

Appendix A

Benchmark Descriptions

In this section we provide results for the 243 benchmarks from the LGSynth91 benchmark set (Tables A.1–A.2) and the ESPRESSO benchmark set (Tables A.3–A.5) as well as three additional benchmarks (Table A.6: *act1* and *act2* — the actel1 and actel2 cells from the FPGA manufacturer Actel; *mult3* — a 3-bit multiplier). These are all benchmarks for that we were able to construct the ROBDDs. Each table is constructed as follows. The first 4 columns contain a description of each benchmark circuit: name, number of input and output variables, and number of ROBDD nodes. In Column 5, the partition of the input variables after signature computation (see Section 3.3) is shown ((x,y) indicates that there are x variable groups of size y in this partition. Note that classes of partial symmetric variables are represented by one variable of this group only.). The last column contains the CPU-time in seconds which was needed to compute all signatures and to construct the partition of the input variables using these signatures on a SUN Sparcstation 10 with 64 MB RAM. A time *0.0 sec.* means that there was no measurable CPU-time. Please see Section 3.3 for detailed comments relating to these results.

| name | #i | #o | #n | groups: (subsets, size) | cpu (in sec.) |
|-----------|-----|-----|-------|-------------------------|---------------|
| 5xp1 | 7 | 10 | 66 | (7,1) | 0.0 |
| 9sym | 9 | 1 | 26 | (1,1) | 0.0 |
| 9symml | 9 | 1 | 26 | (1,1) | 0.0 |
| ADDERFDS | 33 | 17 | 458 | (16,1) | 0.1 |
| C17 | 5 | 2 | 10 | (5,1) | 0.0 |
| C1355 | 41 | 32 | 33195 | (41,1) | 31.4 |
| C432 | 36 | 7 | 31179 | (36,1) | 6.4 |
| C499 | 41 | 32 | 33195 | (41,1) | 29.0 |
| C1908 | 33 | 25 | 12713 | (33,1) | 2.7 |
| C880 | 60 | 26 | 7889 | (57,1) | 5.3 |
| C5315 | 178 | 123 | 21194 | (176,1) | 631.3 |
| CM138 | 6 | 8 | 39 | (5,1) | 0.0 |
| CM150 | 21 | 1 | 64 | (3,1),(3,4),(1,6) | 0.8 |
| CM151 | 12 | 2 | 32 | (3,1),(3,3) | 0.2 |
| mux_cl | 11 | 1 | 18 | (2,1),(3,3) | 0.1 |
| CM162 | 14 | 5 | 63 | (13,1) | 0.0 |
| CM163 | 16 | 5 | 49 | (13,1) | 0.0 |
| CM42 | 4 | 10 | 23 | (4,1) | 0.0 |
| CM82 | 5 | 3 | 17 | (2,1) | 0.0 |
| CM85 | 11 | 3 | 42 | (11,1) | 0.0 |
| DES | 256 | 245 | 7257 | (256,1) | 20.6 |
| PARITYFDS | 16 | 1 | 18 | (1,1) | 0.0 |
| alu2_cl | 10 | 6 | 187 | (10,1) | 0.0 |
| alu4_cl | 14 | 8 | 1168 | (14,1) | 0.1 |
| alupla | 25 | 5 | 2266 | (25,1) | 0.7 |
| apex1 | 45 | 45 | 4519 | (45,1) | 1.8 |
| apex2 | 39 | 3 | 2948 | (34,1) | 1.3 |
| apex3 | 54 | 50 | 10826 | (54,1) | 7.0 |
| apex4 | 9 | 19 | 985 | (9,1) | 0.1 |
| apex5 | 117 | 88 | 2092 | (111,1) | 3.6 |
| apex6 | 135 | 99 | 1623 | (134,1) | 39.3 |
| apex7 | 49 | 37 | 568 | (49,1) | 4.2 |
| b12 | 15 | 9 | 89 | (15,1) | 0.0 |
| b1 | 3 | 4 | 8 | (2,1) | 0.0 |
| b9 | 41 | 21 | 177 | (36,1) | 0.1 |
| bw | 5 | 28 | 104 | (5,1) | 0.0 |
| c8 | 28 | 18 | 156 | (28,1) | 0.0 |
| cc | 21 | 20 | 77 | (21,1) | 0.0 |
| cht | 47 | 36 | 135 | (47,1) | 0.4 |
| clip | 9 | 5 | 227 | (9,1) | 0.0 |
| cmb | 16 | 4 | 37 | (3,1) | 0.0 |
| comp | 32 | 3 | 147 | (32,1) | 0.0 |
| con1 | 7 | 2 | 18 | (7,1) | 0.0 |
| cordic | 23 | 2 | 86 | (8,1),(2,2) | 0.4 |
| count | 35 | 16 | 249 | (34,1) | 0.1 |
| cps | 24 | 109 | 1456 | (21,1) | 0.7 |
| cu | 14 | 11 | 68 | (14,1) | 0.1 |
| dalu | 75 | 16 | 4576 | (74,1) | 64.0 |
| decod | 5 | 16 | 39 | (5,1) | 0.0 |
| duke2 | 22 | 29 | 599 | (22,1) | 0.1 |
| e64 | 65 | 65 | 1761 | (65,1) | 0.7 |
| ex1010 | 10 | 10 | 1074 | (10,1) | 0.1 |
| ex4 | 128 | 28 | 896 | (66,1),(2,2) | 27.4 |

Table A.1: LGSynth91 Benchmarks, Part I

| name | #i | #o | #n | groups: (subsets, size) | cpu (in sec.) |
|------------|-----|-----|-------|-------------------------|---------------|
| ex5 | 8 | 63 | 362 | (8,1) | 0.0 |
| example2 | 85 | 66 | 759 | (85,1) | 3.9 |
| f51m | 8 | 8 | 69 | (8,1) | 0.0 |
| frg1 | 28 | 3 | 186 | (27,1) | 0.1 |
| frg2 | 143 | 139 | 3750 | (143,1) | 30.5 |
| inc | 7 | 9 | 96 | (7,1) | 0.0 |
| i1 | 25 | 16 | 62 | (17,1) | 0.0 |
| i2 | 201 | 1 | 1587 | (21,1) | 135.7 |
| i3 | 132 | 6 | 134 | (1,15),(1,14),(37,1) | 48.2 |
| i4 | 192 | 6 | 350 | (110,1) | 0.8 |
| i5 | 133 | 66 | 963 | (133,1) | 1.4 |
| i6 | 138 | 67 | 417 | (138,1) | 1.2 |
| i7 | 199 | 67 | 505 | (199,1) | 528.6 |
| i8 | 133 | 81 | 2551 | (133,1) | 3.2 |
| i9 | 88 | 63 | 2393 | (88,1) | 1.7 |
| k2 | 45 | 45 | 1616 | (45,1) | 1.4 |
| lal | 26 | 19 | 123 | (17,1),(1,4) | 0.2 |
| misex1 | 8 | 7 | 48 | (8,1) | 0.0 |
| misex2 | 25 | 18 | 151 | (20,1) | 0.0 |
| misex3 | 14 | 14 | 2721 | (14,1) | 0.4 |
| misex3c | 14 | 14 | 483 | (14,1) | 0.1 |
| mux | 21 | 1 | 88 | (3,1),(3,4),(1,6) | 0.9 |
| traffic_cl | 5 | 1 | 9 | (2,1) | 0.0 |
| pair | 173 | 137 | 18523 | (173,1) | 64.2 |
| pcl_e_cl | 19 | 9 | 80 | (19,1) | 0.0 |
| pcler8_cl | 27 | 17 | 141 | (27,1) | 0.0 |
| pdc | 16 | 40 | 1196 | (16,1) | 0.2 |
| pm1 | 16 | 13 | 48 | (11,1) | 0.0 |
| rd53 | 5 | 3 | 18 | (1,1) | 0.0 |
| rd73 | 7 | 3 | 32 | (1,1) | 0.0 |
| rd84 | 8 | 4 | 43 | (1,1) | 0.01 |
| rot | 135 | 107 | 10225 | (130,1) | 29.0 |
| sao2 | 10 | 4 | 123 | (2,1),(4,2) | 0.2 |
| seq | 41 | 35 | 5639 | (39,1) | 3.7 |
| sct | 19 | 15 | 136 | (19,1) | 0.0 |
| spla | 16 | 46 | 1121 | (16,1) | 0.2 |
| squar5 | 5 | 8 | 40 | (5,1) | 0.0 |
| t481 | 16 | 1 | 80 | (4,4) | 0.6 |
| table3 | 14 | 14 | 1962 | (14,1) | 0.2 |
| table5 | 17 | 15 | 1568 | (17,1) | 0.2 |
| tcon | 17 | 16 | 26 | (17,1) | 0.0 |
| term1 | 34 | 10 | 616 | (14,1),(2,2),(3,5) | 12.7 |
| too_large | 38 | 3 | 4404 | (34,1) | 1.3 |
| ttt2 | 24 | 21 | 168 | (24,1) | 0.0 |
| unreg | 36 | 16 | 136 | (36,1) | 0.1 |
| vda | 17 | 39 | 1256 | (17,1) | 0.2 |
| vg2 | 25 | 8 | 391 | (23,1) | 0.6 |
| x1 | 51 | 35 | 1212 | (50,1) | 0.8 |
| x2 | 10 | 7 | 40 | (9,1) | 0.0 |
| x3 | 135 | 99 | 998 | (134,1) | 10.6 |
| x4 | 94 | 71 | 758 | (93,1) | 1.1 |
| xor5 | 5 | 1 | 7 | (1,1) | 0.0 |
| z4ml | 7 | 4 | 38 | (3,1) | 0.0 |

Table A.2: LGSynth91 Benchmarks, Part II

| name | #i | #o | #n | groups: (subsets, size) | cpu (in sec.) |
|---------|-----|-----|------|-------------------------|---------------|
| accpla | 50 | 69 | 3795 | (50,1) | 1.2 |
| al2 | 16 | 47 | 132 | (15,1) | 0.0 |
| alcom | 15 | 38 | 100 | (14,1) | 0.0 |
| alu1 | 12 | 8 | 37 | (12,1) | 0.0 |
| alu2 | 10 | 8 | 99 | (10,1) | 0.0 |
| alu3 | 10 | 8 | 131 | (10,1) | 0.0 |
| amd | 14 | 24 | 345 | (14,1) | 0.1 |
| apla | 10 | 12 | 137 | (10,1) | 0.0 |
| b10 | 15 | 11 | 590 | (15,1) | 0.1 |
| b11 | 8 | 31 | 70 | (8,1) | 0.0 |
| b12 | 15 | 9 | 89 | (15,1) | 0.0 |
| b2 | 16 | 17 | 4059 | (15,1) | 0.5 |
| b3 | 32 | 20 | 1237 | (32,1) | 0.3 |
| b4 | 33 | 23 | 425 | (33,1) | 0.1 |
| b7 | 8 | 31 | 70 | (8,1) | 0.0 |
| b9 | 16 | 5 | 126 | (16,1) | 0.4 |
| bc0 | 26 | 11 | 4254 | (21,1) | 0.7 |
| bca | 26 | 46 | 1591 | (16,1) | 0.2 |
| bcb | 26 | 39 | 1387 | (16,1) | 0.2 |
| bcc | 26 | 45 | 1130 | (16,1) | 0.2 |
| bcd | 26 | 38 | 928 | (16,1) | 0.2 |
| br1 | 12 | 8 | 102 | (11,1) | 0.0 |
| br2 | 12 | 8 | 100 | (12,1) | 0.0 |
| chkn | 29 | 7 | 643 | (25,1) | 0.3 |
| clpl | 11 | 5 | 37 | (10,1) | 0.0 |
| cps | 24 | 109 | 1456 | (21,1) | 0.7 |
| dc1 | 4 | 7 | 25 | (4,1) | 0.0 |
| dc2 | 8 | 7 | 94 | (8,1) | 0.0 |
| dekoder | 4 | 7 | 25 | (4,1) | 0.0 |
| dk17 | 10 | 11 | 112 | (10,1) | 0.0 |
| dk27 | 9 | 9 | 69 | (9,1) | 0.0 |
| dk48 | 15 | 17 | 177 | (15,1) | 0.0 |
| ex4 | 128 | 28 | 896 | (66,1),(2,2) | 27.6 |
| ex5 | 8 | 63 | 362 | (8,1) | 0.0 |
| ex7 | 16 | 5 | 126 | (16,1) | 0.4 |
| exep | 30 | 63 | 1249 | (29,1) | 0.2 |
| exp | 8 | 18 | 197 | (8,1) | 0.0 |
| exps | 8 | 38 | 522 | (8,1) | 0.0 |
| gary | 15 | 11 | 718 | (15,1) | 0.1 |
| ibm | 48 | 17 | 888 | (48,1) | 1.3 |
| in0 | 15 | 11 | 670 | (15,1) | 0.1 |
| in1 | 16 | 17 | 4059 | (15,1) | 0.5 |
| in2 | 19 | 10 | 1384 | (19,1) | 0.2 |
| in3 | 35 | 29 | 665 | (34,1) | 0.2 |
| in4 | 32 | 20 | 1140 | (32,1) | 0.2 |
| in5 | 24 | 14 | 680 | (24,1) | 0.1 |
| in6 | 33 | 23 | 419 | (33,1) | 0.1 |
| in7 | 26 | 10 | 234 | (26,1) | 0.0 |
| inc | 7 | 9 | 96 | (7,1) | 0.0 |
| intb | 15 | 7 | 751 | (15,1) | 0.2 |
| jbp | 36 | 57 | 577 | (36,1) | 0.3 |

Table A.3: ESPRESSO Benchmarks, Part I

| name | #i | #o | #n | groups: (subsets, size) | cpu (in sec.) |
|-----------|----|----|------|-------------------------|---------------|
| lin.rom | 7 | 36 | 414 | (7,1) | 0.0 |
| luc | 8 | 27 | 152 | (8,1) | 0.0 |
| m1 | 6 | 12 | 49 | (6,1) | 0.0 |
| m2 | 8 | 16 | 135 | (8,1) | 0.0 |
| m3 | 8 | 16 | 152 | (8,1) | 0.0 |
| m4 | 8 | 16 | 230 | (8,1) | 0.0 |
| mainpla | 27 | 54 | 9892 | (26,1) | 1.8 |
| mark1 | 20 | 31 | 224 | (20,1) | 0.1 |
| max1024 | 10 | 6 | 482 | (10,1) | 0.1 |
| max128 | 7 | 24 | 169 | (7,1) | 0.0 |
| max46 | 9 | 1 | 84 | (9,1) | 0.0 |
| max512 | 9 | 6 | 169 | (9,1) | 0.0 |
| misg | 56 | 23 | 109 | (31,1),(3,3),(1,4) | 1.6 |
| mish | 94 | 43 | 130 | (53,1) | 0.4 |
| misj | 35 | 14 | 58 | (16,1) | 0.0 |
| mp2d | 14 | 14 | 76 | (13,1) | 0.0 |
| newapla | 12 | 10 | 61 | (11,1) | 0.0 |
| newapla1 | 12 | 7 | 31 | (11,1) | 0.0 |
| newapla2 | 6 | 7 | 18 | (5,1) | 0.0 |
| newbyte | 5 | 8 | 25 | (5,1) | 0.0 |
| newcond | 11 | 2 | 48 | (10,1) | 0.0 |
| newcpla1 | 9 | 16 | 130 | (9,1) | 0.0 |
| newcpla2 | 7 | 10 | 70 | (7,1) | 0.0 |
| newcwp | 4 | 5 | 12 | (4,1) | 0.0 |
| newill | 8 | 1 | 19 | (8,1) | 0.0 |
| newtag | 8 | 1 | 12 | (5,1) | 0.0 |
| newtpla | 15 | 5 | 84 | (13,1) | 0.0 |
| newtpla1 | 10 | 2 | 21 | (6,1) | 0.0 |
| newtpla2 | 10 | 4 | 39 | (10,1) | 0.0 |
| newxcpla1 | 9 | 23 | 105 | (9,1) | 0.0 |
| opa | 17 | 69 | 461 | (15,1) | 0.1 |
| p82 | 5 | 14 | 63 | (5,1) | 0.0 |
| pdc | 16 | 40 | 1196 | (16,1) | 0.2 |
| pope | 6 | 48 | 240 | (6,1) | 0.0 |
| prom1 | 9 | 40 | 1859 | (9,1) | 0.2 |
| prom2 | 9 | 21 | 974 | (9,1) | 0.1 |
| risc | 8 | 31 | 71 | (8,1) | 0.0 |
| ryy6 | 16 | 1 | 27 | (5,1),(2,2) | 0.1 |
| sex | 9 | 14 | 63 | (9,1) | 0.0 |
| shift | 19 | 16 | 63 | (19,1) | 0.1 |
| signet | 39 | 8 | 8539 | (38,1) | 2.8 |
| soar | 83 | 94 | 982 | (77,1) | 1.4 |
| spla | 16 | 46 | 1121 | (16,1) | 0.2 |
| sqn | 7 | 3 | 57 | (7,1) | 0.0 |
| t1 | 21 | 23 | 216 | (21,1) | 0.0 |
| t2 | 17 | 16 | 189 | (17,1) | 0.0 |
| t3 | 12 | 8 | 115 | (11,1) | 0.0 |
| t4 | 12 | 8 | 91 | (12,1) | 0.0 |
| ti | 47 | 72 | 4461 | (43,1) | 1.4 |
| tms | 8 | 16 | 158 | (8,1) | 0.0 |
| ts10 | 22 | 16 | 271 | (16,1),(1,6) | 2.1 |
| vg2 | 25 | 8 | 267 | (23,1) | 0.6 |

Table A.4: ESPRESSO Benchmarks, Part II

| name | #i | #o | #n | groups: (subsets, size) | cpu (in sec.) |
|---------|----|----|------|-------------------------|---------------|
| vtx1 | 27 | 6 | 520 | (24,1) | 0.6 |
| wim | 4 | 7 | 24 | (4,1) | 0.0 |
| x1dn | 27 | 6 | 520 | (24,1) | 0.6 |
| x2dn | 82 | 56 | 266 | (62,1) | 0.5 |
| x6dn | 39 | 5 | 6243 | (35,1) | 2.0 |
| x7dn | 66 | 15 | 2020 | (61,1) | 1.6 |
| x9dn | 27 | 7 | 595 | (24,1) | 0.8 |
| xparc | 41 | 73 | 5319 | (38,1) | 2.0 |
| Z5xp1 | 7 | 10 | 96 | (7,1) | 0.0 |
| Z9sym | 9 | 1 | 26 | (1,1) | 0.0 |
| add6 | 12 | 7 | 55 | (6,1) | 0.0 |
| addm4 | 9 | 8 | 225 | (1,1),(4,2) | 0.6 |
| adr4 | 8 | 5 | 44 | (4,1) | 0.0 |
| bcd | 4 | 4 | 20 | (4,1) | 0.0 |
| co14 | 14 | 1 | 28 | (1,1) | 0.0 |
| dist | 8 | 5 | 135 | (4,2) | 0.3 |
| f51m | 8 | 8 | 73 | (8,1) | 0.0 |
| l8err | 8 | 8 | 104 | (8,1) | 0.0 |
| life | 9 | 1 | 27 | (2,1) | 0.0 |
| log8mod | 8 | 5 | 76 | (7,1) | 0.0 |
| m181 | 15 | 9 | 89 | (15,1) | 0.0 |
| mlp4 | 8 | 8 | 141 | (4,2) | 0.3 |
| radd | 8 | 5 | 39 | (4,1) | 0.0 |
| rckl | 32 | 7 | 196 | (32,1) | 0.0 |
| rd53 | 5 | 3 | 18 | (1,1) | 0.0 |
| rd73 | 7 | 3 | 32 | (1,1) | 0.0 |
| root | 8 | 5 | 100 | (7,1) | 0.0 |
| sqr6 | 6 | 12 | 70 | (6,1) | 0.0 |
| sym10 | 10 | 1 | 32 | (1,1) | 0.0 |
| tial | 14 | 8 | 1273 | (14,1) | 0.2 |
| z4 | 7 | 4 | 48 | (3,1) | 0.0 |

Table A.5: ESPRESSO Benchmarks, Part III

| name | #i | #o | #n | groups: (subsets, size) | cpu (in sec.) |
|-------|----|----|----|-------------------------|---------------|
| act1 | 8 | 1 | 15 | (7,1) | 0.0 |
| act2 | 8 | 1 | 12 | (2,1), (2,2) | 0.0 |
| mult3 | 6 | 6 | 44 | (3,2) | 0.1 |

Table A.6: Other Benchmarks