratios, different shapes, and variations in other design details. Also as in NBS-12, test pattern NBS-24 contains some parameter test structures such as contact resistors and cross-bridge sheet resistors to support the primary developmental studies.

Both test patterns employ modular test structures and a 2-by-10 probe-pad array [9].

2. DESIGN RULES

The following design rules were observed for test patterns NBS-12 and NBS-24:

1. Minimum linewidth: 6 μm.
2. Minimum base (source/drain) to channel stop separation: 8 μm.
3. Minimum source-to-drain separation: 10 μm.
4. Minimum metal separation: 8 μm.
5. Minimum metal overlap at contacts: 4 μm.
6. Minimum diffusion overlap at contacts: 4 μm.
7. Minimum contact window dimensions: 6 μm.
8. Minimum polysilicon separation: 8 μm.
9. Lines on each mask level are located so that they do not coincide with lines on another mask level (no coincident lines).

The design rules were generally maintained, except that certain circumstances on NBS-24 required that they be violated. The source-to-drain separation of the source-follower electrometer transistor is 6 μm, violating rule 3. The avoidance of coincidental lines (rule 9) is violated by the implant and second gate oxide mask levels of test pattern NBS-24.

3. PROCESS NOTES

The process suitable for NBS-12 is a modified bipolar process which contains a gate oxidation step and is referred to as a BiMOS process [10]. The base diffusion for the bipolar transistors also serves as the source/drain diffusion for the MOSFETs. Similarly, the emitter diffusion for the bipolar transistors can be used to reduce the contact resistance to collector regions and can serve as a channel stop. Certain compromises in the details of the processing are made so as to accommodate both uses for each diffusion. The terms base and source/drain or emitter and channel stop are used interchangeably as regards the diffusions.

The process for NBS-24 is an MOS process which includes a channel stop. The mask set can be used for a nonaligned gate process or for a self-aligned gate process, depending on the mask sequence. When the nonaligned gate process sequence is used, many integrated gated-diode electrometers with metal gates

and with polysilicon gates, which have the same design geometries, will function. When the self-aligned gate process sequence is used, only the structures designed for self-aligned polysilicon gates will function. The mask levels and process sequence are slightly different for the two test patterns and are given in the discussions of the individual patterns. The mask sets can be used to form either *n*-channel or *p*-channel MOSFETs; the choice depends on the conductivity type of the starting material.

4. MICROELECTRONIC TEST PATTERN NBS-12

Of the 122 test structures contained in test pattern NBS-12, 91 are cross and/or bridge structures for use in evaluating the design of the cross-bridge sheet resistor test structure. The pattern size is 5.08 mm (200 mil) by 3.51 mm (138 mil). There are seven mask levels. In the order they would be used during fabrication, they are:

1. base contact
2. base
3. emitter
4. gate oxide
5. contact
6. metal
7. passivation

Table 1 contains the specifications of all of the test structures in test pattern NBS-12. The table is divided into seven parts. The first part lists all of the individual structures. Succeeding parts contain functional descriptions of the cross sheet resistors, cross-bridge sheet resistors, transistors, advanced or integrated test structures, and miscellaneous structures, including the NBS-12 logo and alignment marks. The last part of table 1 is a chart which shows the identification of the corresponding crosses and cross-bridges in the various conducting layers.

Throughout table 1, the computer numbers of the structures are used as a key. The computer number refers to the file number under which the digital information describing that structure was stored in a computer during composition of the pattern.

The pattern is divided into four quadrants. The entire pattern is shown in figure 1. Figures 2 through 5 show each of the four quadrants with each test structure labeled according to its computer number.

5. MICROELECTRONIC TEST PATTERN NBS-24

The developmental test pattern NBS-24 contains designs for the integrated gated-diode electrometer [4,5] and for the MOSFET dc profiler [6,7,8] test structures, along with a variety of parameter test structures. This test pattern is a square chip, 5.08 mm (200 mil) on a side. There are nine mask levels and two process sequences associated with this test pattern.

The mask levels are:

1. source/drain

2. channel stop
3. implant
4. gate oxide
5. polysilicon
6. second gate oxide
7. contact
8. metal
9. passivation

The implant mask opens up windows in the gate region of selected test structures (primarily MOSFET dc profilers) and defines a cross-bridge sheet resistor and part of a contact resistor. The second gate oxide mask affects only the dual gate MOSFET dc profiler [4].

For a nonaligned gate MOS process, the mask sequence is 1, 2, 3 (if used), 4, 5, 6 (if used), 7, 8, and 9. All but a few devices will function when this sequence is used. The devices that will not function are those which were designed to have self-aligned polysilicon gates. The self-aligned gate integrated gated-diode electrometers are located in quadrant D. Self-aligned gate MOSFETs are in quadrants C and D. The mask sequence for the self-aligned gate process used to properly fabricate the self-aligned gate structures is 2, 1, 5, 7, 8, and 9. Most of the rest of the structures in the pattern will not function if the self-aligned gate process is used.

The pattern is divided into four quadrants. Table 2 contains the descriptions, locations, and identifications of the 123 test structures contained in test pattern NBS-24. In this table, the computer number of a structure is not unique. This computer number refers to the complete set of geometrical shapes for a generic structure present in all mask levels, while a particular structure on the test pattern is typically composed of the shapes on only some of the mask levels. All cross bridges, for example, have the same computer number even though the conducting channel is formed by a different layer for each structure.

Part V of table 2 gives brief descriptions and geometrical specifications for the gated diodes used in the integrated gated-diode electrometer test structures on NBS-24. Inverted refers to gated diodes where the diode junction surrounds the gate, instead of the reverse which is commonly encountered. Guarded means there is a field plate surrounding the gated diode so that any surface leakage can be controlled. This scheme replaces the channel stop which is usually used.

The complete pattern is shown in figure 6. Figures 7 through 10 show each of the four quadrants with each test structure labeled according to its design code. The integrated gated-diode electrometers have two design codes because the gated diodes and the electrometer amplifiers were designed separately. Structures can also be located using the probe-pad numbers appearing in table 2. The numbering scheme starts with the upper left probe pad of each column (2-by-10 array) as pad number 1 and proceeds sequentially down the left side of the array and up the right side of the array. In quadrant B, there are a few structures located outside the 20-pad columns. These structures are addressable using the 2-by-10 probe card.

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Table 1. Test Pattern NBS-12.

Part I. Test Structure List by Computer Number

Part II. Cross Sheet Resistors; Functional Descriptions

Part III. Cross-Bridge Sheet Resistors; Functional Descriptions

Part IV. Transistors; Functional Descriptions

Part V. Advanced Test Structures; Functional Descriptions

Part VI. Miscellaneous and Integrity Testers; Functional Descriptions

Part VII. Cross and Cross-Bridge Sheet Resistor Correspondence Chart

Notes:

1. Abbreviations: W = Width, L = Length, A = Area, D = Contact arm width. Dimensions associated with these parameters are given in units of μm.

2. Layout numbers are coded in the form: Q(r,c), where Q = Quadrant (A, B, C, or D), r = contact row number, and c = contact column number. The position of the uppermost left-hand contact of a particular structure determines its layout number. Each column is associated with pairs of contact pads.

3. Diffusion notation scheme is consistent for the BIMOS process, *viz.*, if the bulk wafer or epi-layer is n-type, the isolation and base diffusions would be p^+ and the emitter diffusion would be n^+.

4. Design numbers refer to the order in which the original multicolor drawings are filed.

Table 1, Part I. Test Structure List by Computer Number.

Computer Number	Test Pattern Layout Number	Description	Design Number
1	A (1,1)	Metal-to-base contact resistor	55
2	A (2,1)	Base-under-emitter cross sheet resistor	20
3	A (3,1)	Base-under-emitter cross-bridge sheet resistor	18
4	A (4,1)	Base-under-emitter cross-bridge sheet resistor	14
5	A (1,2)	Metal-to-emitter contact resistor	56
6	A (2,2)	Base-under-emitter cross sheet resistor	20B
7	A (3,2)	Base-under-emitter cross-bridge sheet resistor	18A
8	A (4,2)	Base-under-emitter cross-bridge sheet resistor	15
9	A (1,3)	Bipolar transistor	35C
10	A (2,3)	Base-under-emitter cross sheet resistor	20C
11	A (3,3)	Base-under-emitter cross-bridge sheet resistor	18B
12	A (4,3)	Base-under-emitter cross-bridge sheet resistor	16
13	A (1,4)	Bipolar transistor	35F2
14	A (2,4)	Base-under-emitter cross sheet resistor	20D
15	A (3,4)	Base-under-emitter cross-bridge sheet resistor	19
16	A (4,4)	Base-under-emitter cross-bridge sheet resistor	17
17	A (1,5)	Bipolar transistor	35F1
18	A (2,5)	Bipolar transistor	35D
19	A (1,6)	Bipolar transistor	35G1
20	A (2,6)	Bipolar transistor	35G2
21	A (3,6)	Base-under-emitter double-bridge sheet resistor	30
22	A (4,6)	Base-under-emitter double-bridge sheet resistor	31
30	B (1,1)	Base cross-bridge sheet resistor	18
31	B (2,1)	Gated base cross-bridge sheet resistor	24D
32	B (4,1)	Base cross-bridge sheet resistor	14
33	B (1,2)	Base cross-bridge sheet resistor	18A
34	B (2,2)	Partially-gated base cross-bridge sheet resistor	24D
35	B (4,2)	Base cross-bridge sheet resistor	15
36	B (1,3)	Base cross-bridge sheet resistor	18B
37	B (3,3)	Base cross-bridge sheet resistor	24D
38	B (4,3)	Base cross-bridge sheet resistor	16

Computer Number	Test Pattern Layout Number	Description	Design Number
39	B (1,4)	Base cross-bridge sheet resistor	19
41	B (4,4)	Base cross-bridge sheet resistor	17
42	B (1,5)	Collector surface-channel cross resistor	38
43	B (2,5)	Gated collector surface-channel cross resistor	39
44	B (3,5)	Base surface-channel cross resistor	40
45	B (4,5)	Gated base surface-channel cross resistor	41
46	B (2,4)	Base quadrate-cross sheet resistor	32
47	B (3,4)	Base quadrate-cross sheet resistor	34
48	B (1,8)	Base double-bridge sheet resistor	30
49	B (2,8)	Base double-bridge sheet resistor	31
50	B (1,6)	Base γ-factor evaluation tester #1	11A+11B
51	B (3,6)	Base γ-factor evaluation tester #2	11C+11D
52	B (1,7)	Base contact-to-corner distance study bridge resistor #5	13-5
53	B (2,7)	Base contact-to-corner distance study bridge resistor #4	13-4
54	B (3,7)	Base contact-to-corner distance study bridge resistor #3	13-3
55	B (4,7)	Base contact-to-corner distance study bridge resistor #2	13-2
56	B (5,7)	Base contact-to-corner distance study bridge resistor #1	13-1
57	C (1,1)	Metal cross sheet resistor	21
58	C (2,1)	Metal cross sheet resistor	20
59	C (3,1)	Metal cross-bridge sheet resistor	18
60	C (4,1)	Metal cross-bridge sheet resistor	14
61	C (1,2)	Metal cross sheet resistor	22
62	C (2,2)	Metal cross sheet resistor	20B
63	C (3,2)	Metal cross-bridge sheet resistor	18A
64	C (4,2)	Metal cross-bridge sheet resistor	15
65	C (1,3)	Metal cross sheet resistor	23
66	C (2,3)	Metal cross sheet resistor	20C
67	C (3,3)	Metal cross-bridge sheet resistor	18B
68	C (4,3)	Metal cross-bridge sheet resistor	16
69	C (1,4)	Metal cross sheet resistor	24
70	C (2,4)	Metal cross sheet resistor	20D
71	C (3,4)	Metal cross-bridge sheet resistor	19
72	C (4,4)	Metal cross-bridge sheet resistor	17

Computer Number	Test Pattern Layout Number	Description	Design Number
73	C (1,5)	Metal continuity tester	25
74	C (1,8)	Emitter-in-base quadrate-cross sheet resistor	32
75	C (2,8)	Emitter-in-base quadrate-cross sheet resistor	34
76	C (3,8)	Metal double-bridge sheet resistor	30
77	C (4,8)	Metal double-bridge sheet resistor	31
78	C (1,6)	Metal γ-factor evaluation tester #1	11A+11B
79	C (3,6)	Metal γ-factor evaluation tester #2	11C+11D
80	C (1,7)	Metal contact-to-corner distance study bridge resistor #5	13-5
81	C (2,7)	Metal contact-to-corner distance study bridge resistor #4	13-4
82	C (3,7)	Metal contact-to-corner distance study bridge resistor #3	13-3
83	C (4,7)	Metal contact-to-corner distance study bridge resistor #2	13-2
84	C (5,7)	Metal contact-to-corner distance study bridge resistor #1	13-1
85	D (1,1)	Base cross sheet resistor	20
86	D (2,1)	Emitter-in-base cross sheet resistor	20
87	D (3,1)	Emitter-in-base cross-bridge sheet resistor	18
88	D (4,1)	Emitter-in-base cross-bridge sheet resistor	14
89	D (1,2)	Base cross sheet resistor	20B
90	D (2,2)	Emitter-in-base cross sheet resistor	20B
91	D (3,2)	Emitter-in-base cross-bridge sheet resistor	18A
92	D (4,2)	Emitter-in-base cross-bridge sheet resistor	15
93	D (1,3)	Base cross sheet resistor	20C
94	D (2,3)	Emitter-in-base cross sheet resistor	20C
95	D (3,3)	Emitter-in-base cross-bridge sheet resistor	18B
96	D (4,3)	Emitter-in-base cross-bridge sheet resistor	16
97	D (1,4)	Base cross sheet resistor	20D
98	D (2,4)	Emitter-in-base cross sheet resistor	20D
99	D (3,4)	Emitter-in-base cross-bridge sheet resistor	19
100	D (4,4)	Emitter-in-base cross-bridge sheet resistor	17
101+102	A (1,7)	Gated collector-channel cross-bridge resistor	37B
103+102	A (2,7)	Gated collector-channel cross-bridge resistor	37A
104	A (4,7)	Collector-channel cross-bridge resistor	37A
105	A (4,8)	Collector planar four-probe resistivity tester	69
112	A (3,5)	Bipolar transistor	35H

Computer Number	Test Pattern Layout Number	Description	Design Number
113	A (4,5)	Bipolar transistor	35E1
114	A (5,5)	Bipolar transistor	35E2
115	D (1,5)	Field effect transistor	48
116	D (2,5)	Field effect transistor	45
117	D (3,5)	Field effect transistor	46
118	D (4,5)	Field effect transistor	49
119	D (5,5)	Field effect transistor	47
120	D (1,6)	Gated collector surface-channel cross resistor	50
121	D (2,6)	Gated base cross sheet resistor	51
122	D (3,6)	Gated base cross sheet resistor	52
123	D (5,6)	Gated collector cross sheet resistor	53
124	D (1,7)	Gated collector cross sheet resistor	54
125	Center	NBS-12 logo	57
126	A (5,8)	Alignment markers	58
127	D (2,7)	Gated base-collector diode with source-follower FET and saturated high-impedance FET load	59
129	D (4,7)	Gated base-collector diode with source-follower FET	59C
130	D (1,8)	Gated base-collector diode with common-source FET and saturated low-impedance FET load	60
131	D (2,8)	Base-collector diode with common-source FET and saturated low-impedance FET load	60B
132	D (4,8)	Gated base-collector diode with common-source FET	60C
133	B (4,8)	Gated base-collector diode	61
134	B (5,8)	Common-source FET with saturated low-impedance FET load	62
135	A (1,8)	Capacitor	63
136	A (2,8)	Capacitor	64
137	A (3,8)	Pinhole tester	65
138	A (2,8)	Contact tester	68
139	D (5,7)	Pinhole tester	66
140	D (5,8)	Pinhole tester	67

Table 1, Part II. Cross Sheet Resistors; Functional Descriptions.

Functional Type	Layer	Computer Numbers of Structures	Specifications/Notes
Greek cross	Metal	58, 62, 66, 70	W = 6, 12, 18, 24; D = 6.
Greek cross	Emitter-in-base	86, 90, 94, 98	W = 6, 12, 18, 24; D = 6.
Greek cross	Base-under-emitter	2, 6, 10, 14	W = 6, 12, 18, 24; D = 6.
Greek cross	Base	85, 89, 93, 97	W = 6, 12, 18, 24; D = 6.
Greek cross	Metal	57, 61, 65	W = 6; different exposure geometries at intersection of cross.
Greek cross	Metal	69	W = 6; horizontal offset in vertical arms of cross.
Gated Greek cross	Base	121, 122	Gate oxide, field oxide.
Gated Greek cross	Collector	123, 124	Gate oxide, field oxide.
Gated Greek cross	Base surface-channel	45	W = 24.
Gated Greek cross	Collector surface-channel	43	W = 20.
Greek cross	Base surface-channel	44	W = 24.
Greek cross	Collector surface-channel	42	W = 20.
Gated Greek cross	Collector surface-channel	120	W = 44.
Quadrate cross	Emitter-in-base	74	Intersection A = 24 × 24.
Greek cross	Emitter-in-base	75	W = 24; cf structure 74.
Quadrate cross	Base	46	Intersection A = 24 × 24.
Greek cross	Base	47	W = 24; cf structure 46.

Table 1, Part III. Bridge and Cross-Bridge Sheet Resistors; Functional Descriptions.

Functional Type	Layer	Computer Numbers of Structures	Specifications/Notes
Cross-bridge	Metal	59, 63, 67, 71	W = 6, 12, 18, 24; D = 6.
Cross-bridge	Emitter-in-base	87, 91, 95, 99	W = 6, 12, 18, 24; D = 6.
Cross-bridge	Base-under-emitter	3, 7, 11, 15	W = 6, 12, 18, 24; D = 6.
Cross-bridge	Base	30, 33, 36, 39	W = 6, 12, 18, 24; D = 6.
Cross-bridge	Metal	60, 64, 68, 72	W = 6, 12, 18, 24; D = 6; symmetry tabs.
Cross-bridge	Emitter-in-base	88, 92, 96, 100	W = 6, 12, 18, 24; D = 6; symmetry tabs.
Cross-bridge	Base-under-emitter	4, 8, 12, 16	W = 6, 12, 18, 24; D = 6; symmetry tabs.
Cross-bridge	Base	32, 35, 38, 41	W = 6, 12, 18, 24; D = 6; symmetry tabs.
Gated cross-bridge	Base	31, 34, 37	Fully gated, partially gated, ungated; symmetry tabs.
Cross-bridge	Collector surface-channel	101, 103, 104	Gated/no channel stop, gated/channel stop, ungated/channel stop.
Double bridge	Metal	76, 77	W = 12 and 24, W = 6 and 24.
Double bridge	Base-under-emitter	21, 22	W = 12 and 24, W = 6 and 24.
Double bridge	Base	48, 49	W = 12 and 24, W = 6 and 24.
Contact-to-corner distance study bridge	Metal	80, 81, 82, 83, 84	Voltage tap-to-corner distance = 80, 60, 40, 20, 0.
Contact-to-corner distance study bridge	Base	52, 53, 54, 55, 56	Voltage tap-to-corner distance = 80, 60, 40, 20, 0.
γ-factor evaluation tester	Metal	78	W = 24; D = 6, 12, 18, 24.
γ-factor evaluation tester	Metal	79	W = 36; D = 6, 12, 18, 24.
γ-factor evaluation tester	Base	50	W = 24; D = 6, 12, 18, 24.
γ-factor evaluation tester	Base	51	W = 36; D = 6, 12, 18, 24.

Table 1, Part IV. Transistors; Functional Descriptions.

Functional Type	Computer Numbers of Structures	Specifications/Notes
Bipolar transistor	9	Emitter: L/W = 9; A = 18 × 162; emitter channel stop.
Bipolar transistor	13	Emitter: L/W = 9; A = 18 × 162.
Bipolar transistor	17	Emitter: L/W = 3; A = 18 × 54; emitter channel stop.
Bipolar transistor	18	Emitter: L/W = 3; A = 18 × 54.
Bipolar transistor	19	Emitter: L/W = 1; A = 18 × 18; emitter channel stop.
Bipolar transistor	20	Emitter: L/W = 1; A = 18 × 18.
Bipolar transistor	112	Emitter: L/W = 3; A = 24 × 72.
Bipolar transistor	113	Emitter: L/W = 3; A = 36 × 108.
Bipolar transistor	114	Emitter: L/W = 3; A = 54 × 162.
Field effect transistor	115	Channel L = 28; gate oxide; collector under gate; base source/drain.
Field effect transistor	116	Channel L = 36; gate oxide; buried layer under gate*; emitter source/drain in a base island.
Field effect transistor	117	Channel L = 28; gate oxide; base under gate; emitter source/drain.
Field effect transistor	118	Channel L = 28; field oxide; collector under gate; base source/drain.
Field effect transistor	119	Channel L = 28; field oxide; base under gate; emitter source/drain.

*Implanted buried layer would be of the same conductivity type as the base diffusion.

Table 1, Part V. Advanced Test Structures; Functional Descriptions.

Functional Type	Computer Number of Structure	Notes
Gated base-collector diode with source-follower FET and saturated high-impedance FET load	127	
Base-collector diode with source-follower FET	129	Same as 127, except no gate on diode and no load FET. (Requires external resistive load.)
Gated base-collector diode with common-source FET and saturated low-impedance FET load	130	
Base-collector diode with common-source FET and saturated low-impedance FET load	131	Same as 130, except no gate on diode.
Gated base-collector diode with common source FET	132	Same as 130, except no load FET. (Requires external resistive load.)
Gated base-collector diode	133	Bare gated diode without reset switch.
Common-source FET with saturated low-impedance FET load	134	Amplifier of 130.

Table 1, Part VI. Miscellaneous and Integrity Testers; Functional Descriptions.

Functional Type	Layer	Computer Numbers of Structures	Specifications/Notes
Pinhole tester	Emitter and collector field and gate oxides	137	
Pinhole tester	Base oxide	139	
Pinhole tester	Isolation oxide	140	
Oxide integrity tester	Emitter gate oxide breakdown	138	
Contact tester	Metal-to-emitter	5	
Contact tester	Metal-to-base	1	
Planar four-probe resistivity tester	Collector	105	Measures resistivity of bulk wafer.
Alignment markers	All	126	Visual inspection required.
Continuity tester	Metal	73	
Capacitor	Metal-gate oxide-collector	135	
Capacitor	Metal-field oxide-collector	136	
NBS-12 logo	Metal	125	Test pattern identification number; located at center of pattern.

Table 1, Part VII. Cross and Cross-Bridge Sheet Resistor Correspondence Chart, by Computer Number.

Layer	Cross Sheet Resistors	Cross-Bridge Sheet Resistors With Symmetry Tabs	Cross-Bridge Sheet Resistors Without Symmetry Tabs	W
Metal	58	60	59	6
Metal	62	64	63	12
Metal	66	68	67	18
Metal	70	72	71	24
Emitter	86	88	87	6
Emitter	90	92	91	12
Emitter	94	96	95	18
Emitter	98	100	99	24
Base-under-emitter	2	4	3	6
Base-under-emitter	6	8	7	12
Base-under-emitter	10	12	11	18
Base-under-emitter	14	16	15	24
Base	85	32	30	6
Base	89	35	33	12
Base	93	38	36	18
Base	97	41	39	24

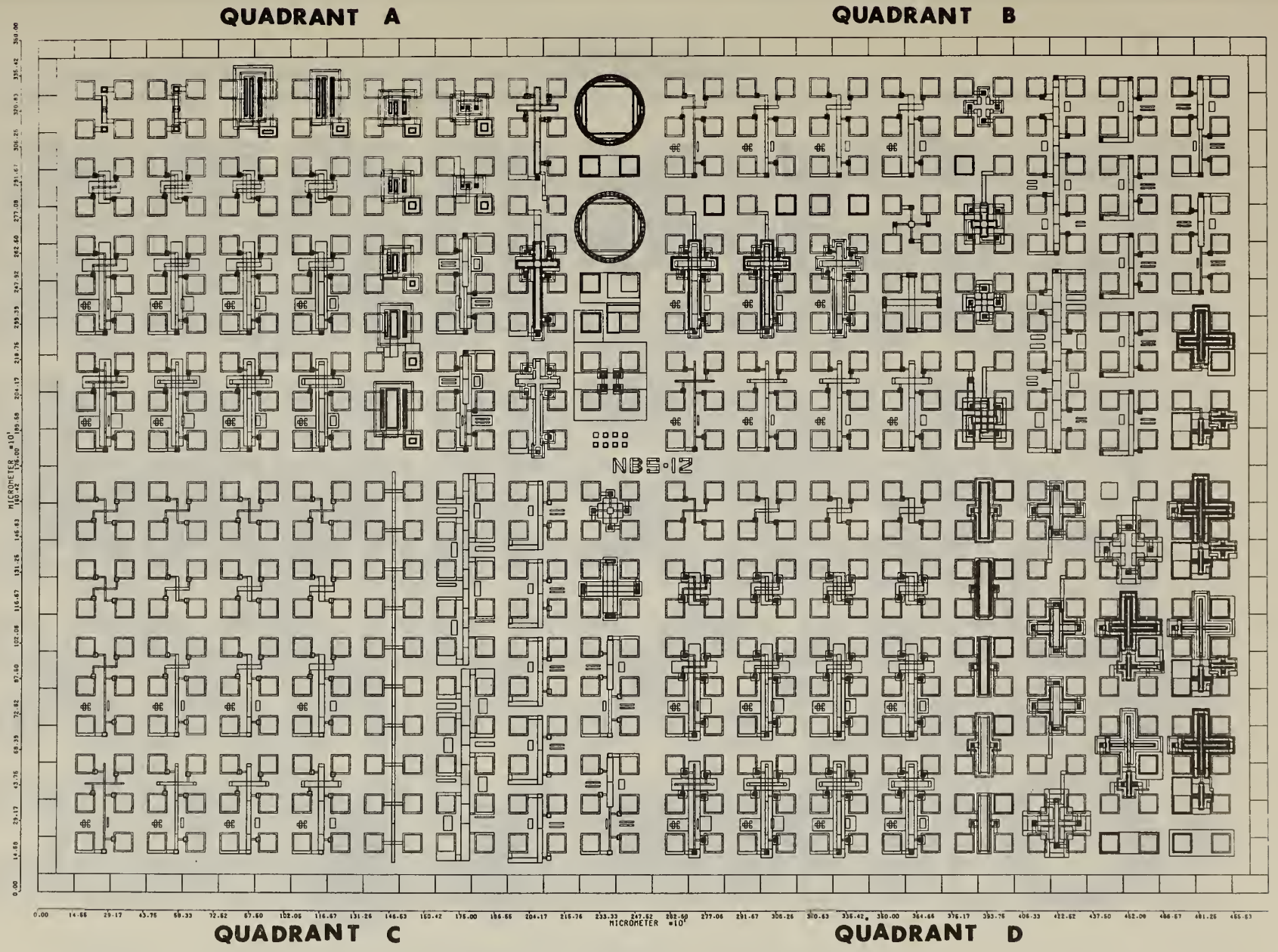

Figure 1. Outline drawing of test pattern NBS-12. The pattern is divided into four quadrants. Each quadrant is composed of test structures arranged in an array of eight columns. In each column, the probe pads are in ten rows, two probe pads per row.

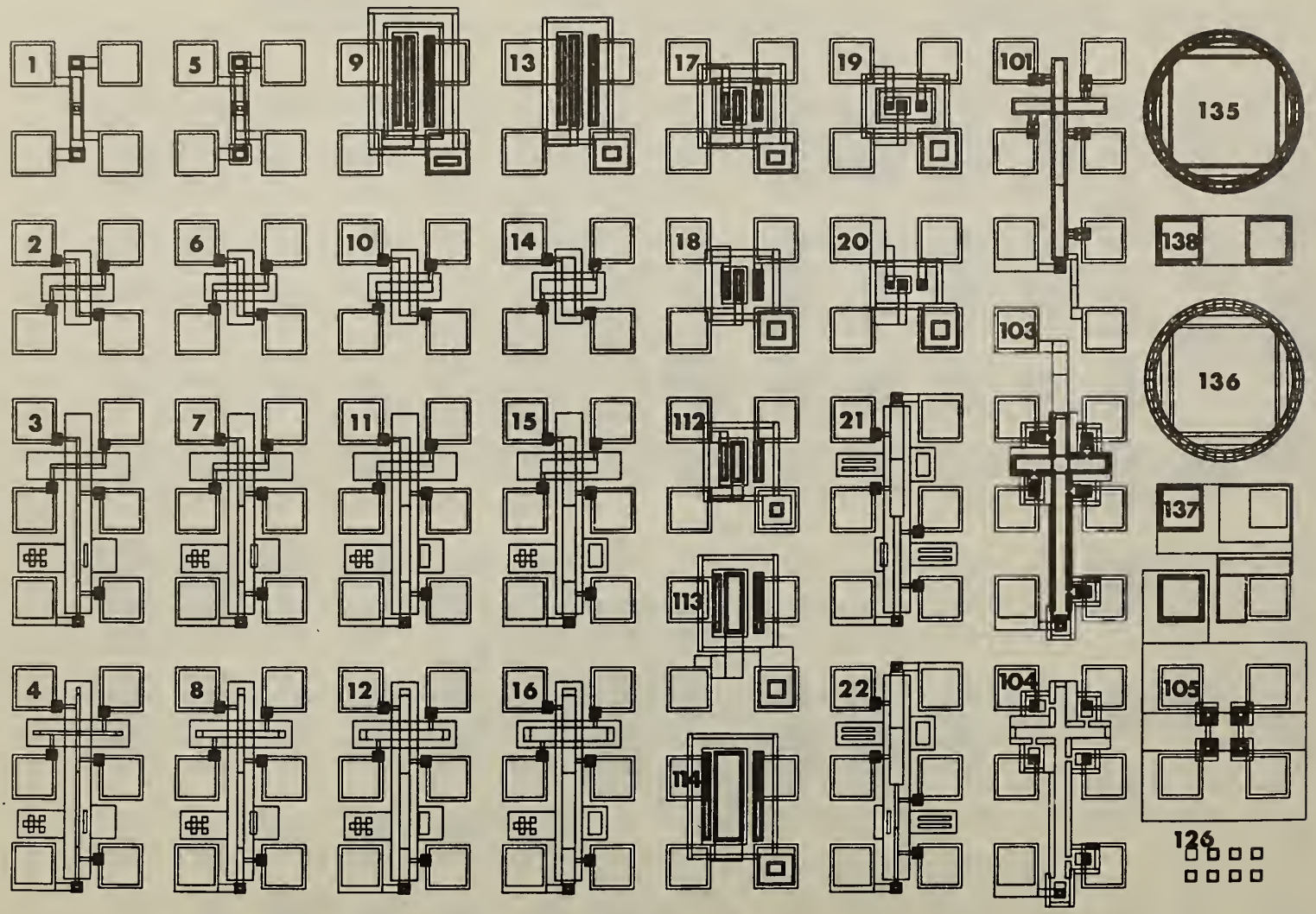

Figure 2. Outline drawing of quadrant A of NBS-12. The computer number for each test structure is located on the uppermost left probe pad of the structure.

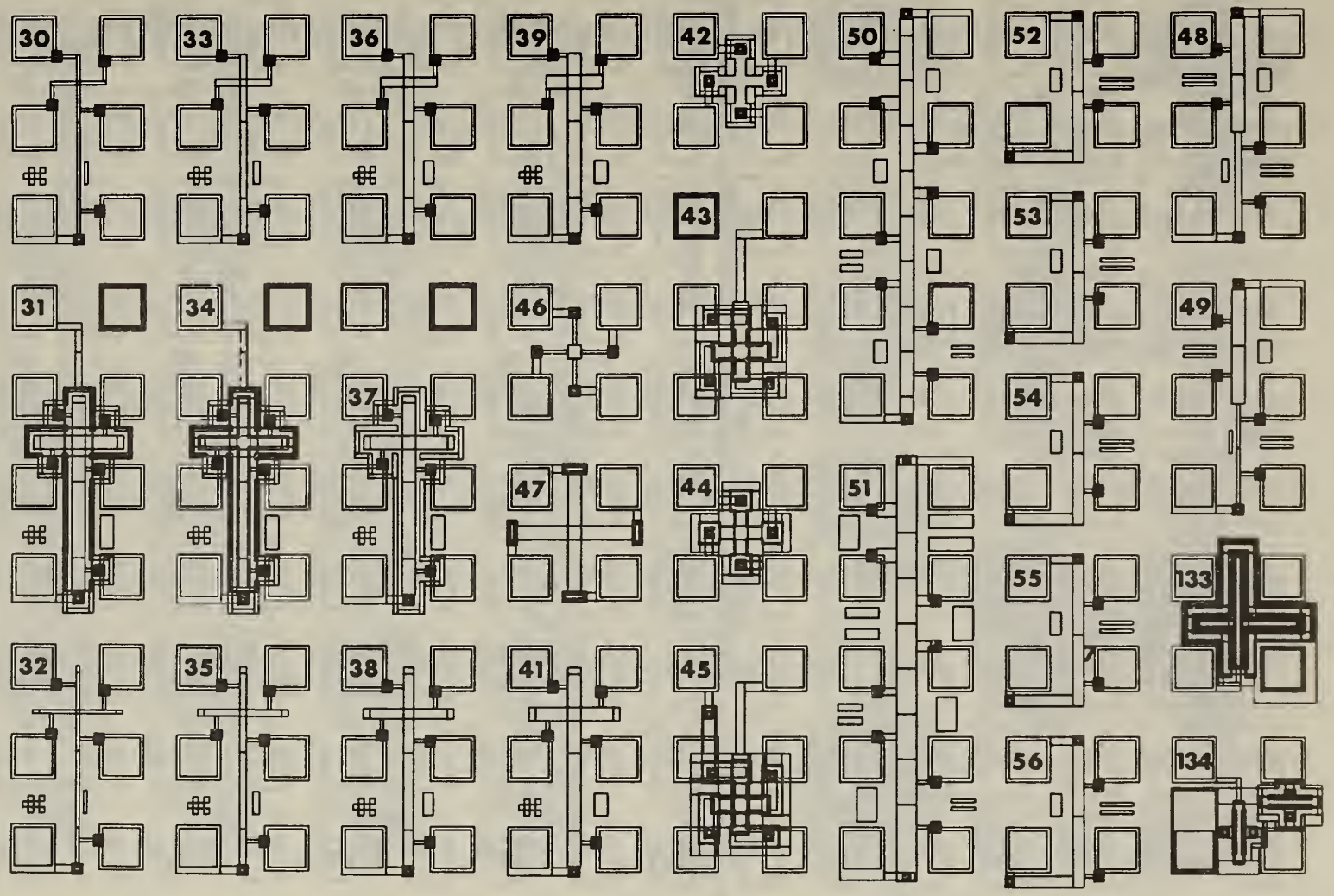

Figure 3. Outline drawing of quadrant B of NBS-12. The computer number for each test structure is located on the uppermost left probe pad of the structure.

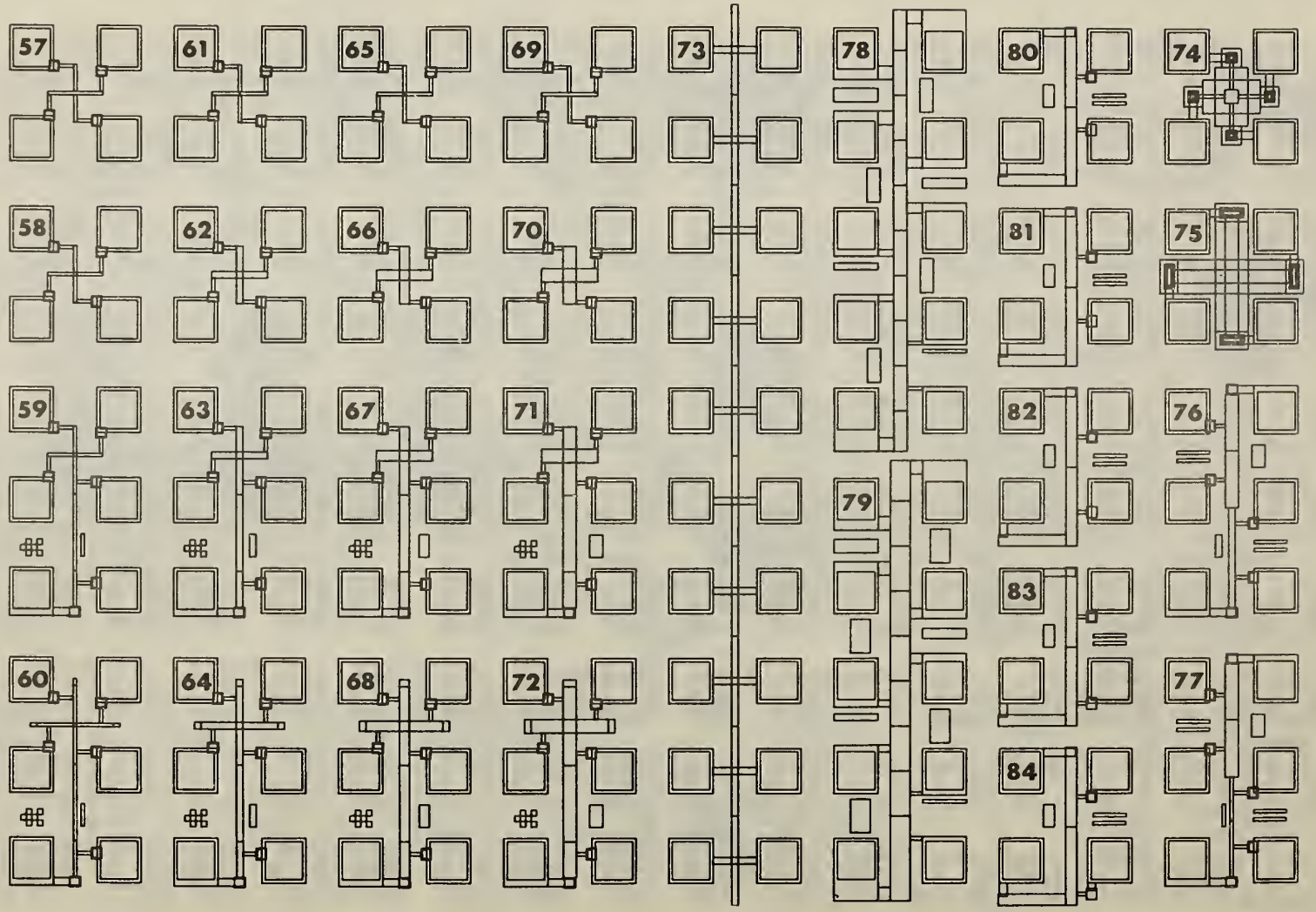

Figure 4. Outline drawing of quadrant C of NBS-12. The computer number for each test structure is located on the uppermost left probe pad of the structure.

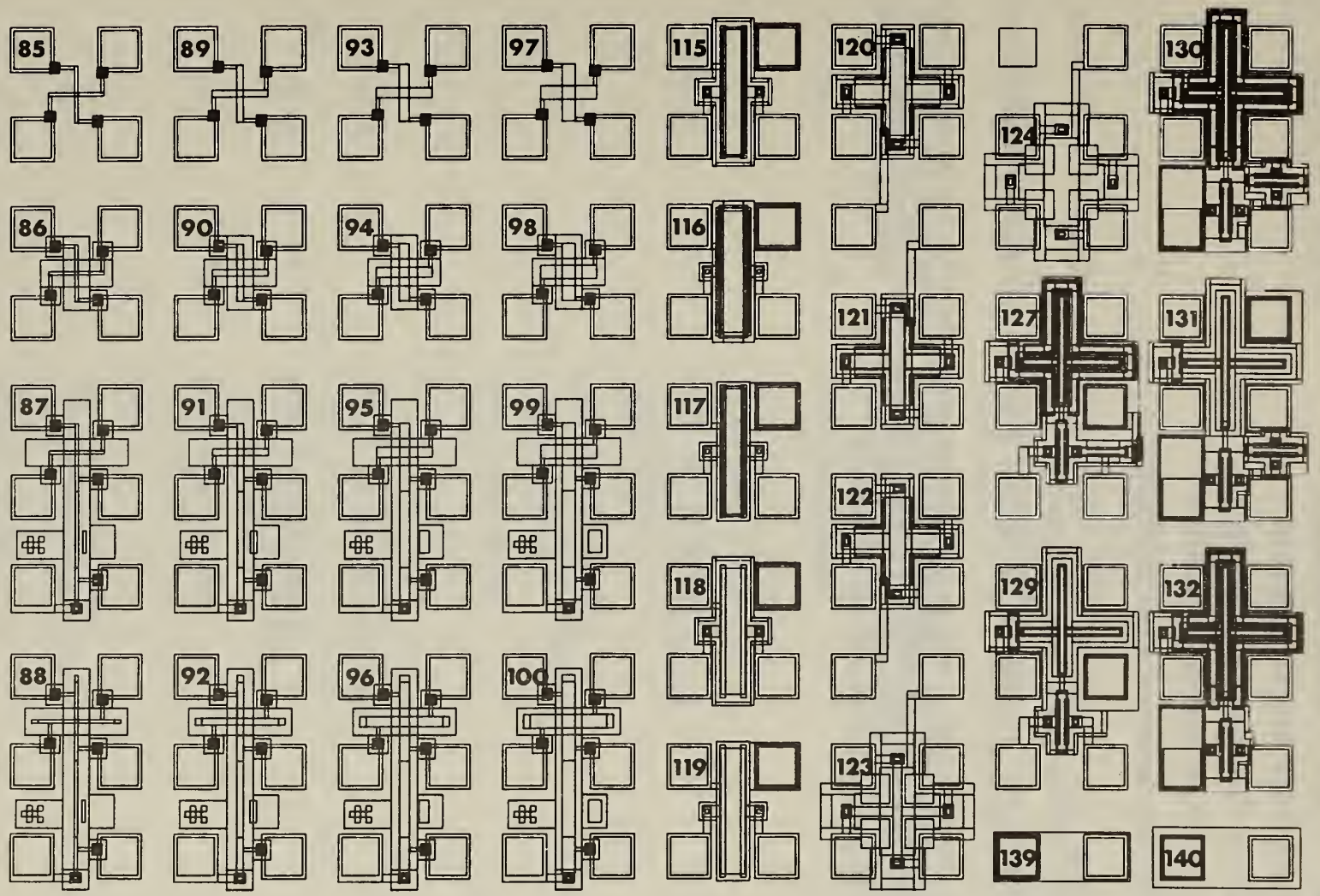

Figure 5. Outline drawing of quadrant D of NBS-12. The computer number for each test structure is located on the uppermost left probe pad of the structure.

Table 2. Test Pattern NBS-24.

Part I. Test Structures Contained in Quadrant A

Part II. Test Structures Contained in Quadrant B

Part III. Test Structures Contained in Quadrant C

Part IV. Test Structures Contained in Quadrant D

Part V. Gated Diode Geometrical Design Specifications

Notes:

1. Quadrant A is the upper left quarter of the pattern. Quadrants B, C, and D are the upper right, lower left, and lower right quarters, respectively.

2. Abbreviations: W = width and L = length. Dimensions associated with these parameters are given in units of μm.

3. The probe-pad numbers refer to the probe-pad sequence within a 2-by-10 array. The pads are numbered from 1 at the upper left of the column to 10 at the lower left and from 11 to 20 beginning at the lower right and ending at the upper right. Several columns in quadrant C have additional devices with pads above the top and below the bottom of the 2-by-10 array. These additional probe pads are not numbered.

Table 2, Part I. Test Structures Contained in Quadrant A.

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
1	GD-1P (A-1P)	11, 1	Gated-diode electrometer Large rectangular gated diode polysilicon gate	1, 2, 3 18, 19, 20
1	CB-1	58	Cross-bridge resistor source/drain	4, 5, 6 15, 16, 17
1	ILD-1	51	Inversion layer detector gate oxide	7, 14
1	GD-1M (A-1M)	11, 1	Gated-oxide electrometer Large rectangular gated diode metal gate	8, 9, 10 11, 12, 13
2	GD-3P (A-1P)	13, 1	Gated-diode electrometer Small rectangular gated-diode (probeable) polysilicon gate	1, 2, 3 18, 19, 20
2	CB-2	58	Cross-bridge resistor channel stop	4, 5, 6 15, 16, 17
2	IDL-2	51	Inversion layer detector field oxide	7, 14
2	GD-3M (A-1M)	13, 1	Gated-diode electrometer Small rectangular gated-diode (probeable) metal gate	8, 9, 10 11, 12, 13
3	GD-6P (A-1P)	16, 1	Gated-diode electrometer Small rectangular gated diode polysilicon gate	1, 2, 3 18, 19, 20
3	CB-3	58	Cross-bridge resistor metal	4, 5, 6 15, 16, 17
3	G	5	Ground	7, 14
3	GD-6M (A-1M)	16, 1	Gated-diode electrometer Small rectangular gated diode metal gate	8, 9, 10 11, 12, 13
4	GD-2P (A-1P)	12, 1	Gated-diode electrometer Cross-shaped gated diode polysilicon gate	1, 2, 3 18, 19, 20
4	CB-4	58	Cross-bridge resistor polysilicon	4, 5, 6 15, 16, 17
4	G	5	Ground	7, 14
4	GD-2M (A-1M)	12, 1	Gated-diode electrometer Cross-shaped gated diode metal gate	8, 9, 10 11, 12, 13
5	GD-10P (A-1P)	20, 1	Gated-diode electrometer Round gated diode polysilicon gate	1, 2, 3 18, 19, 20
5	CB-5	58	Cross-bridge resistor implant	4, 5, 6 15, 16, 17

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
5	G	5	Ground	7, 14
5	GP-1DM (A-1M)	20, 1	Gated-diode electrometer Round gated diode metal gate	8, 9, 10 11, 12, 13
6	GD-7P (A-1P)	17, 1	Gated-diode electrometer Inverted large rectangular gated diode polysilicon gate	1, 2, 3 18, 19, 20
6	GD-127	59	Gated-diode electrometer NBS-12 cross shaped gated diode	4, 5, 6 15, 16, 17
6	G	5	Ground	7, 14
6	GD-7M (A-1M)	17, 1	Gated-diode electrometer Inverted large rectangular gated diode metal gate	8, 9, 10 11, 12, 13
7	GD-11P (A-1P)	21, 1	Gated-diode electrometer Inverted small rectangular gated diode polysilicon gate	1, 2, 3 18, 19, 20
7	CR-1	57	Contact resistor Metal-to-polysilicon	4, 5 16, 17
7	CR-3	57	Contact resistor Metal-to-channel stop	6, 7 14, 15
7	GD-11P (A-1M)	21, 1	Gated-diode electrometer Inverted small rectangular gated diode metal gate	8, 9, 10 11, 12, 13
8	GD-1P (A-2P)	11, 3	Gated-diode electrometer Large rectangular gated diode polysilicon gate	1, 2, 3 18, 19, 20
8	CR-2	57	Contact resistor Metal-to-source/drain	4, 5 16, 17
8	CR-4	57	Contact resistor Metal-to-implant	6, 7 14, 15
8	GP-1M (A-2M)	11, 3	Gated-diode electrometer Large rectangular gated diode metal gate	8, 9, 10 11, 12, 13

Table 2, Part II. Test Structures Contained in Quadrant B.

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
1	GD-9P (A-1P)	19, 1	Gated-diode electrometer Cross shaped gated diode (guarded) polysillcon gate	1, 2, 3, 4 18, 19, 20
1	G	5	Ground	17, 14
1	C-3PI	53	Capacitor polysilicon-gate oxide-implant (no regrowth)	5, 6 15, 16
1	GD-8P (A-1P)	18, 1	Gated diode electrometer Inverted large rectangular gated diode (guarded) polysilicon gate	7, 8, 9, 10 11, 12, 13
2	GD-4P (A-1P)	14, 1	Gated-diode electrometer Large rectangular gated diode (guarded) polysilicon gate	1, 2, 3 17, 18, 19, 20
2	G	5	Ground	4, 7
2	C-3	53	Capacitor Metal-gate oxide-substrate	5, 6 15, 16
2	GD-5P (A-1P)	15, 1	Gated-diode electrometer Small rectangular gated diode (guarded) polysilicon gate	8, 9, 10 11, 12, 13, 14
3		60	Alignment markers	
3	DGP	84	Dual gated MOSFET profiler	2, 3 18, 19, 20
3	G	5	Ground	1, 4, 17
3	C-3F	53	Capacitor Metal-field oxide-substrate	5, 6 15, 16
3	P-7F	79	"Practical" MOSFET profiler Metal gate, field oxide	7, 8 13, 14
3	P-8SI	76	MOSFET profiler polysilicon gate, implant (no regrowth)	9, 10 11, 12
3	P-7IR	79	"Practical" MOSFET profiler metal gate, implant (no regrowth)	
4	GD-12	28	Gated-diode Round gated diode metal gate	
4	EA-1	55, 56	Electrical alignment test structure source/drain-to-contact	1, 2, 3, 4, 5 16, 17, 18, 19, 20
4	EA-2	55, 56	Electrical alignment test structure polysilicon-to-contact	6, 7, 8, 9, 10 11, 12, 13, 14, 15
4	C-3I	53	Capacitor metal over implant (no regrowth)	
5	C-4P	93	Capacitor polysilicon-gate oxide-implant	

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
5	EA-3	65, 66	Electrical alignment test structure polysilicon-to-metal	1, 2, 3, 4, 5 16, 17, 18, 19, 20
5	EA-4	65, 66	Electrical alignment test structure source/drain-to-metal	6, 7, 8, 9, 10 11, 12, 13, 14, 15
5	C-3IR	53	Capacitor metal-gate oxide-implant	
6		61	Level designators	
6	DGP-M	85	MOSFET profiler metal gate over implant	1, 2 19, 20
6	DGP-P	86	MOSFET profiler polysilicon gate over implant	3, 4 17, 18
6	C-3P	53	Capacitor polysilicon-gate oxide-substrate	5, 6 15, 16
6	SIS-1	52	Step Coverage and Isolation Structure	7, 8 13, 14
6	SIS-2	52	Step Coverage and Isolation Structure	9, 10 11, 12
6	P-71	79	"Practical" MOSFET profiler metal gate over implant (no regrowth)	
7	GD-9M (A-1M)	19, 1	Gated-diode electrometer Cross shaped gated diode (guarded) metal gate	1, 2, 3, 4 18, 19, 20
7	G	5	Ground	17, 14
7	C-3PF	53	Capacitor polysilicon-field oxide-substrate	5, 6 15, 16
7	GD-8M (A-1M)	18, 1	Gated-diode electrometer Inverted large rectangular gated diode (guarded) metal gate	7, 8, 9, 10 11, 12, 13
8	GD-4M (A-1M)	14, 1	Gated-diode electrometer Large rectangular gated diode (guarded) metal gate	1, 2, 3 17, 18, 19, 20
8	G	5	Ground	4, 7
8	C-3PIR	53	Capacitor polysilicon-gate oxide-implant	5, 6 15, 16
8	GD-5M (A-1M)	15, 1	Gated-diode electrometer Small rectangular gated diode (guarded) metal gate	8, 9, 10 11, 12, 13, 14

Table 2, Part III. Test Structures Contained in Quadrant C.[1]

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
1	GD-1PF (A-1P)	11, 1	Gated-diode electrometer Large rectangular gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
1	P-1	70	MOSFET profiler metal gate (W=240, L=32)	4, 5 16, 17
1	P-2SP	78	MOSFET profiler sealed polysilicon gate (W=240, L=24)	6, 7 14, 15
1	GD-1MF (A-1M)	11, 1	Gated-diode electrometer Large rectangular gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13
2	GD-3PF (A-1P)	13, 1	Gated-diode electrometer Small rectangular gated diode (probeable) polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
2	P-2	71	MOSFET profiler metal gate (W=240, L=24)	4, 5 16, 17
2	P-2S	77	MOSFET profiler sealed metal gate (W=240, L=24)	6, 7 14, 15
2	GD-3MF (A-1M)	13, 1	Gated-diode electrometer Small rectangular gated diode (probeable) metal gate (no channel stop)	8, 9, 10 11, 12, 13
3	GD-6PF (A-1P)	16, 1	Gated-diode electometer Small rectangular gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
3	P-3	72	MOSFET profiler metal gate (W=240, L=16)	4, 5 16, 17
3	P-3M	81	MOSFET profiler metallized source/drain metal gate (W=240, L=16)	6, 7 14, 15
3	GD-6MF (A-1M)	16, 1	Gated-diode electrometer Small rectangular gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13
4	GD-2PF (A-1P)	12, 1	Gated-diode electrometer Cross shaped gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
4	P-4	73	MOSFET profiler metal gate (W=240, L=8)	4, 5 16, 17
4	PR-2	92	Circular MOSFET profiler metal gate (L=24)	6, 7 14, 15
4	GD-2MF (A-1M)	12, 1	Gated-diode electrometer Cross shaped gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13
5	GD-10PF (A-1P)	20, 1	Gated-diode electrometer Round gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
5	P-5V	74	MOSFET profiler metal gate (W=120, L=24)	4, 5 16, 17

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
5	PR-1	91	Circular MOSFET profiler polysilicon gate (L=24)	6, 7 14, 15
5	GD-10MF (A-1M)	20, 1	Gated-diode electrometer Round gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13
6	GP-7PF (A-1P)	17, 1	Gated-diode electrometer Inverted large rectangular gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
6	P-6	75	MOSFET profiler metal gate (W=48, L=24)	4, 5 16, 17
6	P-2SA	81	MOSFET profiler self-aligned polysilicon gate (L=24)	6, 7 14, 15
6	GD-7MF (A-1M)	17, 1	Gated-diode electrometer Inverted large rectangular gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13
7	GD-11PF (A-1P)	21, 1	Gated-diode electrometer Inverted small rectangular gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
7	P-7	79	"Practical" MOSFET profiler metal gate (W=20, L=8)	4, 5 16, 17
7	P-21	71	MOSFET profiler metal gate over implant (no regrowth)	6, 7 14, 15
7	GD-11MF (A-1M)	21, 1	Gated-diode electrometer Inverted small rectangular gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13
8	GD-1PF (A-2P)	11, 3	Gated-diode electrometer Large rectangular gated diode polysilicon gate (no channel stop)	1, 2, 3 18, 19, 20
8	P-8S	76	MOSFET profiler sealed metal gate (W=40, L=160)	4, 5 16, 17
8	P-2SI	77	MOSFET profiler sealed metal gate over implant (W=236, L=24)	6, 7 14, 15
8	GD-1MF (A-2M)	11, 3	Gated-diode electrometer Large rectangular gated diode metal gate (no channel stop)	8, 9, 10 11, 12, 13

Table 2, Part IV. Test Structures Contained in Quadrant D.

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
1	GD-1SA (A-1SA)	22, 2	Gated-diode electrometer Self-aligned large rectangular gated diode	1, 2, 3 18, 19, 20
1	R	83	Surface channel cross sheet resistor	4,5 16, 17
1	R-I	83	Surface channel cross sheet resistor implant (no regrowth)	6, 7 14, 15
1	GD-1SA (A-1SA)	22, 2	Gated-diode electrometer Self-aligned large rectangular gated diode	8, 9, 10 11, 12, 13
2	GD-1SA (A-1SA)	22, 1	Gated-diode electrometer Self-aligned large rectangular gated diode	1, 2, 3 18, 19, 20
2	R-F	83	Surface channel cross sheet resistor (no channel stop)	4, 5 16, 17
2	R-IR	83	Surface channel cross sheet resistor implant	6, 7 14, 15
2	GD-2SA (A-1SA)	23, 2	Gated-diode electrometer Self-aligned cross shaped gated diode	8, 9, 10 11, 12, 13
3	GD-3SA (A-1SA)	24, 2	Gated-diode electrometer Self-aligned small rectangular gated diode (probeable)	1, 2, 3 18, 19, 20
3	P-2F	71	MOSFET profiler Metal gate over field oxide (W=240, L=24)	4, 5 16, 17
3	P-2IR	71	MOSFET profiler Metal gate over implant (W=240, L=24)	6, 7 14, 15
3	GD-3SA (A-1SA)	24, 2	Gated-diode electrometer Self-aligned small rectangular gated diode (probeable)	8, 9, 10 11, 12, 13
4	GD-6SA (A-1SA)	25, 2	Gated-diode electrometer Self-aligned small rectangular gated diode	1, 2, 3 18, 19, 20
4	P-2SF	77	MOSFET profiler Sealed metal gate over field oxide (W=240, L=24)	4, 5 16, 17
4	P-2SIR	77	MOSFET profiler Sealed metal gate over implant (W=240, L=24)	6, 7 14, 15
4	GD-6SA (A-1SA)	25, 2	Gated-diode electrometer Self-aligned small rectangular gated diode	8, 9, 10 11, 12, 13
5	GD-7SA (A-1SA)	26, 2	Gated-diode electrometer Self-aligned inverted large rectangular gated diode	1, 2, 3 18, 19, 20
5	PR-2F	92	MOSFET profiler Metal gate over field oxide (L=24)	4, 5 16, 17
5	PR-2IR	92	MOSFET profiler Metal gate over implant (L=24)	6, 7 14, 15

Column Number	Design Code(s)	Computer Number(s)	Device Description	Probe Pad Numbers
5	GD-7SA (A-1SA)	26, 2	Gated-diode electrometer Self-aligned inverted large rectangular gated diode	8, 9, 10 11, 12, 13
6	GD-11SA (A-1SA)	27, 2	Gated-diode electrometer Self-aligned small rectangular gated diode	1, 2, 3 18, 19, 20
6	P-2SPF	76	MOSFET profiler Sealed polysilicon gate over field oxide (W=240, L=24)	4, 5 16, 17
6	P-2SPIR	76	MOSFET profiler Sealed polysilicon gate over implant (W=236, L=24)	6, 7 14, 15
6	GD-11SA (A-1SA)	27, 2	Gated-diode electrometer Self-aligned small rectangular gated diode	8, 9, 10 11, 12, 13
7	GD-2SA (A-1SA)	23, 2	Gated-diode electrometer Self-aligned cross-shaped gated diode	1, 2, 3 18, 19, 20
7	P-8SF	91	MOSFET profiler Sealed metal gate over field oxide (W=40, L=160)	4, 5 16, 17
7	P-8SIR	91	MOSFET profiler Sealed metal gate over implant (W=40, L=160)	6, 7 14, 15
7	GD-10P (A-2P)	20, 3	Gated-diode electrometer Round gated diode polysilicon gate	8, 9, 10 11, 12, 13
8	GD-7P (A-2P)	17, 3	Gated-diode electrometer Inverted large rectangular gated diode polysilicon gate	1, 2, 3 18, 19, 20
8	PR-1F	92	MOSFET profiler polysilicon gate over field oxide (L=24)	4, 5 16, 17
8	PR-1IR	92	MOSFET profiler polysilicon gate over implant (L=24)	6, 7 14, 15
8	GD-6P (A-2P)	16, 2	Gated-diode electrometer Small rectangular gated diode polysilicon gate	8, 9, 10 11, 12, 13

Table 2, Part V. Gated Diode Geometrical Design Specifications.

Design Code(GD#)	Gated Diode Description	Junction Area[a] (cm^2)	Gate Area[b] (cm^2)	Junction Perimeter[c] (cm)	Junction Perimeter/Area[d] (cm^{-1})
1	Large rectangle	4.88×10^{-4}	2.19×10^{-4}	8.72×10^{-2}	180
2	Cross shape	2.08×10^{-4}	2.19×10^{-4}	8.82×10^{-2}	420
3	Small rectangle	2.44×10^{-4}	1.57×10^{-4}	7.00×10^{-2}	290
4	Large rectangle (guarded)	4.88×10^{-4}	1.38×10^{-4}	8.56×10^{-2}	180
5	Small rectangle (guarded)	2.44×10^{-4}	1.53×10^{-4}	7.00×10^{-2}	290
6	Small rectangle	2.44×10^{-4}	1.53×10^{-4}	7.00×10^{-2}	290
7	Inverted large rectangle	1.52×10^{-4}	3.97×10^{-4}	8.00×10^{-2}	530
8	Inverted large rectangle (guarded)	1.52×10^{-4}	3.97×10^{-4}	8.00×10^{-2}	530
9	Cross shape (guarded)	2.08×10^{-4}	1.39×10^{-4}	8.82×10^{-2}	420
10	Round	$\approx 4.23 \times 10^{-4}$	$\approx 1.83 \times 10^{-4}$	$\approx 7.42 \times 10^{-2}$	≈ 180
11	Inverted small rectangle	8.93×10^{-5}	2.06×10^{-4}	5.06×10^{-4}	630
1SA	Self-aligned large rectangle	4.67×10^{-4}	2.61×10^{-4}	8.62×10^{-2}	180
2SA	Self-aligned cross shape	1.88×10^{-4}	2.39×10^{-4}	8.70×10^{-2}	460
3SA	Self-aligned small rectangle	2.28×10^{-4}	1.87×10^{-4}	6.10×10^{-2}	270
6SA	Self-aligned small rectangle	2.28×10^{-4}	1.82×10^{-4}	6.06×10^{-2}	270
7SA	Self-aligned inverted large rectangle	1.43×10^{-4}	4.14×10^{-4}	8.16×10^{-2}	570
11SA	Self-aligned inverted small rectangle	7.64×10^{-5}	2.06×10^{-4}	5.76×10^{-2}	750
127	Test Pattern NBS-12 cross-shaped gated-diode electrometer	1.36×10^{-4}	6.36×10^{-5}	6.08×10^{-2}*	450

NOTES

a The junction area is the total design area of the diode junction.
b The gate area is the area of the gate not including regions where the gate overlaps the junction, the channel stop (if present), or field oxide.
c The junction perimeter is only the length of the boundary of the diode junction beneath or adjacent to the gate.
d The junction perimeter/area is the ratio of the junction perimeter[a] to the junction area.[b]

* Approximately 25% of the junction outer boundary of this structure is ungated.

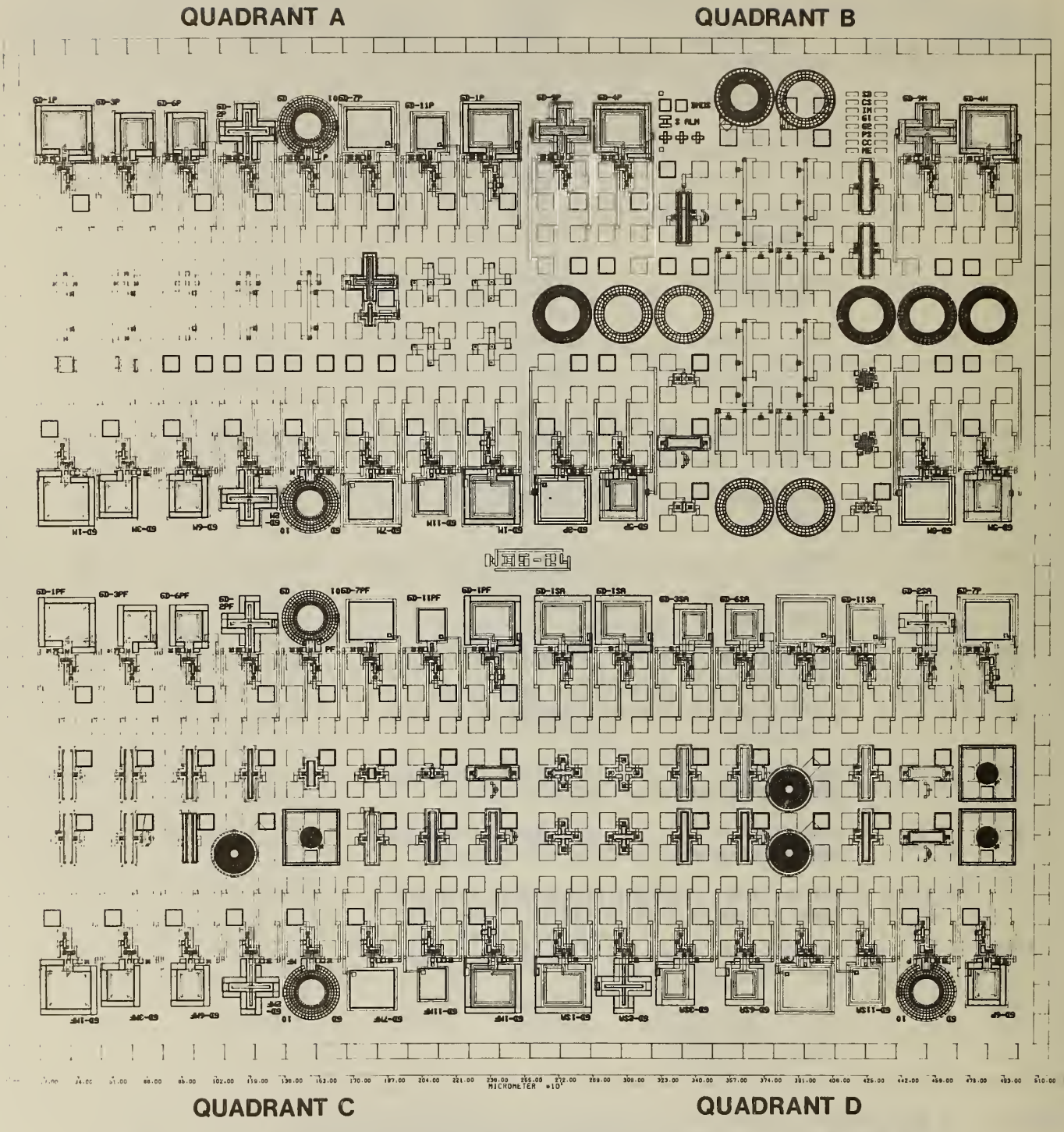

Figure 6. Outline drawing of test pattern NBS-24. The pattern is divided into four quadrants. Each quadrant is divided into eight columns of test structures. Certain columns have additional test structures above and/or below, thus lengthening the basic 2-by-10 probe-pad array.

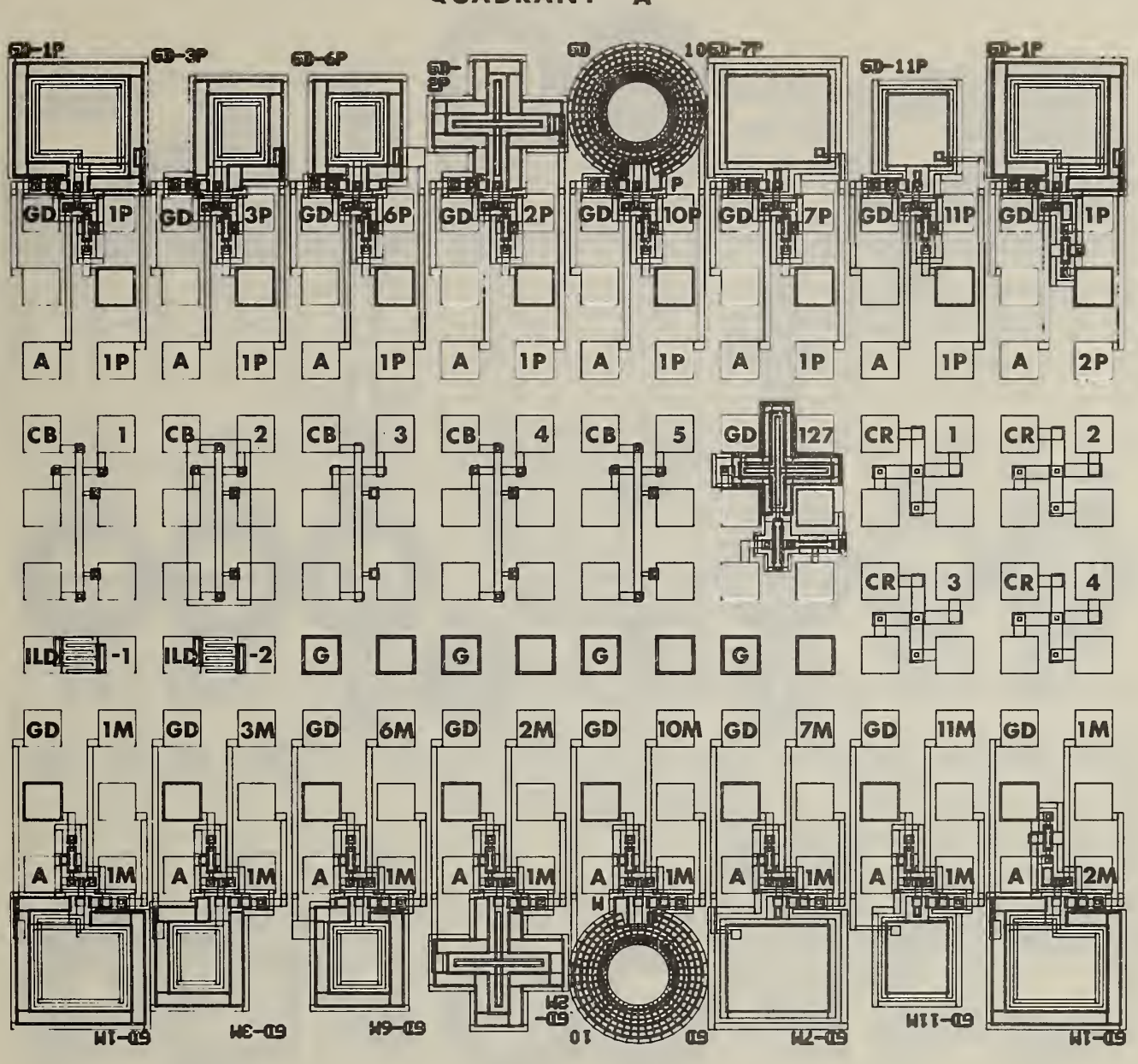

Figure 7. Outline drawing of quadrant A of NBS-24. The design code of each test structure is located on the upper probe pad(s) of the structure.

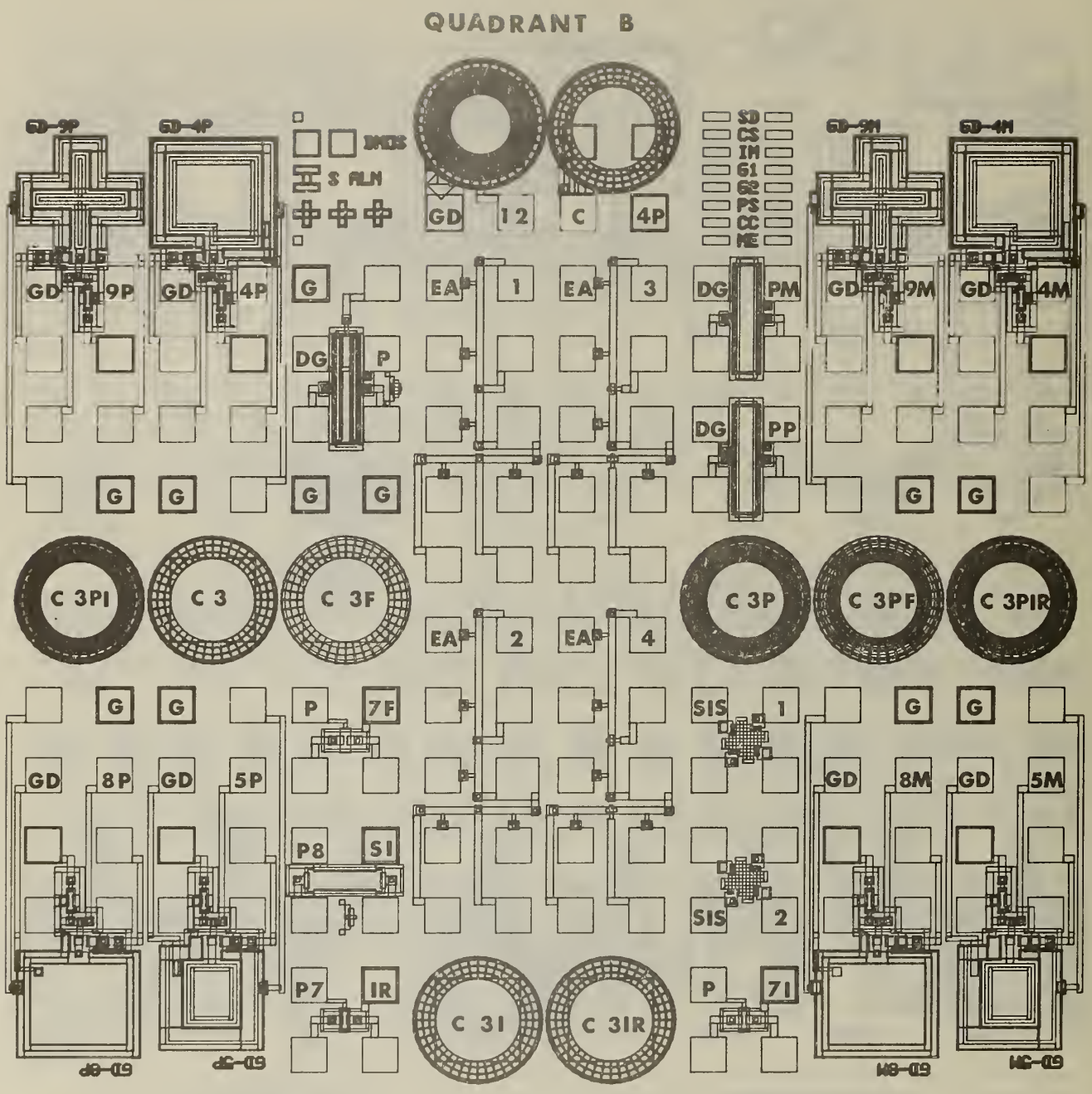

Figure 8. Outline drawing of quadrant B of NBS-24. The design code of each test structure is located on the upper probe pad(s) of the structure.

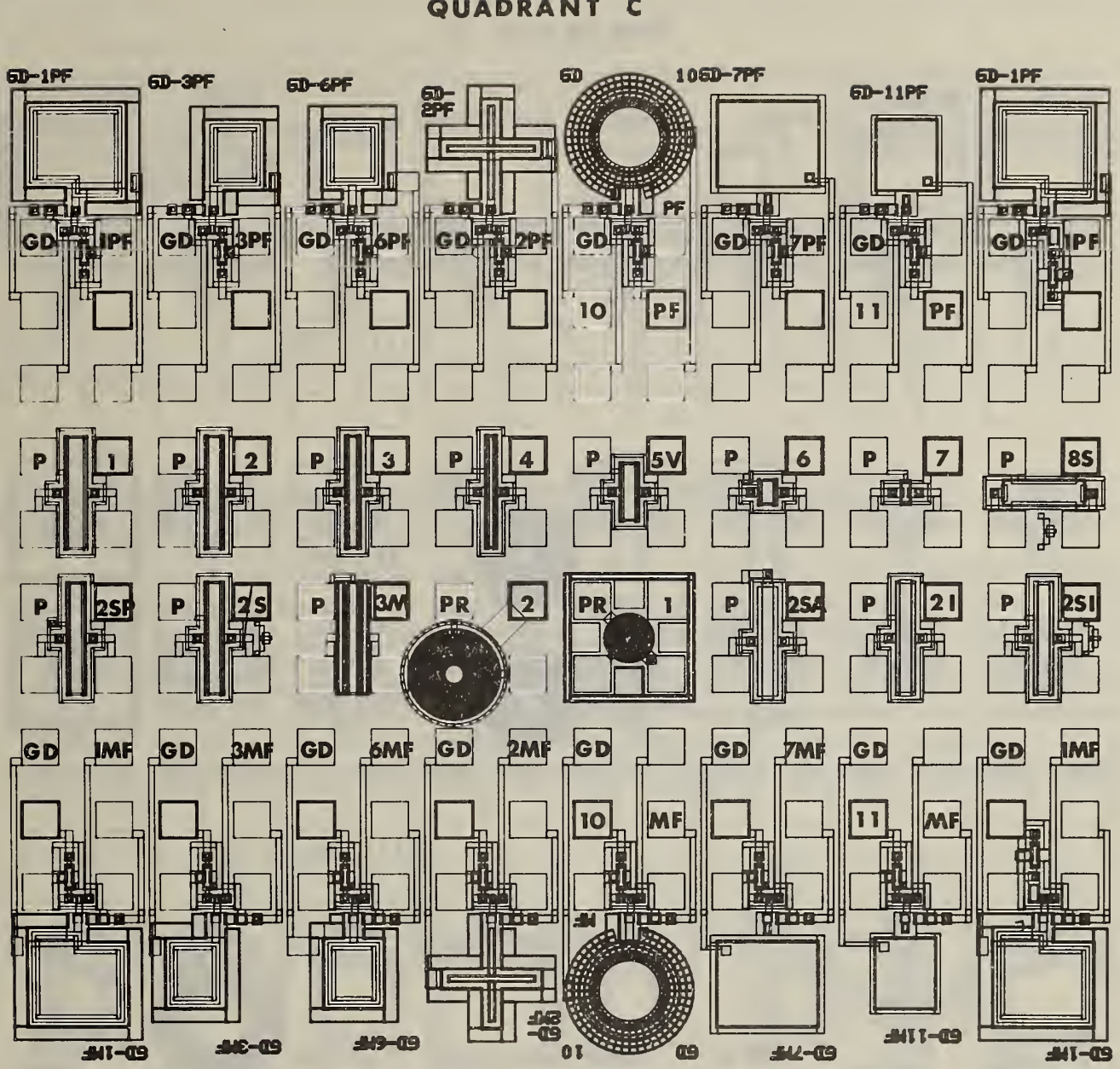

Figure 9. Outline drawing of quadrant C of NBS-24. The design code of each test structure is located on the upper probe pad(s) of the structure.

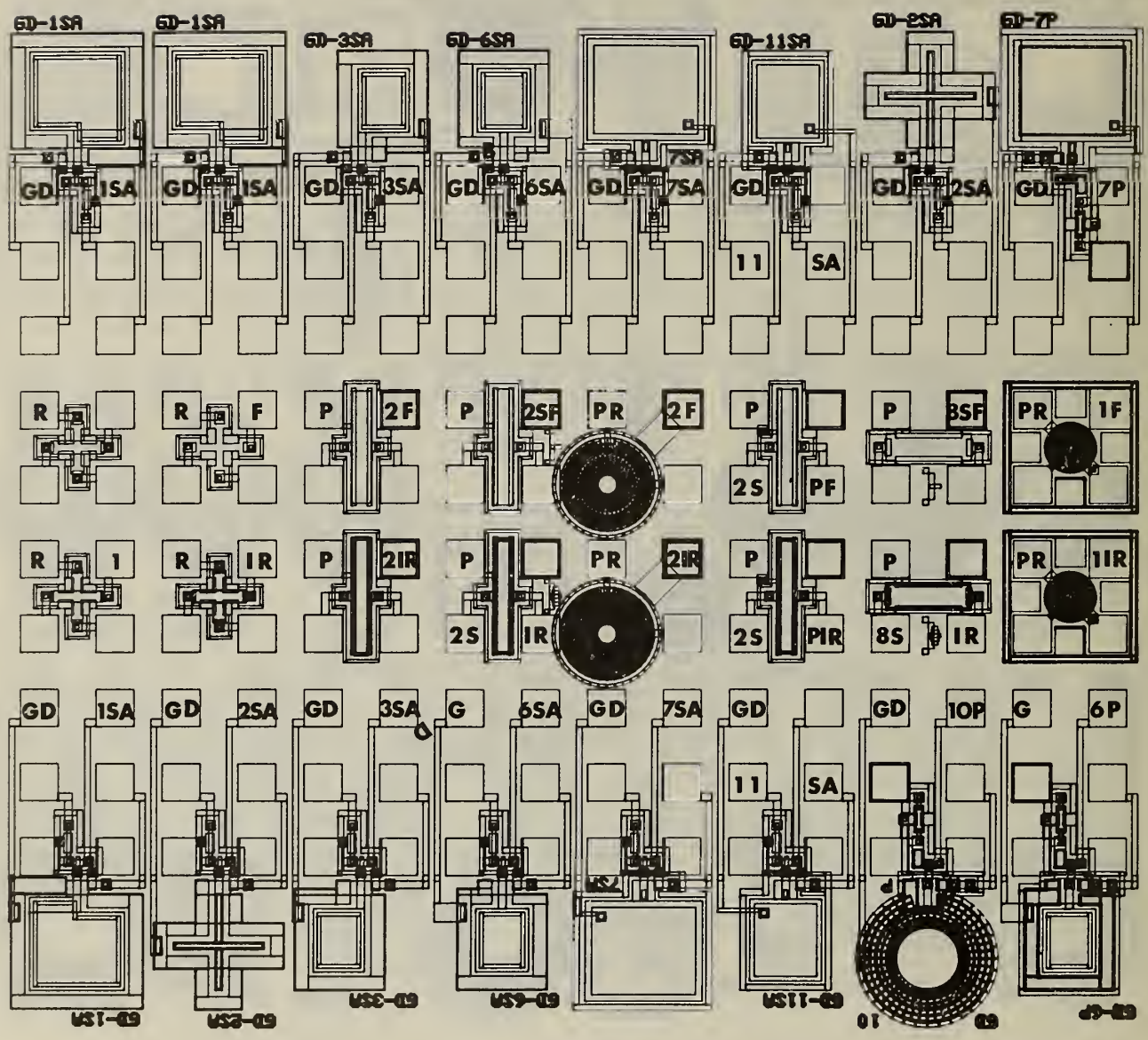

Figure 10. Outline drawing of quadrant D of NBS-24. The design code of each test structure is located on the upper probe pad(s) of the structure.

NBS-114A (REV. 2-80)

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Microelectronic test patterns NBS-12 and NBS-24 are modular developmental patterns for experimentally evaluating improved designs of certain test structures. NBS-12 addresses geometric design considerations for the cross-bridge sheet resistor test structure. NBS-24 contains a variety of preliminary designs for the integrated gated-diode electrometer and a series of variations on the design of the MOSFET dc profiler. Both patterns also include assorted process parameter test structures. Tables of design parameters, functional descriptions of the test structures in each pattern, and computer-composed outline drawings showing all of the test structures are included.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Cross-bridge sheet resistor; integrated gated-diode electrometer; microelectronic test pattern; microelectronic test structure; MOSFET dc profiler.

13. AVAILABILITY

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