

www.lip.pt/~pedjor/PCLD2014

Refs:

Cyclone II device Handbook, Altera corp.
Quartus II Handbook , Altera corp.
DE2 documentation
Verilog HDL, S. Palnitkar, Prentice Hall

- Introduction
 - FPGAs
 - Laboratory
 - Verilog
 - combinatorial logic
 - Sequential Logic
- State Machines
- Advanced verilog (video, etc.)

Programming Digital Logic...

Estrutura

Assignments:

Ex1: Ola Mundo

Ex2: StopWatch

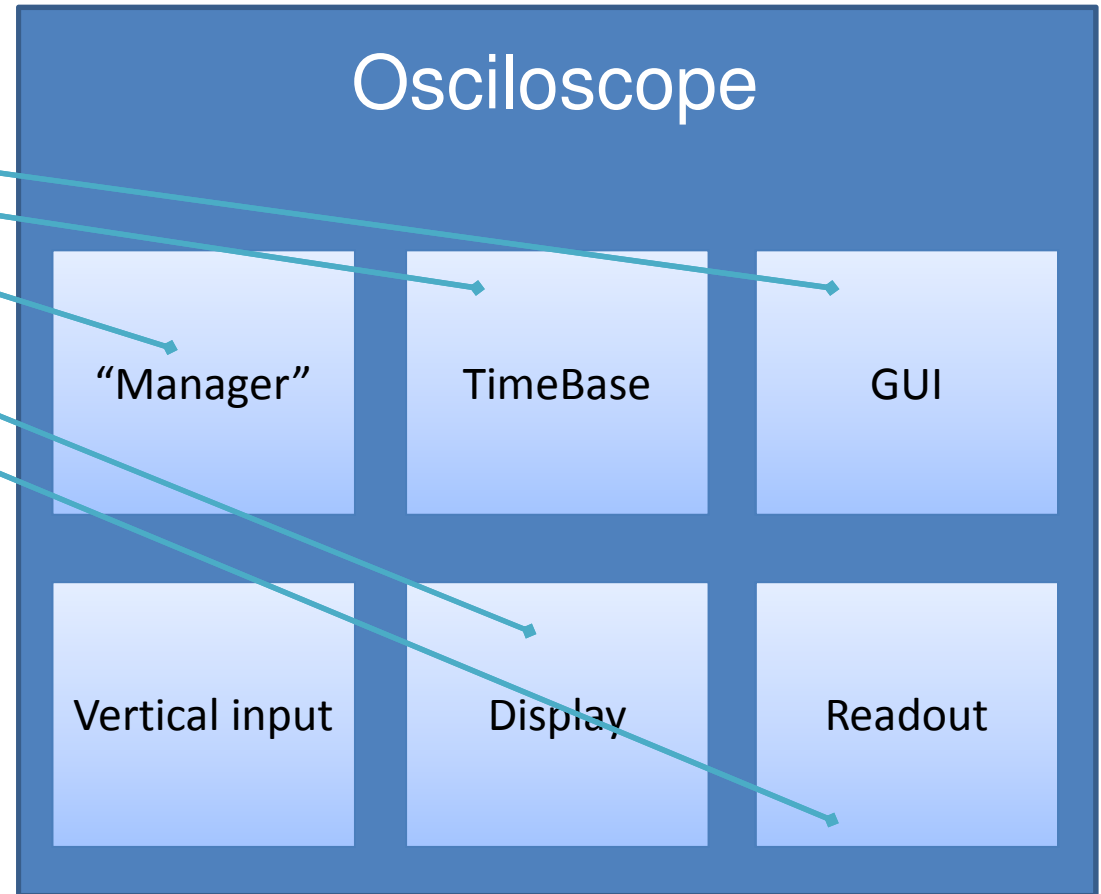
Ex3: State Machine

Ex4: Test Image

Ex5: Microprocessor

W: Oscilloscope

Pr: To be negotiated



Evaluation

Exercises evaluated in trinary (0,1,2); worth 25%

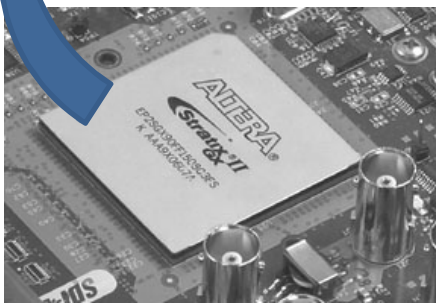
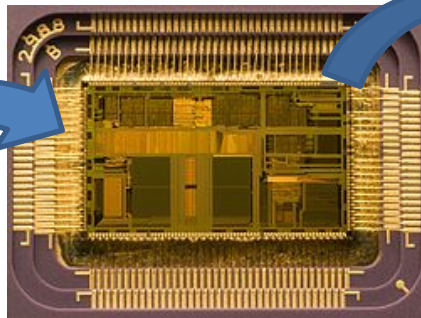
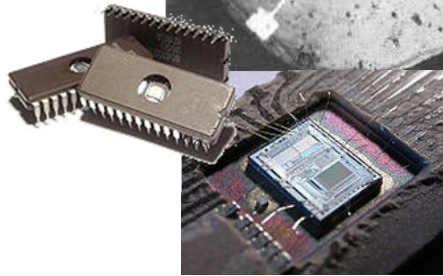
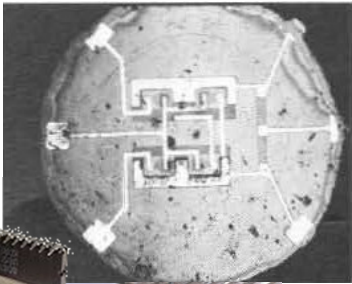
Work: Evaluation 0-20; worth 25%

Project: Evaluation 0-20; worth 50%

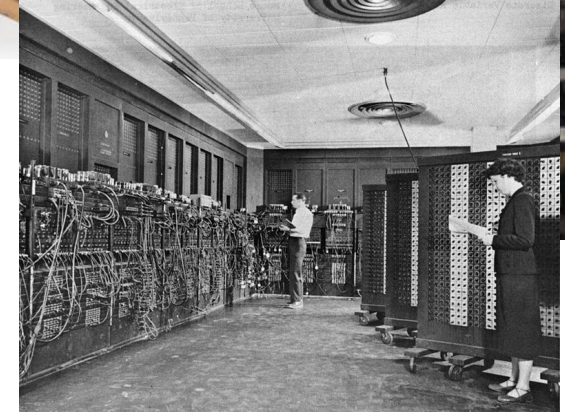
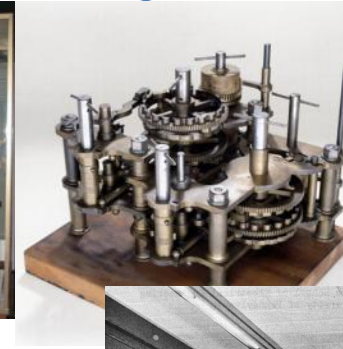
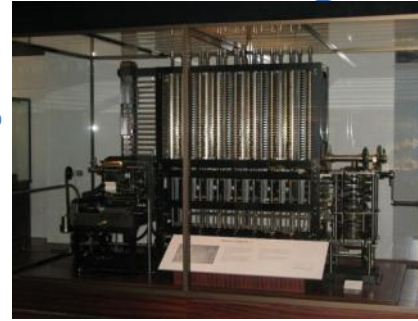
$$\text{Nota} = (\text{Ex1} + \text{Ex2} + \text{Ex3} + \text{Ex4} + \text{Ex5}) / 5 * 10 * 0.25 + W * 0.25 + Pr * 0.5$$

Lógica Digital

Programação



Babbage
difference engine



Lógica Digital de Programação

Everything works either by magic or by gnomes...

Programming microprocessors (assembly, c++, etc.)



Programming Digital Logic (FPGAs+HDL)

Give the gnome a list of objects/machines to build

Several machines execute several tasks in parallel

Give the “gnome” a list (consecutive of operations to perform

1 Machine executes several consecutive tasks



In high level languages there is some confusion



2+2?
Result x 2?

A=2+2
Cout << A
A=A*2
Cout << A

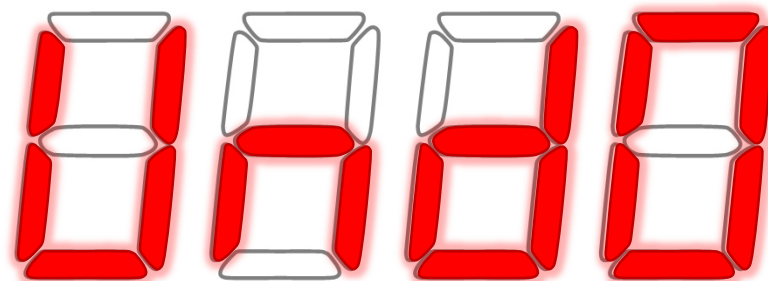
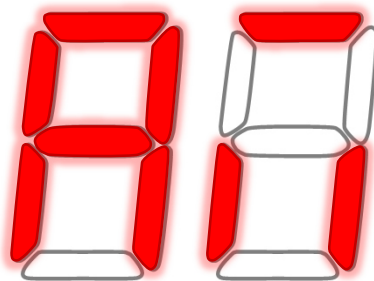
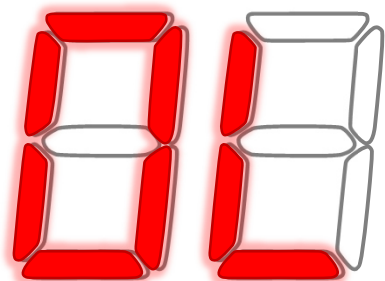
A=4
4!
A=8
8!

time

A=2+2
Output A
A=A*2
Output A

Adder: A=4
“at the same time”
Multiplier: A=A*2
Out ??? (glitches?)

An FPGA working...



First exercise...

Hardware

DLA7Uhd0



OLA!Undo



DE2_Pin Table.pdf

Signal Name	PPGA Pin No.	Description
SW[0]	PNL_A05	Toggle Switch[0]
SW[1]	PNL_A06	Toggle Switch[1]
SW[2]	PNL_P20	Toggle Switch[2]
SW[3]	PNL_A04	Toggle Switch[3]
SW[4]	PNL_A07	Toggle Switch[4]
SW[5]	PNL_A03	Toggle Switch[5]
SW[6]	PNL_A01	Toggle Switch[6]
SW[7]	PNL_C13	Toggle Switch[7]
SW[8]	PNL_B13	Toggle Switch[8]
SW[9]	PNL_A13	Toggle Switch[9]
SW[10]	PNL_V1	Toggle Switch[10]
SW[11]	PNL_P1	Toggle Switch[11]
SW[12]	PNL_A02	Toggle Switch[12]
SW[13]	PNL_T7	Toggle Switch[13]
SW[14]	PNL_U8	Toggle Switch[14]
SW[15]	PNL_U4	Toggle Switch[15]
SW[16]	PNL_V1	Toggle Switch[16]
SW[17]	PNL_V2	Toggle Switch[17]
Signal Name PPGA Pin No. Description		
DRAM_A0[0:3]	PNL_T8	SRAM Address[0]
DRAM_A0[4:7]	PNL_V4	SRAM Address[1]
DRAM_A0[8:11]	PNL_V3	SRAM Address[2]
DRAM_A0[12:15]	PNL_W2	SRAM Address[3]
DRAM_A0[16:19]	PNL_P1	SRAM Address[4]
DRAM_A0[20:23]	PNL_U8	SRAM Address[5]
DRAM_A0[24:27]	PNL_U7	SRAM Address[6]
DRAM_A0[28:31]	PNL_U6	SRAM Address[7]
DRAM_A0[32:35]	PNL_W4	SRAM Address[8]
DRAM_A0[36:39]	PNL_P3	SRAM Address[9]
DRAM_A0[40:43]	PNL_V1	SRAM Address[10]
DRAM_A0[44:47]	PNL_V5	SRAM Address[11]
DRAM_D0[0:3]	PNL_A02	SRAM Data[0]
DRAM_D0[4:7]	PNL_A03	SRAM Data[1]
DRAM_D0[8:11]	PNL_A04	SRAM Data[2]
DRAM_D0[12:15]	PNL_A05	SRAM Data[3]
DRAM_D0[16:19]	PNL_A06	SRAM Data[4]
DRAM_D0[20:23]	PNL_A07	SRAM Data[5]
DRAM_D0[24:27]	PNL_A08	SRAM Data[6]
DRAM_D0[28:31]	PNL_A09	SRAM Data[7]
DRAM_D0[32:35]	PNL_A10	SRAM Data[8]
DRAM_D0[36:39]	PNL_A11	SRAM Data[9]
DRAM_D0[40:43]	PNL_A12	SRAM Data[10]
DRAM_D0[44:47]	PNL_A13	SRAM Data[11]
DRAM_D0[48:51]	PNL_A14	SRAM Data[12]
DRAM_D0[52:55]	PNL_A15	SRAM Data[13]
DRAM_D0[56:59]	PNL_A16	SRAM Data[14]
DRAM_D0[60:63]	PNL_A17	SRAM Data[15]
DRAM_D0[64:67]	PNL_A18	SRAM Data[16]
DRAM_D0[68:71]	PNL_A19	SRAM Data[17]
DRAM_D0[72:75]	PNL_A20	SRAM Data[18]
DRAM_D0[76:79]	PNL_A21	SRAM Data[19]
DRAM_D0[80:83]	PNL_A22	SRAM Data[20]
DRAM_D0[84:87]	PNL_A23	SRAM Data[21]
DRAM_D0[88:91]	PNL_A24	SRAM Data[22]
DRAM_D0[92:95]	PNL_A25	SRAM Data[23]
DRAM_D0[96:99]	PNL_A26	SRAM Data[24]
DRAM_D0[100:103]	PNL_A27	SRAM Data[25]
DRAM_D0[104:107]	PNL_A28	SRAM Data[26]
DRAM_D0[108:111]	PNL_A29	SRAM Data[27]
DRAM_D0[112:115]	PNL_A30	SRAM Data[28]
DRAM_D0[116:119]	PNL_A31	SRAM Data[29]
DRAM_D0[120:123]	PNL_A32	SRAM Data[30]
DRAM_D0[124:127]	PNL_A33	SRAM Data[31]
DRAM_D0[128:131]	PNL_A34	SRAM Data[32]
DRAM_D0[132:135]	PNL_A35	SRAM Data[33]
DRAM_D0[136:139]	PNL_A36	SRAM Data[34]
DRAM_D0[140:143]	PNL_A37	SRAM Data[35]
DRAM_D0[144:147]	PNL_A38	SRAM Data[36]
DRAM_D0[148:151]	PNL_A39	SRAM Data[37]
DRAM_D0[152:155]	PNL_A40	SRAM Data[38]
DRAM_D0[156:159]	PNL_A41	SRAM Data[39]
DRAM_D0[160:163]	PNL_A42	SRAM Data[40]
DRAM_D0[164:167]	PNL_A43	SRAM Data[41]
DRAM_D0[168:171]	PNL_A44	SRAM Data[42]
DRAM_D0[172:175]	PNL_A45	SRAM Data[43]
DRAM_D0[176:179]	PNL_A46	SRAM Data[44]
DRAM_D0[180:183]	PNL_A47	SRAM Data[45]
DRAM_D0[184:187]	PNL_A48	SRAM Data[46]
DRAM_D0[188:191]	PNL_A49	SRAM Data[47]
DRAM_D0[192:195]	PNL_A50	SRAM Data[48]
DRAM_D0[196:199]	PNL_A51	SRAM Data[49]
DRAM_D0[200:203]	PNL_A52	SRAM Data[50]
DRAM_D0[204:207]	PNL_A53	SRAM Data[51]
DRAM_D0[208:211]	PNL_A54	SRAM Data[52]
DRAM_D0[212:215]	PNL_A55	SRAM Data[53]
DRAM_D0[216:219]	PNL_A56	SRAM Data[54]
DRAM_D0[220:223]	PNL_A57	SRAM Data[55]
DRAM_D0[224:227]	PNL_A58	SRAM Data[56]
DRAM_D0[228:231]	PNL_A59	SRAM Data[57]
DRAM_D0[232:235]	PNL_A60	SRAM Data[58]
DRAM_D0[236:239]	PNL_A61	SRAM Data[59]
DRAM_D0[240:243]	PNL_A62	SRAM Data[60]
DRAM_D0[244:247]	PNL_A63	SRAM Data[61]
DRAM_D0[248:251]	PNL_A64	SRAM Data[62]
DRAM_D0[252:255]	PNL_A65	SRAM Data[63]
DRAM_D0[256:259]	PNL_A66	SRAM Data[64]
DRAM_D0[260:263]	PNL_A67	SRAM Data[65]
DRAM_D0[264:267]	PNL_A68	SRAM Data[66]
DRAM_D0[268:271]	PNL_A69	SRAM Data[67]
DRAM_D0[272:275]	PNL_A70	SRAM Data[68]
DRAM_D0[276:279]	PNL_A71	SRAM Data[69]
DRAM_D0[280:283]	PNL_A72	SRAM Data[70]
DRAM_D0[284:287]	PNL_A73	SRAM Data[71]
DRAM_D0[288:291]	PNL_A74	SRAM Data[72]
DRAM_D0[292:295]	PNL_A75	SRAM Data[73]
DRAM_D0[296:299]	PNL_A76	SRAM Data[74]
DRAM_D0[300:303]	PNL_A77	SRAM Data[75]
DRAM_D0[304:307]	PNL_A78	SRAM Data[76]
DRAM_D0[308:311]	PNL_A79	SRAM Data[77]
DRAM_D0[312:315]	PNL_A80	SRAM Data[78]
DRAM_D0[316:319]	PNL_A81	SRAM Data[79]
DRAM_D0[320:323]	PNL_A82	SRAM Data[80]
DRAM_D0[324:327]	PNL_A83	SRAM Data[81]
DRAM_D0[328:331]	PNL_A84	SRAM Data[82]
DRAM_D0[332:335]	PNL_A85	SRAM Data[83]
DRAM_D0[336:339]	PNL_A86	SRAM Data[84]
DRAM_D0[340:343]	PNL_A87	SRAM Data[85]
DRAM_D0[344:347]	PNL_A88	SRAM Data[86]
DRAM_D0[348:351]	PNL_A89	SRAM Data[87]
DRAM_D0[352:355]	PNL_A90	SRAM Data[88]
DRAM_D0[356:359]	PNL_A91	SRAM Data[89]
DRAM_D0[360:363]	PNL_A92	SRAM Data[90]
DRAM_D0[364:367]	PNL_A93	SRAM Data[91]
DRAM_D0[368:371]	PNL_A94	SRAM Data[92]
DRAM_D0[372:375]	PNL_A95	SRAM Data[93]
DRAM_D0[376:379]	PNL_A96	SRAM Data[94]
DRAM_D0[380:383]	PNL_A97	SRAM Data[95]
DRAM_D0[384:387]	PNL_A98	SRAM Data[96]
DRAM_D0[388:391]	PNL_A99	SRAM Data[97]
DRAM_D0[392:395]	PNL_A100	SRAM Data[98]
DRAM_D0[396:399]	PNL_A101	SRAM Data[99]
DRAM_D0[400:403]	PNL_A102	SRAM Data[100]
DRAM_D0[404:407]	PNL_A103	SRAM Data[101]
DRAM_D0[408:411]	PNL_A104	SRAM Data[102]
DRAM_D0[412:415]	PNL_A105	SRAM Data[103]
DRAM_D0[416:419]	PNL_A106	SRAM Data[104]
DRAM_D0[420:423]	PNL_A107	SRAM Data[105]
DRAM_D0[424:427]	PNL_A108	SRAM Data[106]
DRAM_D0[428:431]	PNL_A109	SRAM Data[107]
DRAM_D0[432:435]	PNL_A110	SRAM Data[108]
DRAM_D0[436:439]	PNL_A111	SRAM Data[109]
DRAM_D0[440:443]	PNL_A112	SRAM Data[110]
DRAM_D0[444:447]	PNL_A113	SRAM Data[111]
DRAM_D0[448:451]	PNL_A114	SRAM Data[112]
DRAM_D0[452:455]	PNL_A115	SRAM Data[113]
DRAM_D0[456:459]	PNL_A116	SRAM Data[114]
DRAM_D0[460:463]	PNL_A117	SRAM Data[115]
DRAM_D0[464:467]	PNL_A118	SRAM Data[116]
DRAM_D0[468:471]	PNL_A119	SRAM Data[117]
DRAM_D0[472:475]	PNL_A120	SRAM Data[118]
DRAM_D0[476:479]	PNL_A121	SRAM Data[119]
DRAM_D0[480:483]	PNL_A122	SRAM Data[120]
DRAM_D0[484:487]	PNL_A123	SRAM Data[121]
DRAM_D0[488:491]	PNL_A124	SRAM Data[122]
DRAM_D0[492:495]	PNL_A125	SRAM Data[123]
DRAM_D0[496:499]	PNL_A126	SRAM Data[124]
DRAM_D0[500:503]	PNL_A127	SRAM Data[125]
DRAM_D0[504:507]	PNL_A128	SRAM Data[126]
DRAM_D0[508:511]	PNL_A129	SRAM Data[127]
DRAM_D0[512:515]	PNL_A130	SRAM Data[128]
DRAM_D0[516:519]	PNL_A131	SRAM Data[129]
DRAM_D0[520:523]	PNL_A132	SRAM Data[130]
DRAM_D0[524:527]	PNL_A133	SRAM Data[131]
DRAM_D0[528:531]	PNL_A134	SRAM Data[132]
DRAM_D0[532:535]	PNL_A135	SRAM Data[133]
DRAM_D0[536:539]	PNL_A136	SRAM Data[134]
DRAM_D0[540:543]	PNL_A137	SRAM Data[135]
DRAM_D0[544:547]	PNL_A138	SRAM Data[136]
DRAM_D0[548:551]	PNL_A139	SRAM Data[137]
DRAM_D0[552:555]	PNL_A140	SRAM Data[138]
DRAM_D0[556:559]	PNL_A141	SRAM Data[139]
DRAM_D0[560:563]	PNL_A142	SRAM Data[140]
DRAM_D0[564:567]	PNL_A143	SRAM Data[141]
DRAM_D0[568:571]	PNL_A144	SRAM Data[142]
DRAM_D0[572:575]	PNL_A145	SRAM Data[143]
DRAM_D0[576:579]	PNL_A146	SRAM Data[144]
DRAM_D0[580:583]	PNL_A147	SRAM Data[145]
DRAM_D0[584:587]	PNL_A148	SRAM Data[146]
DRAM_D0[588:591]	PNL_A149	SRAM Data[147]
DRAM_D0[592:595]	PNL_A150	SRAM Data[148]
DRAM_D0[596:599]	PNL_A151	SRAM Data[149]
DRAM_D0[600:603]	PNL_A152	SRAM Data[150]
DRAM_D0[604:607]	PNL_A153	SRAM Data[151]
DRAM_D0[608:611]	PNL_A154	SRAM Data[152]
DRAM_D0[612:615]	PNL_A155	SRAM Data[153]
DRAM_D0[616:619]	PNL_A156	SRAM Data[154]
DRAM_D0[620:623]	PNL_A157	SRAM Data[155]
DRAM_D0[624:627]	PNL_A158	SRAM Data[156]
DRAM_D0[628:631]	PNL_A159	SRAM Data[157]
DRAM_D0[632:635]	PNL_A160	SRAM Data[158]
DRAM_D0[636:639]	PNL_A161	SRAM Data[159]
DRAM_D0[640:643]	PNL_A162	SRAM Data[160]
DRAM_D0[644:647]	PNL_A163	SRAM Data[161]
DRAM_D0[648:651]	PNL_A164	SRAM Data[162]
DRAM_D0[652:655]	PNL_A165	SRAM Data[163]
DRAM_D0[656:659]	PNL_A166	SRAM Data[164]
DRAM_D0[660:663]	PNL_A167	SRAM Data[165]
DRAM_D0[664:667]	PNL_A168	SRAM Data[166]
DRAM_D0[668:671]	PNL_A169	SRAM Data[167]
DRAM_D0[672:675]	PNL_A170	SRAM Data[168]
DRAM_D0[676:679]	PNL_A171	SRAM Data[169]
DRAM_D0[680:683]	PNL_A172	SRAM Data[170]
DRAM_D0[684:687]	PNL_A173	SRAM Data[171]
DRAM_D0[688:691]	PNL_A174	SRAM Data[172]
DRAM_D0[692:695]	PNL_A175	SRAM Data[173]
DRAM_D0[696:699]	PNL_A176	SRAM Data[174]
DRAM_D0[700:703]	PNL_A177	SRAM Data[175]
DRAM_D0[704:707]	PNL_A178	SRAM Data[176]
DRAM_D0[708:711]	PNL_A179	SRAM Data[177]
DRAM_D0[712:715]	PNL_A180	SRAM Data[178]
DRAM_D0[716:719]	PNL_A181	SRAM Data[179]
DRAM_D0[720:723]	PNL_A182	SRAM Data[180]
DRAM_D0[724:727]	PNL_A183	SRAM Data[181]
DRAM_D0[728:731]	PNL_A184	SRAM Data[182]
DRAM_D0[732:735]	PNL_A185	SRAM Data[183]
DRAM_D0[736:739]	PNL_A186	SRAM Data[184]
DRAM_D0[740:743]	PNL_A187	SRAM Data[185]
DRAM_D0[744:747]	PNL_A188	SRAM Data[186]
DRAM_D0[748:751]	PNL_A189	SRAM Data[187]
DRAM_D0[752:755]	PNL_A190	SRAM Data[188]
DRAM_D0[756:759]	PNL_A191	SRAM Data[189]
DRAM_D0[760:763]	PNL_A192	SRAM Data[190]
DRAM_D0[764:767]	PNL_A193	SRAM Data[191]
DRAM_D0[768:771]	PNL_A194	SRAM Data[192]
DRAM_D0[772:775]	PNL_A195	SRAM Data[193]
DRAM_D0[776:779]	PNL_A196	SRAM Data[194]
DRAM_D0[780:783]	PNL_A197	SRAM Data[195]
DRAM_D0[784:787]	PNL_A198	SRAM Data[196]
DRAM_D0[788:791]	PNL_A199	SRAM Data[197]
DRAM_D0[792:795]	PNL_A200	SRAM Data[198]
DRAM_D0[796:799]	PNL_A201	SRAM Data[199]
DRAM_D0[800:803]	PNL_A202	SRAM Data[200]
DRAM_D0[804:807]	PNL_A203	SRAM Data[201]
DRAM_D0[808:811]	PNL_A204	SRAM Data[202]
DRAM_D0[812:815]	PNL_A205	SRAM Data[203]
DRAM_D0[816:819]	PNL_A206	SRAM Data[204]
DRAM_D0[820:823]	PNL_A207	SRAM Data[205]
DRAM_D0[824:827]	PNL_A208	SRAM Data[206]
DRAM_D0[828:831]	PNL_A209	SRAM Data[207]
DRAM_D0[832:835]	PNL_A210	SRAM Data[208]
DRAM_D0[836:839]	PNL_A211	SRAM Data[209]
DRAM_D0[840:843]	PNL_A212	SRAM Data[210]
DRAM_D0[844:847]	PNL_A213	SRAM Data[211]
DRAM_D0[848:851]	PNL_A214	SRAM Data[212]
DRAM_D0[852:855]	PNL_A215	SRAM Data[213]
DRAM_D0[856:859]	PNL_A216	SRAM Data[214]
DRAM_D0[860:863]	PNL_A217	SRAM Data[215]
DRAM_D0[864:867]	PNL_A218	SRAM Data[216]
DRAM_D0[868:871]	PNL_A219	SRAM Data[217]
DRAM_D0[872:875]	PNL_A220	SRAM Data[218]
DRAM_D0[876:879]	PNL_A221	SRAM Data[219]
DRAM_D0[880:883]	PNL_A222	SRAM Data[220]
DRAM_D0[884:887]	PNL_A223	SRAM Data[221]
DRAM_D0[888:891]	PNL_A224	SRAM Data[222]
DRAM_D0[892:895]	PNL_A225	SRAM Data[223]
DRAM_D0[896:899]	PNL_A226	SRAM Data[224]
DRAM_D0[900:903]	PNL_A227	SRAM Data[225]
DRAM_D0[904:907]	PNL_A228	SRAM Data[226]
DRAM_D0[908:911]	PNL_A229	SRAM Data[227]
DRAM_D0[912:915]	PNL_A230	SRAM Data[228]
DRAM_D0[916:919]	PNL_A231	SRAM Data[229]
DRAM_D0[920:923]	PNL_A232	SRAM Data[230]
DRAM_D0[924:927]	PNL_A233	SRAM Data[231]
DRAM_D0[928:931]	PNL_A234	SRAM Data[232]
DRAM_D0[932:935]	PNL_A235	SRAM Data[233]
DRAM_D0[936:939]	PNL_A236	SRAM Data[234]
DRAM_D0[940:943]	PNL_A237	SRAM Data[235]
DRAM_D0[944:947]	PNL_A238	SRAM Data[236]
DRAM_D0[948:951]	PNL_A239	SRAM Data[237]
DRAM_D0[952:955]	PNL_A240	SRAM Data[238]
DRAM_D0[956:959]	PNL_A241	SRAM Data[239]
DRAM_D0[960:963]	PNL_A242	SRAM Data[240]
DRAM_D0[964:967]	PNL_A243	SRAM Data[241]
DRAM_D0[968:971]	PNL_A244	SRAM Data[242]
DRAM_D0[972:975]	PNL_A245	SRAM Data[243]
DRAM_D0[976:979]	PNL_A246	SRAM Data[244]
DRAM_D0[980:983]	PNL_A247	SRAM Data[245]
DRAM_D0[984:987]	PNL_A248	SRAM Data[246]
DRAM_D0[988:991]	PNL_A249	SRAM Data[247]
DRAM_D0[992:995]	PNL_A250	SRAM Data[248]
DRAM_D0[996:999]	PNL_A251	SRAM Data[249]

Altera DE2 Board Pin Table			
LED[0:3]	PNL_A01	LED Red[0]	
LED[4:7]	PNL_A02	LED Red[1]	
LED[8:11]	PNL_A03	LED Red[2]	
LED[12:15]	PNL_A04	LED Red[3]	
LED[16:19]	PNL_A05	LED Red[4]	
LED[20:23]	PNL_A06	LED Red[5]	
LED[24:27]	PNL_A07	LED Red[6]	
LED[28:31]	PNL_A08	LED Red[7]	
LED[32:35]	PNL_A09	LED Red[8]	
LED[36:39]	PNL_A10	LED Red[9]	
LED[40:43]	PNL_V13	LED Red[10]	
LED[44:47]	PNL_A13	LED Red[10]	
LED[48:51]	PNL_A14	LED Red[11]	
LED[52:55]	PNL_A15	LED Red[12]	
LED[56:59]	PNL_A16	LED Red[13]	
LED[60:63]	PNL_A17	LED Red[14]	
LED[64:67]	PNL_A18	LED Red[15]	
LED[68:71]	PNL_A19	LED Red[16]	
LED[72:75]	PNL_A20	LED Red[17]	
LED[76:79]	PNL_A21	LED Green[0]	
LED[80:83]	PNL_V16	LED Green[1]	
LED[84:87]	PNL_V17	LED Green[2]	
LED[88:91]	PNL_V18	LED Green[3]	
LED[92:95]	PNL_V19	LED Green[4]	
LED[96:99]	PNL_V20	LED Green[5]	
LED[100:103]	PNL_V21	LED Green[6]	
LED[104:107]	PNL_V22	LED Green[7]	
LED[108:111]	PNL_V23	LED Green[8]	
LED[112:115]	PNL_V24	LED Green[9]	
LED[116:119]	PNL_V25	LED Green[10]	
LED[120:123]	PNL_V26	LED Green[11]	
LED[124:127]	PNL_V27	LED Green[12]	
LED[128:131]	PNL_V28	LED Green[13]	
LED[132:135]	PNL_V29	LED Green[14]	
LED[136:139]	PNL_V30	LED Green[15]	
LED[140:143]	PNL_V31	LED Green[16]	
LED[144:147]	PNL_V32	LED Green[17]	
LED[148:151]	PNL_V33	LED Green[18]	
LED[152:155]	PNL_V34	LED Green[19]	
LED[156:159]	PNL_V35	LED Green[20]	
LED[160:163]	PNL_V36	LED Green[21]	
LED[164:167]	PNL_V37	LED Green[22]	
LED[168:171]	PNL_V38	LED Green[23]	
LED[172:175]	PNL_V39	LED Green[24]	
LED[176:179]	PNL_V40	LED Green[25]	
LED[180:183]	PNL_V41	LED Green[26]	
LED[184:187]	PNL_V42	LED Green[27]	
LED[188:191]	PNL_V43	LED Green[28]	
LED[192:195]	PNL_V44	LED Green[29]	
LED[196:199]	PNL_V45	LED Green[30]	
LED[200:203]	PNL_V46	LED Green[31]	
LED[204:207]	PNL_V47	LED Green[32]	
LED[208:211]	PNL_V48	LED Green[33]	
LED[212:215]	PNL_V49	LED Green[34]	
LED[216:219]	PNL_V50	LED Green[35]	
LED[220:223]	PNL_V51	LED Green[36]	
LED[224:227]	PNL_V52	LED Green[37]	
LED[228:231]	PNL_V53	LED Green[38]	
LED[232:235]	PNL_V54	LED Green[39]	
LED[236:239]	PNL_V55	LED Green[40]	
LED[240:243]	PNL_V56	LED Green[41]	
LED[244:247]	PNL_V57	LED Green[42]	
LED[248:251]	PNL_V58	LED Green[43]	
LED[252:255]	PNL_V59	LED Green[44]	
LED[256:259]	PNL_V60	LED Green[45]	
LED[260:263]	PNL_V61	LED Green[46]	
LED[264:267]	PNL_V62	LED Green[47]	
LED[268:271]	PNL_V63	LED Green[48]	
LED[272:275]	PNL_V64	LED Green[49]	
LED[276:279]	PNL_V65	LED Green[50]	
LED[280:283]	PNL_V66	LED Green[51]	
LED[284:287]	PNL_V67	LED Green[52]	
LED[288:291]	PNL_V68	LED Green[53]	
LED[292:295]	PNL_V69	LED Green[54]	
LED[296:299]	PNL_V70	LED Green[55]	
LED[300:303]	PNL_V71	LED Green[56]	
LED[304:307]	PNL_V72	LED Green[57]	
LED[308:311]	PNL_V73	LED Green[58]	
LED[312:315]	PNL_V74	LED Green[59]	
LED[316:319]	PNL_V75	LED Green[60]	
LED[320:323]	PNL_V76	LED Green[61]	
LED[324:327]	PNL_V77	LED Green[62]	
LED[328:331]	PNL_V78	LED Green[63]	
LED[332:335]	PNL_V79	LED Green[64]	
LED[336:339]	PNL_V80	LED Green[65]	
LED[340:343]	PNL_V81	LED Green[66]	
LED[344:347]	PNL_V82	LED Green[67]	
LED[348:351]	PNL_V83	LED Green[68]	
LED[352:355]	PNL_V84	LED Green[69]	
LED[356:359]	PNL_V85	LED Green[70]	
LED[360:363]	PNL_V86	LED Green[71]	
LED[364:367]	PNL_V87	LED Green[72]	
LED[368:371]	PNL_V88	LED Green[73]	
LED[372:375]	PNL_V89	LED Green[74]	
LED[376:379]	PNL_V90	LED Green[75]	
LED[380:383]	PNL_V91	LED Green[76]	
LED[384:387]	PNL_V92	LED Green[77]	
LED[388:391]	PNL_V93	LED Green[78]	
LED[392:395]	PNL_V94	LED Green[79]	
LED[396:399]	PNL_V95	LED Green[80]	
LED[400:403]	PNL_V96	LED Green[81]	
LED[404:407]	PNL_V97	LED Green[82]	
LED[408:411]	PNL_V98	LED Green[83]	
LED[412:415]	PNL_V99	LED Green[84]	
LED[416:419]	PNL_V100	LED Green[85]	
LED[420:423]	PNL_V101	LED Green[86]	
LED[424:427]	PNL_V102	LED Green[87]	
LED[428:431]	PNL_V103	LED Green[88]	
LED[432:435]	PNL_V104	LED Green[89]	
LED[436:439]	PNL_V105	LED Green[90]	
LED[440:443]	PNL_V106	LED Green[91]	
LED[444:447]	PNL_V107	LED Green[92]	
LED[448:451]	PNL_V108	LED Green[93]	
LED[452:455]	PNL_V109	LED Green[94]	
LED[456:459]	PNL_V110	LED Green[95]	
LED[460:463]	PNL_V111	LED Green[96]	
LED[464:467]	PNL_V112	LED Green[97]	
LED[468:471]	PNL_V113	LED Green[98]	
LED[472:475]	PNL_V114	LED Green[99]	
LED[476:479]	PNL_V115	LED Green[100]	
LED[480:483]	PNL_V116	LED Green[101]	
LED[484:487]	PNL_V117	LED Green[102]	
LED[488:491]	PNL_V118	LED Green[103]	
LED[492:495]	PNL_V119	LED Green[104]	
LED[496:499]	PNL_V120	LED Green[105]	
LED[500:503]	PNL_V121	LED Green[106]	
LED[504:507]	PNL_V122	LED Green[107]	
LED[508:511]	PNL_V123	LED Green[108]	
LED[512:515]	PNL_V124	LED Green[109]	
LED[516:519]	PNL_V125	LED Green[110]	
LED[520:523]	PNL_V126	LED Green[111]	
LED[524:527]	PNL_V127	LED Green[112]	
LED[528:531]	PNL_V128	LED Green[113]	
LED[532:535]	PNL_V129	LED Green[114]	
LED[536:539]	PNL_V130	LED Green[115]	
LED[540:543]	PNL_V131	LED Green[116]	
LED[544:547]	PNL_V132	LED Green[117]	
LED[548:551]	PNL_V133	LED Green[118]	
LED[552:555]	PNL_V134	LED Green[119]	
LED[556:559]	PNL_V135	LED Green[120]	
LED[560:563]	PNL_V136	LED Green[121]	
LED[564:567]	PNL_V137	LED Green[122]	
LED[568:571]	PNL_V138	LED Green[123]	
LED[572:575]	PNL_V139	LED Green[124]	
LED[576:579]	PNL_V140	LED Green[125]	
LED[580:583]	PNL_V141	LED Green[126]	
LED[584:587]	PNL_V142	LED Green[127]	
LED[588:591]	PNL_V143	LED Green[128]	
LED[592:595]	PNL_V144	LED Green[129]	
LED[596:599]	PNL_V145	LED Green[130]	
LED[600:603]	PNL_V146	LED Green[131]	
LED[604:607]	PNL_V147	LED Green[132]	
LED[608:611]	PNL_V148	LED Green[133]	
LED[612:615]	PNL_V149	LED Green[134]	
LED[616:619]	PNL_V150	LED Green[135]	
LED[620:623]	PNL_V151	LED Green[136]	
LED[624:627]	PNL_V152	LED Green[137]	
LED[628:631]	PNL_V153	LED Green[138]	
LED[632:635]	PNL_V154	LED Green[139]	
LED[636:639]	PNL_V155	LED Green[140]	
LED[640:643]	PNL_V156	LED Green[141]	
LED[644:647]	PNL_V157	LED Green[142]	
LED[648:651]	PNL_V158	LED Green[143]	
LED[652:655]	PNL_V159	LED Green[144]	
LED[656:659]	PNL_V160	LED Green[145]	
LED[660:663]	PNL_V161	LED Green[146]	
LED[664:667]	PNL_V162	LED Green[147]	
LED[668:671]	PNL_V163	LED Green[148]	
LED[672:675]	PNL_V164	LED Green[149]	
LED[676:679]	PNL_V165	LED Green[150]	
LED[680:683]	PNL_V166	LED Green[151]	
LED[684:687]	PNL_V167	LED Green[152]	
LED[688:691]	PNL_V168	LED Green[153]	
LED[692:695]	PNL_V169	LED Green[154]	
LED[696:699]	PNL_V170	LED Green[155]	
LED[700:703]	PNL_V171	LED Green[156]	
LED[704:707]	PNL_V172	LED Green[157]	
LED[708:711]	PNL_V173	LED Green[158]	
LED[712:715]	PNL_V174	LED Green[159]	
LED[716:719]	PNL_V175	LED Green[160]	
LED[720:723]	PNL_V176	LED Green[161]	
LED[724:727]	PNL_V177	LED Green[162]	
LED[728:731]	PNL_V178	LED Green[163]	
LED[732:735]	PNL_V179	LED Green[164]	
LED[736:739]	PNL_V180	LED Green[165]	
LED[740:743]	PNL_V181	LED Green[166]	
LED[744:747]	PNL_V182	LED Green[167]	
LED[748:751]	PNL_V183	LED Green[168]	
LED[752:755]	PNL_V184	LED Green[169]	
LED[756:759]	PNL_V185	LED Green[170]	
LED[760:763]	PNL_V186	LED Green[171]	
LED[764:767]	PNL_V187	LED Green[172]	
LED[768:771]	PNL_V188	LED Green[173]	
LED[772:775]	PNL_V189	LED Green[174]	
LED[776:779]	PNL_V190	LED Green[175]	
LED[780:783]	PNL_V191	LED Green[176]	
LED[784:787]	PNL_V192	LED Green[177]	
LED[788:791]	PNL_V193	LED Green[178]	
LED[792:795]	PNL_V194	LED Green[179]	
LED[796:799]	PNL_V195	LED Green[180]	
LED[800:803]	PNL_V196	LED Green[181]	
LED[804:807]	PNL_V197	LED Green[182]	
LED[808:811]	PNL_V198	LED Green[183]	
LED[812:815]	PNL_V199	LED Green[184]	
LED[816:819]	PNL_V200	LED Green[185]	
LED[820:823]	PNL_V201	LED Green[186]	
LED[824:827]	PNL_V202	LED Green[187]	
LED[828:831]	PNL_V203	LED Green[188]	
LED[832:835]	PNL_V204	LED Green[189]	
LED[836:839]	PNL_V205	LED Green[190]	
LED[840:843]	PNL_V206	LED Green[191]	
LED[844:847]	PNL_V207	LED Green[192]	
LED[848:851]	PNL_V208	LED Green[193]	
LED[852:855]	PNL_V209	LED Green[194]	
LED[856:859]	PNL_V210	LED Green[195]	
LED[860:863]	PNL_V211	LED Green[196]	
LED[864:867]	PNL_V212	LED Green[197]	
LED[868:871]	PNL_V213	LED Green[198]	
LED[872:875]	PNL_V214	LED Green[199]	
LED[876:879]	PNL_V215	LED Green[200]	
LED[880:883]	PNL_V216	LED Green[201]	
LED[884:887]	PNL_V217	LED Green[202]	
LED[888:891]	PNL_V218	LED Green[203]	
LED[892:895]	PNL_V219	LED Green[204]	
LED[896:899]	PNL_V220	LED Green[205]	
LED[900:903]	PNL_V221	LED Green[206]	
LED[904:907]	PNL_V222	LED Green[207]	
LED[908:911]	PNL_V223	LED Green[208]	
LED[912:915]	PNL_V224	LED Green[209]	
LED[916:919]	PNL_V225	LED Green[210]	
LED[920:923]	PNL_V226	LED Green[211]	
LED[924:927]	PNL_V227	LED Green[212]	
LED[928:931]	PNL_V228	LED Green[213]	
LED[932:935]	PNL_V229	LED Green[214]	
LED[936:939]	PNL_V230	LED Green[215]	
LED[940:943]	PNL_V231	LED Green[216]	
LED[944:947]	PNL_V232	LED Green[217]	
LED[948:951]	PNL_V233	LED Green[218]	
LED[952:955]	PNL_V234	LED Green[219]	
LED[956:959]	PNL_V235	LED Green[220]	
LED[960:963]	PNL_V236	LED Green[221]	
LED[964:967]	PNL_V237	LED Green[222]	
LED[968:971]	PNL_V238	LED Green[223]	
LED[972:975]	PNL_V239	LED Green[224]	
LED[976:979]	PNL_V240	LED Green[225]	
LED[980:983]	PNL_V241	LED Green[226]	
LED[984:987]	PNL_V242	LED Green[227]	
LED[988:991]	PNL_V243	LED Green[228]	
LED[992:995]	PNL_V244	LED Green[229]	
LED[996:999]	PNL_V245	LED Green[230]	
Signal Name	PPGA Pin No.	Description	
CLOCK_0	PNL_D13	On Board 27 MHz	
CLOCK_00	PNL_D13	On Board 50 MHz	
EXT_CLOCK	PNL_D15	External Clock	
Signal Name	PPGA Pin No.	Description	
UART_RXD	PNL_U01	UART Receiver	
UART_TXD	PNL_U02	UART Transmitter	
Signal Name	PPGA Pin No.	Description	
PNL_C00	PNL_C00	PNL Clock	
PNL_DAT	PNL_C04	PNL Data	
Signal Name	PPGA Pin No.	Description	
PNL_SCLK	PNL_S00	PNL SCLK	
Signal Name	PPGA Pin No.	Description	
PNL_A01	PNL_A01	PNL A[0]	
TO_DAT[0]	PNL_E08	TV Decoder Dem[0]	
TO_DAT[1]	PNL_E09	TV Decoder Dem[1]	
TO_DAT[2]	PNL_E10	TV Decoder Dem[2]	
TO_DAT[3]	PNL_H10	TV Decoder Dem[3]	
TO_DAT[4]	PNL_G09	TV Decoder Dem[4]	
TO_DAT[5]	PNL_F09	TV Decoder Dem[5]	
TO_DAT[6]	PNL_D09	TV Decoder Dem[6]	
TO_DAT[7]	PNL_C07	TV Decoder Dem[7]	
TO_DAT[8]	PNL_B08	TV Decoder Dem[8]	
TO_DAT[9]	PNL_A07	TV Decoder Dem[9]	
TO_DAT[10]	PNL_Z07	TV Decoder Dem[10]	
TO_DAT[11]	PNL_Y07	TV Decoder Dem[11]	
TO_DAT[12]	PNL_X08	TV Decoder Dem[12]	
TO_DAT[13]	PNL_W08	TV Decoder Dem[13]	
TO_DAT[14]	PNL_V08	TV Decoder Dem[14]	
TO_DAT[15]	PNL_U08	TV Decoder Dem[15]	
TO_DAT[16]	PNL_T08	TV Decoder Dem[16]	
TO_DAT[17]	PNL_S08	TV Decoder Dem[17]	
TO_DAT[18]	PNL_R08	TV Decoder Dem[18]	
TO_DAT[19]	PNL_Q08	TV Decoder Dem[19]	
TO_DAT[20]	PNL_P08	TV Decoder Dem[20]	
TO_DAT[21]	PNL_O08	TV Decoder Dem[21]	
TO_DAT[22]	PNL_N08	TV Decoder Dem[22]	
TO_DAT[23]	PNL_M08	TV Decoder Dem[23]	
TO_DAT[24]	PNL_L08	TV Decoder Dem[24]	
TO_DAT[25]	PNL_K08	TV Decoder Dem[25]	
TO_DAT[26]	PNL_J08	TV Decoder Dem[26]	
TO_DAT[27]	PNL_I08	TV Decoder Dem[27]	
TO_DAT[28]	PNL_H08	TV Decoder Dem[28]	
TO_DAT[29]	PNL_G08	TV Decoder Dem[29]	
TO_DAT[30]	PNL_F08	TV Decoder Dem[30]	
TO_DAT[3			

HEX3[5]	PIN_U22	Seven Segment Digit 3[5]
HEX3[6]	PIN_W24	Seven Segment Digit 3[6]
HEX4[0]	PIN_U9	Seven Segment Digit 4[0]
HEX4[1]	PIN_U1	Seven Segment Digit 4[1]
HEX4[2]	PIN_U2	Seven Segment Digit 4[2]
HEX4[3]	PIN_T4	Seven Segment Digit 4[3]
HEX4[4]	PIN_R7	Seven Segment Digit 4[4]
HEX4[5]	PIN_R6	Seven Segment Digit 4[5]
HEX4[6]	PIN_T3	Seven Segment Digit 4[6]
HEX5[0]	PIN_T2	Seven Segment Digit 5[0]
HEX5[1]	PIN_P6	Seven Segment Digit 5[1]
HEX5[2]	PIN_P7	Seven Segment Digit 5[2]
HEX5[3]	PIN_T9	Seven Segment Digit 5[3]
HEX5[4]	PIN_R5	Seven Segment Digit 5[4]
HEX5[5]	PIN_R4	Seven Segment Digit 5[5]
HEX5[6]	PIN_R3	Seven Segment Digit 5[6]
HEX6[0]	PIN_R2	Seven Segment Digit 6[0]
HEX6[1]	PIN_P4	Seven Segment Digit 6[1]
HEX6[2]	PIN_P3	Seven Segment Digit 6[2]
HEX6[3]	PIN_M2	Seven Segment Digit 6[3]
HEX6[4]	PIN_M3	Seven Segment Digit 6[4]
HEX6[5]	PIN_M5	Seven Segment Digit 6[5]
HEX6[6]	PIN_M4	Seven Segment Digit 6[6]
HEX7[0]	PIN_L3	Seven Segment Digit 7[0]
HEX7[1]	PIN_L2	Seven Segment Digit 7[1]
HEX7[2]	PIN_L9	Seven Segment Digit 7[2]
HEX7[3]	PIN_L6	Seven Segment Digit 7[3]
HEX7[4]	PIN_L7	Seven Segment Digit 7[4]
HEX7[5]	PIN_P9	Seven Segment Digit 7[5]
HEX7[6]	PIN_N9	Seven Segment Digit 7[6]
Signal Name	FPGA Pin No.	Description



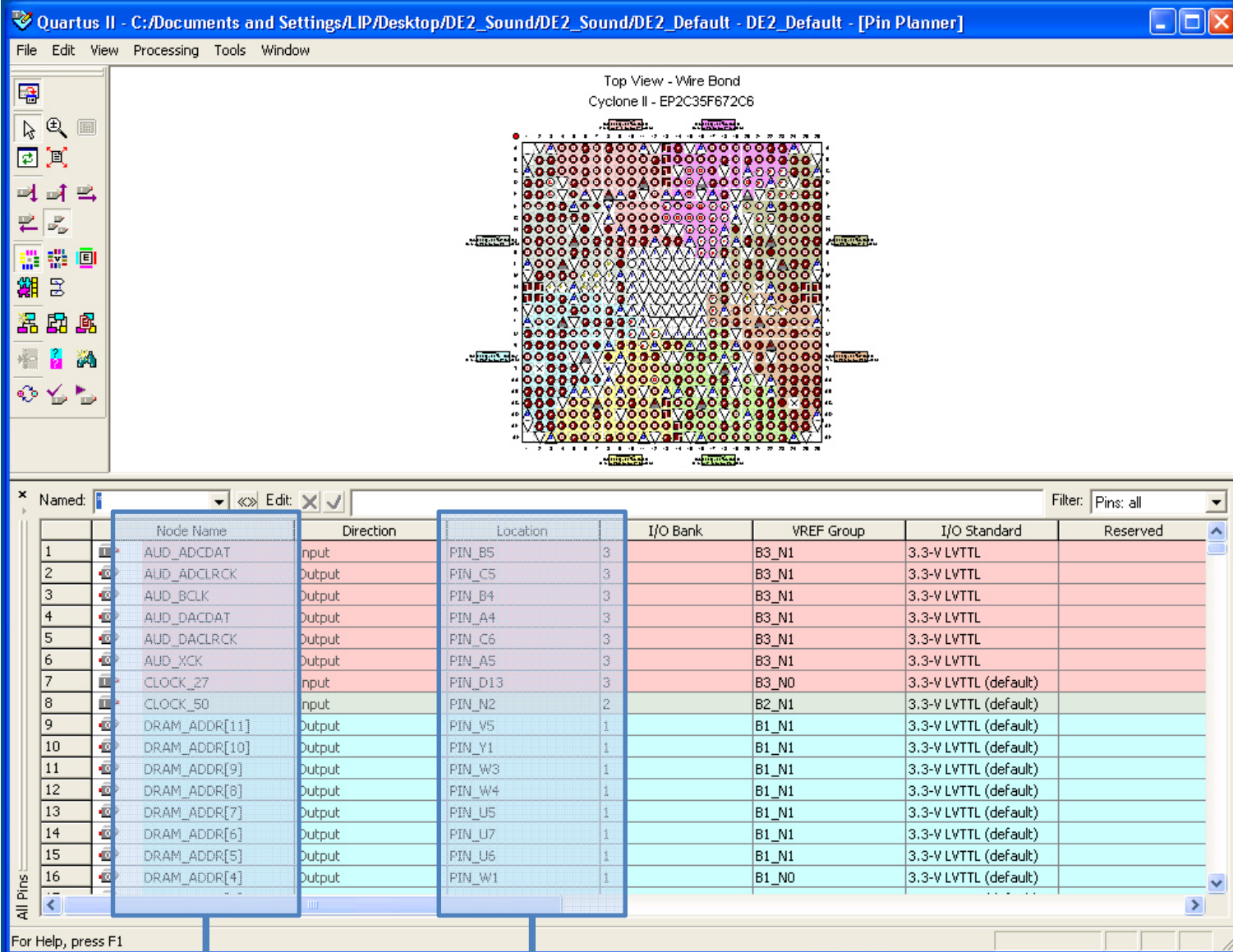
Physical Pins of FPGA

On the “compiler” / “programmer”

Quartus II - C:/Documents and Settings/LIP/Desktop/DE2_Sound/DE2_Sound/DE2_Default - DE2_Default - [Pin Planner]

File Edit View Processing Tools Window

Top View - Wire Bond
Cyclone II - EP2C35F672C6



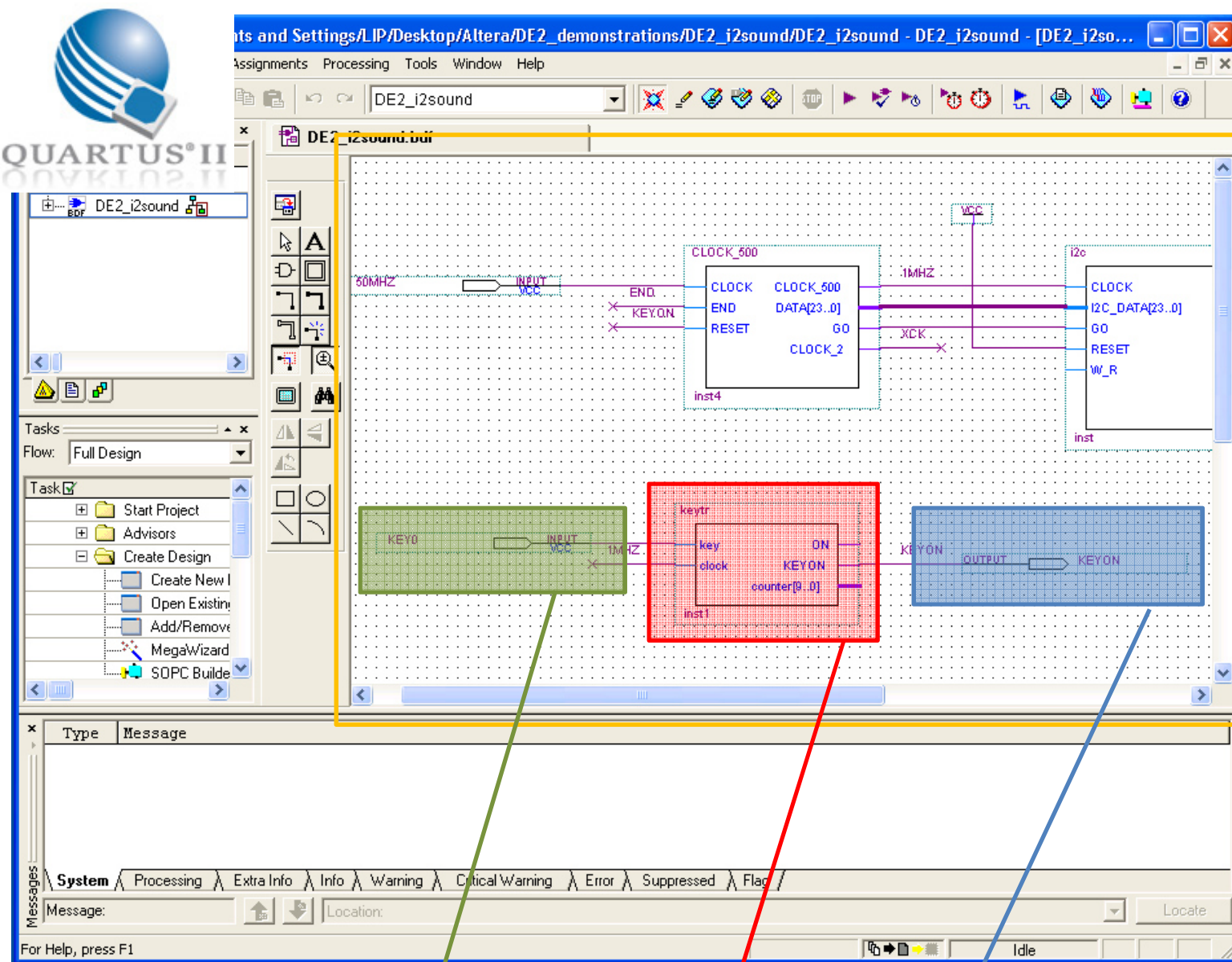
The Pin Planner window displays a top view of the Cyclone II chip (EP2C35F672C6) with a grid of pins. Below the chip view is a table of pin assignments. The table has columns for Node Name, Direction, Location, I/O Bank, VREF Group, I/O Standard, and Reserved. The table lists 16 pins, with the first 16 rows highlighted in blue. The first 16 rows are: 1. AUD_ADCDAT (Input, PIN_B5, Bank 3, B3_N1, 3.3-V LVTTTL), 2. AUD_ADCLCK (Output, PIN_C5, Bank 3, B3_N1, 3.3-V LVTTTL), 3. AUD_BCLK (Output, PIN_B4, Bank 3, B3_N1, 3.3-V LVTTTL), 4. AUD_DACDAT (Output, PIN_A4, Bank 3, B3_N1, 3.3-V LVTTTL), 5. AUD_DACLCK (Output, PIN_C6, Bank 3, B3_N1, 3.3-V LVTTTL), 6. AUD_XCK (Output, PIN_A5, Bank 3, B3_N1, 3.3-V LVTTTL), 7. CLOCK_27 (Input, PIN_D13, Bank 3, B3_N0, 3.3-V LVTTTL (default)), 8. CLOCK_50 (Input, PIN_N2, Bank 2, B2_N1, 3.3-V LVTTTL (default)), 9. DRAM_ADDR[11] (Output, PIN_V5, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 10. DRAM_ADDR[10] (Output, PIN_Y1, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 11. DRAM_ADDR[9] (Output, PIN_W3, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 12. DRAM_ADDR[8] (Output, PIN_W4, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 13. DRAM_ADDR[7] (Output, PIN_U5, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 14. DRAM_ADDR[6] (Output, PIN_U7, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 15. DRAM_ADDR[5] (Output, PIN_U6, Bank 1, B1_N1, 3.3-V LVTTTL (default)), 16. DRAM_ADDR[4] (Output, PIN_W1, Bank 1, B1_N0, 3.3-V LVTTTL (default)).

	Node Name	Direction	Location	I/O Bank	VREF Group	I/O Standard	Reserved
1	AUD_ADCDAT	Input	PIN_B5	3	B3_N1	3.3-V LVTTTL	
2	AUD_ADCLCK	Output	PIN_C5	3	B3_N1	3.3-V LVTTTL	
3	AUD_BCLK	Output	PIN_B4	3	B3_N1	3.3-V LVTTTL	
4	AUD_DACDAT	Output	PIN_A4	3	B3_N1	3.3-V LVTTTL	
5	AUD_DACLCK	Output	PIN_C6	3	B3_N1	3.3-V LVTTTL	
6	AUD_XCK	Output	PIN_A5	3	B3_N1	3.3-V LVTTTL	
7	CLOCK_27	Input	PIN_D13	3	B3_N0	3.3-V LVTTTL (default)	
8	CLOCK_50	Input	PIN_N2	2	B2_N1	3.3-V LVTTTL (default)	
9	DRAM_ADDR[11]	Output	PIN_V5	1	B1_N1	3.3-V LVTTTL (default)	
10	DRAM_ADDR[10]	Output	PIN_Y1	1	B1_N1	3.3-V LVTTTL (default)	
11	DRAM_ADDR[9]	Output	PIN_W3	1	B1_N1	3.3-V LVTTTL (default)	
12	DRAM_ADDR[8]	Output	PIN_W4	1	B1_N1	3.3-V LVTTTL (default)	
13	DRAM_ADDR[7]	Output	PIN_U5	1	B1_N1	3.3-V LVTTTL (default)	
14	DRAM_ADDR[6]	Output	PIN_U7	1	B1_N1	3.3-V LVTTTL (default)	
15	DRAM_ADDR[5]	Output	PIN_U6	1	B1_N1	3.3-V LVTTTL (default)	
16	DRAM_ADDR[4]	Output	PIN_W1	1	B1_N0	3.3-V LVTTTL (default)	

For Help, press F1

Friendly Name

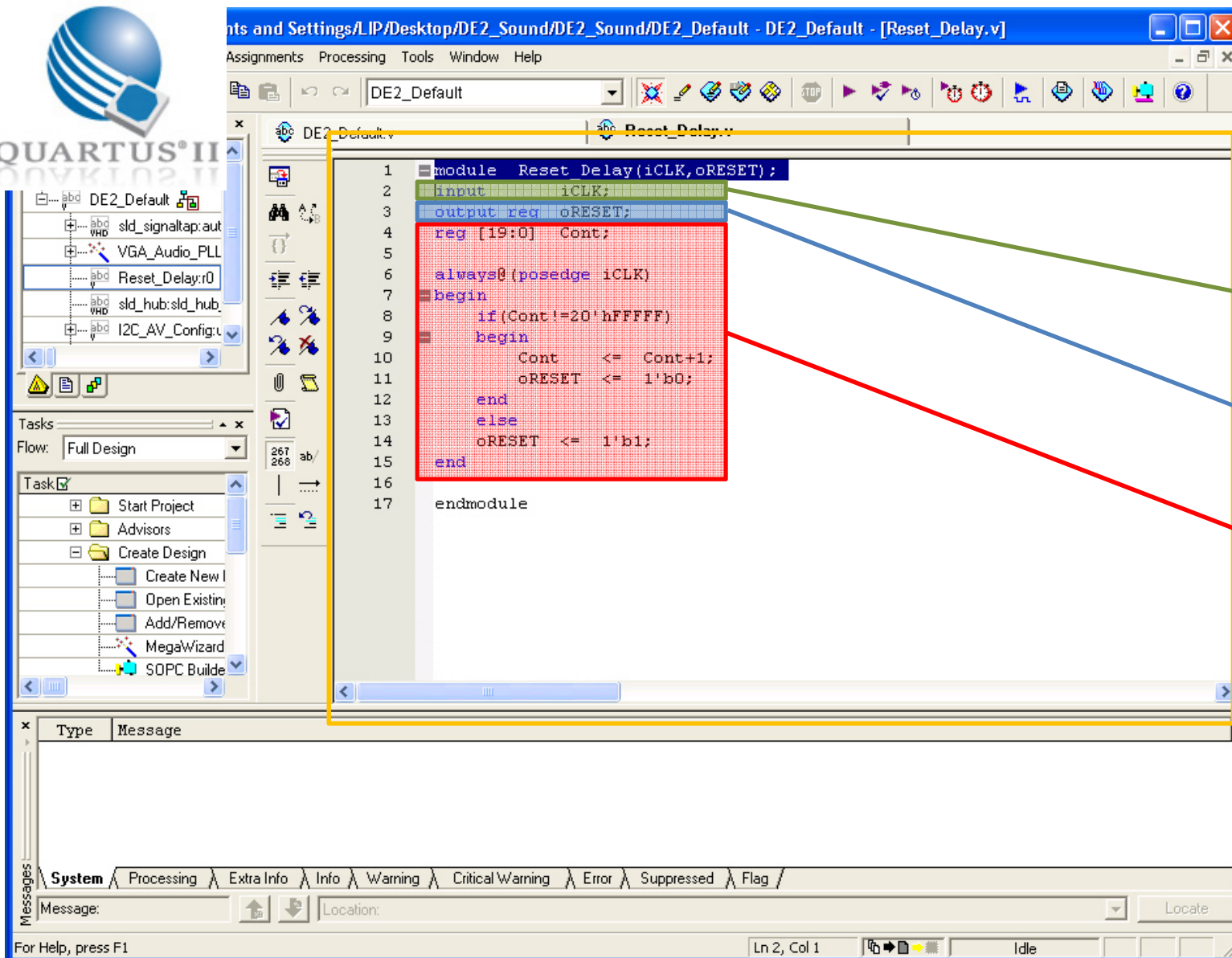
Physical Names



Input

Logic

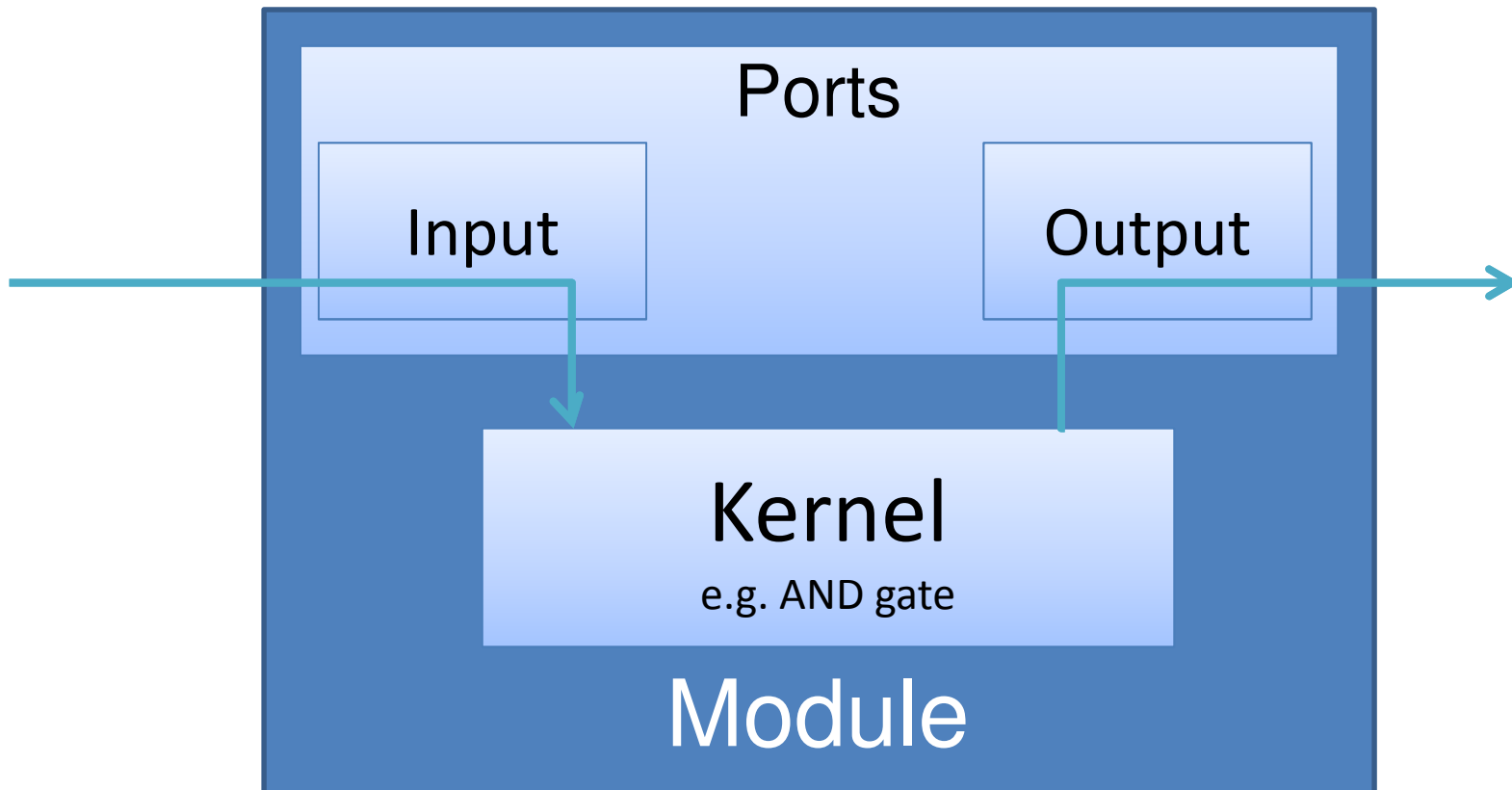
Output



Structuring... Modules

Modules are the building blocks in Verilog!

There is at least one module: The top one that has the name of the project!



Ports in the top level module link directly to the pins

Now, the text you need to write that the compiler will interpret with the configuration for the FPGA to do what you want.
a.k.a. code

```
module mux(input a,b,sel, output q, qbar);  
  wire selbar, q1, q2;  
  not n1(selbar, sel);  
  and a1(q1, a, selbar);  
  and a2(q2, b, sel);  
  or o1(q, q1, q2);  
  not n2(qbar, q)  
endmodule
```

Selbar, q1, q2 are names
given to wires

not, and, or are modules!
n1, a1, a2, o1, n2 are
names of instances

Another way...

```
module mux(input a,b,sel, output q, qbar);
```

```
    assign q = sel? a : b;  
    assign qbar = ~ q;
```

```
endmodule
```

Same as
If (sel) then a else b

Assign means that

Left Hand Side (LHS)

of '=' takes 'immediately' the value that results from
Right Hand Side (RHS)

Yet another way...

Notice the **reg** keyword...

```
module mux(input a,b,sel, output reg q, qbar);
```

```
    always @ (a,b,sel) begin
```

```
        if (sel) q=a;
```

```
        else q=b;
```

```
    end
```

```
    assign qbar = ~ q;
```

```
endmodule
```

“Whenever a,b or sel changes”

Can be replaced by
always @ (*)

“Whenever anything changes”

If and cases can be used

Verilog data values

Value	Meaning
0	Logic zero, “Low”
1	Logic one, “High”
Z or ?	High Impedance (tri-state)
X	Unknow (simulation)

Numeric constants

Full format: <Width>'<Radix>value

Width: number

Radix: d=decimal, h=hex, o=ocatl, b=binary

Value	Meaning
123	Default: decimal radix
'd123	'd=decimal radix
'h7B	'h=hexadecimal radix
'o173	'o=ocatl radix
'b111_101	'b=binary radix
16'b11111	A binary with 16 bits
16'd5	A 16 bit decimal = 'b0000_0000_0000_0101

How many bits?

Wire ab;	A 1 bit wire called <u>ab</u>
Wire ab,cd;	Two 1 bit wires called <u>ab</u> and <u>cd</u>
wire [31:0] ef;	A 32 bits wire bus called <u>ef</u> ;
{ab,cd}	Concatenation of <u>ab</u> and <u>cd</u> ;
ef[15]	Bit #15 (the sixteenth) of <u>ef</u>
ef[7:0]	First 8 bits of <u>ef</u> (the ones to the right)

What does this means?

```
wire [31:0] kk;  
Wire [7:0] a,b,c,d;  
Assign kk={d,c,b,a}
```

Boolean operators

- **Bitwise operators** perform bit-oriented operations on vectors
 - $\sim(4'b0101) = \{\sim 0, \sim 1, \sim 0, \sim 1\} = 4'b1010$
 - $4'b0101 \& 4'b0011 = \{0\&0, 1\&0, 0\&1, 1\&1\} = 4'b0001$
- **Reduction operators** act on each bit of a single input vector
 - $\&(4'b0101) = 0 \& 1 \& 0 \& 1 = 1'b0$
- **Logical operators** return one-bit (true/false) results
 - $!(4'b0101) = 1'b0$

Bitwise

$\sim a$	NOT
$a \& b$	AND
$a b$	OR
$a \wedge b$	XOR
$a \sim\wedge b$ $a \wedge\sim b$	XNOR

Reduction

$\&a$	AND
$\sim\&a$	NAND
$ a$	OR
$\sim a$	NOR
$\wedge a$	XOR
$\sim\wedge a$ $\wedge\sim a$	XNOR

Logical

$!a$	NOT
$a \&\& b$	AND
$a b$	OR
$a == b$ $a != b$	[in]equality returns x when x or z in bits. Else returns 0 or 1
$a === b$ $a !== b$	case [in]equality returns 0 or 1 based on bit by bit comparison

*Note distinction between $\sim a$ and $!a$
when operating on multi-bit values*

Other operators

Conditional

$a ? b : c$	If a then b else c
-------------	--------------------

Relational

$a > b$	greater than
$a \geq b$	greater than or equal
$a < b$	Less than
$a \leq b$	Less than or equal

Arithmetic

$-a$	negate
$a + b$	add
$a - b$	subtract
$a * b$	multiply
a / b	divide
$a \% b$	modulus
$a ** b$	exponentiate
$a \ll b$	logical left shift
$a \gg b$	logical right shift
$a \lll b$	arithmetic left shift
$a \ggg b$	arithmetic right shift

And now our lab session...

Two simple exercises:

1) “OLA MUNDO” just play directly with bits

2) Make a module that has:

Inputs: 4 bits code binary number

Outputs: the 7 lines of one 7-segment display

kernel: activate display segments to show decimal number

Helps...

Using DE2 you get all hardware issues “solved”

DE2_TOP project is a bare project: use it

DE2_TOP already has “friendly names”

DE2_TOP has some assigns... Play with them

File→Open Project→DE2_top

Quartus II - C:/Documents and Settings/LIP/Desktop/Altera/DE2_demonstrations/DE2_Top/DE2_TOP - DE2_TOP - [DE2_TOP.v]

File Edit View Project Assignments Processing Tools Window Help

DE2_TOP

Project Navigator

Entity

Cyclone II: EP2C35F672C6

DE2_TOP

Tasks

Flow: Full Design

Task

Start Project

Advisors

Create Design

Create New I

Open Existing

Add/Remove

MegaWizard

SOPC Builder

Assign Constraint

DE2_TOP.v

```
42 // V1.2 :| Johnny Chen :| 05/11/16 :| Fixed ISP1362 INT/
43 // -----
44
45 module DE2_TOP
46
47 // Clock Input
48 CLOCK_27, // 27 MHz
49 CLOCK_50, // 50 MHz
50 EXT_CLOCK, // External Clock
51 // Push Button
52 KEY, // Pushbutton[3:0]
53 // DPDT Switch
54 SW, // Toggle Switch[17:0]
55 // 7-SEG Display
56 HEX0, // Seven Segment Digit 0
57 HEX1, // Seven Segment Digit 1
58 HEX2, // Seven Segment Digit 2
59 HEX3, // Seven Segment Digit 3
60 HEX4, // Seven Segment Digit 4
61 HEX5, // Seven Segment Digit 5
62 HEX6, // Seven Segment Digit 6
63 HEX7, // Seven Segment Digit 7
64 // LED
65 LEDG, // LED Green[8:0]
66 LEDR, // LED Red[17:0]
67 // UART
68 UART_TXD, // UART Transmitter
69 UART_RXD, // UART Receiver
```

```
174 // Clock Input
175 input CLOCK_27; // 27 MHz
176 input CLOCK_50; // 50 MHz
177 input EXT_CLOCK; // External Clock
178 // Push Button
179 input [3:0] KEY; // Pushbutton[3:0]
180 // DPDT Switch
181 input [17:0] SW; // Toggle Switch[17:0]
182 // 7-SEG Display
183 output [6:0] HEX0; // Seven Segment Digit 0
184 output [6:0] HEX1; // Seven Segment Digit 1
185 output [6:0] HEX2; // Seven Segment Digit 2
186 output [6:0] HEX3; // Seven Segment Digit 3
187 output [6:0] HEX4; // Seven Segment Digit 4
188 output [6:0] HEX5; // Seven Segment Digit 5
189 output [6:0] HEX6; // Seven Segment Digit 6
190 output [6:0] HEX7; // Seven Segment Digit 7
191 // LED
192 output [8:0] LEDG; // LED Green[8:0]
193 output [17:0] LEDR; // LED Red[17:0]
194 // UART
195 output UART_TXD; // UART Transmitter
196 input UART_RXD; // UART Receiver
197 // IRDA
198 output IRDA_TXD; // IRDA Transmitter
199 input IRDA_RXD; // IRDA Receiver
200 // SDRAM Interface
201 inout [15:0] DRAM_DQ; // SDRAM Data bus 16 Bits
202 output [11:0] DRAM_ADDR; // SDRAM Address bus 12 Bits
```

```
300 // Turn on all display
301 assign HEX0 = 7'h00;
302 assign HEX1 = 7'h00;
303 assign HEX2 = 7'h00;
304 assign HEX3 = 7'h00;
305 assign HEX4 = 7'h00;
306 assign HEX5 = 7'h00;
307 assign HEX6 = 7'h00;
308 assign HEX7 = 7'h00;
309 assign LEDG = 9'h1FF;
310 assign LEDR = 18'h3FFFF;
311 assign LCD_ON = 1'b1;
312 assign LCD_BLON = 1'b1;
313
314 // All inout port turn to tri-state
315 assign DRAM_DQ = 16'hzzzz;
316 assign FL_DQ = 8'hzz;
317 assign SRAM_DQ = 16'hzzzz;
318 assign OTG_DATA = 16'hzzzz;
319 assign LCD_DATA = 8'hzz;
320 assign SD_DAT = 1'bz;
321 assign I2C_SDAT = 1'bz;
322 assign ENET_DATA = 16'hzzzz;
323 assign AUD_ADCLRCK = 1'bz;
324 assign AUD_DACLK = 1'bz;
325 assign AUD_BCLK = 1'bz;
326 assign GPIO_0 = 36'hzzzzzzzzzz;
327 assign GPIO_1 = 36'hzzzzzzzzzz;
328
```

