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Understanding Embedded - FPGAs (Field Programmable Gate Array)

Embedded - FPGAs, or Field Programmable Gate Arrays, are advanced integrated circuits that offer unparalleled flexibility and performance for digital systems. Unlike traditional fixed-function logic devices, FPGAs can be programmed and reprogrammed to execute a wide array of logical operations, enabling customized functionality tailored to specific applications. This reprogrammability allows developers to iterate designs quickly and implement complex functions without the need for custom hardware.

Applications of Embedded - FPGAs

The versatility of Embedded - FPGAs makes them indispensable in numerous fields. In telecommunications.

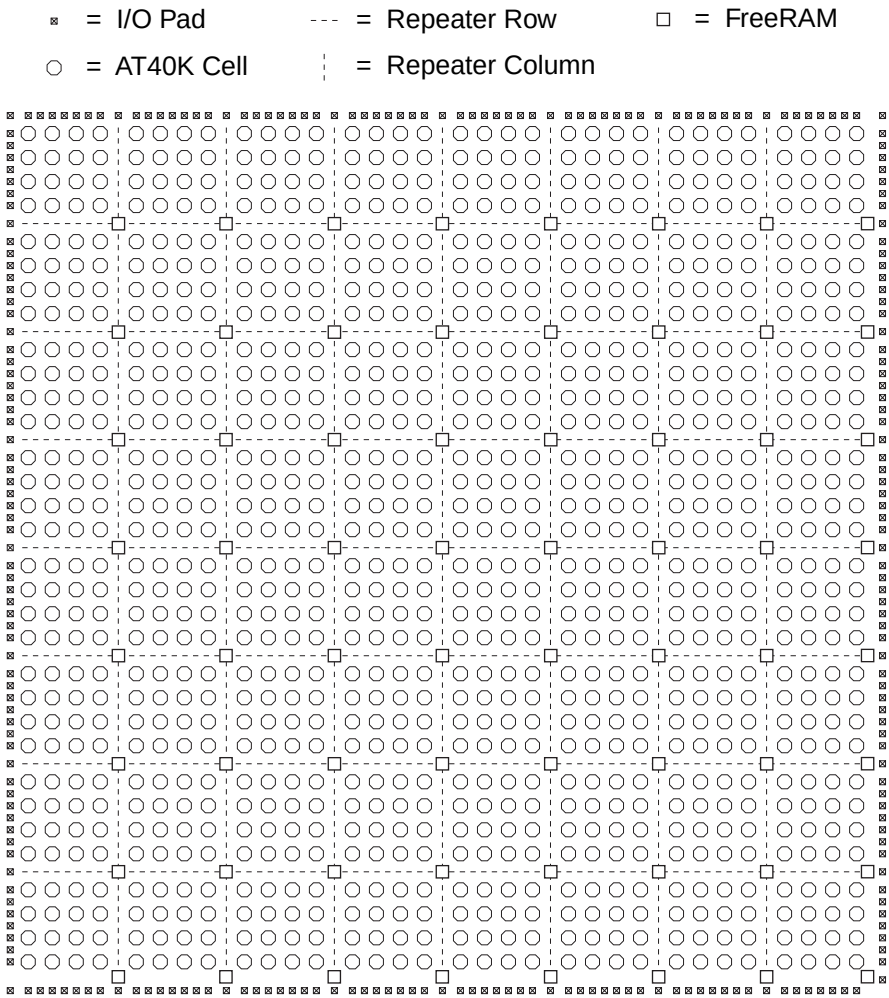
Details	
Product Status	Obsolete
Number of LABs/CLBs	-
Number of Logic Elements/Cells	2304
Total RAM Bits	18432
Number of I/O	193
Number of Gates	50000
Voltage - Supply	3V ~ 3.6V
Mounting Type	Surface Mount
Operating Temperature	0°C ~ 70°C
Package / Case	240-BFQFP
Supplier Device Package	240-PQFP (32x32)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/at40k40al-1eqc

The Symmetrical Array

At the heart of the Atmel architecture is a symmetrical array of identical cells, see Figure 1. The array is continuous from one edge to the other, except for bus repeaters spaced every four cells, see Figure 2 on page 5. At the intersection of each repeater row and column there is a 32 x 4 RAM block accessible by adjacent buses. The RAM can be configured as either a single-ported or dual-ported RAM(1), with either synchronous or asynchronous operation.

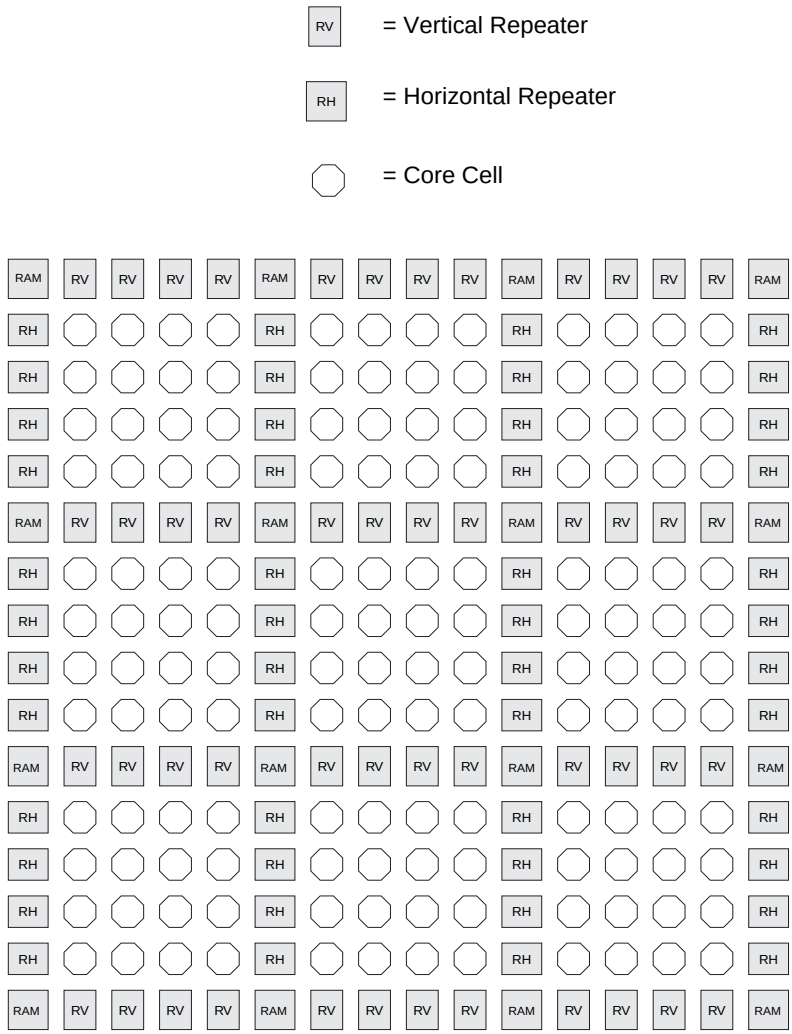
Note: 1. The right-most column can only be used as single-port RAM.

Figure 1. Symmetrical Array Surrounded by I/O (AT40K20AL)(1)



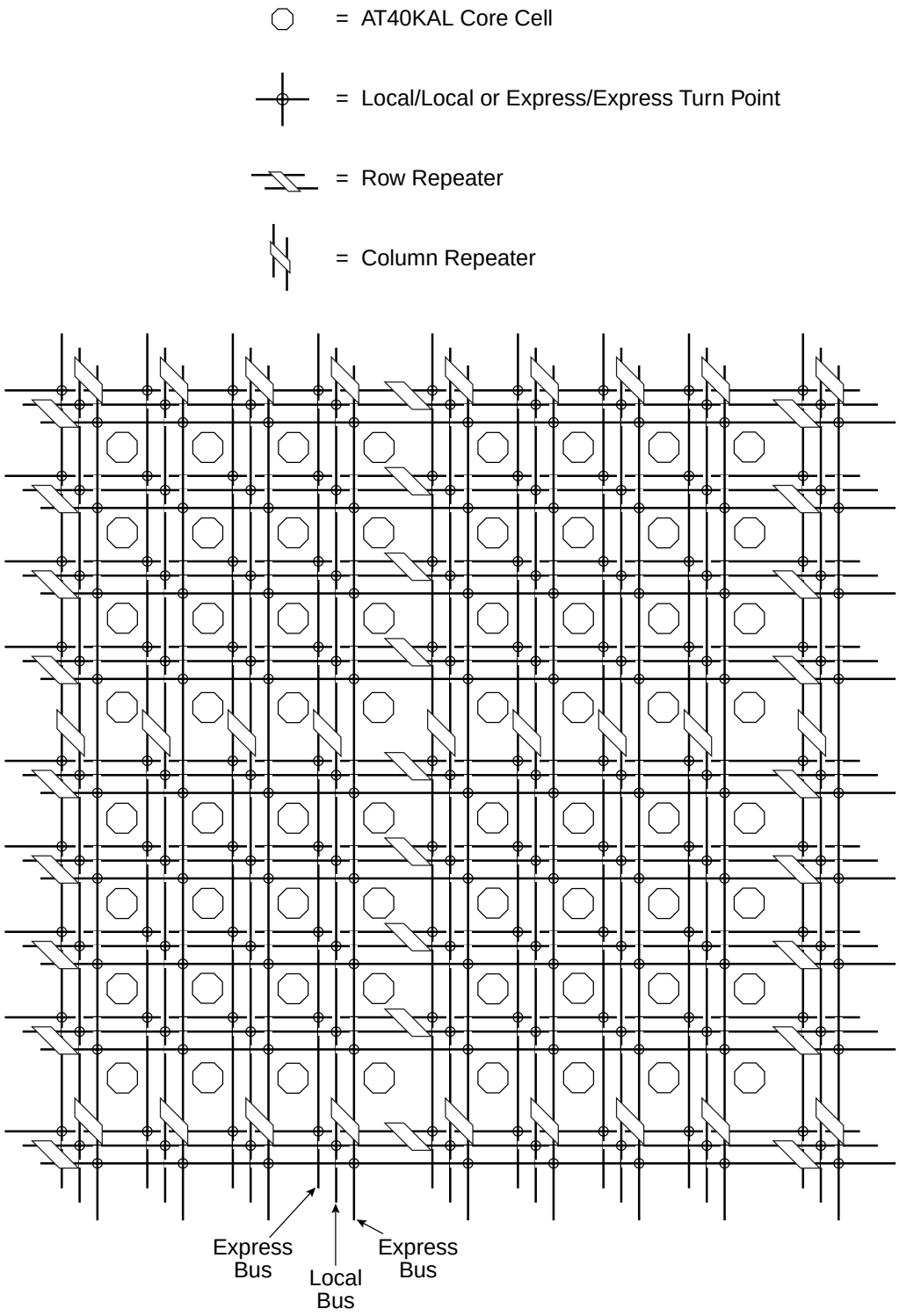
Note: 1. AT40KAL has registered I/Os. Group enable on every sector for tri-states on obufe's.

Figure 2. Floor Plan (Representative Portion)[1]



Note: 1. Repeaters regenerate signals and can connect any bus to any other bus (all pathways are legal) on the same plane. Each repeater has connections to two adjacent local-bus segments and two express-bus segments. This is done automatically using the integrated development system (IDS) tool.

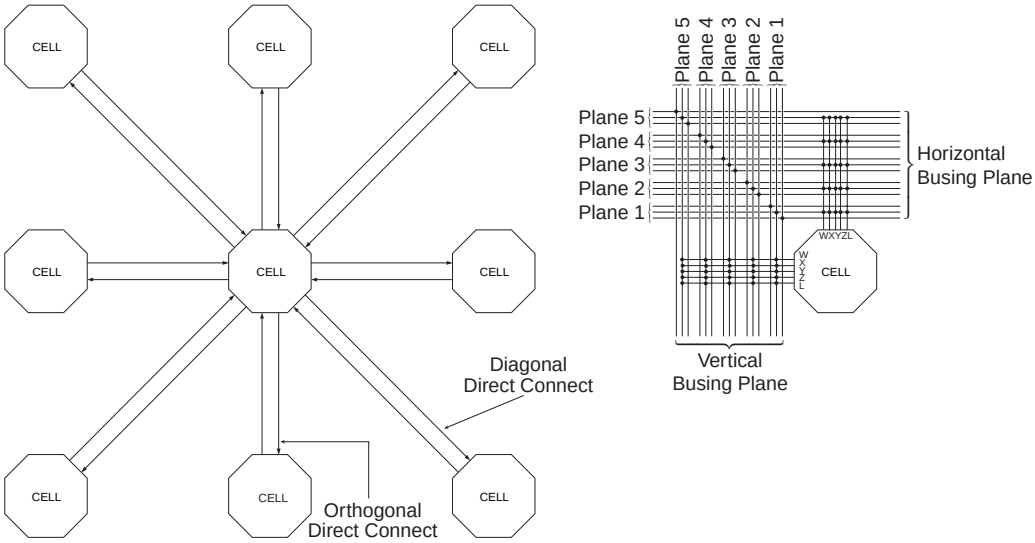
Figure 3. Busing Plane (One of Five)



Cell Connections

Figure 4(a) depicts direct connections between a cell and its eight nearest neighbors. Figure 4(b) shows the connections between a cell and five horizontal local buses (1 per busing plane) and five vertical local buses (1 per busing plane).

Figure 4. Cell Connections



(a) Cell-to-cell Connections

(b) Cell-to-bus Connections

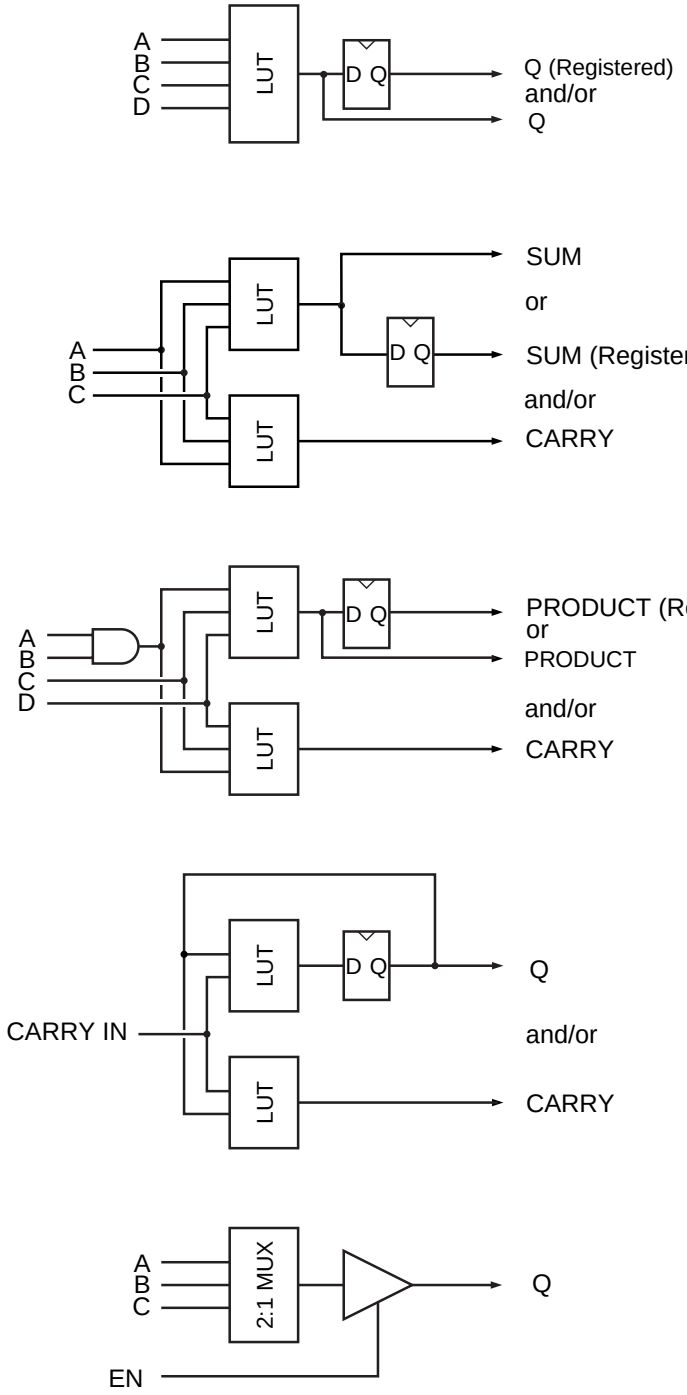
The Cell

Figure 5 depicts the AT40KAL cell. Configuration bits for separate muxes and pass gates are independent. All permutations of programmable muxes and pass gates are legal. V_n (V_1 - V_5) is connected to the vertical local bus in plane n. H_n (H_1 - H_5) is connected to the horizontal local bus in plane *n*. A local/local turn in plane n is achieved by turning on the two pass gates connected to V_n and H_n. Pass gates are opened to let signals into the cell from a local bus or to drive a signal out onto a local bus. Signals coming into the logic cell on one local bus plane can be switched onto another plane by opening two of the pass gates. This allows bus signals to switch planes to achieve greater route ability. Up to five simultaneous local/local turns are possible.

The AT40KAL FPGA core cell is a highly configurable logic block based around two 3-input LUTs (8 x 1 ROM), which can be combined to produce one 4-input LUT. This means that any core cell can implement two functions of 3 inputs or one function of 4 inputs. There is a Set/Reset D flip-flop in every cell, the output of which may be tri-stated and fed back internally within the core cell. There is also a 2-to-1 multiplexer in every cell, and an upstream AND gate in the “front end” of the cell. This AND gate is an important feature in the implementation of efficient array multipliers.

With this functionality in each core cell, the core cell can be configured in several “modes”. The core cell flexibility makes the AT40KAL architecture well suited to most digital design application areas, see Figure 6.

Figure 6. Some Single Cell Modes



Synthesis Mode. This mode is particularly important for the use of VHDL/Verilog design. VHDL/Verilog Synthesis tools generally will produce as their output large amounts of random logic functions. Having a 4-input LUT structure gives efficient random logic optimization without the delays associated with larger LUT structures. The output of any cell may be registered, tri-stated and/or fed back into a core cell.

Arithmetic Mode is frequently used in many designs. As can be seen in the figure, the AT40KAL core cell can implement a 1-bit full adder (2-input adder with both Carry In and Carry Out) in one core cell. Note that the sum output in this diagram is registered. This output could then be tri-stated and/or fed back into the cell.

DSP/Multiplier Mode. This mode is used to efficiently implement array multipliers. An array multiplier is an array of bitwise multipliers, each implemented as a full adder with an upstream AND gate. Using this AND gate and the diagonal interconnects between cells, the array multiplier structure fits very well into the AT40KAL architecture.

Counter Mode. Counters are fundamental to almost all digital designs. They are the basis of state machines, timing chains and clock dividers. A counter is essentially an increment by one function (i.e., an adder), with the input being an output (or a decode of an output) from the previous stage. A 1-bit counter can be implemented in one core cell. Again, the output can be registered, tri-stated and/or fed back.

Tri-state/Mux Mode. This mode is used in many telecommunications applications, where data needs to be routed through more than one possible path. The output of the core cell is very often tri-statable for many inputs to many outputs data switching.

RAM

32 x 4 dual-ported RAM blocks are dispersed throughout the array, see Figure 7. A 4-bit Input Data Bus connects to four horizontal local buses distributed over four sector rows (plane 1). A 4-bit Output Data Bus connects to four horizontal local buses distributed over four sector rows (plane 2). A 5-bit Input Address Bus connects to five vertical express buses in the same column. A 5-bit Output Address Bus connects to five vertical express buses in the same column. Ain (input address) and Aout (output address) alternate positions in horizontally aligned RAM blocks. For the left-most RAM blocks, Aout is on the left and Ain is on the right. For the right-most RAM blocks, Ain is on the left and Aout is tied off, thus it can only be configured as a single port. For single-ported RAM, Ain is the READ/WRITE address port and Din is the (bi-directional) data port. Right-most RAM blocks can be used only for single-ported memories. WEN and OEN connect to the vertical express buses in the same column.

Figure 7. RAM Connections (One Ram Block)

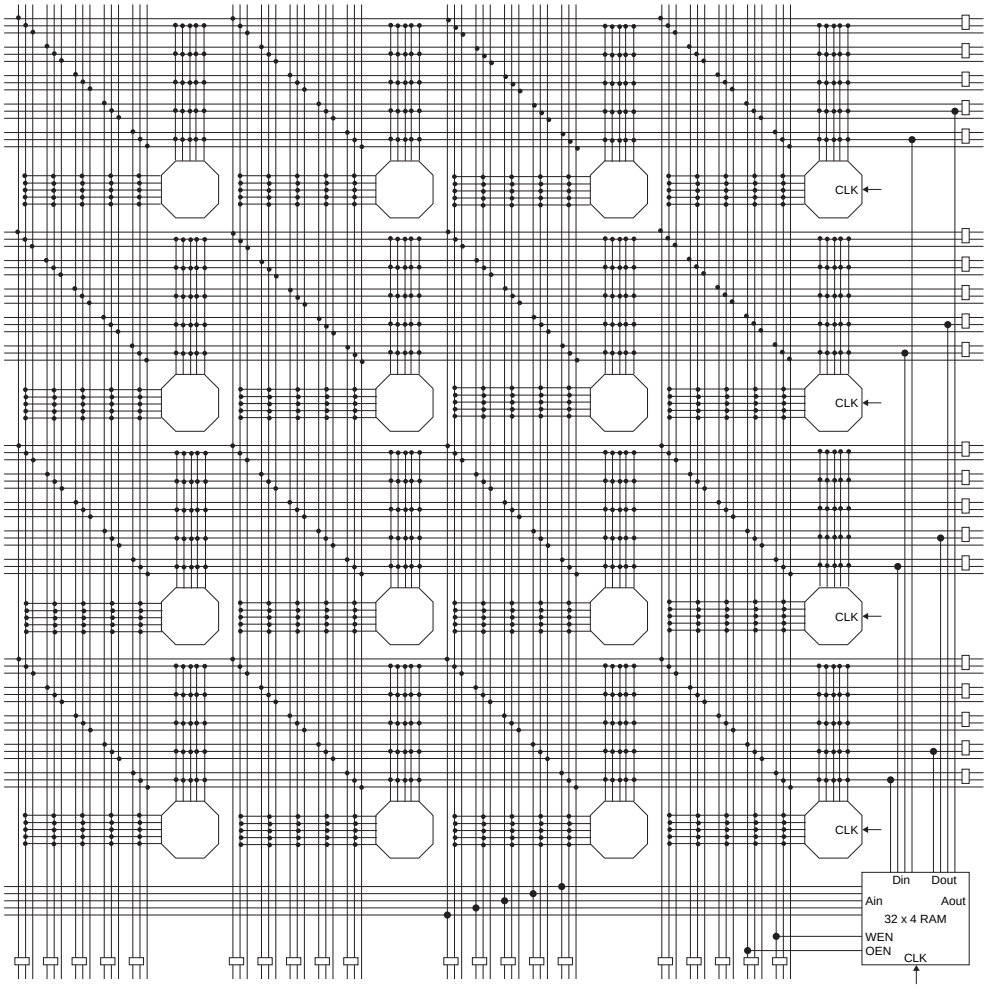


Figure 10. Clocking (for One Column of Cells)

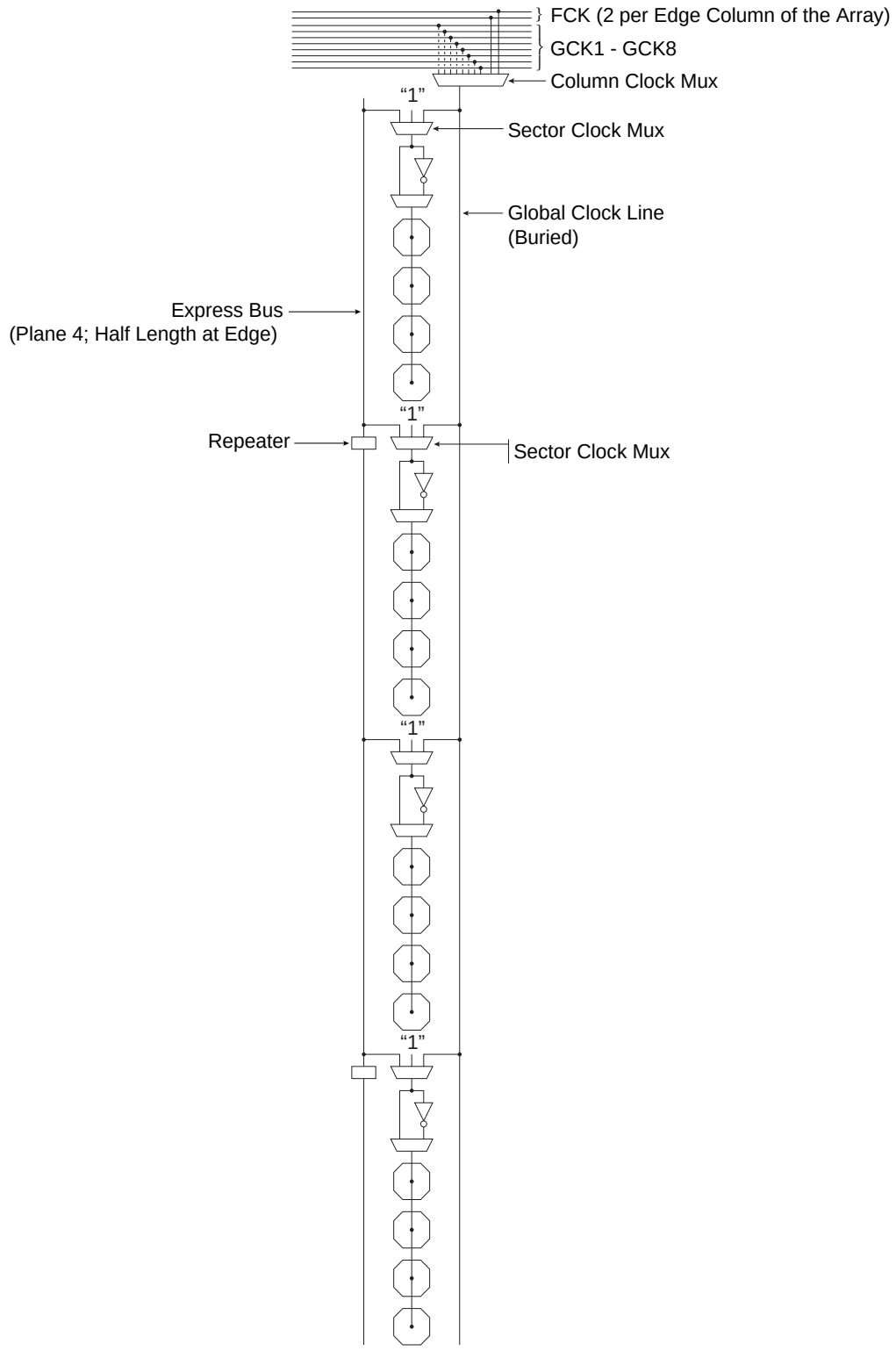
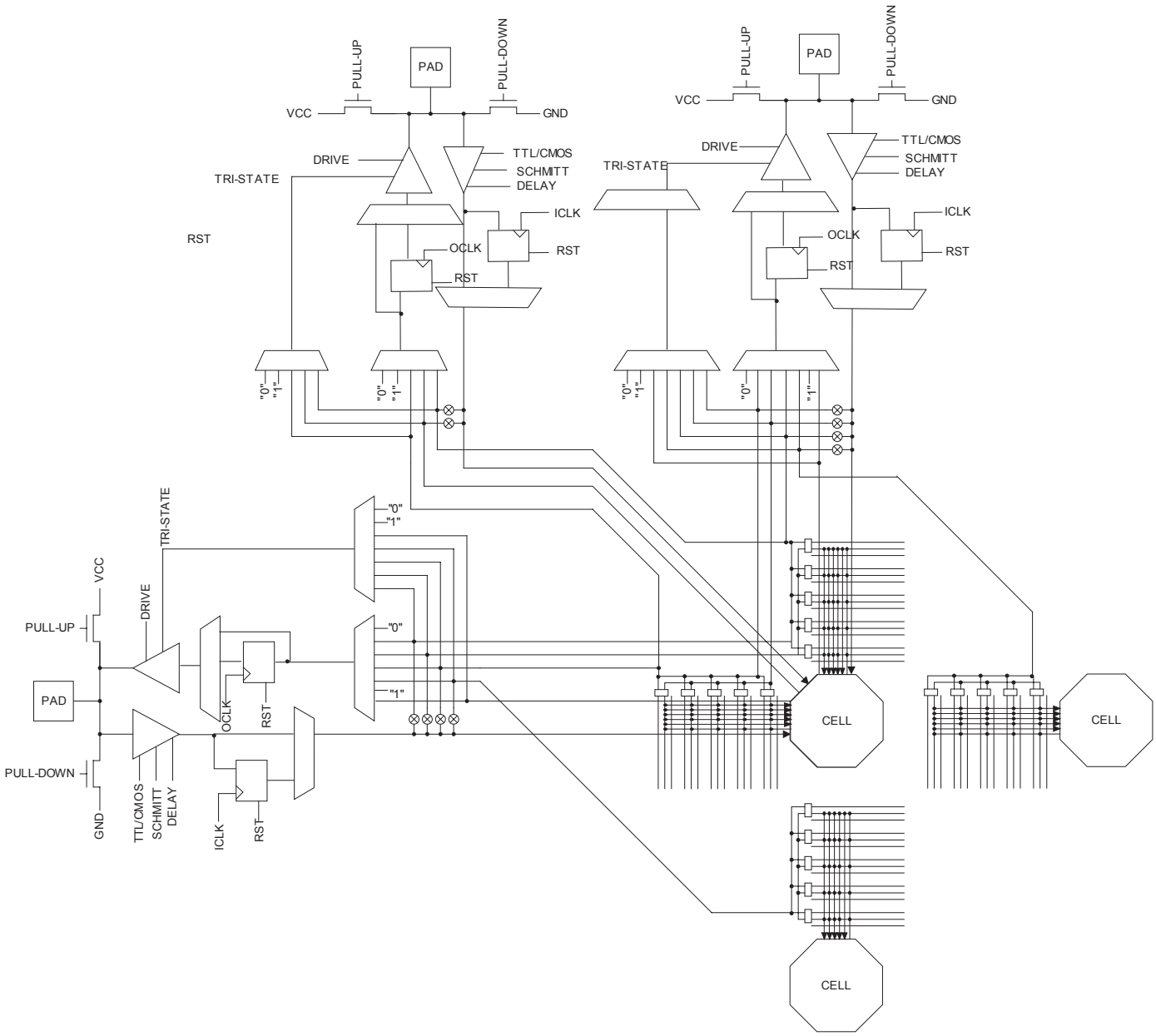


Figure 14. Northwest Corner I/O (Similar NE/SE/SW Corners)



Power-On Power Supply Requirements

Atmel FPGAs require a minimum rated power supply current capacity to insure proper initialization, and the power supply ramp-up time does affect the current required. A fast ramp-up time requires more current than a slow ramp-up time.

Table 3. Power-On Power Supply Requirements[1]

Device	Description	Maximum Current[2][3]
AT40K05AL AT40K10AL	Maximum Current Supply	50 mA
AT40K20AL AT40K40AL	Maximum Current Supply	100 mA

Notes:
1. This specification applies to Commercial and Industrial grade products only.
2. Devices are guaranteed to initialize properly at 50% of the minimum current listed above. A larger capacity power supply may result in a larger initialization current.
3. Ramp-up time is measured from 0 V DC to 3.6 V DC. Peak current required lasts less than 2 ms, and occurs near the internal power on reset threshold voltage.

AC Timing Characteristics – 3.3V Operation

Delays are based on fixed loads and are described in the notes.
Maximum times based on worst case: V_{CC} = 3.00V, temperature = 70°C
Minimum times based on best case: V_{CC} = 3.60V, temperature = 0°C
Maximum delays are the average of t_{PDLH} and t_{PDHL}.

Cell Function	Parameter	Path	-1	Units	Notes
Core					
2-input Gate	t_{PD} (Maximum)	x/y -> x/y	1.8	ns	1 unit load
3-input Gate	t_{PD} (Maximum)	x/y/z -> x/y	2.1	ns	1 unit load
3-input Gate	t_{PD} (Maximum)	x/y/w -> x/y	2.2	ns	1 unit load
4-input Gate	t_{PD} (Maximum)	x/y/w/z -> x/y	2.2	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	y -> y	1.4	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	x -> y	1.7	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	y -> x	1.8	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	x -> x	1.5	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	w -> y	2.2	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	w -> x	2.3	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	z -> y	2.3	ns	1 unit load
Fast Carry	t_{PD} (Maximum)	z -> x	1.7	ns	1 unit load
DFF	t_{PD} (Maximum)	q -> x/y	1.8	ns	1 unit load
DFF	t_{PD} (Maximum)	R -> x/y	2.2	ns	1 unit load
DFF	t_{PD} (Maximum)	S -> x/y	2.2	ns	1 unit load
DFF	t_{PD} (Maximum)	q -> w	1.8	ns	
Incremental -> L	t_{PD} (Maximum)	x/y -> L	1.5	ns	1 unit load
Local Output Enable	t_{PZX} (Maximum)	oe -> L	1.4	ns	1 unit load
Local Output Enable	t_{PXZ} (Maximum)	oe -> L	1.8	ns	

AC Timing Characteristics – 3.3V Operation

Delays are based on fixed loads and are described in the notes.
Maximum times based on worst case: V_{CC} = 3.0V, temperature = 70°C
Minimum times based on best case: V_{CC} = 3.6V, temperature = 0°C
Maximum delays are the average of t_{PDLH} and t_{PDHL}.

All input IO characteristics measured from a V_{IH} of 50% of V_{DD} at the pad (CMOS threshold) to the internal V_{IH} of 50% of V_{DD}. All output IO characteristics are measured as the average of t_{PDLH} and t_{PDHL} to the pad V_{IH} of 50% of V_{DD}.

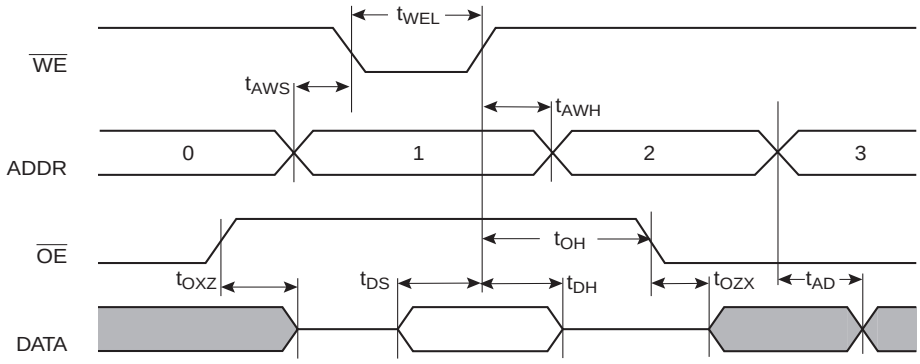
Cell Function	Parameter	Path	-1	Units	Notes
Repeaters					
Repeater	t_{PD} (Maximum)	L -> E	1.3	ns	1 unit load
Repeater	t_{PD} (Maximum)	E -> E	1.3	ns	1 unit load
Repeater	t_{PD} (Maximum)	L -> L	1.3	ns	1 unit load
Repeater	t_{PD} (Maximum)	E -> L	1.3	ns	1 unit load
Repeater	t_{PD} (Maximum)	E -> IO	0.8	ns	1 unit load
Repeater	t_{PD} (Maximum)	L -> IO	0.8	ns	1 unit load

All input IO characteristics measured from a V_{IH} of 50% of V_{DD} at the pad (CMOS threshold) to the internal V_{IH} of 50% of V_{DD}. All output IO characteristics are measured as the average of t_{PDLH} and t_{PDHL} to the pad V_{IH} of 50% of V_{DD}.

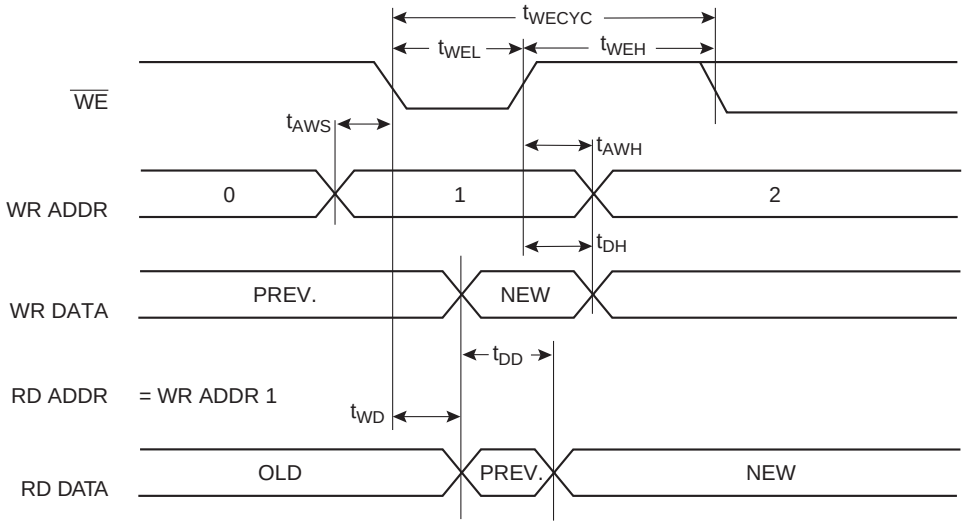
Cell Function	Parameter	Path	-1	Units	Notes
IO					
Input	t_{PD} (Maximum)	pad -> x/y	1.2	ns	No extra delay
Input	t_{PD} (Maximum)	pad -> x/y	3.6	ns	1 extra delay
Input	t_{PD} (Maximum)	pad -> x/y	7.3	ns	2 extra delays
Input	t_{PD} (Maximum)	pad -> x/y	10.8	ns	3 extra delays
Output, Slow	t_{PD} (Maximum)	x/y/E/L -> pad	5.9	ns	50 pf load
Output, Medium	t_{PD} (Maximum)	x/y/E/L -> pad	4.8	ns	50 pf load
Output, Fast	t_{PD} (Maximum)	x/y/E/L -> pad	3.9	ns	50 pf load
Output, Slow	t_{PZX} (Maximum)	oe -> pad	6.2	ns	50 pf load
Output, Slow	t_{PXZ} (Maximum)	oe -> pad	1.3	ns	50 pf load
Output, Medium	t_{PZX} (Maximum)	oe -> pad	4.8	ns	50 pf load
Output, Medium	t_{PXZ} (Maximum)	oe -> pad	1.9	ns	50 pf load
Output, Fast	t_{PZX} (Maximum)	oe -> pad	3.7	ns	50 pf load
Output, Fast	t_{PXZ} (Maximum)	oe -> pad	1.6	ns	50 pf load

FreeRAM Asynchronous Timing Characteristics

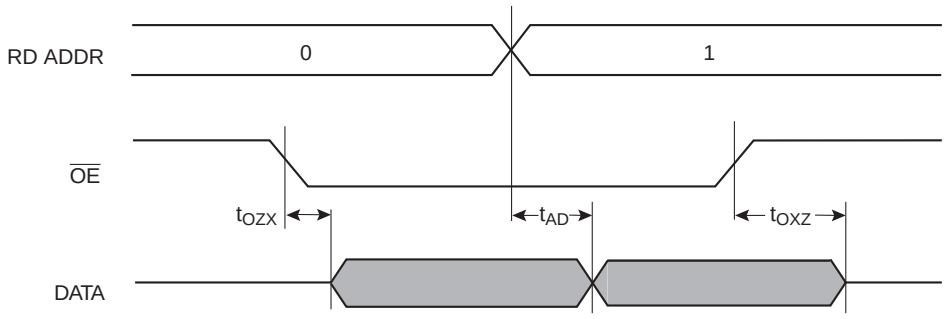
Single-port Write/Read



Dual-port Write with Read



Dual-port Read



AT40K05AL	AT40K10AL	AT40K20AL	AT40K40AL	Left Side (Top to Bottom)				
128 I/O	192 I/O	256 I/O	384 I/O	84 PLCC	100 TQFP	144 LQFP	208 PQFP	240 PQFP
I/O17	I/O25	I/O33	I/O49	23	13	19	27	31
I/O18	I/O26	I/O34	I/O50	24	14	20	28	32
			I/O51					
			I/O52					
I/O19	I/O27	I/O35	I/O53		15	21	29	33
I/O20	I/O28	I/O36	I/O54			22	30	34
			GND					
	I/O29	I/O37	I/O55				31	35
	I/O30	I/O38	I/O56				32	36
		I/O39	I/O57					
		I/O40	I/O58					
			I/O59					
			I/O60					
			VCC					
		GND	GND					37
		I/O41	I/O61					
		I/O42	I/O62					
			I/O63					
			I/O64					
			I/O65					
			I/O66					
			GND					
	I/O31	I/O43	I/O67					38
	I/O32	I/O44	I/O68					39
	VCC	VCC	VCC					40
I/O21	I/O33	I/O45	I/O69	25	16	23	33	41
I/O22	I/O34	I/O46	I/O70	26	17	24	34	42
I/O23	I/O35	I/O47	I/O71			25	35	43
I/O24, FCK2	I/O36, FCK2	I/O48, FCK2	I/O72, FCK2			26	36	44
GND	GND	GND	GND			27	37	45
		I/O49	I/O73					
		I/O50	I/O74					
	I/O37	I/O51	I/O75					46

Note: 1. On-chip tri-state

AT40K05AL	AT40K10AL	AT40K20AL	AT40K40AL	Right Side (Bottom to Top)				
128 I/O	192 I/O	256 I/O	384 I/O	84 PLCC	100 TQFP	144 LQFP	208 PQFP	240 PQFP
I/O73, FCK3	I/O111, FCK3	I/O147, FCK3	I/O219, FCK3			82	120	138
I/O74	I/O112	I/O148	I/O220			83	121	139
	VCC	VCC	VCC					140
I/O75 (D5)	I/O113 (D5)	I/O149 (D5)	I/O221 (D5)	59	57	84	122	141
I/O76 (CS0)	I/O114 (CS0)	I/O150 (CS0)	I/O222 (CS0)	60	58	85	123	142
			GND					
			I/O223					
			I/O224					
			I/O225					
			I/O226					
		I/O151	I/O227					
		I/O152	I/O228					
		GND	GND					143
			VCC					
			I/O229					
			I/O230					
		I/O153	I/O231					
		I/O154	I/O232					
	I/O115	I/O155	I/O233				124	144
	I/O116	I/O156	I/O234				125	145
			GND					
I/O77	I/O117	I/O157	I/O235		59	86	126	146
I/O78	I/O118	I/O158	I/O236		60	87	127	147
			I/O237					
			I/O238					
I/O79(D4)	I/O119(D4)	I/O159(D4)	I/O239(D4)	61	61	88	128	148
I/O80	I/O120	I/O160	I/O240	62	62	89	129	149
VCC	VCC	VCC	VCC	63	63	90	130	150
GND	GND	GND	GND	64	64	91	131	151
I/O81 (D3)	I/O121 (D3)	I/O161 (D3)	I/O241 (D3)	65	65	92	132	152
I/O82 ($\overline{\text{CHECK}}$)	I/O122 ($\overline{\text{CHECK}}$)	I/O162 ($\overline{\text{CHECK}}$)	I/O242 ($\overline{\text{CHECK}}$)	66	66	93	133	153

AT40K05AL	AT40K10AL	AT40K20AL	AT40K40AL	Top Side (Right to Left)				
128 I/O	192 I/O	256 I/O	384 I/O	84 PLCC	100 TQFP	144 LQFP	208 PQFP	240 PQFP
I/O113 (A8)	I/O169 (A8)	I/O225 (A8)	I/O337 (A8)	3	90	129	184	213
I/O114 (A9)	I/O170 (A9)	I/O226 (A9)	I/O338 (A9)	4	91	130	185	214
			I/O339					
			I/O340					
			I/O341					
			I/O342					
			GND					
I/O115	I/O171	I/O227	I/O343		92	131	186	215
I/O116	I/O172	I/O228	I/O344		93	132	187	216
	I/O173	I/O229	I/O345				188	217
	I/O174	I/O230	I/O346				189	218
I/O117 (A10)	I/O175 (A10)	I/O231 (A10)	I/O347 (A10)	5	94	133	190	220
I/O118 (A11)	I/O176 (A11)	I/O232 (A11)	I/O348 (A11)	6	95	134	191	221
			VCC					
		GND	GND					
		I/O233	I/O349					
		I/O234	I/O350					
			I/O351					
			I/O352					
			I/O353					
			I/O354					
			GND					
		I/O235	I/O355					
		I/O236	I/O356					
	VCC	VCC	VCC					222
	I/O177	I/O237	I/O357					223
	I/O178	I/O238	I/O358					224
I/O119	I/O179	I/O239	I/O359			135	192	225
I/O120	I/O180	I/O240	I/O360			136	193	226
GND	GND	GND	GND			137	194	227
		I/O241	I/O361					

Note: 1. Shared with TSTCLK. No Connect.

AT40K05AL Ordering Information

Usable Gates	Operating Voltage	Speed Grade (ns)	Ordering Code	Package	Operation Range[1]
5,000 - 10,000	3.3V	1	AT40K05AL-1AJC AT40K05AL-1AQC AT40K05AL-1BQC AT40K05AL-1DQC	84J 100T1 144L1 208Q1	Commercial (0°C to 70°C)
5,000 - 10,000	3.3V	1	AT40K05AL-1AJI AT40K05AL-1AQI AT40K05AL-1BQI AT40K05AL-1DQI	84J 100T1 144L1 208Q1	Industrial (-40°C to 85°C)

AT40K10AL Ordering Information

Usable Gates	Operating Voltage	Speed Grade (ns)	Ordering Code	Package	Operation Range[1]
10,000 - 20,000	3.3V	1	AT40K10AL-1AJC AT40K10AL-1AQC AT40K10AL-1BQC AT40K10AL-1DQC	84J 100T1 144L1 208Q1	Commercial (0°C to 70°C)
10,000 - 20,000	3.3V	1	AT40K10AL-1AJI AT40K10AL-1AQI AT40K10AL-1BQI AT40K10AL-1DQI	84J 100T1 144L1 208Q1	Industrial (-40°C to 85°C)

AT40K20AL Ordering Information

Usable Gates	Operating Voltage	Speed Grade (ns)	Ordering Code	Package	Operation Range[1]
20,000 - 30,000	3.3V	1	AT40K20AL-1AJC AT40K20AL-1AQC AT40K20AL-1BQC AT40K20AL-1DQC	84J 100T1 144L1 208Q1	Commercial (0°C to 70°C)
20,000 - 30,000	3.3V	1	AT40K20AL-1AJI AT40K20AL-1AQI AT40K20AL-1BQI AT40K20AL-1DQI	84J 100T1 144L1 208Q1	Industrial (-40°C to 85°C)

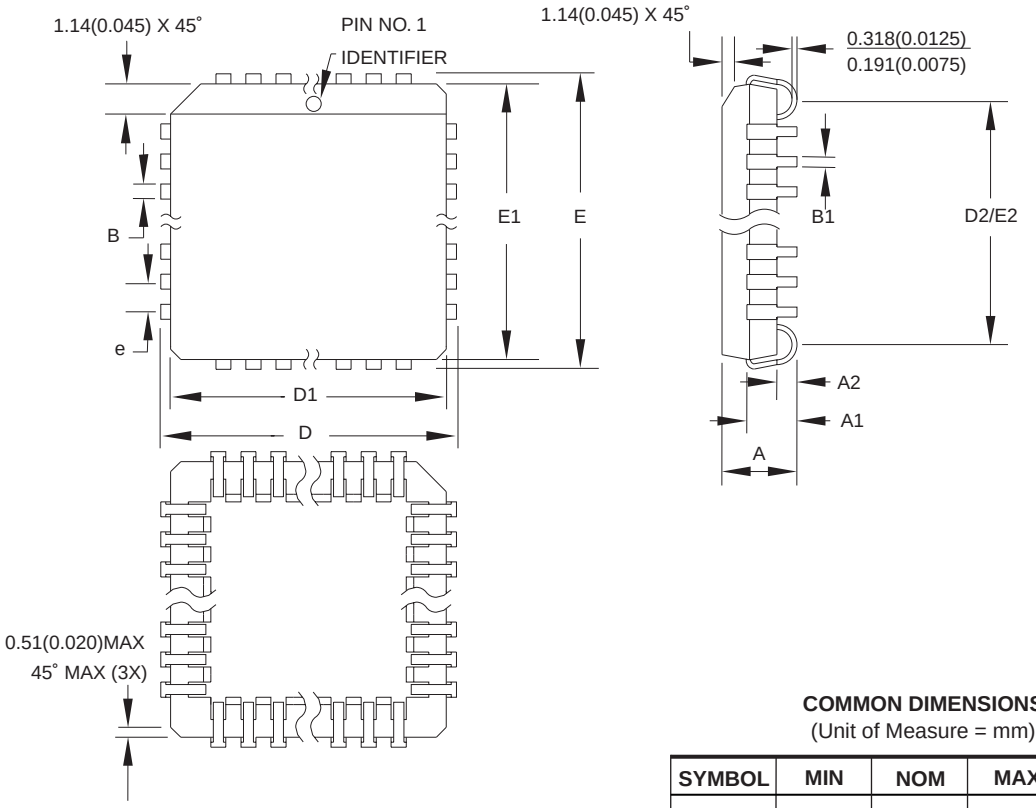
AT40K40AL Ordering Information

Usable Gates	Operating Voltage	Speed Grade (ns)	Ordering Code	Package	Operation Range[1]
40,000 - 50,000	3.3V	1	AT40K40AL-1BQC AT40K40AL-1DQC AT40K40AL-1EQC	144L1 208Q1 240Q1	Commercial (0°C to 70°C)
40,000 - 50,000	3.3V	1	AT40K40AL-1BQI AT40K40AL-1DQI AT40K40AL-1EQI	144L1 208Q1 240Q1	Industrial (-40°C to 85°C)

Note: 1. For military parts, contact Atmel at fpga@atmel.com.

Packaging Information

84J – PLCC



COMMON DIMENSIONS
(Unit of Measure = mm)

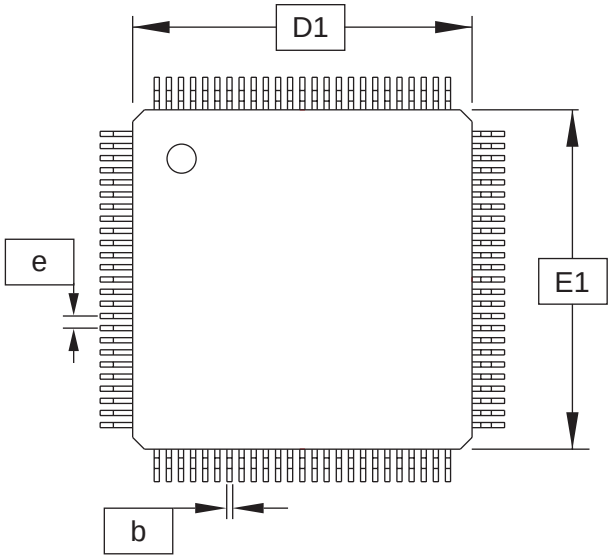
SYMBOL	MIN	NOM	MAX	NOTE
A	4.191	–	4.572	
A1	2.286	–	3.048	
A2	0.508	–	–	
D	30.099	–	30.353	
D1	29.210	–	29.413	Note 2
E	30.099	–	30.353	
E1	29.210	–	29.413	Note 2
D2/E2	27.686	–	28.702	
B	0.660	–	0.813	
B1	0.330	–	0.533	
e	1.270 TYP			

Notes:
1. This package conforms to JEDEC reference MS-018, Variation AF.
2. Dimensions D1 and E1 do not include mold protrusion. Allowable protrusion is .010"(0.254 mm) per side. Dimension D1 and E1 include mold mismatch and are measured at the extreme material condition at the upper or lower parting line.
3. Lead coplanarity is 0.004" (0.102 mm) maximum.

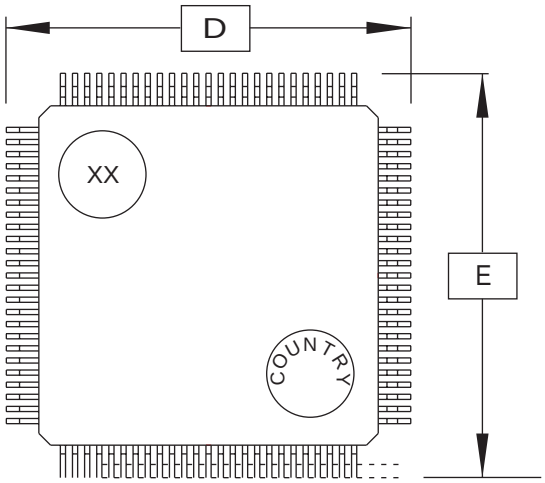
10/04/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**84J**, 84-lead, Plastic J-leaded Chip Carrier (PLCC)	84J	B

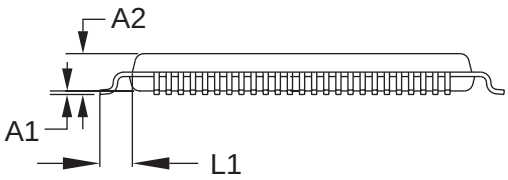
100T1 – TQFP



Top View



Bottom View



Side View

COMMON DIMENSIONS
(Unit of Measure = mm)

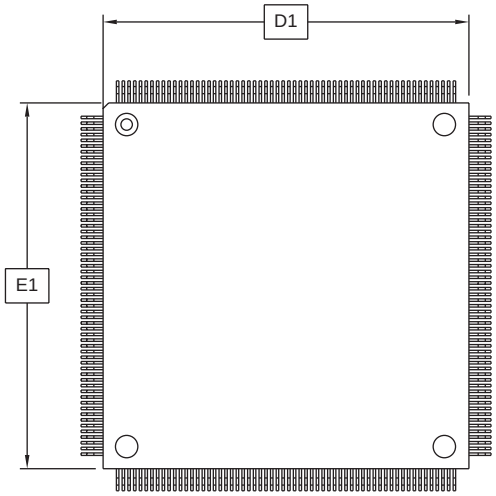
SYMBOL	MIN	NOM	MAX	NOTE
A1	0.05		0.15	6
A2	0.95	1.00	1.05	
D		16.00 BSC		
D1		14.00 BSC		2, 3
E		16.00 BSC		
E1		14.00 BSC		2, 3
e		0.50 BSC		
b	0.17	0.22	0.27	4, 5
L1		1.00 REF		

Notes:
1. This drawing is for general information only. Refer to JEDEC Drawing MO-153, Variation AA, for proper dimensions, tolerances, datums, etc.
2. The top package body size may be smaller than the bottom package size by as much as 0.15 mm.
3. Dimensions D1 and E1 do not include mold protrusions. Allowable protrusion is 0.25 mm per side. D1 and E1 are maximum plastic body size dimensions, including mold mismatch.
4. Dimension b does not include Dambar protrusion. Allowable Dambar protrusion shall not cause the lead width to exceed the maximum b dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. Minimum space between protrusion and an adjacent lead is 0.07 mm for 0.4 and 0.5 mm pitch packages.
5. These dimensions apply to the flat section of the lead between 0.10 mm and 0.25 mm from the lead tip.
6. A1 is defined as the distance from the seating place to the lowest point on the package body.

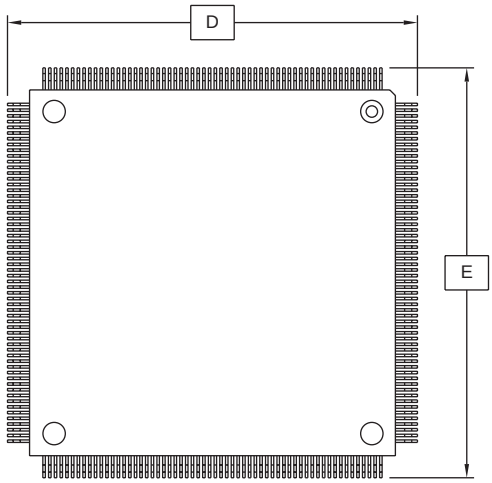
11/30/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**100T1**, 100-lead (14 x 14 x 1.0 mm Body), Thin Plastic Quad Flat Pack (TQFP)	100T1	A

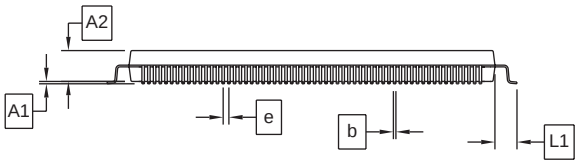
240Q1 – PQFP



Top View



Bottom View



Side View

COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A1	0.25	–	0.50	
A2	3.20	3.40	3.60	
D		34.60 BSC		3
D1		32.00 BSC		2, 4
E		34.60 BSC		3
E1		32.00 BSC		2, 4
e		0.50 BSC		
b	0.17	–	0.27	5
L1		1.30 REF		

Notes:
1. This drawing is for general information only. Refer to JEDEC Drawing MS-029, Variation GA, for additional information.
2. All dimensioning and tolerancing conforms to ASME Y14.5M-1994.
3. To be determined at seating plane.
4. Dimensions D1 and E1 do not include mold protrusions. Allowable protrusion is 0.25 mm per side. D1 and E1 are maximum plastic body size dimensions including mold mismatch. Dimensions D1 and E1 shall be determined at datum plane.
5. Dimension b does not include Dambar protrusion. Allowable Dambar protrusion shall not cause the lead width to exceed the maximum b dimension by more than 0.08 mm. Dambar cannot be located on the lower radius or the foot. The minimum space between protrusion and an adjacent lead shall not be less than 0.07 mm.

3/29/02

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**240Q1,** 240-lead, 32 x 32 mm Body, 2.6 Form Opt., Plastic Quad Flat Pack (PQFP)	240Q1	A

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