



ACT™ 2 Field Programmable Gate Arrays

Features

- Up to 8000 Gate Array Gates
(20,000 PLD/LCA™ equivalent gates)
- Replaces up to 210 TTL Packages
- Replaces up to 69 20-Pin PAL Packages
- Design Library with over 250 Macros
- Single-Module Sequential Functions
- Wide-Input Combinatorial Functions
- Up to 1232 Programmable Logic Modules
- Up to 998 Flip-Flops
- 16-Bit Counter Performance to 85 MHz
- 16-Bit Accumulator Performance to 33 MHz
- Two In-Circuit Diagnostic Probe Pins Support Speed Analysis to 50 MHz
- Two High-Speed, Low-Skew Clock Networks
- I/O Drive to 10 mA
- Nonvolatile, User Programmable
- Logic Fully Tested Prior to Shipment

Product Family Profile

Device	A1280	A1240	A1225
Capacity			
Gate Array Equivalent Gates	8,000	4,000	2,500
PLD/LCA Equivalent Gates	20,000	10,000	6,250
TTL Equivalent Packages	210	105	70
20-Pin PAL Equivalent Packages	69	34	23
Logic Modules	1,232	684	451
S-Modules	624	348	231
C-Modules	608	336	220
Flip-Flops (maximum)	998	565	382
Routing Resources			
Horizontal Tracks/Channel	36	36	36
Vertical Tracks/Column	15	15	15
PLICE® Antifuse Elements	750,000	400,000	250,000
User I/Os (maximum)	140	104	83
Packages ¹	176 CPGA 160 PQFP 172 CQFP	132 CPGA 144 PQFP 84 PLCC	100 CPGA 100 PQFP 84 PLCC
Performance ²			
16-Bit Counters	55 MHz	75 MHz	85 MHz
16-Bit Accumulators	30 MHz	33 MHz	33 MHz
CMOS Process	1.2 µm	1.2 µm	1.2 µm

Note:

1. See product plan for package availability.
2. Performance is based on a -1 speed graded device at commercial worst-case operating conditions.



Figure 1. A1280 176-Pin CPGA

Description

The ACT™ 2 family represents Actel's second generation of field programmable gate arrays (FPGAs). The ACT 2 family presents a two-module architecture, consisting of C-Modules and S-Modules. These modules are optimized for both combinatorial and sequential designs. Based on Actel's patented channeled array architecture, the ACT 2 family provides significant enhancements to gate density and performance while maintaining upward compatibility with the ACT 1 design environment. The devices are implemented in silicon gate, 1.2-µm, two-level metal CMOS, and employ Actel's PLICE antifuse technology. This revolutionary architecture offers gate array design flexibility, high performance and fast time-to-production through user programming. The ACT 2 family is supported by the Action Logic™ System (ALS), which offers automatic pin assignment, validation of electrical and design rules, automatic placement and routing, timing analysis, user programming, and debug and diagnostic probe capabilities. The Action Logic System is supported on the following platforms: 386/486 PC and Sun®, HP® and Apollo® workstations. It provides CAE interfaces to the following design environments: Valid™, Viewlogic®, Mentor Graphics®, HP DCS and OrCAD™.

ACT 2 Architecture

This section of the datasheet is meant to familiarize the user with the architecture of ACT 2 family devices. A generic description of the family will be presented first, followed by a detailed description of the logic blocks, the routing structure, the antifuses, and the special function circuits. Diagrams for the A1280, A1240, and A1225 are provided at the end of the datasheet. The additional circuitry required to program and test the devices will not be covered.

Array Topology

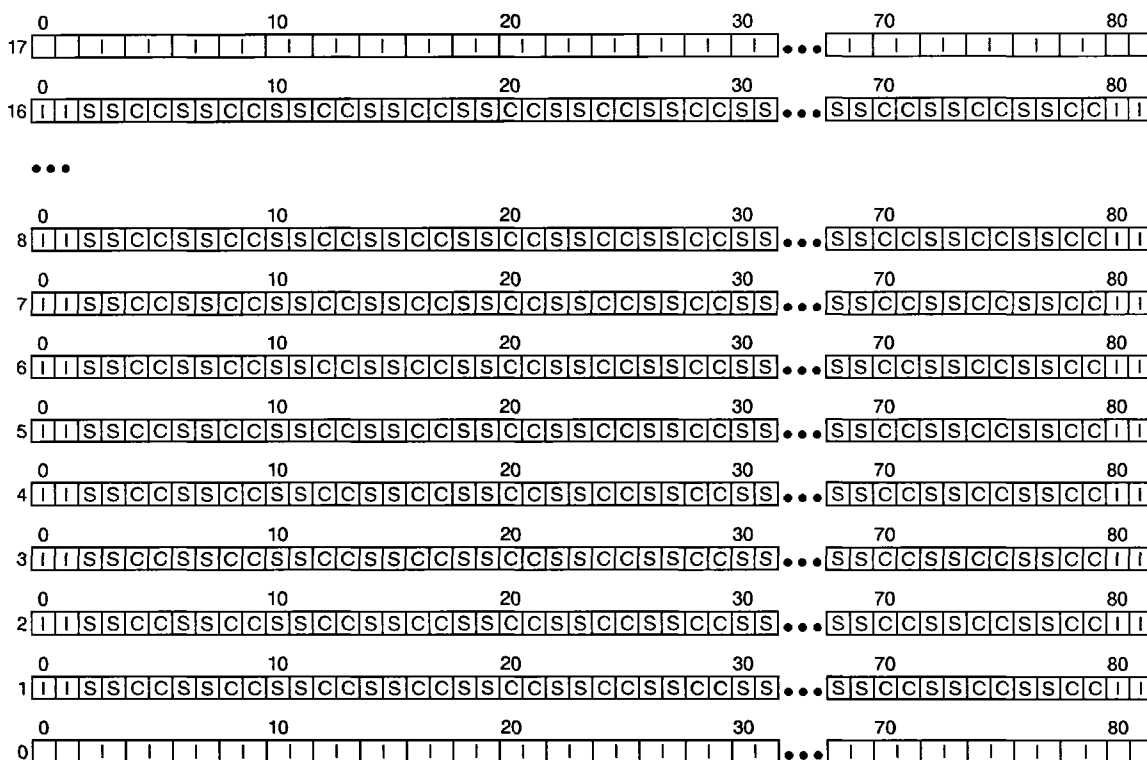
The ACT 2 family architecture is composed of five key elements or building blocks: Logic modules, I/O modules, Routing Tracks, Global Clock Networks, and Probe Circuits. The basic structure is

similar for all devices in the family, differing only in the number of rows, columns, and I/Os.

Table 1. Array Sizes

Device	Rows	Columns	Logic	I/O
A1280	18	82	1232	140
A1240	14	62	684	104
A1225	13	46	451	83

The Logic and I/O modules are arranged in a two-dimensional array (Figure 2). There are three types of modules: Logic, I/O, and Bin. Logic and I/O modules are available as user resources. Bin modules are used during testing and are not available to users.



S = Sequential Module, C = Combinatorial Module, I = I/O Module

Figure 2. A1280 Simplified Floor Plan

Logic Modules

Logic modules are classified into two types: combinational C-modules and sequential S-modules (see Figures 3 and 4). The C-module is an enhanced version of the Act 1 family logic module optimized to implement high fan-in combinational macros, such as 5-input AND, 5-input OR, etc. The S-module is designed to implement high speed flip-flop functions within a single module. S-modules also include combinational logic, which allows an additional level of logic to be implemented without additional propagation delay. C-modules and S-modules are arranged in pairs called module-pairs. Module-pairs are arranged in alternating pairs (shown in Figure 2) and make up the bulk of the array. This arrangement allows the placement software to support two-module macros of four types (CC, CS, SC, and SS). I/O-modules are arranged around the periphery of the array.

The combinational module (shown in Figure 2) implements the following function:

$$Z = !S1 * (D00 * !S0 + D01 * S0) + S1 * (D10 * !S0 + D11 * S0)$$

where:

$$S0 = A0 * B0$$

$$S1 = A1 + B1$$

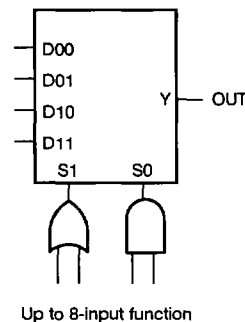


Figure 3. C-Module Implementation

The sequential module implements this same function Z, followed by a sequential block. The sequential block can be configured to implement either a D-type flip-flop or transparent latch. It can also be fully transparent so that S-modules can be used to implement purely combinational functions. The function of the sequential module is determined by the macro selection from the design library of hard macros. Allowable S-module implementations are shown in Figure 4.

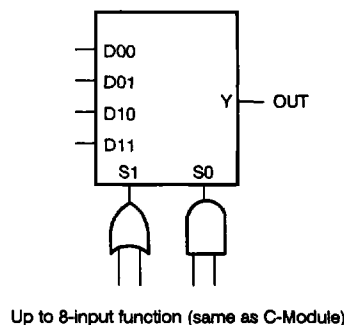
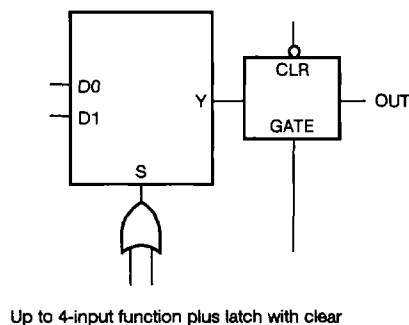
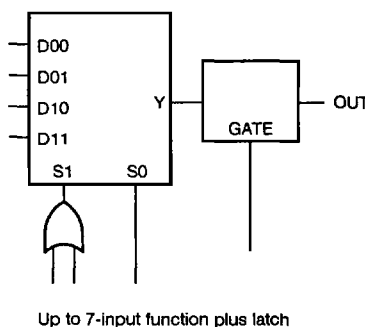
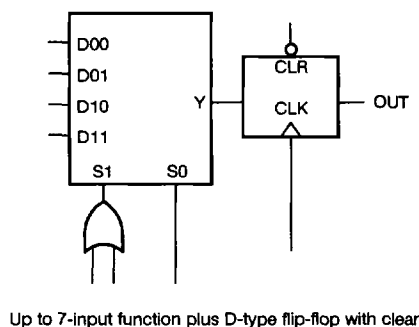


Figure 4. S-Module Implementations

I/Os

The I/O architecture consists of pad drivers located near the bonding pads and I/O modules located in the array. Top/bottom I/O modules are located in the top and bottom rows respectively. Side I/O modules occupy the leftmost two columns and the rightmost two columns of the array. The function of all I/O modules is identical, but the top/bottom I/O modules have a different routing interface to the array than the side I/O modules. I/Os implement a variety of user functions determined by library macro selection.

Special Purpose I/Os

Certain I/O pads are temporarily used for programming and testing the device. During normal user operation, these special I/O pads are identical to other I/O pads. The following special I/O pads and their functions, are shown in Table 2.

Table 2. Special I/O Pads

SDI	Serial Data In
SDIO	Serial Data Out
BININ	Binning Circuit In
BINOUT	Binning Circuit Out
DCLK	Serial Data Clock In
PRA	Probe A Output
PRB	Probe B Output

Two other pads, CLKA and CLKB, also differ from normal I/Os in that they can be used to drive the global clock networks. Power, Ground, and Programming pads are not considered I/O functions. Their function is summarized as follows:

VCCA, VCCQ, VCCI	Power
GNDA, GNDQ, GNDI	Circuit Ground
VSV, VKS	Programming Pads
MODE	Program/Debug Control

I/O Pads

I/O pads are located on the periphery of the die and consist of the bonding pad, the high-drive CMOS drivers, and the TTL level-shifter inputs. Each I/O pad is associated with a specific I/O module. Connections from the I/O pad to the I/O module are made using the signals DATAOUT, DATAIN and EN (shown in Figure 5).

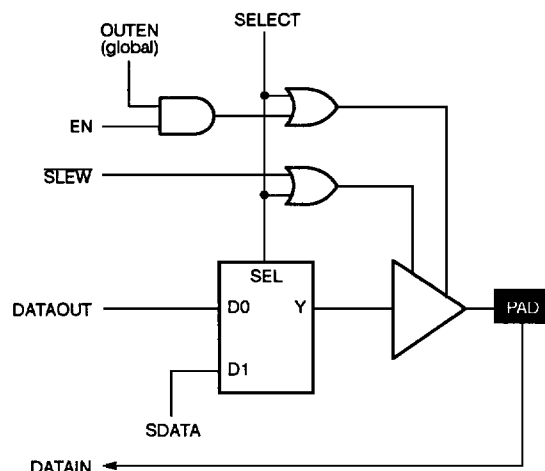


Figure 5. I/O Pad Signals

I/O Modules

There are two types of I/O modules: side and top/bottom. The I/O module schematic is shown in Figure 6. In the side I/O modules, there are two inputs supplying the data to be output from the chip: UO1 and UO2. (UO stands for user output). Two are used so that the router can choose to take the signal from either the routing channel above or the routing channel below the I/O module. The top/bottom I/O modules interact with only one channel and therefore have only one UO input.

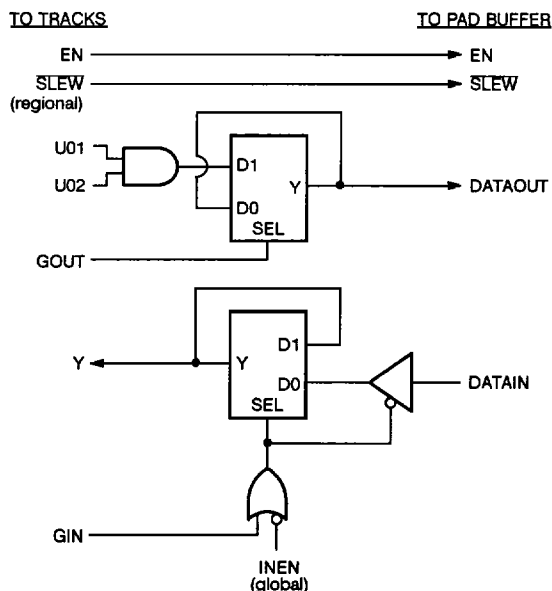


Figure 6. I/O Module

The EN input enables the tristate output buffer. The global signals INEN and OUTEN (Figure 5) are used to disable the inputs and outputs during certain test modes. Latches are provided in the input and output path. When GOUT is low, the output signal on UO1/UO2 is latched. When it is high, the latch is transparent. The latch can be used as the second stage of a rising-edge flip-flop as described in the Applications note accompanying this data sheet. GIN is the reverse of GOUT. When GIN is high, the input data is latched; when it is low, the input latch becomes transparent.

The output of the module, Y, is used for data being input to the chip. Side I/O modules have a dedicated output segment for Y extending into the routing channels above and below it (similar to logic modules). Side I/O modules may also connect to the array through nondedicated Long Vertical Tracks (LVTs). Top/Bottom I/O modules have no dedicated output segment. Signals coming into the chip from the top or bottom must be routed using F-fuses and LVTs (F-fuses and LVTs are explained in detail in the routing section). As a result, I/O signals connected to I/O modules on either the top or bottom of the array may incur a slight delay penalty (~1ns) over signals connected to I/O modules on the sides.

Hard Macros

Designing within the Actel design environment is accomplished using a building block approach. Over 250 logic function macros are provided in the ACT 2 design library. Hard macro logic functions range from simple SSI gates such as AND, NOR, and Exclusive OR to more complex functions such as flip-flops with 4:1 Multiplexed Data inputs. Hard macros are implemented in the ACT 2 architecture by using one or more C-modules or S-modules. Over 150 of the macros are implemented in a single module, while several two-module macros are also available. Two-module hard

macros always utilize a module-pair, either SS, CC, CS, or SC. Because one- and two-module macros have small propagation delay variances, their performances can be predicted very accurately. Hard macro propagation delays are specified in the datasheet. Soft macros are comprised of multiple hard macros connected together to form complex functions. These functions range from MSI functions to 16-bit counters and accumulators. A large number of TTL equivalent hard and soft macros are also provided. Soft macro delays are not specified in the datasheet.

Routing Structure

The ACT 2 architecture uses Vertical and Horizontal routing tracks to interconnect the various logic and I/O modules. These routing tracks are metal interconnects that may either be of continuous length or broken into pieces called segments. Segments can be joined together at the ends using antifuses to increase their lengths up to the full length of the track.

Horizontal Routing

Horizontal channels are located between the rows of modules and are composed of several routing tracks. The horizontal routing tracks within the channel are divided into one or more segments. The minimum horizontal segment length is the width of a module-pair, and the maximum horizontal segment length is the full length of the channel. Any segment that spans more than one-third the row length is considered a long horizontal segment. A typical channel is shown in Figure 7. Nondedicated horizontal routing tracks are used to route signal nets. Dedicated routing tracks are used for the global clock networks and for power and ground tie-off tracks.

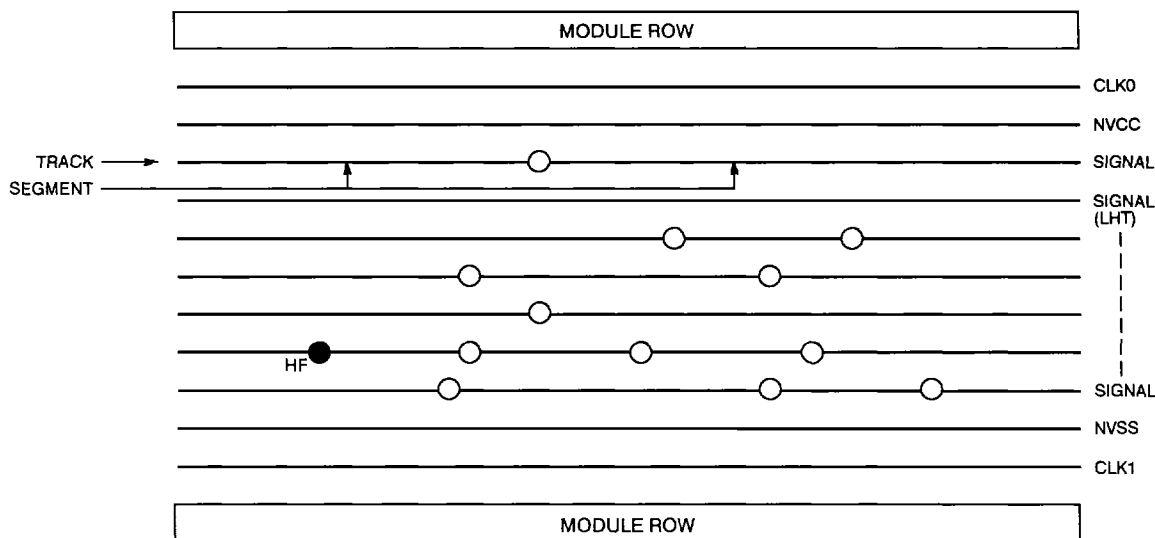


Figure 7. Horizontal Routing Tracks and Segments

Vertical Routing

Other tracks run vertically through the modules. Vertical tracks are also divided into one or more segments. Each segment in an input track is dedicated to the input of a particular module. Each segment in an output track is dedicated to the output of a particular module. Long segments are uncommitted and can be assigned during routing. Each output segment spans four channels (two above and two below), except near the top and bottom of the array where edge effects occur. LVTs contain either one or two segments. An example of vertical routing tracks and segments is shown in Figure 8.

An antifuse is a “normally open” structure as opposed to the normally closed fuse structure used in PROMs or PAL®s. The use of antifuses to implement a Programmable Logic Device results in highly testable structures as well as efficient programming algorithms. The structure is highly testable because there are no pre-existing connections, therefore temporary connections can be made using pass transistors. These temporary connections can isolate individual antifuses to be programmed as well as isolate individual circuit structures to be tested. This can be done both before and after programming. For example, all metal tracks can be tested for continuity and shorts between adjacent tracks, and the functionality of all logic modules can be verified.

Antifuse Structures

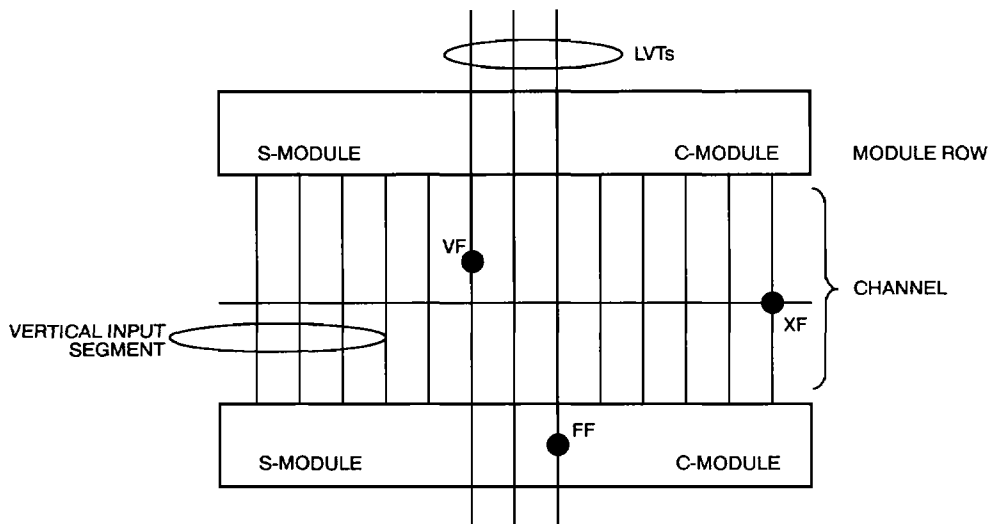


Figure 8. Vertical Routing Tracks and Segments

Antifuse Connections

Four types of antifuse connections are used in the routing structure of the Act 2 array. (The physical structure of the antifuse is identical in each case, only the usage differs.) The four types are:

XF	Cross connected antifuse	Most intersections of horizontal and vertical tracks have an XF that connects the perpendicular tracks.
HF	Horizontally connected antifuse	Adjacent segments in the same horizontal track are connected end-to-end by an HF.
VF	Vertically connected antifuse	Some long vertical tracks are divided into two segments. Adjacent long segments are connected end-to-end by a VF.
FF	"Fast-Fuse" antifuse	The FF connects a module output directly to a long vertical track.

Examples of all four antifuse connections are shown in Figures 7 and 8.

Antifuse Programming

The ACT 2 family uses the PLICE™ antifuse developed by Actel. The PLICE element is programmed by placing a high voltage (~20 V) across the element and supplying current (~5 mA) for a short duration (<1ms). In the ACT 2 architecture, most antifuses are programmed to ~500 ohms resistance, except for the F-fuses which are programmed to ~250 ohms. The programming circuits are transparent to the user.

Clock Networks

Two low-skew, high fan-out clock distribution networks are provided in the ACT 2 architecture (Figure 9). These networks are referred to as CLK0 and CLK1. Each network has a clock module (CLKMOD) that selects the source of the clock signal and may be driven as follows:

1. externally from the CLKA pad
2. externally from the CLKB pad
3. internally from the CLKINA input
4. internally from the CLKINB input

The clock modules are located in the top row of I/O modules. Clock drivers and a dedicated horizontal clock track are located in each horizontal routing channel.

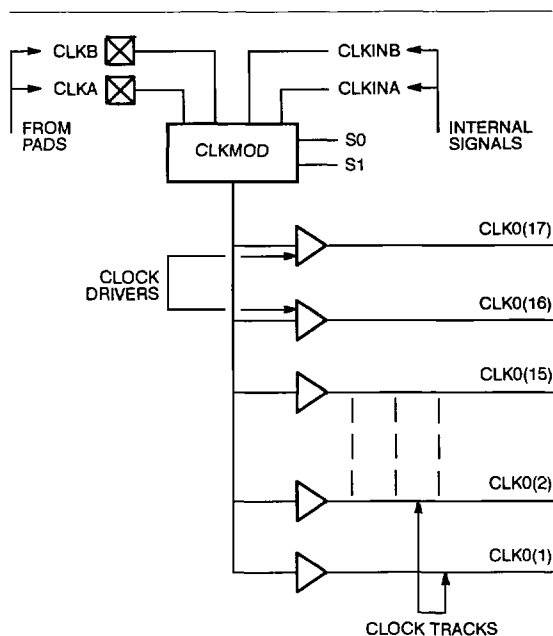


Figure 9. Clock Networks

The user configures the clock module by selecting one of two clock macros from the macro library. The macro CLKBUF is used to connect one of the two external clock pins to a clock network, and the macro CLKINT is used to connect an internally generated clock signal to a clock network. Since both clock networks are identical, the user does not care whether CLK0 or CLK1 is being used.

The clock input pads may also be used as normal I/Os, by-passing the clock networks.

Module Interface

Connections to Logic and I/O modules are made through vertical segments that connect to the module inputs and outputs. These vertical segments lie on vertical tracks that span the entire height of the array.

Module Input Connections

Vertical tracks span the vertical height of the array. The tracks dedicated to module inputs are segmented by pass transistors in each module row. During normal user operation, the pass transistors are inactive (off), which isolates the inputs of a module from the inputs of the module directly above or below it. During certain test modes, the pass transistors are active (on) to verify the continuity of the metal tracks. Vertical input segments span only one channel. Inputs to the array modules come either from the channel above or the channel below. The logic modules are arranged such that half of the inputs are connected to the channel above and half of the inputs to segments in the channel below (Figure 10).

Module Output Connections

Module outputs have dedicated output segments. Output segments extend vertically two channels above and two channels below, except at the top or bottom of the array. Output segments twist, as shown in Figure 10, so that only four vertical tracks are required.

LVT Connections

Outputs may also connect to non-dedicated segments (LVTs). Each module pair in the array shares three LVTs that span the length of column as shown in Figure 9. Any module in the column pair can connect to one of the LVTs in the column using an FF connection. The FF connection uses antifuses connected directly to the driver stage of the module output, by-passing the isolation transistor. FF antifuses are programmed at a higher current level than HF, VF, or XF antifuses to produce a lower resistance value.

Antifuse Connections

In general every intersection of a vertical segment and a horizontal segment contains an unprogrammed antifuse (XF-type). One exception is in the case of the clock networks.

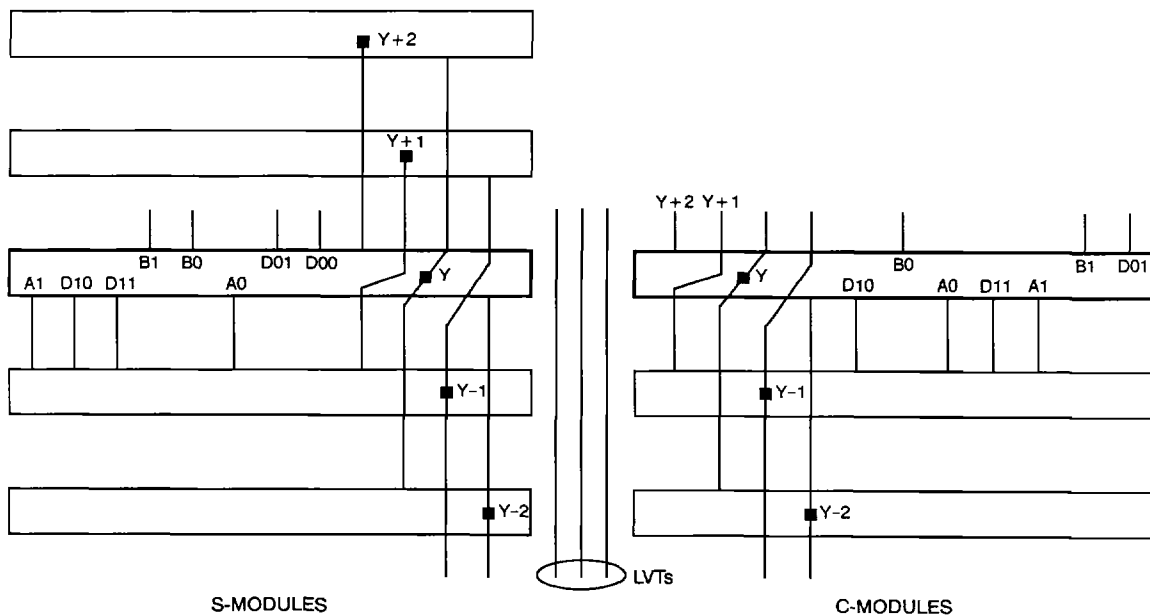


Figure 10. Logic Module Routing Interface

Clock Connections

To minimize loading on the clock networks, only a subset of inputs has fuses on the clock tracks. Only a few of the C-module and

S-module inputs can be connected to the clock networks. To further reduce loading on the clock network, only a subset of the horizontal routing tracks can connect to the clock inputs of the S-Module. Both of these are illustrated in Figure 11.

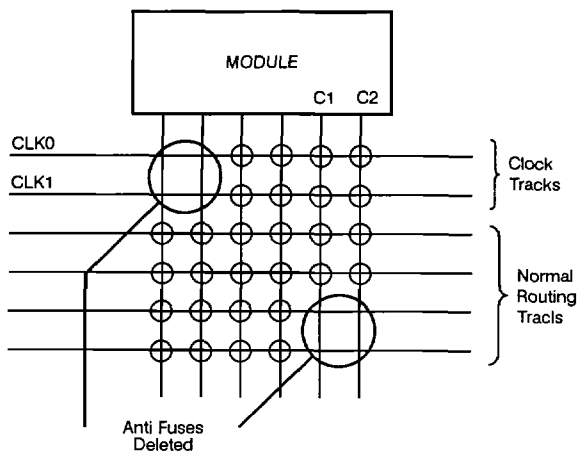


Figure 11. Fuse Deletion on Clock Networks

Programming and Test Circuits

The array of logic and I/O modules is surrounded by test and programming circuits controlled by the external pins: MODE, SDI, DCLK. The function of these pins is summarized below. When MODE is low (GND), the device is in normal or user mode. When MODE is high (VCC), the device is placed into one of several programming or test states. The SDI pin (when MODE is high) is used to input serial data to the Mode register and various address

registers surrounding the array. Data is clocked into these registers using the DCLK pin. The registers are connected as a long series of shift registers as shown in Figure 12. The Mode register determines the test or programming state of the device. Many of the test modes are used during wafer sort and final test at the factory. Other test modes are used during programming in the Activator® 2, and some of the modes are available only after programming. The Actionprobe® function is one such function available to users.

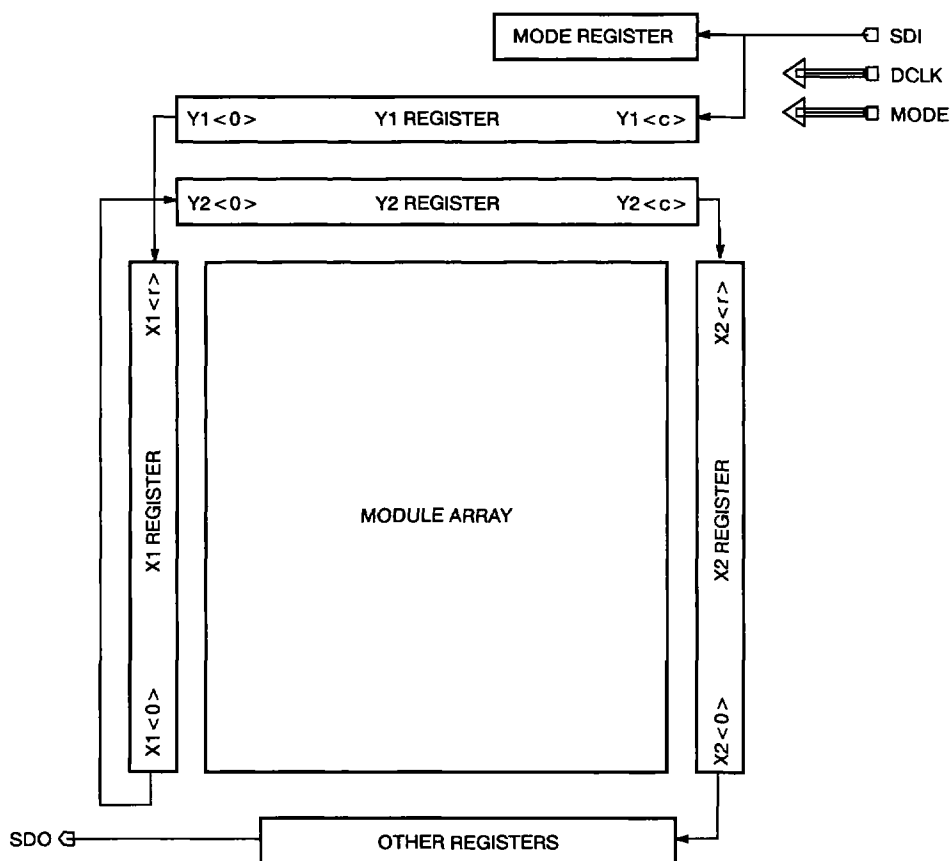


Figure 12. ACT 2 Shift Register

Actionprobe

If a device has been successfully programmed and the security fuse has not been programmed, any internal logic or I/O module output can be observed using the Actionprobe circuitry and the PRA and/or PRB pins. The Actionprobe Diagnostic system provides the software and hardware required to perform real-time debugging. The software automatically performs the following functions.

A pattern of "1s" and "0s" is shifted into the device from the SDI pin at each positive edge transition of DCLK. The complete sequence contains 10 bits of counter, 21 bits of Mode Register, n bits of zeros (filler of unused fields, where n depends on the particular device type), R bits of X2, C bits of Y2, R bits of X1, C bits of Y1, and a stop bit ("0" or "1"). After the stop bit has been shifted in, DCLK is left high (see definitions below). X1 and Y1 represent the (X,Y) location in the array for the Actionprobe output, PRA.

X2 and Y2 represent the (X,Y) location in the array for the Actionprobe output, PRB. R and C are the row and column size as defined in Table 1. The filler bits, counter pattern, and Mode register pattern are shown in Table 3. Addressing for rows and columns is active high, i.e. unselected rows and columns are "zeros"

and the selected row and column is "high." The timing sequence is shown in Figure 13. The recommended frequency is 10 MHz with 10 nS setup and hold times allowing for SDI and DCLK transitions. The selected module output will be present at the PRA or PRB output approximately 20 nS after the stop-bit transition.

Table 3. Bit Stream Definitions for Actionprobe Diagnostics

Device	Probe_Mode	Filler (n)	Counter_Pattern	Mode_Register_Pattern	# of clocks
A1280	Probe A only	443	0011011111	000000110001111100000	675
A1280	Probe B only	443	0011011111	000000101001111100000	675
A1280	Probe A and B	443	0011011111	000000111001111100000	675
A1240	Probe A only	361	1111000001	000000110001111100000	541
A1240	Probe B only	361	1111000001	000000101001111100000	541
A1240	Probe A and B	361	1111000001	000000111001111100000	541
A1225	Probe A only	308	1101011010	000000110001111100000	458
A1225	Probe B only	308	1101011010	000000101001111100000	458
A1225	Probe A and B	308	1101011010	000000111001111100000	458

For Example: Selecting PRA for A1280 results in the following bit stream:

0011011111_000000110001111100000_

(443 zeros) _X2<0>...X2<17>_Y2<81>...Y2<0>_X1<0>...X1<0>...X1<17>_Y1<0>...Y1<81>_0,

where "_" is used for clarity only.

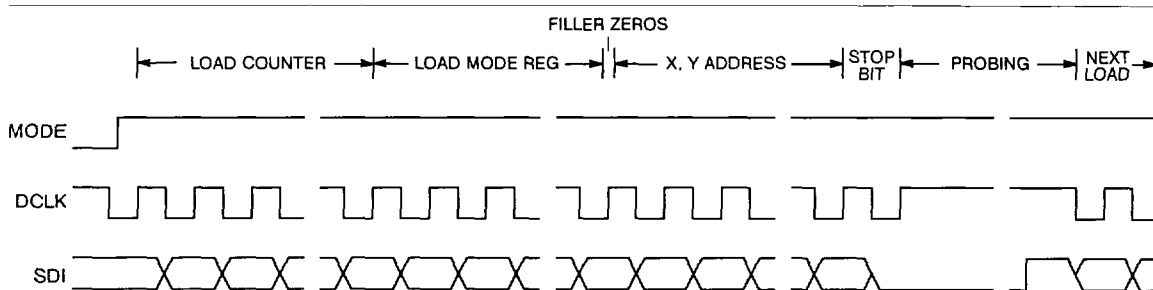
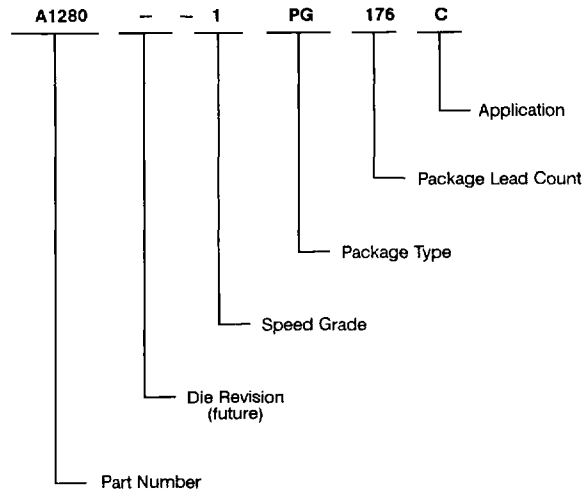


Figure 13. Timing Waveforms

Ordering Information



Product Plan

1

	Speed Grade		Application				
	Std	-1*	C	I	M	B	E
A1280 Device							
176-pin Ceramic Pin Grid Array (PG)	✓	✓	✓	-	✓	✓	-
160-pin Plastic Quad Flatpack (PQ)	✓	✓	✓	✓	✓	✓	-
172-pin Ceramic Quad Flatpack (CQ)	✓	P	✓	-	✓	✓	✓
A1240 Device							
132-pin Ceramic Pin Grid Array (PG)	✓	✓	✓	-	✓	✓	-
144-pin Plastic Quad Flatpack (PQ)	✓	✓	✓	✓	-	-	-
84-pin Plastic Leaded Chip Carrier (PL)	✓	✓	✓	✓	-	-	-
A1225 Device							
100-pin Ceramic Pin Grid Array (PG)	✓	✓	✓	-	-	-	-
100-pin Plastic Quad Flatpack (PQ)	✓	✓	✓	✓	-	-	-
84-pin Plastic Leaded Chip Carrier (PL)	✓	✓	✓	✓	-	-	-

Applications: C = Commercial
I = Industrial
M = Military
B = 883B
E = Extended Flow

Availability: ✓ = Available
P = Planned
- = Not Planned

* Speed Grade: -1 = 15% faster than Standard

Device Resources

Device Series	Logic Modules	Gates	User I/Os							
			CPGA			PQFP			PLCC	CQFP
			176-pin	132-pin	100-pin	160-pin	144-pin	100-pin	84-pin	172-pin
A1280	1232	8000	140	-	-	125	-	-	-	140
A1240	684	4000	-	104	-	-	104	-	72	-
A1225	451	2500	-	-	83	-	-	-	72	-

Pin Description

CLKA Clock A (Input)

TTL Clock input for clock distribution networks. The Clock input is buffered prior to clocking the logic modules. This pin can also be used as an I/O.

CLKB Clock B (Input)

TTL Clock input for clock distribution networks. The Clock input is buffered prior to clocking the logic modules. This pin can also be used as an I/O.

DCLK Diagnostic Clock (Input)

TTL Clock input for diagnostic probe and device programming. DCLK is active when the MODE pin is HIGH. This pin functions as an I/O when the MODE pin is LOW.

GND Ground (Input)

Input LOW supply voltage.

I/O Input/Output (Input, Output)

I/O pins function as an input, output, three-state, or bidirectional buffer. Input and output levels are compatible with standard TTL and CMOS specifications. Unused I/O pins are automatically driven LOW by the ALS software.

MODE Mode (Input)

The MODE pin controls the use of multi-function pins (DCLK, PRA, PRB, SDI, SDO). When the MODE pin is HIGH, the special functions are active. When the MODE pin is LOW, the pins function as I/Os.

NC No Connection

This pin is not connected to circuitry within the device.

PRA Probe A (Output)

The Probe A pin is used to output data from any user-defined design node within the device. This independent diagnostic pin is used in conjunction with the Probe B pin to allow real-time diagnostic output of any signal path within the device. The Probe A

pin can be used as a user-defined I/O when debugging has been completed. The pin's probe capabilities can be permanently disabled to protect programmed design confidentiality. PRA is active when the MODE pin is HIGH. This pin functions as an I/O when the MODE pin is LOW.

PRB Probe B (Output)

The Probe B pin is used to output data from any user-defined design node within the device. This independent diagnostic pin is used in conjunction with the Probe A pin to allow real-time diagnostic output of any signal path within the device. The Probe B pin can be used as a user-defined I/O when debugging has been completed. The pin's probe capabilities can be permanently disabled to protect programmed design confidentiality. PRB is active when the MODE pin is HIGH. This pin functions as an I/O when the MODE pin is LOW.

SDI Serial Data Input (Input)

Serial data input for diagnostic probe and device programming. SDI is active when the MODE pin is HIGH. This pin functions as an I/O when the MODE pin is LOW.

SDO Serial Data Output (Output)

Serial data output for diagnostic probe. SDO is active when the MODE pin is HIGH. This pin functions as an I/O when the MODE pin is LOW.

V_{CC} Supply Voltage (Input)

Input HIGH supply voltage.

V_{KS} Programming Voltage (Input)

Input supply voltage used for device programming. This pin must be connected to GND during normal operation.

V_{PP} Programming Voltage (Input)

Input supply voltage used for device programming. This pin must be connected to V_{CC} during normal operation.

V_{SV} Programming Voltage (Input)

Input supply voltage used for device programming. This pin must be connected to V_{CC} during normal operation.

Absolute Maximum Ratings

Free air temperature range

Symbol	Parameter	Limits	Units
V_{CC}	DC Supply Voltage ^{1,2,3}	-0.5 to +7.0	Volts
V_I	Input Voltage	-0.5 to $V_{CC} + 0.5$	Volts
V_O	Output Voltage	-0.5 to $V_{CC} + 0.5$	Volts
I_{IK}	Input Clamp Current	± 20	mA
I_{OK}	Output Clamp Current	± 20	mA
I_{OK}	Continuous Output Current	± 25	mA
T_{STG}	Storage Temperature	-65 to +150	°C

Stresses beyond those listed above may cause permanent damage to the device. Exposure to absolute maximum rated conditions for extended periods may affect device reliability. Device should not be operated outside the Recommended Operating Conditions.

Notes:

1. $V_{PP} = V_{CC}$, except during device programming.
2. $V_{SV} = V_{CC}$, except during device programming.
3. $V_{KS} = GND$, except during device programming.

Recommended Operating Conditions

Parameter	Commercial	Industrial	Military	Units
Temperature Range ¹	0 to +70	-40 to +85	-55 to +125	°C
Power Supply Tolerance	± 5	± 10	± 10	% V_{CC}

Note:

1. Ambient temperature (T_A) used for commercial and industrial. Case temperature (T_C) used for military.

Electrical Specifications

Parameter	Commercial		Industrial		Military		Units
	Min.	Max.	Min.	Max.	Min.	Max.	
V_{OH}^1	($I_{OH} = -10 \text{ mA}$) ²						V
							V
	($I_{OH} = -6 \text{ mA}$)						V
V_{OL}^1	($I_{OL} = 10 \text{ mA}$) ²						V
							V
	($I_{OL} = 6 \text{ mA}$)						V
V_{IL}	-0.3	0.8	-0.3	0.8	-0.3	0.8	V
V_{IH}	2.0	$V_{CC} + 0.3$	2.0	$V_{CC} + 0.3$	2.0	$V_{CC} + 0.3$	V
Input Transition Time t_R, t_F^2		500		500		500	ns
C_{IO} I/O Capacitance ^{2,3}		10		10		10	pF
Standby Current, I_{CC}^4		10		20		25	mA
Leakage Current ⁵	-10	10	-10	10	-10	10	μA

Notes:

1. Only one output tested at a time. $V_{CC} = \text{min.}$
2. Not tested, for information only.
3. Includes worst-case 176 CPGA package capacitance. $V_{OUT} = 0 \text{ V}$, $f = 1 \text{ MHz}$.
4. All outputs unloaded. All inputs = V_{CC} or GND, typical $I_{CC} = 1 \text{ mA}$.
5. $V_O, V_{IN} = V_{CC}$ or GND.

Package Thermal Characteristics

The device junction to case thermal characteristic is θ_{jc} , and the junction to ambient air characteristic is θ_{ja} . The thermal characteristics for θ_{ja} are shown with two different air flow rates.

Maximum junction temperature is 150°C.

A sample calculation of the maximum power dissipation for a CPGA 176-pin package at commercial temperature is as follows:

$$\frac{\text{Max. junction temp. (°C)} - \text{Max. military temp. (°C)}}{\theta_{ja} \text{ (°C/W)}} = \frac{150^{\circ}\text{C} - 70^{\circ}\text{C}}{20^{\circ}\text{C/W}} = 4.0 \text{ W}$$

Package Type	Pin Count	θ_{jc}	θ_{ja} Still air	θ_{ja} 300 ft/min.	Units
CPGA	100	5	35	17	°C/W
	132	5	30	15	°C/W
	176	2	20	8	°C/W
PQFP ¹	100	13	55	47	°C/W
	144	15	35	26	°C/W
	160	15	33	24	°C/W
PLCC	84	12	44	33	°C/W

Note:

1. Maximum Power Dissipation for PQFP Package = 2.0 Watts

Power Dissipation

$$P = [I_{CC} + I_{\text{active}}] \cdot V_{CC} + I_{OL} \cdot V_{OL} \cdot N + I_{OH} \cdot (V_{CC} - V_{OH}) \cdot M$$

Where:

I_{CC} is the current flowing when no inputs or outputs are changing.

I_{active} is the current flowing due to CMOS switching.

I_{OL} , I_{OH} are TTL sink/source currents.

V_{OL} , V_{OH} are TTL level output voltages.

N equals the number of outputs driving TTL loads to V_{OL} .

M equals the number of outputs driving TTL loads to V_{OH} .

An accurate determination of N and M is problematical because their values depend on the design and on the system I/O. The power can be divided into two components: static and active.

Static Power

Static power dissipation is typically a small component of the overall power. From the values provided in the Electrical Specifications, the maximum static power (commercial) dissipation is:

$$10 \text{ mA} \times 5.25 \text{ V} = 52.5 \text{ mW}$$

The static power dissipated by TTL loads depends on the number of outputs that drive high or low and the DC lead current flowing. Again, this number is typically small. For instance, a 32-bit bus driving TTL loads will generate 42 mW ATT with all outputs driving low or 140 mW with all outputs driving high. The actual dissipation will average somewhere between as I/Os switch states with time.

Active Power

The active power component in CMOS devices is frequency dependent and depends on the user's logic and the external I/O. Active power dissipation results from charging internal chip capacitance such as that associated with the interconnect,

unprogrammed antifuses, module inputs, and module outputs plus external capacitance due to PC board traces and load device inputs. An additional component of active power dissipation is due to totem-pole current in CMOS transistor pairs. The net effect can be associated with an equivalent capacitance that can be combined with frequency and voltage to represent active power dissipation.

Equivalent Capacitance

The power dissipated by a CMOS circuit can be expressed by Equation 1.

$$\text{Power } (\mu\text{W}) = C_{EQ} \cdot V_{CC}^2 \cdot f \quad (1)$$

Where:

C_{EQ} is the equivalent capacitance expressed in pF.

V_{CC} is power supply in volts.

f is the switching frequency in MHz.

Equivalent capacitance is calculated by measuring I_{active} at a specified frequency and voltage for each circuit component of interest. The results for ACT 2 devices are:

	C_{EQ} (pF)
Modules	7.7
Input Buffers	18.0
Output Buffers	25.0
Clock Buffer Loads	2.5

To calculate the active power that is dissipated from the complete design, you must solve Equation 1 for each component. In order to do this, you must know the switching frequency of each part of the logic. The exact equation is a piece-wise linear summation over all components, as shown in Equation 2.

$$\text{Power} = [(m \cdot 7.7 \cdot f_1) + (n \cdot 18.0 \cdot f_2) + (p \cdot (25.0 + C_L) \cdot f_3) + (q \cdot 2.5 \cdot f)] \cdot V_{CC}^2 \quad (2)$$

Where:

- n = Number of logic modules switching at frequency f_1
- m = Number of input buffers switching at frequency f_2
- p = Number of output buffers switching at frequency f_3
- q = Number of clock loads on the global clock network
- f = Frequency of global clock
- f_1 = Average logic module switching rate in MHz
- f_2 = Average input buffer switching rate in MHz
- f_3 = Average output buffer switching rate in MHz
- C_L = Output load capacitance

Determining Average Switching Frequency

In order to determine the switching frequency for a design, you must have a detailed understanding of the data input values to the circuit. The following rules will help you to determine average switching frequency in logic circuits. These rules are meant to represent worst-case scenarios so that they can be generally used for predicting the upper limits of power dissipation. These rules are as follows:

Module Utilization = 80% of combinatorial modules

Average Module Frequency = $F/10$

Inputs = 1/3 of I/O

Average Input Frequency = $F/5$

Outputs = 2/3 of I/Os

Average Output Frequency = $F/10$

Clock Net 1 Loading = 40% of sequential modules

Clock Net 1 Frequency = F

Clock Net 2 Loading = 40% of sequential modules

Clock Net 2 Frequency = $F/2$

Estimated Power

The results of estimating active power are displayed in Figure 14. The graphs provide a simple guideline for estimating power. The tables may be interpolated when your application has different resource utilizations or frequencies.

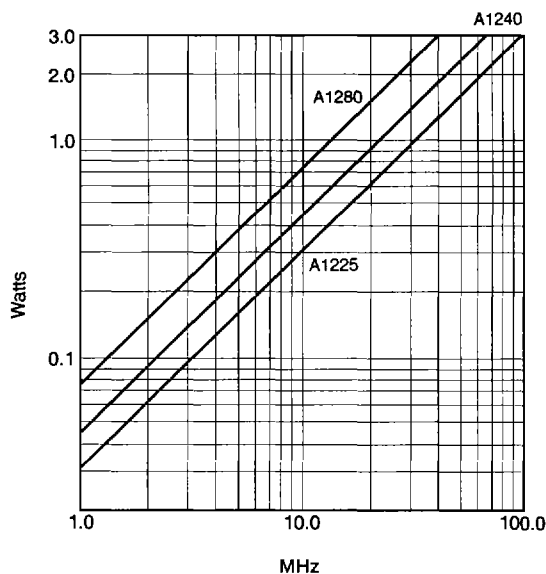
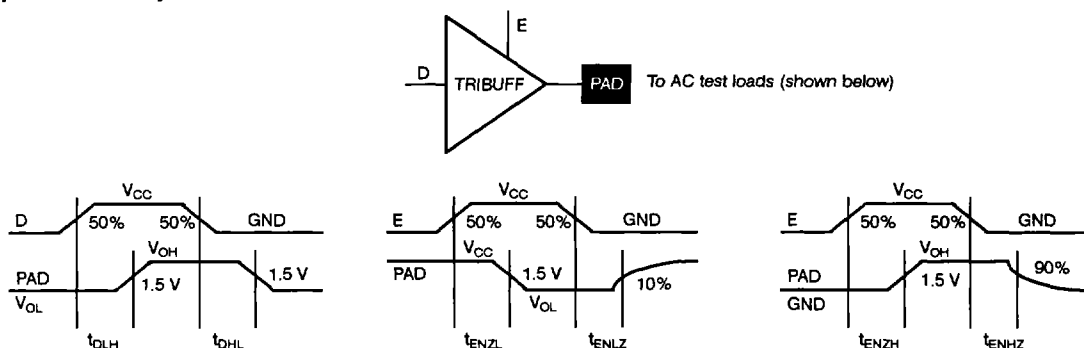


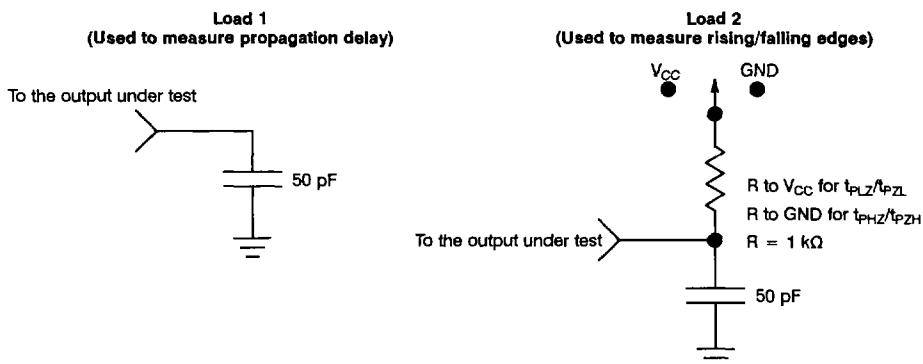
Figure 14. ACT 2 Power Estimates

Parameter Measurement

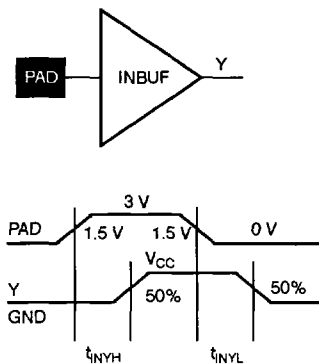
Output Buffer Delays



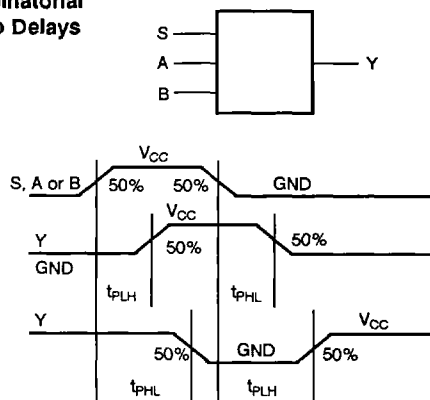
AC Test Loads



Input Buffer Delays

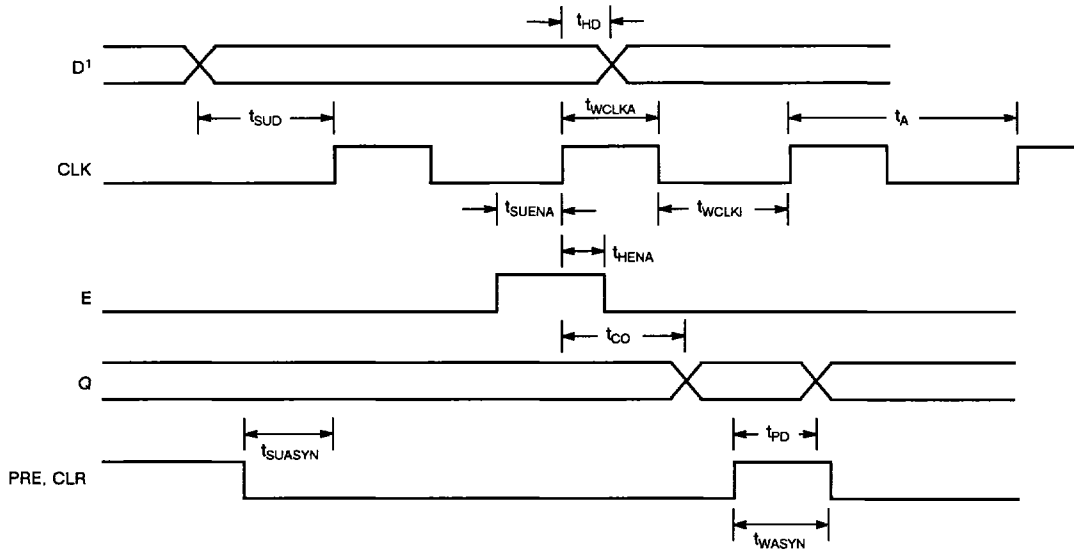
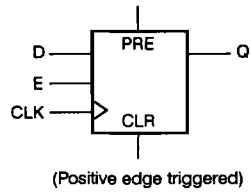


Combinatorial Macro Delays



Sequential Timing Characteristics

Flip-Flops and Latches

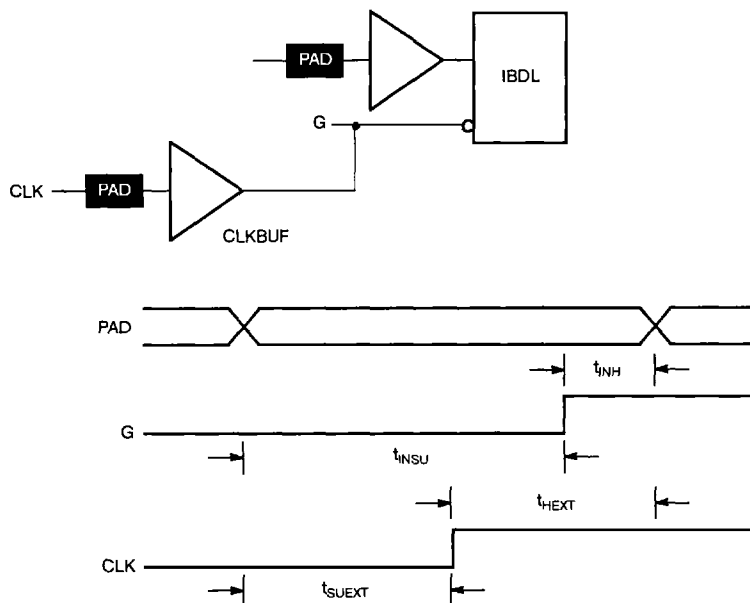


Notes:

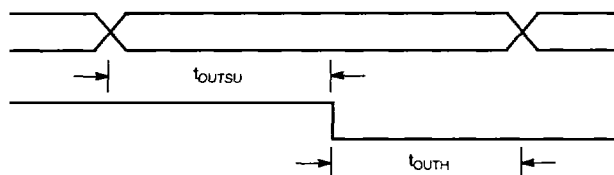
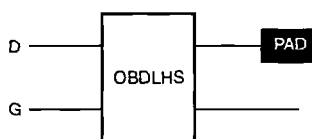
1. D represents all data functions involving A, B, and S for multiplexed flip-flops.

Sequential Timing Characteristics (continued)

Input Buffer Latches



Output Buffer Latches



Timing Characteristics

Timing characteristics for ACT arrays fall into three categories: family dependent, device dependent, and design dependent. The output buffer characteristics are common to all ACT 2 family members. Internal module delays are device dependent. Internal wiring delays between modules are design dependent. Design dependency means actual delays are not determined until after placement and routing of the users design is complete. Delay values may then be determined by using the ALS Timer utility or performing simulation with post-layout delays.

The macro propagation delays shown in the Timing Characteristics tables include the module delay plus estimates derived from statistical analysis for wiring delay. This statistical estimate is based on fully utilized devices (90% module utilization).

Critical Nets and Typical Nets

Propagation delays are expressed for two types of nets: critical and typical. Critical nets are determined by net property assignment before placement and routing. Up to 6% of the nets in a design may be designated as *critical*, while 90% of the nets in a design are *typical*.

Fan-Out Dependency

Propagation delays depend on the fan-out (number of loads) driven by a macro. Delay time increases when fan-out increases due to the capacitive loading of the macro's inputs, as well as the interconnect's resistance and capacitance.

Timing Derating Factor (x typical)

Commercial		Industrial		Military	
Best-Case	Worst-Case	Best-Case	Worst-Case	Best-Case	Worst-Case
0.40	1.40	0.37	1.50	0.35	1.6

Note:

"Best-case" reflects maximum operating voltage, minimum operating temperature, and best-case processing. "Worst-case" reflects minimum operating voltage, maximum operating temperature, and worst-case

Long Tracks

Some nets in the design use *long tracks*. Long tracks are special routing resources that span multiple rows or columns or modules, and are used frequently in large fan-out (> 10) situations. Long tracks employ three and sometimes four antifuse connections. This increased capacitance and resistance results in longer net delays for macros connected to long tracks. Typically up to 6% of the nets in a fully utilized device require long tracks. Long tracks contribute an additional 10 ns to 15 ns delay.

Timing Derating

Operating temperature, operating voltage, and device processing conditions, along with device die size and speed grade, account for variations in array timing characteristics. These variations are summarized into a derating factor for ACT 2 array typical timing specifications. The derating factors shown in the table below are based on the recommended operating conditions for ACT 2 applications. The derating curves in Figure 15 show worst-to-best case operating voltage range and best-to-worst case operating temperature range. The temperature derating curve is based on device junction temperature. Actual junction temperature is determined from Ambient Temperature, Power Dissipation, and Package Thermal characteristics.

1

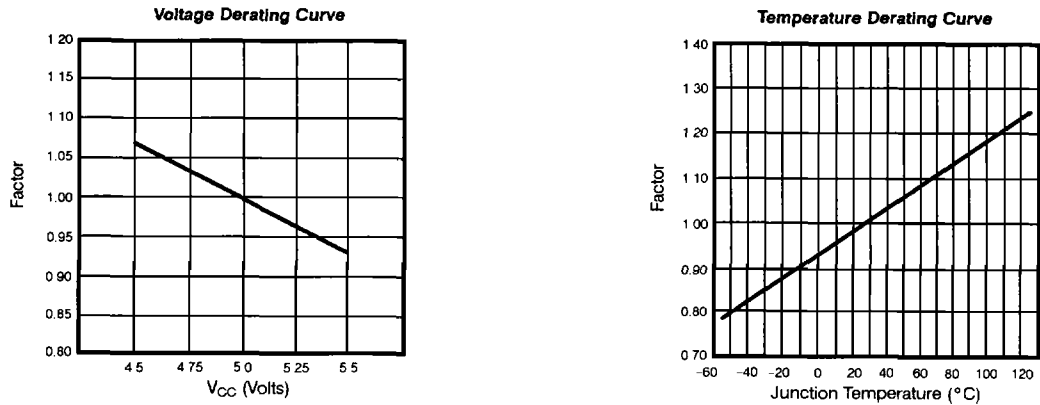


Figure 15. Operating Curves

A1280 Timing Characteristics

Propagation Delays ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	Output Net	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{PD1}	Single Module	Critical	4.5	5.0	5.5	6.0	—	ns
t_{PD1}	Single Module	Typical	5.7	6.2	6.7	8.2	11.7	ns
t_{PD2}	Dual Module	Critical	7.5	8.0	8.5	9.0	—	ns
t_{PD2}	Dual Module	Typical	8.7	9.2	9.7	11.2	14.7	ns
t_{CO}	Sequential Clk to Q	Critical	4.5	5.0	5.5	6.0	—	ns
t_{CO}	Sequential Clk to Q	Typical	5.7	6.2	6.7	8.2	11.7	ns
t_{GQ}	Latch G to Q	Critical	4.5	5.0	5.5	6.0	—	ns
t_{GQ}	Latch G to Q	Typical	5.7	6.2	6.7	8.2	11.7	ns
t_{PD}	Asynchronous to Q	Critical	4.5	5.0	5.5	6.0	—	ns
t_{PD}	Asynchronous to Q	Typical	5.7	6.2	6.7	8.2	11.7	ns

Sequential Timing Characteristics (Over Worst-Case Recommended Operating Conditions; No Further Derating Required)

Parameter	Description	Commercial		Industrial		Military		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
t_{SUD}	Flip-Flop (Latch) Data Input Setup	0.4		0.5		1.0		ns
t_{SUASYN}	Flip-Flop (Latch) Asynchronous Input Setup	1.0		1.5		2.0		ns
t_{HD}	Flip-Flop (Latch) Data Input Hold		0.0		0.0		0.0	ns
t_{SUENA}	Flip-Flop (Latch) Enable Setup	1.0		1.5		2.0		ns
t_{HENA}	Flip-Flop (Latch) Enable Hold		0.0		0.0		0.0	ns
t_{WCLKA}	Flip-Flop (Latch) Clock Active Pulse Width	4.0		4.5		5.0		ns
t_{WASYN}	Flip-Flop (Latch) Asynchronous Pulse Width	4.0		4.5		5.0		ns
t_A	Flip-Flop Clock Input Period	18.0		20.0		22.0		ns
t_{INH}	Input Buffer Latch Hold		2.0		2.5		2.5	ns
t_{INSU}	Input Buffer Latch Setup	-2.5		-3.0		-3.5		ns
t_{OUTH}	Output Buffer Latch Hold		0.0		0.0		0.0	ns
t_{OUTSU}	Output Buffer Latch Setup	0.4		0.5		1.0		ns
f_{MAX}	Flip-Flop (Latch) Clock Frequency		48.0		43.0		39.0	MHz

Notes:

1. Data applies to macros based on the sequential (S-type) module. Timing parameters for sequential macros constructed from C-type modules can be obtained from the ALS Timer utility.
2. Setup and hold timing parameters for the Input Buffer Latch are defined with respect to the PAD and the G input. External setup/hold timing parameters must account for delay from an external PAD signal to the G inputs. Delay from an external PAD signal to the G input subtracts (adds) to the internal setup (hold) time.

A1280 Timing Characteristics (continued)I/O Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{NYH}	Pad to Y High	6.7	7.2	7.7	8.2	11.7	ns
t_{NYL}	Pad to Y Low	6.6	7.1	7.6	8.1	11.5	ns
t_{NGH}	G to Y High	6.6	7.2	7.7	8.2	11.7	ns
t_{NGL}	G to Y Low	6.4	6.9	7.5	8.0	11.4	ns

Global Clock Network ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 32	FO = 128	FO = 384	Units
t_{CKH}	Input Low to High	9.1	10.1	12.3	ns
t_{CKL}	Input High to Low	9.1	10.2	12.5	ns
t_{PWH}	Minimum Pulse Width High	4.0	4.5	5.0	ns
t_{PWL}	Minimum Pulse Width Low	4.0	4.5	5.0	ns
t_{CKSW}	Maximum Skew	0.5	1.0	2.5	ns
t_{SUEXT}	Input Latch External Setup ¹	0.0	0.0	0.0	ns
t_{HEXT}	Input Latch External Hold ¹	7.0	8.0	11.2	ns
t_P	Minimum Period	13.3	14.3	15.3	ns
f_{MAX}	Maximum Frequency	75.0	70.0	65.0	MHz

Note:

1. Derating does not apply to this parameter.

Output Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	TTL	CMOS	Units
t_{DLH}	Data to Pad High	4.6	6.7	ns
t_{DHL}	Data to Pad Low	6.5	4.9	ns
t_{ENZH}	Enable Pad Z to High	8.3	8.3	ns
t_{ENZL}	Enable Pad Z to Low	5.5	5.5	ns
t_{ENHZ}	Enable Pad High to Z	4.5	4.5	ns
t_{ENLZ}	Enable Pad Low to Z	6.0	6.0	ns
t_{GLH}	G to Pad High	4.6	4.6	ns
t_{GHL}	G to Pad Low	6.5	6.5	ns
d_{TLH}	Delta Low to High	0.06	0.11	ns/pF
d_{THL}	Delta High to Low	0.11	0.08	ns/pF

A1280-1 Timing Characteristics

Propagation Delays ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	Output Net	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{PD1}	Single Module	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{PD1}	Single Module	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{PD2}	Dual Module	Critical Net	7.5	8.0	8.5	9.0	—	ns
t_{PD2}	Dual Module	Typical Net	7.9	8.3	8.7	10.0	13.0	ns
t_{CO}	Sequential Clk to Q	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{CO}	Sequential Clk to Q	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{GO}	Latch G to Q	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{GO}	Latch G to Q	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{PD}	Asynchronous to Q	Critical	3.9	4.3	4.8	5.3	—	ns
t_{PD}	Asynchronous to Q	Typical	4.9	5.3	5.7	7.0	10.0	ns

Sequential Timing Characteristics (Over Worst-Case Recommended Operating Conditions; No Further Derating Required)

Parameter	Description	Commercial		Industrial		Military		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
t_{SUD}	Flip-Flop (Latch) Data Input Setup	0.4		0.5		1.0		ns
t_{SUASYN}	Flip-Flop (Latch) Asynchronous Input Setup	1.0		1.5		2.0		ns
t_{HD}	Flip-Flop (Latch) Data Input Hold		0.0		0.0		0.0	ns
t_{SUENA}	Flip-Flop (Latch) Enable Setup	1.0		1.5		2.0		ns
t_{HENA}	Flip-Flop (Latch) Enable Hold		0.0		0.0		0.0	ns
t_{WCLKA}	Flip-Flop (Latch) Clock Active Pulse Width	4.0		4.5		5.0		ns
t_{WASYN}	Flip-Flop (Latch) Asynchronous Pulse Width	4.0		4.5		5.0		ns
t_A	Flip-Flop Clock Input Period	15.0		18.0		20.0		ns
t_{INH}	Input Buffer Latch Hold		2.0		2.5		2.5	ns
t_{NSU}	Input Buffer Latch Setup	-2.5		-3.0		-3.5		ns
t_{OUTH}	Output Buffer Latch Hold		0.0		0.0		0.0	ns
t_{OUTSU}	Output Buffer Latch Setup	0.4		0.5		1.0		ns
f_{MAX}	Flip-Flop (Latch) Clock Frequency		65.0		60.0		50.0	MHz

Notes:

1. Data applies to macros based on the sequential (S-type) module. Timing parameters for sequential macros constructed from C-type modules can be obtained from the ALS Timer utility.
2. Setup and hold timing parameters for the Input Buffer Latch are defined with respect to the PAD and the G input. External setup/hold timing parameters must account for delay from an external PAD signal to the G inputs. Delay from an external PAD signal to the G input subtracts (adds) to the internal setup (hold) time.

A1280-1 Timing Characteristics (continued)I/O Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{INYH}	Pad to Y High	6.1	6.5	5.9	7.4	10.5	ns
t_{INYL}	Pad to Y Low	5.9	6.4	6.8	7.3	10.4	ns
t_{INGH}	G to Y High	6.1	6.5	5.9	7.4	10.5	ns
t_{INGL}	G to Y Low	5.9	6.4	6.8	7.3	10.4	ns

Global Clock Network ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 32	FO = 128	FO = 384	Units
t_{CKH}	Input Low to High	7.8	8.7	10.4	ns
t_{CKL}	Input High to Low	7.8	8.8	10.6	ns
t_{PWH}	Minimum Pulse Width High	4.0	4.5	5.0	ns
t_{PWL}	Minimum Pulse Width Low	4.0	4.5	5.0	ns
t_{CKSW}	Maximum Skew	0.5	1.0	2.5	ns
t_{SUEXT}	Input Latch External Setup ¹	0.0	0.0	0.0	ns
t_{HEXT}	Input Latch External Hold ¹	7.0	8.0	11.2	ns
t_P	Minimum Period	11.4	12.0	13.0	ns
f_{MAX}	Maximum Frequency	89.0	83.0	77.0	MHz

Note:

1. Derating does not apply to this parameter.

Output Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	TTL	CMOS	Units
t_{OLH}	Data to Pad High	4.6	6.7	ns
t_{OHL}	Data to Pad Low	6.5	4.9	ns
t_{ENZH}	Enable Pad Z to High	8.3	8.3	ns
t_{ENZL}	Enable Pad Z to Low	5.5	5.5	ns
t_{ENHZ}	Enable Pad High to Z	4.5	4.5	ns
t_{ENLZ}	Enable Pad Low to Z	6.0	6.0	ns
t_{GLH}	G to Pad High	4.6	4.6	ns
t_{GHL}	G to Pad Low	6.5	6.5	ns
d_{TLH}	Delta Low to High	0.06	0.11	ns/pF
d_{THL}	Delta High to Low	0.11	0.08	ns/pF

A1240 Timing Characteristics

PRELIMINARY DATA

Propagation Delays ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	Output Net	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{PD1}	Single Module	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{PD1}	Single Module	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{PD2}	Dual Module	Critical Net	7.5	8.0	8.5	9.0	—	ns
t_{PD2}	Dual Module	Typical Net	7.9	8.3	8.7	10.0	13.0	ns
t_{CO}	Sequential Clk to Q	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{CO}	Sequential Clk to Q	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{GO}	Latch G to Q	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{GO}	Latch G to Q	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{PD}	Asynchronous to Q	Critical	3.9	4.3	4.8	5.3	—	ns
t_{PD}	Asynchronous to Q	Typical	4.9	5.3	5.7	7.0	10.0	ns

Sequential Timing Characteristics (Over Worst-Case Recommended Operating Conditions; No Further Derating Required)

Parameter	Description	Commercial		Industrial		Military		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
t_{SUD}	Flip-Flop (Latch) Data Input Setup	0.4		0.5		1.0		ns
t_{SUASYN}	Flip-Flop (Latch) Asynchronous Input Setup	1.0		1.5		2.0		ns
t_{HD}	Flip-Flop (Latch) Data Input Hold		0.0		0.0		0.0	ns
t_{SUENA}	Flip-Flop (Latch) Enable Setup	1.0		1.5		2.0		ns
t_{HENA}	Flip-Flop (Latch) Enable Hold		0.0		0.0		0.0	ns
t_{WCLKA}	Flip-Flop (Latch) Clock Active Pulse Width	4.0		4.5		5.0		ns
t_{WASYN}	Flip-Flop (Latch) Asynchronous Pulse Width	4.0		4.5		5.0		ns
t_A	Flip-Flop Clock Input Period	15.0		18.0		20.0		ns
t_{INH}	Input Buffer Latch Hold		2.0		2.5		2.5	ns
t_{INSU}	Input Buffer Latch Setup	-2.5		-3.0		-3.5		ns
t_{OUTH}	Output Buffer Latch Hold		0.0		0.0		0.0	ns
t_{OUTSU}	Output Buffer Latch Setup	0.4		0.5		1.0		ns
f_{MAX}	Flip-Flop (Latch) Clock Frequency		66.0		55.0		50.0	MHz

Notes:

1. Data applies to macros based on the sequential (S-type) module. Timing parameters for sequential macros constructed from C-type modules can be obtained from the ALS Timer utility.
2. Setup and hold timing parameters for the Input Buffer Latch are defined with respect to the PAD and the G input. External setup/hold timing parameters must account for delay from an external PAD signal to the G inputs. Delay from an external PAD signal to the G input subtracts (adds) to the internal setup (hold) time.

A1240 Timing Characteristics (continued)**PRELIMINARY DATA**I/O Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{INYH}	Pad to Y High	6.1	6.5	5.9	7.4	10.5	ns
t_{INYL}	Pad to Y Low	5.9	6.4	6.8	7.3	10.4	ns
t_{INGH}	G to Y High	6.1	6.5	5.9	7.4	10.5	ns
t_{INGL}	G to Y Low	5.9	6.4	6.8	7.3	10.4	ns

Global Clock Network ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 32	FO = 128	FO = 256	Units
t_{CKH}	Input Low to High	9.1	10.1	11.2	ns
t_{CKL}	Input High to Low	9.1	10.2	11.3	ns
t_{PWH}	Minimum Pulse Width High	4.0	4.5	5.0	ns
t_{PWL}	Minimum Pulse Width Low	4.0	4.5	5.0	ns
t_{CKSW}	Maximum Skew	0.5	1.0	2.5	ns
t_{SUEXT}	Input Latch External Setup ¹	0.0	0.0	0.0	ns
t_{HEXT}	Input Latch External Hold ¹	7.0	8.0	11.2	ns
t_P	Minimum Period	11.1	11.5	11.8	ns
f_{MAX}	Maximum Frequency	90.0	87.0	85.0	MHz

Note:

1. Derating does not apply to this parameter.

Output Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	TTL	CMOS	Units
t_{DLH}	Data to Pad High	4.6	6.7	ns
t_{DHL}	Data to Pad Low	6.5	4.9	ns
t_{ENZH}	Enable Pad Z to High	8.3	8.3	ns
t_{ENZL}	Enable Pad Z to Low	5.5	5.5	ns
t_{ENHZ}	Enable Pad High to Z	4.5	4.5	ns
t_{ENLZ}	Enable Pad Low to Z	6.0	6.0	ns
t_{GLH}	G to Pad High	4.6	4.6	ns
t_{GHL}	G to Pad Low	6.5	6.5	ns
d_{TLH}	Delta Low to High	0.06	0.11	ns/pF
d_{THL}	Delta High to Low	0.11	0.08	ns/pF

A1240-1 Timing Characteristics

PRELIMINARY DATA

Propagation Delays ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	Output Net	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{PD1}	Single Module	Critical Net	3.5	3.9	4.3	4.8	—	ns
t_{PD1}	Single Module	Typical Net	4.4	4.8	5.1	6.3	9.0	ns
t_{PD2}	Dual Module	Critical Net	7.5	8.0	8.5	9.0	—	ns
t_{PD2}	Dual Module	Typical Net	7.4	7.8	8.1	9.3	12.0	ns
t_{CO}	Sequential Clk to Q	Critical Net	3.5	3.9	4.3	4.8	—	ns
t_{CO}	Sequential Clk to Q	Typical Net	4.4	4.8	5.1	6.3	9.0	ns
t_{GO}	Latch G to Q	Critical Net	3.5	3.9	4.3	4.8	—	ns
t_{GO}	Latch G to Q	Typical Net	4.4	4.8	5.1	6.3	9.0	ns
t_{PD}	Asynchronous to Q	Critical	3.5	3.9	4.3	4.8	—	ns
t_{PD}	Asynchronous to Q	Typical	4.4	4.8	5.1	6.3	9.0	ns

Sequential Timing Characteristics (Over Worst-Case Recommended Operating Conditions; No Further Derating Required)

Parameter	Description	Commercial		Industrial		Military		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
t_{SUD}	Flip-Flop (Latch) Data Input Setup	0.4		0.5		1.0		ns
t_{SUASYN}	Flip-Flop (Latch) Asynchronous Input Setup	1.0		1.5		2.0		ns
t_{HD}	Flip-Flop (Latch) Data Input Hold		0.0		0.0		0.0	ns
t_{SUENA}	Flip-Flop (Latch) Enable Setup	1.0		1.5		2.0		ns
t_{HENA}	Flip-Flop (Latch) Enable Hold		0.0		0.0		0.0	ns
t_{WCLKA}	Flip-Flop (Latch) Clock Active Pulse Width	4.0		4.5		5.0		ns
t_{WASYN}	Flip-Flop (Latch) Asynchronous Pulse Width	4.0		4.5		5.0		ns
t_A	Flip-Flop Clock Input Period	13.0		15.0		18.0		ns
t_{INH}	Input Buffer Latch Hold		2.0		2.5		2.5	ns
t_{INSU}	Input Buffer Latch Setup	-2.5		-3.0		-3.5		ns
t_{OUTH}	Output Buffer Latch Hold		0.0		0.0		0.0	ns
t_{OUTSU}	Output Buffer Latch Setup	0.4		0.5		1.0		ns
f_{MAX}	Flip-Flop (Latch) Clock Frequency		75.0		66.0		55.0	MHz

Notes:

1. Data applies to macros based on the sequential (S-type) module. Timing parameters for sequential macros constructed from C-type modules can be obtained from the ALS Timer utility.
2. Setup and hold timing parameters for the Input Buffer Latch are defined with respect to the PAD and the G input. External setup/hold timing parameters must account for delay from an external PAD signal to the G inputs. Delay from an external PAD signal to the G input subtracts (adds) to the internal setup (hold) time.

A1240-1 Timing Characteristics (continued)**PRELIMINARY DATA**I/O Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{NYH}	Pad to Y High	5.5	5.9	5.3	6.7	9.5	ns
t_{NYL}	Pad to Y Low	5.3	5.8	6.1	6.6	9.4	ns
t_{NGH}	G to Y High	5.5	5.9	5.3	6.7	9.5	ns
t_{NGL}	G to Y Low	5.3	5.8	6.1	6.6	9.4	ns

Global Clock Network ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 32	FO = 128	FO = 256	Units
t_{CKH}	Input Low to High	7.8	8.7	9.3	ns
t_{CKL}	Input High to Low	7.8	8.8	9.4	ns
t_{PWH}	Minimum Pulse Width High	4.0	4.5	5.0	ns
t_{PWL}	Minimum Pulse Width Low	4.0	4.5	5.0	ns
t_{CKSW}	Maximum Skew	0.5	1.0	2.5	ns
t_{SUEXT}	Input Latch External Setup ¹	0.0	0.0	0.0	ns
t_{HEXT}	Input Latch External Hold ¹	7.0	8.0	11.2	ns
t_P	Minimum Period	9.1	19.5	10.0	ns
f_{MAX}	Maximum Frequency	110.0	105.0	100.0	MHz

Note:

1. Derating does not apply to this parameter.

Output Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	TTL	CMOS	Units
t_{DLH}	Data to Pad High	4.6	6.7	ns
t_{DHL}	Data to Pad Low	6.5	4.9	ns
t_{ENZH}	Enable Pad Z to High	8.3	8.3	ns
t_{ENZL}	Enable Pad Z to Low	5.5	5.5	ns
t_{ENHZ}	Enable Pad High to Z	4.5	4.5	ns
t_{ENLZ}	Enable Pad Low to Z	6.0	6.0	ns
t_{GLH}	G to Pad High	4.6	4.6	ns
t_{GHL}	G to Pad Low	6.5	6.5	ns
d_{TLH}	Delta Low to High	0.06	0.11	ns/pF
d_{THL}	Delta High to Low	0.11	0.08	ns/pF

A1225 Timing Characteristics

PRELIMINARY DATA

Propagation Delays ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	Output Net	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{PD1}	Single Module	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{PD1}	Single Module	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{PD2}	Dual Module	Critical Net	7.5	8.0	8.5	9.0	—	ns
t_{PD2}	Dual Module	Typical Net	7.9	8.3	8.7	10.0	13.0	ns
t_{CO}	Sequential Clk to Q	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{CO}	Sequential Clk to Q	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{GO}	Latch G to Q	Critical Net	3.9	4.3	4.8	5.3	—	ns
t_{GO}	Latch G to Q	Typical Net	4.9	5.3	5.7	7.0	10.0	ns
t_{FD}	Asynchronous to Q	Critical	3.9	4.3	4.8	5.3	—	ns
t_{FD}	Asynchronous to Q	Typical	4.9	5.3	5.7	7.0	10.0	ns

Sequential Timing Characteristics (Over Worst-Case Recommended Operating Conditions; No Further Derating Required)

Parameter	Description	Commercial		Industrial		Units
		Min.	Max.	Min.	Max.	
t_{SUD}	Flip-Flop (Latch) Data Input Setup	0.4		0.5		ns
t_{SUASYN}	Flip-Flop (Latch) Asynchronous Input Setup	1.0		1.5		ns
t_{HD}	Flip-Flop (Latch) Data Input Hold		0.0		0.0	ns
t_{SUENA}	Flip-Flop (Latch) Enable Setup	1.0		1.5		ns
t_{HENA}	Flip-Flop (Latch) Enable Hold		0.0		0.0	ns
t_{WCLKA}	Flip-Flop (Latch) Clock Active Pulse Width	4.0		4.5		ns
t_{WASYN}	Flip-Flop (Latch) Asynchronous Pulse Width	4.0		4.5		ns
t_A	Flip-Flop Clock Input Period	13.0		15.0		ns
t_{INH}	Input Buffer Latch Hold		2.0		2.5	ns
t_{INSU}	Input Buffer Latch Setup	-2.5		-3.0		ns
t_{OUTH}	Output Buffer Latch Hold		0.0		0.0	ns
t_{OUTSU}	Output Buffer Latch Setup	0.4		0.5		ns
f_{MAX}	Flip-Flop (Latch) Clock Frequency		75.0		66.0	MHz

Notes:

1. Data applies to macros based on the sequential (S-type) module. Timing parameters for sequential macros constructed from C-type modules can be obtained from the ALS Timer utility.
2. Setup and hold timing parameters for the Input Buffer Latch are defined with respect to the PAD and the G input. External setup/hold timing parameters must account for delay from an external PAD signal to the G inputs. Delay from an external PAD signal to the G input subtracts (adds) to the internal setup (hold) time.

PRELIMINARY DATA

A1225 Timing Characteristics (continued)

I/O Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{INH}	Pad to Y High	6.1	6.5	5.9	7.4	10.5	ns
t_{INL}	Pad to Y Low	5.9	6.4	6.8	7.3	10.4	ns
t_{NGH}	G to Y High	6.1	6.5	5.9	7.4	10.5	ns
t_{NGL}	G to Y Low	5.9	6.4	6.8	7.3	10.4	ns

Global Clock Network ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 32	FO = 128	FO = 256	Units
t_{CKH}	Input Low to High	7.8	8.7	9.3	ns
t_{CKL}	Input High to Low	7.8	8.8	9.4	ns
t_{PWH}	Minimum Pulse Width High	4.5	5.1	5.5	ns
t_{PWL}	Minimum Pulse Width Low	4.5	5.1	5.5	ns
t_{CKSW}	Maximum Skew	0.5	1.0	2.5	ns
t_{SUEXT}	Input Latch External Setup ¹	0.0	0.0	0.0	ns
t_{HEXT}	Input Latch External Hold ¹	7.0	8.0	11.2	ns
t_P	Minimum Period	9.1	9.5	10.0	ns
f_{MAX}	Maximum Frequency	110.0	105.0	100.0	MHz

Note:

1. Derating does not apply to this parameter.

Output Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	TTL	CMOS	Units
t_{DLH}	Data to Pad High	4.6	6.7	ns
t_{DHL}	Data to Pad Low	6.5	4.9	ns
t_{ENZH}	Enable Pad Z to High	8.3	8.3	ns
t_{ENZL}	Enable Pad Z to Low	5.5	5.5	ns
t_{ENHZ}	Enable Pad High to Z	4.5	4.5	ns
t_{ENLZ}	Enable Pad Low to Z	6.0	6.0	ns
t_{GLH}	G to Pad High	4.6	4.6	ns
t_{GHL}	G to Pad Low	6.5	6.5	ns
d_{TLH}	Delta Low to High	0.06	0.11	ns/pF
d_{THL}	Delta High to Low	0.11	0.08	ns/pF

A1225-1 Timing Characteristics

PRELIMINARY DATA

Propagation Delays ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	Output Net	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{PD1}	Single Module	Critical Net	3.5	3.9	4.3	4.8	—	ns
t_{PD1}	Single Module	Typical Net	4.4	4.8	5.1	6.3	9.0	ns
t_{PD2}	Dual Module	Critical Net	7.5	8.0	8.5	9.0	—	ns
t_{PD2}	Dual Module	Typical Net	7.4	7.8	8.1	9.3	12.0	ns
t_{CO}	Sequential Clk to Q	Critical Net	3.5	3.9	4.3	4.8	—	ns
t_{CO}	Sequential Clk to Q	Typical Net	4.4	4.8	5.1	6.3	9.0	ns
t_{GO}	Latch G to Q	Critical Net	3.5	3.9	4.3	4.8	—	ns
t_{GO}	Latch G to Q	Typical Net	4.4	4.8	5.1	6.3	9.0	ns
t_{PD}	Asynchronous to Q	Critical	3.5	3.9	4.3	4.8	—	ns
t_{PD}	Asynchronous to Q	Typical	4.4	4.8	5.1	6.3	9.0	ns

Sequential Timing Characteristics (Over Worst-Case Recommended Operating Conditions; No Further Derating Required)

Parameter	Description	Commercial		Industrial		Units
		Min.	Max.	Min.	Max.	
t_{SUD}	Flip-Flop (Latch) Data Input Setup	0.4		0.5		ns
t_{SUASYN}	Flip-Flop (Latch) Asynchronous Input Setup	1.0		1.5		ns
t_{HD}	Flip-Flop (Latch) Data Input Hold		0.0		0.0	ns
t_{SUENA}	Flip-Flop (Latch) Enable Setup	1.0		1.5		ns
t_{HENA}	Flip-Flop (Latch) Enable Hold		0.0		0.0	ns
t_{WCLKA}	Flip-Flop (Latch) Clock Active Pulse Width	4.0		4.5		ns
t_{WASYN}	Flip-Flop (Latch) Asynchronous Pulse Width	4.0		4.5		ns
t_A	Flip-Flop Clock Input Period	11.7		13.3		ns
t_{INH}	Input Buffer Latch Hold		2.0		2.5	ns
t_{INSU}	Input Buffer Latch Setup	-2.5		-3.0		ns
t_{OUTH}	Output Buffer Latch Hold		0.0		0.0	ns
t_{OUTSU}	Output Buffer Latch Setup	0.4		0.5		ns
f_{MAX}	Flip-Flop (Latch) Clock Frequency		85.0		75.0	MHz

Notes:

1. Data applies to macros based on the sequential (S-type) module. Timing parameters for sequential macros constructed from C-type modules can be obtained from the ALS Timer utility.
2. Setup and hold timing parameters for the Input Buffer Latch are defined with respect to the PAD and the G input. External setup/hold timing parameters must account for delay from an external PAD signal to the G inputs. Delay from an external PAD signal to the G input subtracts (adds) to the internal setup (hold) time.

A1225-1 Timing Characteristics (continued)**PRELIMINARY DATA****I/O Buffer Timing** ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 1	FO = 2	FO = 3	FO = 4	FO = 8	Units
t_{NYH}	Pad to Y High	5.5	5.9	5.3	6.7	9.5	ns
t_{NYL}	Pad to Y Low	5.3	5.8	6.1	6.6	9.4	ns
t_{NGH}	G to Y High	5.5	5.9	5.3	6.7	9.5	ns
t_{NGL}	G to Y Low	5.3	5.8	6.1	6.6	9.4	ns

Global Clock Network ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	FO = 32	FO = 128	FO = 256	Units
t_{CKH}	Input Low to High	7.0	7.8	8.6	ns
t_{CKL}	Input High to Low	7.0	7.8	8.6	ns
t_{PWH}	Minimum Pulse Width High	4.2	4.5	5.0	ns
t_{PWL}	Minimum Pulse Width Low	4.2	4.5	5.0	ns
t_{CKSW}	Maximum Skew	0.5	1.0	2.5	ns
t_{SUEXT}	Input Latch External Setup ¹	0.0	0.0	0.0	ns
t_{HEXT}	Input Latch External Hold ¹	7.0	8.0	11.2	ns
t_P	Minimum Period	8.3	8.7	9.1	ns
f_{MAX}	Maximum Frequency	120.0	115.0	110.0	MHz

Note:

1. Derating does not apply to this parameter.

Output Buffer Timing ($V_{CC} = 5.0\text{ V}$; $T_J = 25^\circ\text{C}$; Process = Typical; Derating Required)

Parameter	Description	TTL	CMOS	Units
t_{DLH}	Data to Pad High	4.6	6.7	ns
t_{DHL}	Data to Pad Low	6.5	4.9	ns
t_{ENZH}	Enable Pad Z to High	8.3	8.3	ns
t_{ENZL}	Enable Pad Z to Low	5.5	5.5	ns
t_{ENHZ}	Enable Pad High to Z	4.5	4.5	ns
t_{ENLZ}	Enable Pad Low to Z	6.0	6.0	ns
t_{GLH}	G to Pad High	4.6	4.6	ns
t_{GHL}	G to Pad Low	6.5	6.5	ns
d_{TLH}	Delta Low to High	0.06	0.11	ns/pF
d_{THL}	Delta High to Low	0.11	0.08	ns/pF

1

Macro Library

Overview

The following tables describe ACT 2 macros, which are building blocks for designing FPGAs with the ALS and your CAE interface.

Equation Statement Elements

Combinatorial Elements

All equations for combinatorial logic elements use the following operators:

Operator	Symbol
AND	See Note 1
NOT	!
OR	+
XOR	^

Notes:

1. A space between the 'A' and 'B' in the equation $Y = A B$ means **A AND B**.
2. Order of operators in decreasing precedence is: NOT, AND, XOR, and OR.
3. Signals expressed in bold have a dual module delay.

The macros are divided into four categories: I/O Macros, Hard Macros (Combinable and Non-Combinable), Soft Macros, and TTL Macros.

Sequential Elements

All equations for sequential logic elements use the following formula:

$Q = <!\> (<!\> \text{CLK or G, } <\text{data equation}>, <!\> \text{CLR}, <!\> \text{PRE})$

<!>	Optional Inversion
CLK	Flip-Flop Clock Pin
G	Latch Gate Pin
CLR	Asynchronous Clear Pin
PRE	Asynchronous Preset Pin

ACT 2 Macro Selections

I/O Macros

Macro Name	No. of Modules		Description
	I/O	Clock	
INBUF	1		Input
IBDL	1		Input with Input Latch
BBDLHS	1		Bidirectional with Input Latch and Output Latch
BBHS	1		Bidirectional
BIBUF	1		Bidirectional
CLKBIBUF	1	1	Bidirectional with Input Dedicated to Clock Network
CLKBUF	1	1	Input for Dedicated Clock Network
OBDLHS	1		Output with Output Latch
OBHS	1		Output
OUTBUF	1		Output
TBDLHS	1		Three State Output with Latch
TBHS	1		Three State Output
TRIBUFF	1		Three State Output

Note:

The following are functionally identical:
OBHS and OUTBUF; TRIBUFF and TBHS; BBHS and BIBUF.

TTL Macros

Macro Name	Description	Logic Levels	No. of Modules	
			Seq.	Comb.
TA00	2-input NAND	1		1
TA02	2-input NOR	1		1
TA04	Inverter	1		1
TA07	Buffer	1		1
TA08	2-input AND	1		1
TA10	3-input NAND	1		1
TA11	3-input AND	1		1
TA20	4-input NAND	1		2
TA21	4-input AND	1		1
TA27	3-input NOR	1		1
TA32	2-input OR	1		1
TA40	4-input NAND	1		2
TA42	4 to 10 decoder	1		10
TA51	AND-OR-Invert	1		2
TA54	4-wide AND-OR-Invert	2		5
TA55	2-wide 4-input AND-OR-Invert	2		3
TA86	2-input exclusive OR	1		1
TA138	3 to 8 decoder with enable and active low outputs	2		12
TA139	2 to 4 decoder with enable and active low outputs	1		4
TA150	16 to 1 multiplexor	3		6
TA151	8 to 1 multiplexor with enable and active low outputs	3		5
TA153	4 to 1 multiplexor	2		2
TA154	4 to 16 decoder	2		22
TA157	2 to 1 multiplexor	1		1
TA160	4-bit decode counter with clear	4	4	12
TA161	4-bit binary counter with clear	3	4	10
TA164	8-bit serial in, parallel out shift register	1	8	
TA169	4-bit up/down counter	6	4	14
TA174	Hex D-type flip-flop with clear	1	6	
TA175	Quadruple D-type flip-flop with clear	1	4	
TA190	4-bit up/down decode counter with up/down mode	7	4	31
TA191	4-bit up/down binary counter with up/down mode	7	4	30
TA194	4-bit shift register	1	4	4
TA195	4-bit shift register	1	4	1
TA269	8-bit up/down binary counter	8	8	28
TA273	Octal register with clear	1	8	
TA280	Parity generator and checker	4		9
TA377	Octal register with active low enable	1	8	
TA688	8-bit identity comparator	3		9

Soft Macros

Function	Description	Macro Name	Logic Levels	No. of Modules	
				Seq.	Comb.
Counters	4-bit binary counter with load, clear	CNT4A	4	4	8
	4-bit binary counter with load, clear, carry in, carry out	CNT4B	4	4	7
	4-bit up/down counter with load, carry in, and carry out	UDCNT4A	5	4	13
	very fast 16-bit down counter	VCNT16C	1	34	31
	2-bit down counter, prescaler	VCNT2CP	1	5	2
	2-bit down counter, most significant bit	VCNT2CU	1	2	3
	4-bit down counter, middle bits	VCNT4C	1	4	8
	4-bit down counter, low order bits	VCNT4CL	1	4	7
Decoders	2 to 4 decoder	DEC2X4	1		4
	2 to 4 decoder with active low outputs	DEC2X4A	1		4
	3 to 8 decoder	DEC3X8	1		8
	3 to 8 decoder with active low outputs	DEC3X8A	1		8
	4 to 16 decoder with active low outputs	DEC4X16A	2		20
	2 to 4 decoder with enable	DECE2X4	1		4
	2 to 4 decoder with enable and active low outputs	DECE2X4A	1		4
	3 to 8 decoder with enable	DECE3X8	2		11
Registers	3 to 8 decoder with enable and active low outputs	DECE3X8A	2		11
	octal latch with clear	DLC8A	1	8	
	octal latch with enable	DLE8	1	8	
	octal latch with multiplexed data	DLM8	1	8	
	4-bit shift register with clear	SREG4A	1	4	
Adders	8-bit shift register with clear	SREG8A	1	8	
	8-bit adder	FADD8	3		44
	9-bit adder	FADD9	3		49
	10-bit adder	FADD10	3		56
	12-bit adder	FADD12	4		69
	16-bit adder	FADD16	5		97
	2-bit sum generator	SUMX1A	2		5
	very fast 16-bit adder	VADD16C	3		97
Comparators	4-bit identity comparator	ICMP4	2		5
	8-bit identity comparator	ICMP8	3		5
	2-bit magnitude comparator with enable	MCMP2C	3		9
	4-bit magnitude comparator with enable	MCMP4C	4		18
	8-bit magnitude comparator with enable	MCMP8C	6		36
Multiplexors	8 to 1 multiplexor	MX8	2		3
	8 to 1 multiplexor with active low outputs	MX8A	2		3
	16 to 1 multiplexor	MX16	2		5

Combinable Hard Macros 1 (for DF1, DF1B, DFC1B, DFC1D, DL1, DL1B, DLC, and DLCA)

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
AND	2-input	AND2	$Y = A \cdot B$		1
		AND2A	$Y = \neg A \cdot B$		1
		AND2B	$Y = A \cdot \neg B$		1
		AND3B	$Y = \neg A \cdot \neg B \cdot C$		1
AND-OR		AO1A	$Y = ((\neg A) \cdot B) + C$		1
		AO1D	$Y = (\neg A \cdot \neg B) + C$		1
AND-OR Invert		AO11D	$Y = \neg((\neg A \cdot \neg B) + \neg C)$		1
Buffers and Inverters		BUF	$Y = A$		1
		BUFA	$Y = \neg(\neg A)$		1
		INV	$Y = \neg A$		1
		INVA	$Y = \neg A$		1
Clock Net Interface		GAND2	$Y = A \cdot G$		1
		GNOR2	$Y = \neg(A + G)$		1
		GOR2	$Y = A + G$		1
Multiplexor	2:1	MX2	$Y = (A \cdot S) + (B \cdot \neg S)$		1
NAND	2-input	NAND2A	$Y = \neg(\neg A \cdot B)$		1
		NAND2B	$Y = \neg(\neg A \cdot \neg B)$		1
	3-input	NAND3C	$Y = \neg(\neg A \cdot \neg B \cdot \neg C)$		1
NOR	2-input	NOR2	$Y = \neg(A + B)$		1
		NOR2A	$Y = \neg(\neg A + B)$		1
		NOR2B	$Y = \neg(\neg A + \neg B)$		1
	3-input	NOR3A	$Y = \neg(\neg A + B + C)$		1
OR-AND		OA1	$Y = (A + B) \cdot C$		1
OR	2-input	OR2	$Y = A + B$		1
		OR2A	$Y = \neg A + B$		1
	3-input	OR3	$Y = A + B + C$		1

Combinable Hard Macros 2 (for DF1, DF1B, DFC1B, DFC1D, DL1, and DL1B)

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
AND	3-input	AND3	$Y = A B C$		1
		AND3A	$Y = !A B C$		1
		AND3C	$Y = !A !B !C$		1
	4-input	AND4B	$Y = !A !B C D$		1
		AND4C	$Y = !A !B !C D$		1
AND-OR		AO1	$Y = (A B) + C$		1
		AO1B	$Y = (A B) + (!C)$		1
		AO1C	$Y = ((!A B) + (!C))$		1
		AO1E	$Y = (!A !B) + !C$		1
		AO11	$Y = A B + ((A + B) C)$		1
		AO2	$Y = ((A B) + C + D)$		1
		AO2A	$Y = ((!A B) + C + D)$		1
		AO2B	$Y = (!A !B) + C + D$		1
		AO2C	$Y = (!A B) + !C + D$		1
		AO2D	$Y = (!A !B) + !C + D$		1
		AO3	$Y = (!A B C) + D$		1
		AO3B	$Y = (!A !B C) + D$		1
		AO3C	$Y = (!A !B !C) + D$		1
		A04A	$Y = (!A B C) + (A C D)$		1
		A05A	$Y = (!A B) + (A C) + D$		1
AND-OR Invert		AOI1A	$Y = !(((A B) + C))$		1
		AOI1B	$Y = !(((A B) + !C))$		1
		AOI1C	$Y = !(((A !B) + C))$		1
		AOI2A	$Y = !(((A B) + C + D))$		1
		AOI3A	$Y = !(((A !B !C) + (!A !D)))$		1
Exclusive OR	XNOR, AND-XOR	AX1B	$Y = (!A !B) \wedge C$		1
Boolean		CS2	$Y = !(((A + S) B) C + ((A + S) B) D)$		1
		CY2B	$Y = A1 B1 + (A0+B0) A1 + (A0+B0) B1$		1
Clock Net Interface		GMX4	$Y = (D0 !S0 !G) + (D1 !G S0) + (D2 G !S0) + (D3 S0 G)$		1
		GNAND2	$Y = !(A G)$		1
		GXOR2	$Y = A \wedge G$		1
AND-OR		MAJ3	$Y = (A B) + (B C) + (A C)$		1
Multiplexor		MX2A	$Y = (!A !S) + (B S)$		1
		MX2C	$Y = (!A !S) + (!B S)$		1
	4:1	MX4	$Y = (D0 !S0 !S1) + (D1 S0 !S1) + (D2 !S0 S1) + (D3 S0 S1)$		1
NAND	2-input	NAND2	$Y = !(A B)$		1
	3-input	NAND3A	$Y = !(A B C)$		1
		NAND3B	$Y = !(A !B C)$		1
	4-input	NAND4C	$Y = !(A !B !C D)$		1
		NAND4D	$Y = !(A !B !C !D)$		1
NOR	3-input	NOR3	$Y = !(A + B + C)$		1
		NOR3B	$Y = !(A + !B + C)$		1
		NOR3C	$Y = !(A + !B + !C)$		1
	4-input	NOR4A	$Y = !(A + B + C + D)$		1
		NOR4B	$Y = !(A + !B + C + D)$		1

Combinable Hard Macros 2 (continued) (for DF1, DF1B, DFC1B, DFC1D, DL1, and DL1B)

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
OR-AND		OA1A	$Y = !(A + B) C$		1
		OA1B	$Y = (A + B) !C$		1
		OA1C	$Y = !(A + B) !C$		1
		OA2	$Y = (A + B) (C + D)$		1
		OA2A	$Y = !(A + B) (C + D)$		1
		OA3	$Y = ((A + B) C D)$		1
		OA3A	$Y = ((A + B) !C D)$		1
		OA4	$Y = (A + B + C) D$		1
		OA4A	$Y = ((A + B + !C) D)$		1
		OA5	$Y = (A + B + C)(A + D)$		1
OR-AND Invert		OAI1	$Y = !((A + B) C)$		1
		OAI2A	$Y = !((A + B + C) !D)$		1
		OAI3A	$Y = !((A + B) !C !D)$		1
OR	3-input	OR3A	$Y = !A + B + C$		1
		OR3B	$Y = !A + !B + C$		1
	4-input	OR4	$Y = A + B + C + D$		1
		OR4A	$Y = !A + B + C + D$		1
Exclusive OR	XOR	XOR	$Y = A \wedge B$		1
		XO1	$Y = (A \wedge B) + C$		1
		XO1A	$Y = !(A \wedge B) + C$		1
	XNOR, AND-XOR	XNOR	$Y = !(A \wedge B)$		1
		XA1	$Y = (A \wedge B) C$		1
		XA1A	$Y = !(A \wedge B) C$		1

Non-Combinable Hard Macros

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
AND	4-input	AND4	$Y = A B C D$		1
		AND4A	$Y = (!A B C D)$		1
		AND4D	$Y = !A !B !C !D$		2
	5-input	AND5B	$Y = !A !B C D E$		1
OR	2-input	OR2B	$Y = !A + !B$		1
	3-input	OR3C	$Y = !A + !B + !C$		1
	4-input	OR4B	$Y = !A + !B + C + D$		1
		OR4C	$Y = !A + !B + !C + D$		1
		OR4D	$Y = !A + !B + !C + !D$		2
	5-input	OR5B	$Y = !A + !B + C + D + E$		1
NAND	3-input	NAND3	$Y = !(A B C)$		1
	4-input	NAND4	$Y = !(A B C D)$		2
		NAND4A	$Y = !(A B C D)$		1
		NAND4B	$Y = !(A !B C D)$		1
	5-input	NAND5C	$Y = !(A !B !C D E)$		1
NOR	4-input	NOR4	$X = !(A + B + C + D)$		2
		NOR4C	$Y = !(A + !B + !C + D)$		1
		NOR4D	$Y = !(A + !B + !C + !D)$		1
	5-input	NOR5C	$Y = !(A + !B + !C + D + E)$		1
Exclusive OR	XNOR, AND-XOR	AX1	$Y = (!A B) \wedge C$		1
		AX1A	$Y = !(A B) \wedge C$		2
		AX1C	$Y = (A B) \wedge C$		1
AND-OR		AO2E	$Y = (!A !B) + !C + !D$		1
		AO3A	$Y = (A B C) + D$		1
		AO6	$Y = A B + C D$		1
		AO6A	$Y = A B + C !D$		1
		AO7	$Y = A B C + D + E$		1
		AO8	$Y = (A B) + (!C !D) + E$		1
		AO9	$Y = (A B) + C + D + E$		1
		AO10	$Y = (A B + C) (D + E)$		1
AND-OR Invert		AOI1	$Y = !(A B + C)$		1
		AOI2B	$Y = !((A B) + !C + D)$		1
		AOI4	$Y = !((A B) + (C D))$		2
		AOI4A	$Y = !(A B + !C D)$		1
OR-AND		OA3B	$Y = ((A + B) !C D)$		1
OR-AND Invert		OAI3	$Y = !((A + B) C D)$		1
Multiplexor	2:1	MX2B	$Y = (A !S) + (!B S)$		1

Non-Combinable Hard Macros (continued)

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
Adders	half	HA1	$CO = A \cdot B$ $S = A \oplus B$		2
		HA1A	$CO = !A \cdot B$ $S = !(A \oplus B)$		2
		HA1B	$CO = !(A \cdot B)$ $S = !(A \oplus B)$		2
		HA1C	$CO = !(A \cdot B)$ $S = (A \oplus B)$		2
	full	FA1A	$CO = (CI \cdot !B \cdot !A) + (A \cdot !B \cdot C) + (B \cdot CI \cdot A)$ $S = (B \cdot !A \cdot !CI) + (CO \cdot !A \cdot CI) + (CO \cdot A \cdot !CI) + (B \cdot A \cdot CI)$		2
		FA1B	$CO = !A \cdot (!B + B \cdot CI) + A \cdot (!B \cdot CI)$ $S = !A \cdot (!CI \cdot CO + CI \cdot B) + A \cdot (!CI \cdot B + CI \cdot CO)$		2
		FA2A	$CO = (CI \cdot !B \cdot !(A0 + A1)) + (!B \cdot (A0 + A1)) + (B \cdot CI \cdot (A0 + A1))$ $S = (B \cdot !(A0 + A1) \cdot !CI) + (CO \cdot !(A0 + A1) \cdot CI) + (CO \cdot (A0 + A1) \cdot !CI) + (B \cdot (A0 + A1) \cdot CI)$		2
	Boolean	CS1	$Y = !(A + S \cdot B) \cdot C + D \cdot (A + S \cdot B)$		1
		CY2A	$Y = A1 \cdot B1 + A0 \cdot B0 \cdot A1 + A0 \cdot B0 \cdot B1$		1
		MXT	$Y = (!S1 \cdot (!S0A \cdot D0) + (S0A \cdot D1)) + (S1 \cdot (!S0B \cdot D2 + S0B \cdot D3))$		2
		MXC1	$Y = !(!(S \cdot A + S \cdot B) \cdot C + !(S \cdot A + S \cdot B) \cdot D)$		2
D-type Flip-Flops		DF1	$Q = (CLK, D, -, -)$	1	
		DF1A	$QN = !(CLK, D, -, -)$	1	
		DF1B	$Q = !(CLK, D, -, -)$	1	
		DF1C	$QN = !(CLK, D, -, -)$	1	
	with clear	DFC1	$Q = (CLK, D, CLR, -)$	1	1
		DFC1A	$Q = !(CLK, D, CLR, -)$	1	1
		DFC1B	$Q = (CLK, D, !CLR, -)$	1	
		DFC1D	$Q = !(CLK, D, !CLR, -)$	1	
		DFC1E	$QN = !(CLK, D, !CLR, -)$	1	1
		DFC1G	$QN = !(CLK, D, !CLR, -)$	1	1
	with enable	DfE	$Q = (CLK, !E \cdot Q + E \cdot D, -, -)$	1	
		DfE1B	$Q = (CLK, !E \cdot D + E \cdot Q, -, -)$	1	
		DfE1C	$Q = !(CLK, D \cdot !E + Q \cdot E, -, -)$	1	
		DfE3A	$Q = (CLK, D \cdot E + Q \cdot !E, !CLR, -)$	1	
		DfE3B	$Q = !(CLK, D \cdot E + Q \cdot !E, !CLR, -)$	1	
		DfE3C	$Q = (CLK, D \cdot !E + Q \cdot E, !CLR, -)$	1	
		DfE3D	$Q = !(CLK, D \cdot !E + Q \cdot E, !CLR, -)$	1	
		DfEA	$Q = !(CLK, !E \cdot Q + E \cdot D, -, -)$	1	1

Non-Combinable Hard Macros (continued)

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
D-type Flip-Flops (continued)	with multiplexed data	DFM	$Q = (CLK, A !S + B S, -, -)$	1	
		DFM1B	$QN = !(CLK, A !S + B S, -, -)$	1	
		DFM1C	$QN = !(CLK, A !S + B S, -, -)$	1	
		DFM3	$Q = (CLK, A !S + B S, CLR, -)$	1	1
		DFM3B	$Q = (CLK, A !S + B S, !CLR, -)$	1	
		DFM3E	$Q = (CLK, A !S + B S, CLR, -)$	1	1
		DFM4C	$QN = !(CLK, !A !S + !B S, -, !PRE)$	1	
		DFM4D	$QN = !(CLK, A !S + B S, -, !PRE)$	1	
		DFM6A	$Q = (CLK, (D0 !S0 !S1 + D1 S0 !S1 + D2 !S0 S1 + D3 S0 S1), !CLR, -)$	1	
		DFM6B	$Q = (CLK, (D0 !S0 !S1 + D1 S0 !S1 + D2 !S0 S1 + D3 S0 S1), !CLR, -)$	1	
		DFM7A	$Q = (CLK, !CLR, (D0 !S0 + D1 S0) !(S10 + S11) + (D2 !S0 + D3 S0) (S10 + S11))$	1	
		DFM7B	$Q = (CLK, !CLR, (D0 !S0 + D1 S0) !(S10 + S11) + (D2 !S0 + D3 S0) (S10 + S11))$	1	
		DFMA	$Q = (CLK, A !S + B S, -, -)$	1	
		DFMB	$Q = (CLK, A !S + B S, !CLR, -)$	1	
		DFME1A	$Q = (CLK, !E A !S + !E B S + E Q, -, -)$	1	
	with preset	DFP1	$Q = (CLK, D, -, PRE)$		2
		DFP1A	$Q = (CLK, D, -, PRE)$		2
		DFP1B	$Q = (CLK, D, -, !PRE)$		2
		DFP1C	$QN = !(CLK, D, -, PRE)$	1	1
		DFP1D	$Q = (CLK, D, -, !PRE)$	2	
		DFP1E	$QN = !(CLK, D, -, !PRE)$	1	
		DFP1F	$Q = (CLK, D, -, PRE)$	1	1
		DFP1G	$QN = !(CLK, D, -, !PRE)$		1
	with clear and preset	DFPC	$Q = (CLK, D, CLR, PRE)$		2
		DFPCA	$Q = (CLK, D, !CLR, PRE)$		2
JK Flip-Flops		JKF	$Q = (CLK, !Q J + Q K, -, -)$	1	
		JKF1B	$Q = (CLK, !Q J + Q K, -, -)$	1	
		JKF2A	$Q = (CLK, !Q J + Q K, !CLR, -)$	1	
		JKF2B	$Q = (CLK, !Q J + Q K, !CLR, -)$	1	
		JKF2C	$Q = (CLK, !Q J + Q K, CLR, -)$	1	1
		JKF2D	$Q = (CLK, !Q J + Q K, CLR, -)$	1	1
T-type Flip-Flops		TF1A	$Q = (CLK, T !Q + !T Q, !CLR, -)$	1	
		TF1B	$Q = (CLK, T !Q + !T Q, !CLR, -)$	1	
Data Latch		DL1	$Q = (G, D, -, -)$	1	
		DL1A	$QN = !(G, D, -, -)$	1	
		DL1B	$Q = (G, D, -, -)$	1	
		DL1C	$QN = !(G, D, -, -)$	1	
		DL2A	$Q = (G, D, !CLR, PRE)$		2
		DL2B	$QN = !(G, D, !CLR, PRE)$		2
		DL2C	$Q = (G, D, !CLR, PRE)$		2
		DL2D	$QN = !(G, D, !CLR, !PRE)$		2

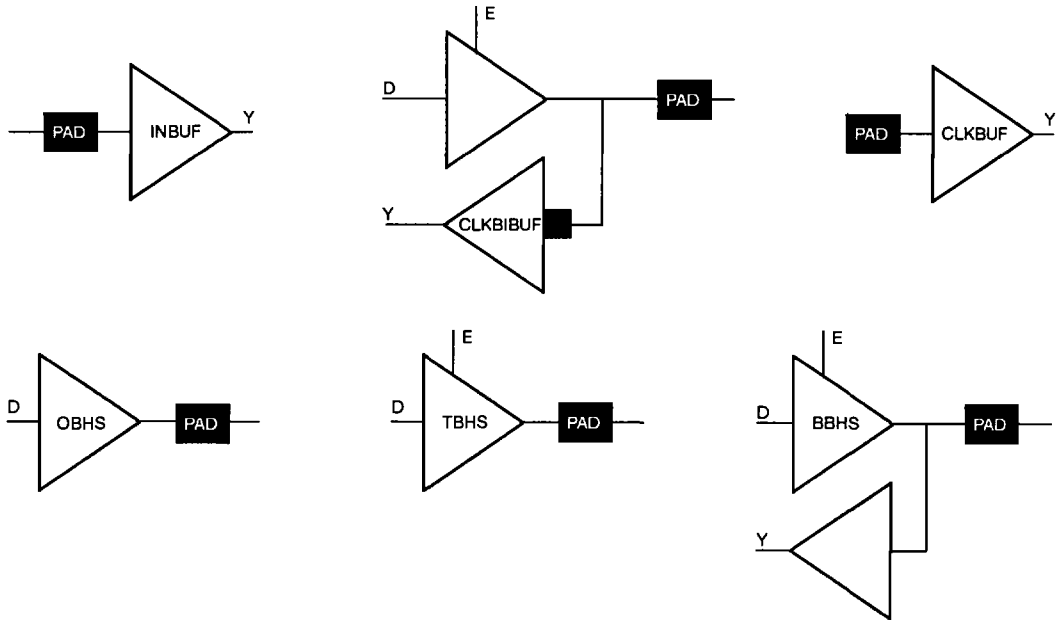
Non-Combinable Hard Macros (continued)

Function	Description	Macro Name	Equation(s)	No. of Modules	
				Seq.	Comb.
Data latch (continued)	with clear	DLC	$Q = (G, D, !CLR, -)$	1	
		DLC1	$Q = (G, D, CLR, -)$		1
		DLC1A	$Q = (!G, D, CLR, -)$		1
		DLC1F	$QN = !(G, D, CLR, -)$		1
		DLC1G	$QN = !(G, D, CLR, -)$		1
		DLCA	$Q = (!G, D, !CLR, -)$	1	
	with enable	DLE	$Q = (G, Q !E + D E, -, -)$	1	
		DLE1D	$QN = !(G, !E !D + E QN, -, -)$	1	
		DLE2A	$Q = (!G, Q !E + D E, CLR, -)$	1	1
		DLE2B	$Q = (!G, D !E + Q E, !CLR, -)$	1	
		DLE2C	$Q = (!G, !E D + Q E, CLR, -)$		1
		DLE3A	$Q = (!G, E D + Q !E, -, PRE)$		2
		DLE3B	$Q = (!G, !E D + Q E, -, PRE)$		1
		DLE3C	$Q = (!G, !E D + Q E, -, !PRE)$		1
		DLEA	$Q = (G, Q E + D !E, -, -)$	1	
		DLEB	$Q = (!G, Q !E + D E, -, -)$	1	
		DLEC	$Q = (!G, Q E + D !E, -, -)$	1	
	with multiplexed data	DLM	$Q = (G, A !S + B S, -, -)$	1	
		DLM2A	$Q = (!G, A !S + B S, CLR, -)$	1	1
		DLM3	$Q = (G, D0 !S0 !S1 + D1 S0 !S1 + D2 !S0 S1 + D3 S0 S1, -, -)$	1	
		DLM3A	$Q = (!G, D0 !S0 !S1 + D1 S0 !S1 + D2 !S0 S1 + D3 S0 S1, -, -)$	1	
		DLMA	$Q = (!G, A !S + B S, -, -)$	1	
	with multiplexed data and enable	DLME1A	$Q = (!G, A !S !E + B S !E + E Q, -, -)$	1	
	with preset	DLP1	$Q = (G, D, -, PRE)$		1
		DLP1A	$Q = (!G, D, -, PRE)$		1
		DLP1B	$Q = (G, D, -, !PRE)$		1
		DLP1C	$Q = (!G, D, -, PRE)$		1
		DLP1D	$QN = !(G, D, -, !PRE)$	1	
		DLP1E	$QN = !(G, D, -, !PRE)$	1	
Clock Net Interface		CLKINT		clock modules = 1	
Tie-Off		VCC		modules = 0	
		GND		modules = 0	

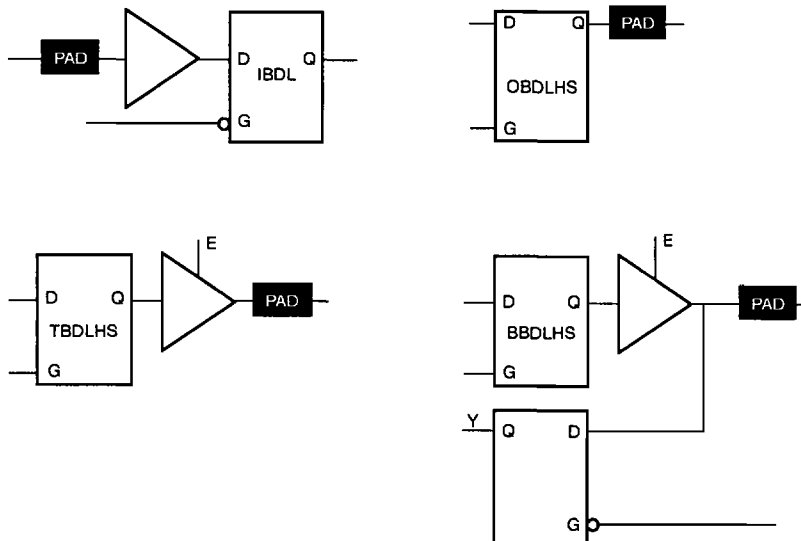
Hard Macro Symbols

I/O Buffers

(I/O Module Count = 1)

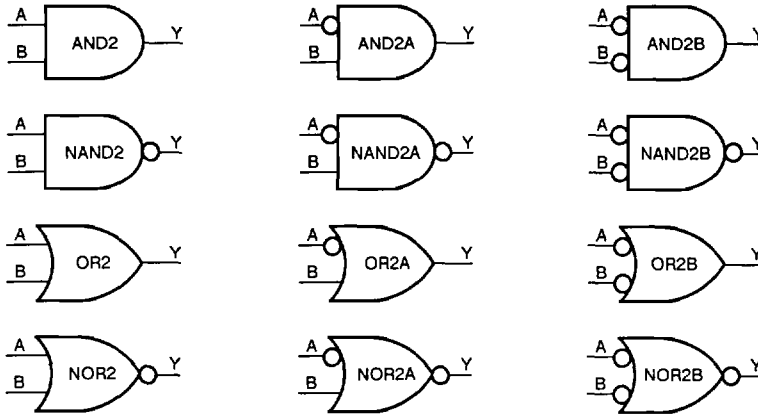


I/O Buffers with Latches



2-Input Gates

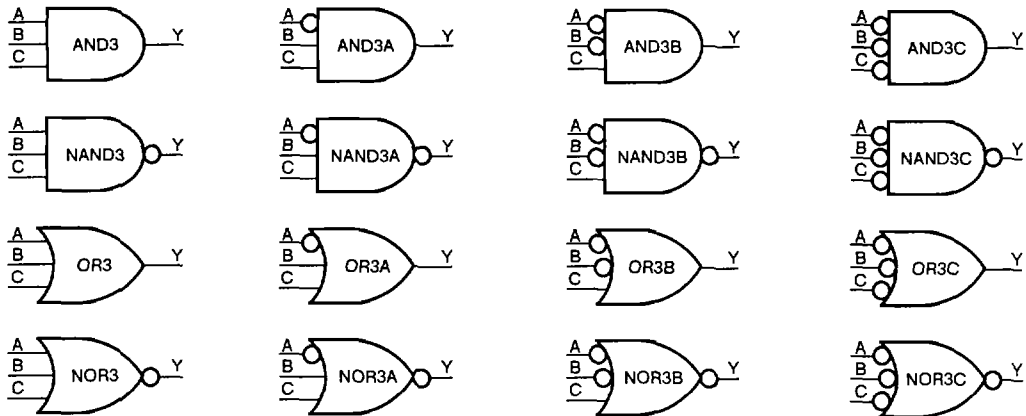
(Module Count = 1)



1

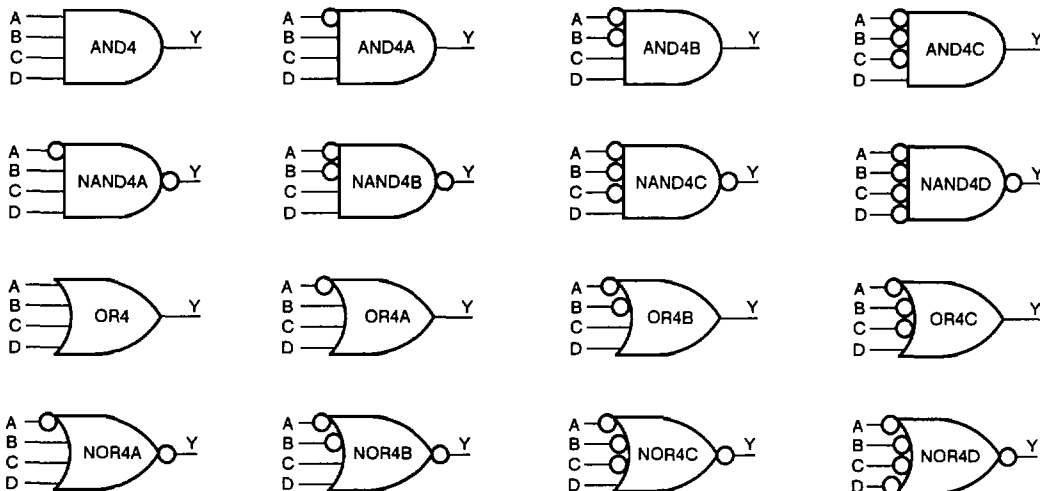
3-Input Gates

(Module Count = 1)



4-Input Gates

(Module Count = 1)



(Module Count = 2)



▲ Indicates extra delay input

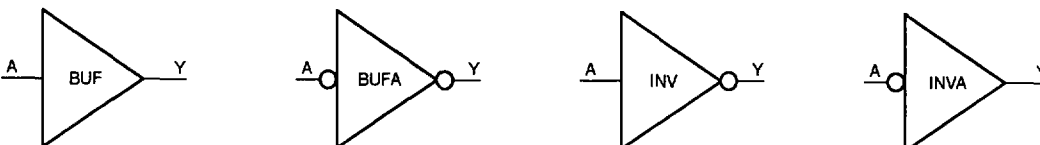
5-Input Gates

(Module Count = 1)

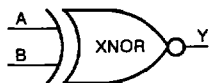


Buffers

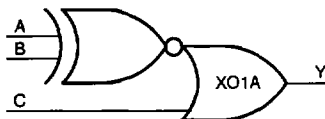
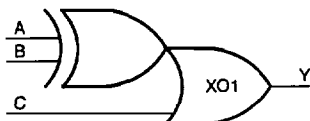
(Module Count = 1)



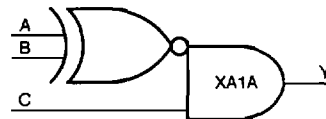
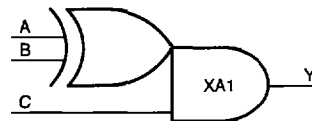
XOR Gates (Module Count = 1)



XOR-OR Gates (Module Count = 1)

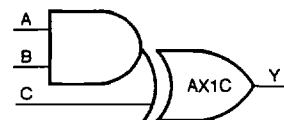
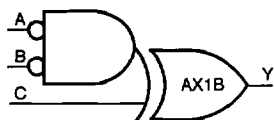
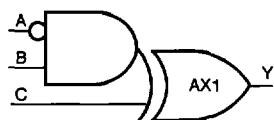


XOR-AND Gates (Module Count = 1)

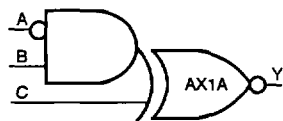


AND-XOR Gates

(Module Count = 1)

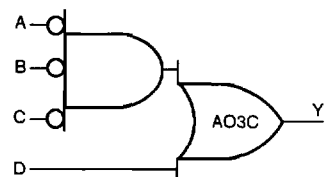
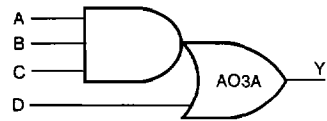
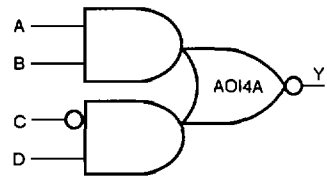
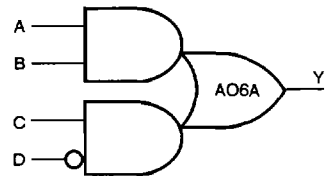
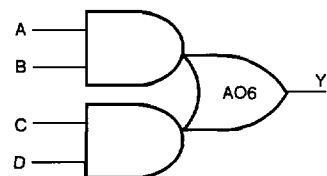
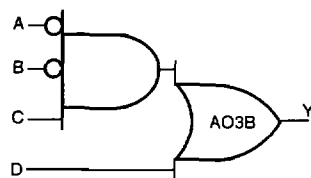
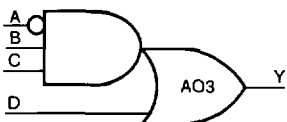
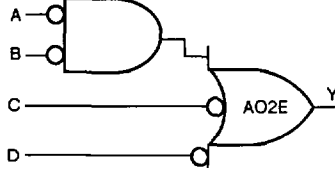
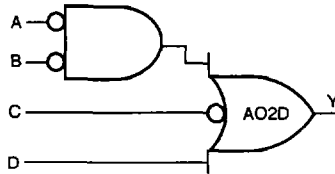
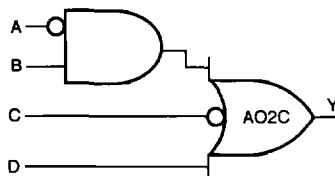
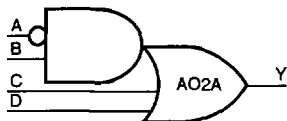
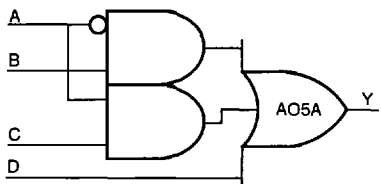
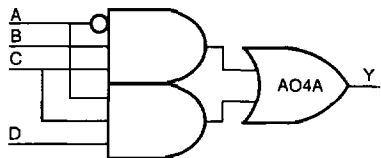
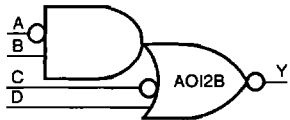
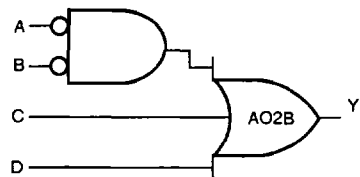
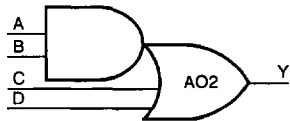
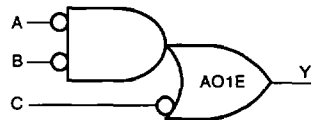
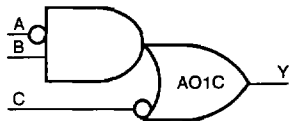
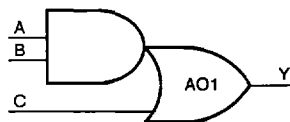


(Module Count = 2)



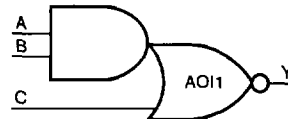
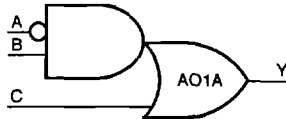
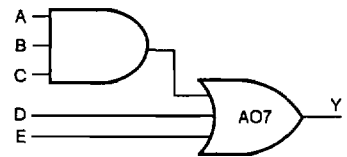
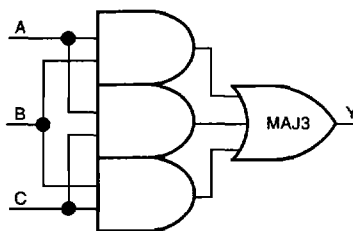
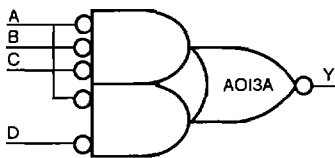
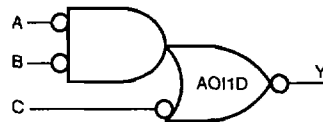
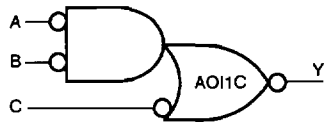
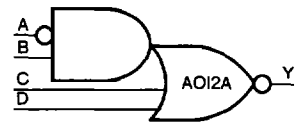
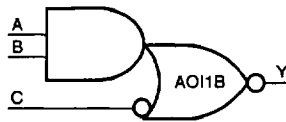
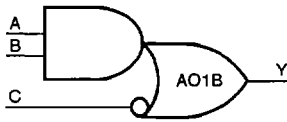
AND-OR Gates

(Module Count = 1)

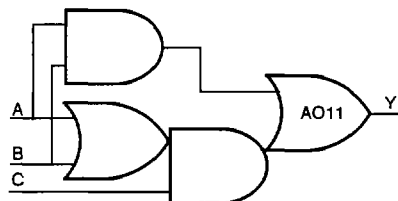
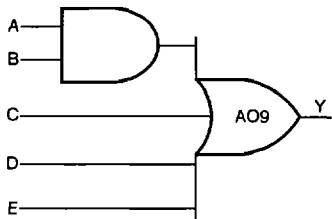
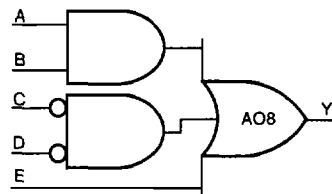
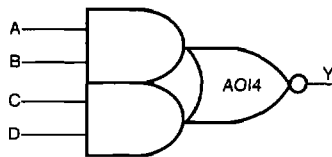


AND-OR Gates, continued

(Module Count = 1)

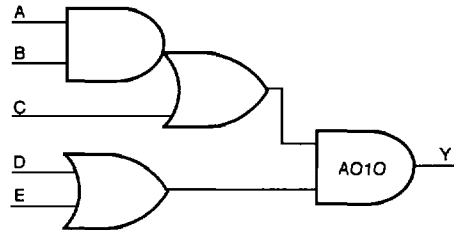
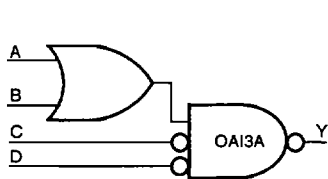
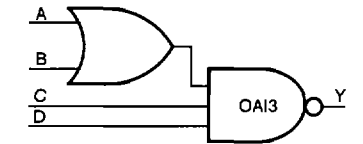
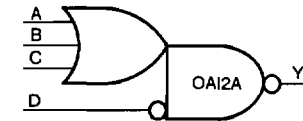
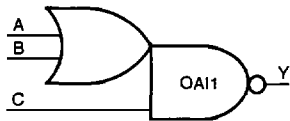
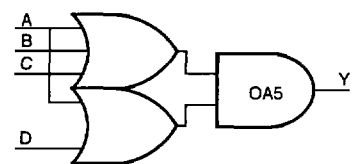
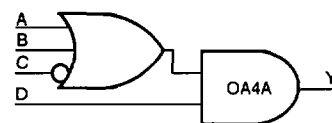
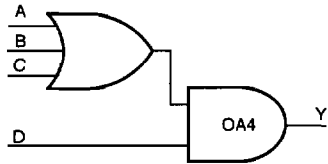
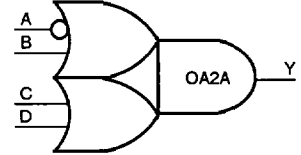
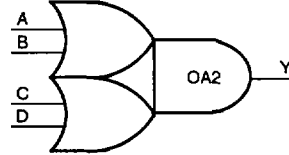
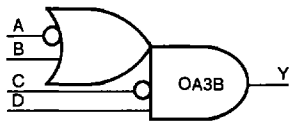
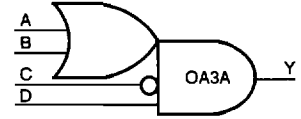
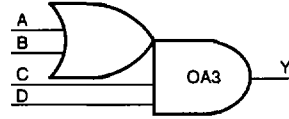
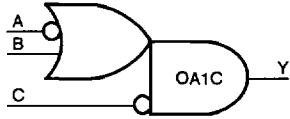
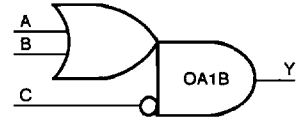
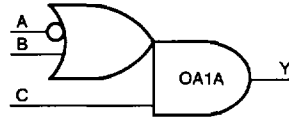
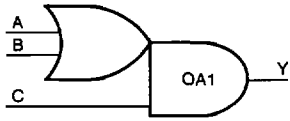


(Module Count = 2)



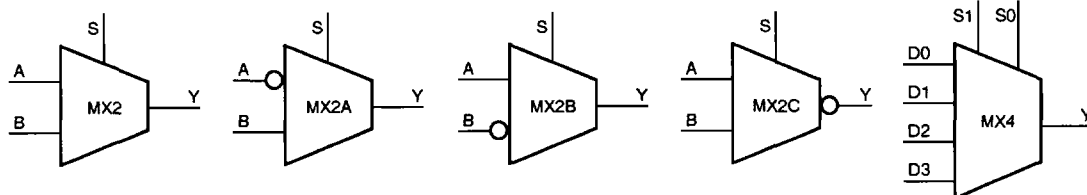
OR-AND Gates

(Module Count = 1)

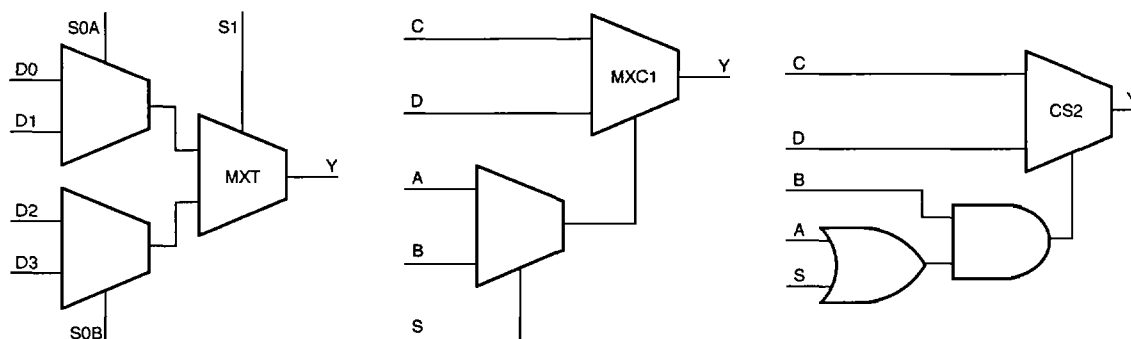


Multiplexors

(Module Count = 1)



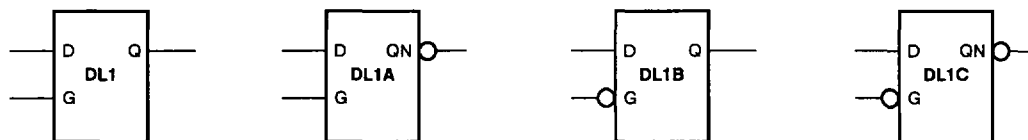
(Module Count = 2)



1

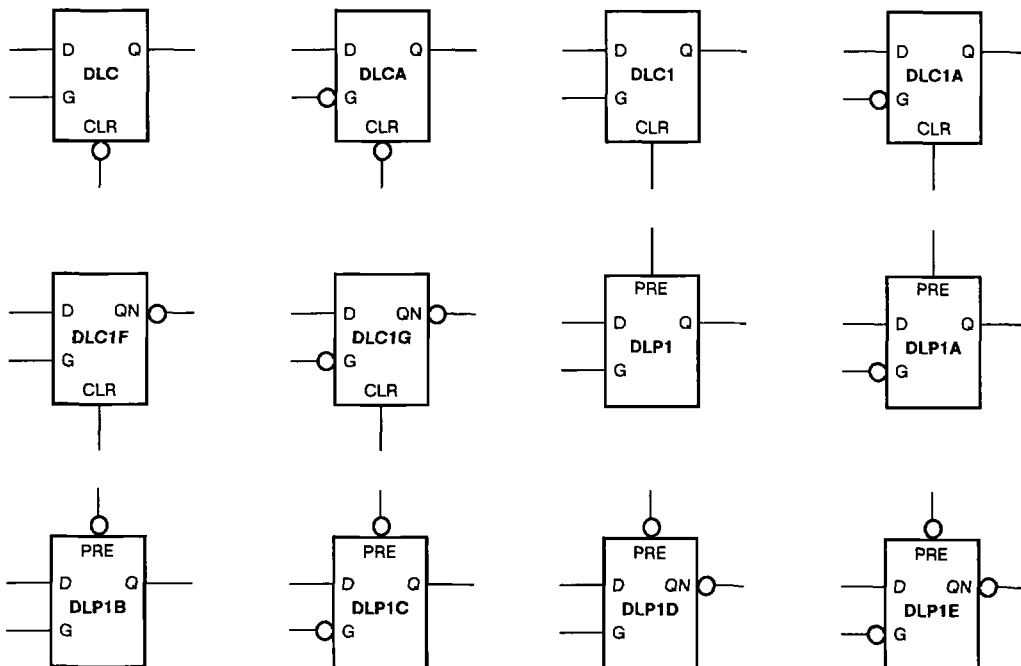
Latches

(Module Count = 1)

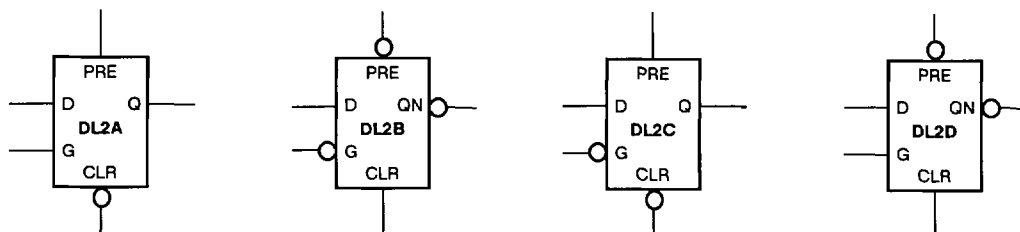


D-Latches with Clear

(Module Count = 1)

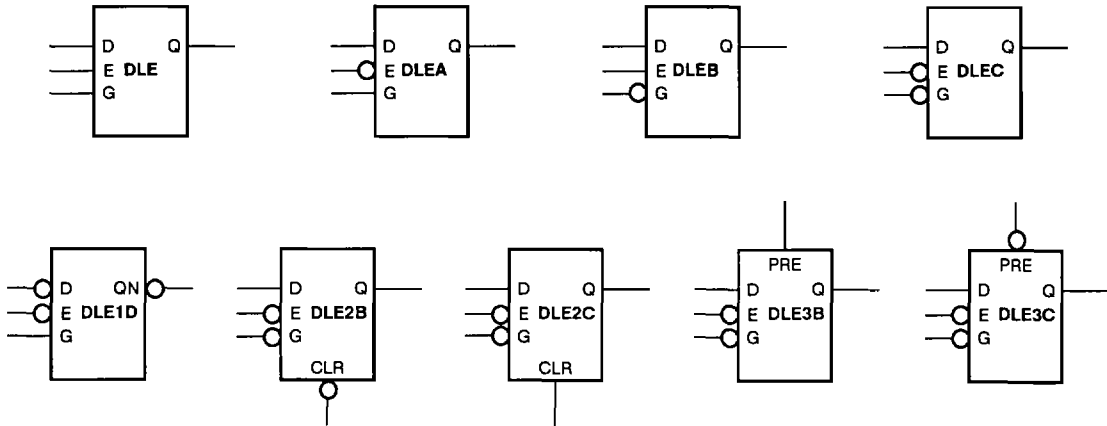


(Module Count = 2)

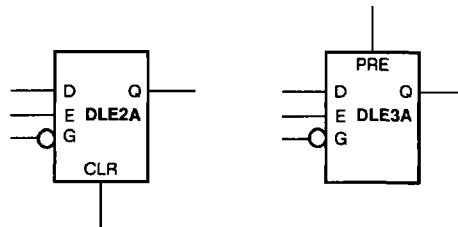


D-Latches with Enable

(Module Count = 1)



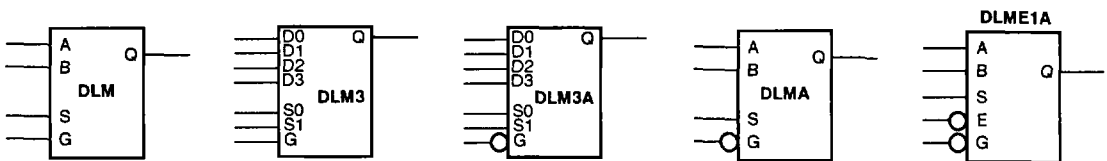
(Module Count = 2)



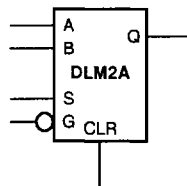
1

Mux Latches

(Module Count = 1)

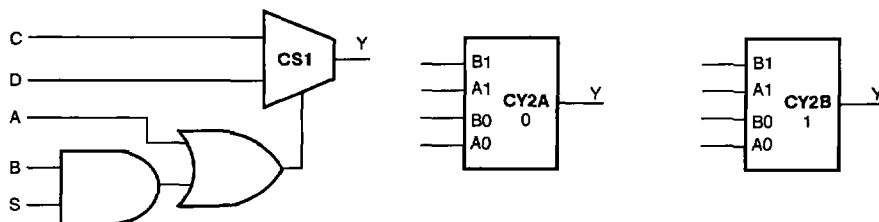


(Module Count = 2)

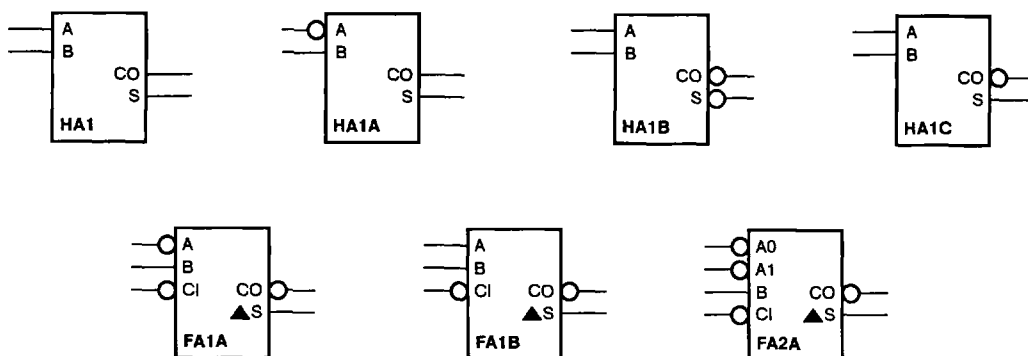


Adders

(Module Count = 1)



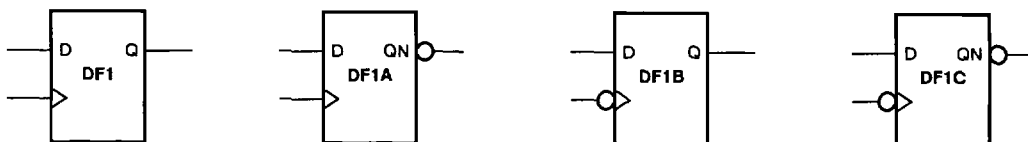
(Module Count = 2)



Macros FA1A, FA1B, and FA2A have two level delays from the inputs to the S outputs, as indicated by the ▲

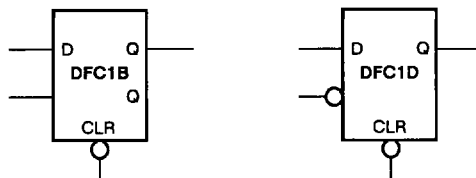
D-Type Flip-Flops

(Module Count = 1)

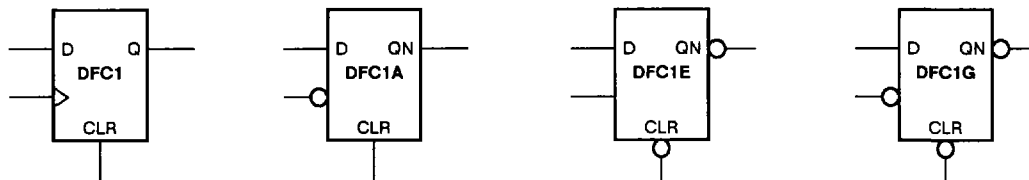


D-Type Flip-Flops with Clear

(Module Count = 1)

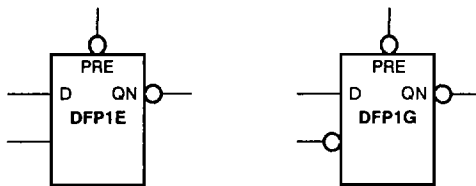


(Module Count = 2)

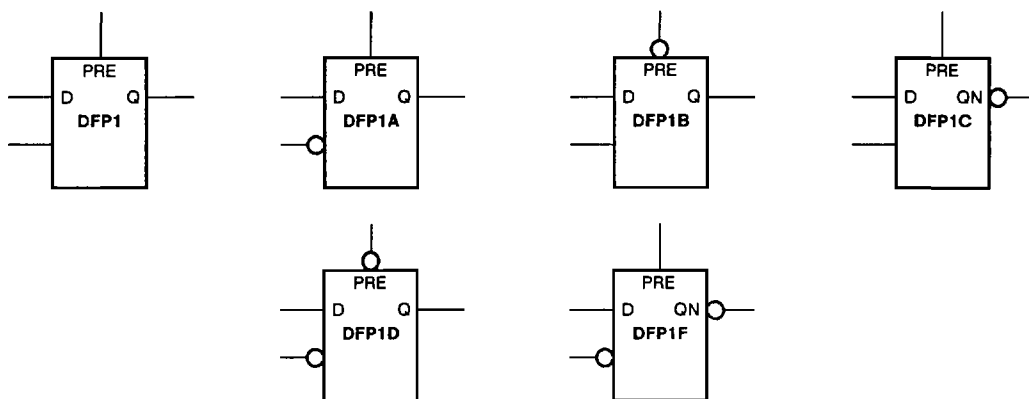


D-Type Flip-Flops with Preset

(Module Count = 1)

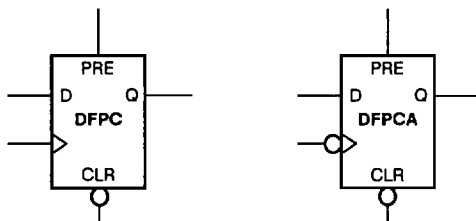


(Module Count = 2)



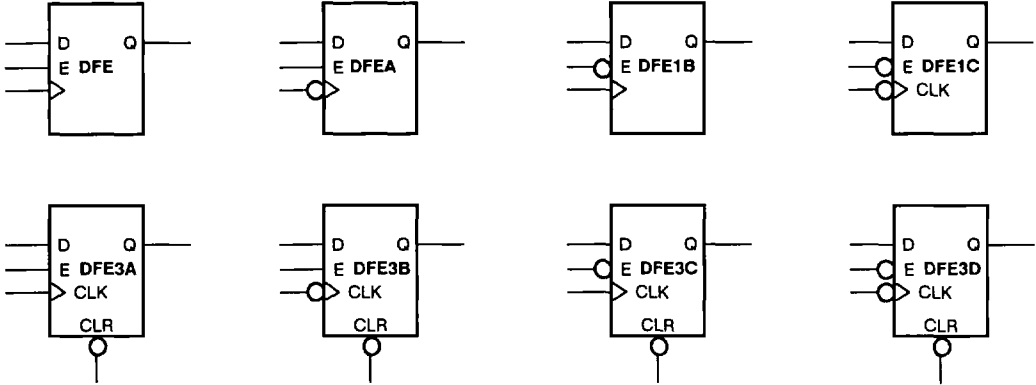
D-Type Flip-Flops with Preset and Clear

(Module Count = 2)



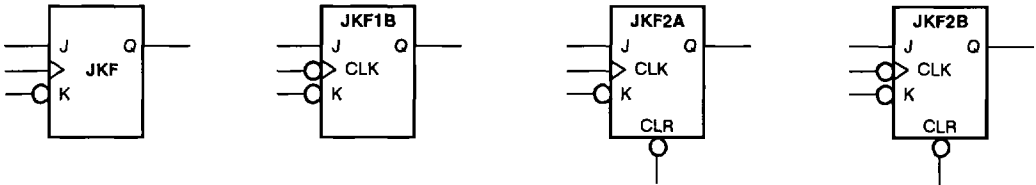
D-Type Flip-Flops with Enable

(Module Count = 1)

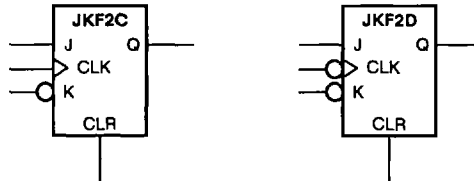


JK Flip-Flops

(Module Count = 1)

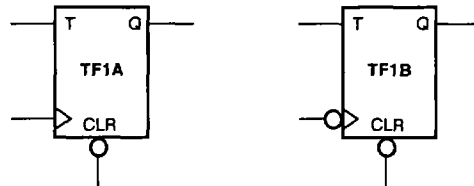


(Module Count = 2)



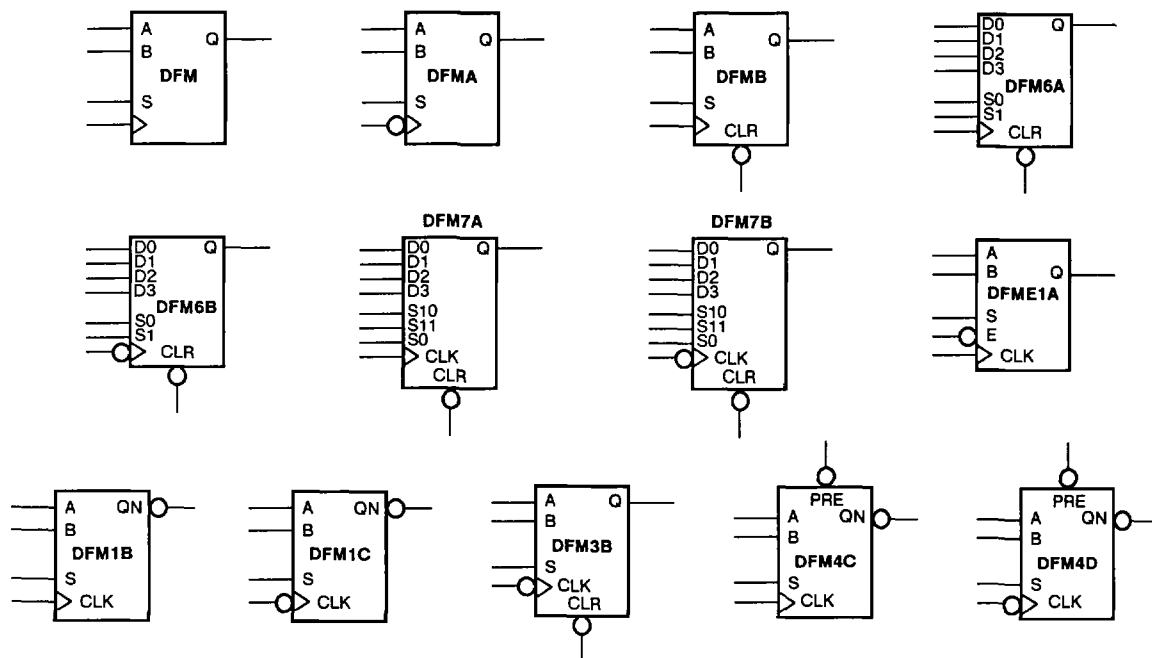
Toggle Flip-Flops

(Module Count = 1)



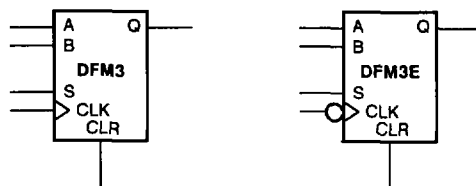
Mux Flip-Flops

(Module Count = 1)



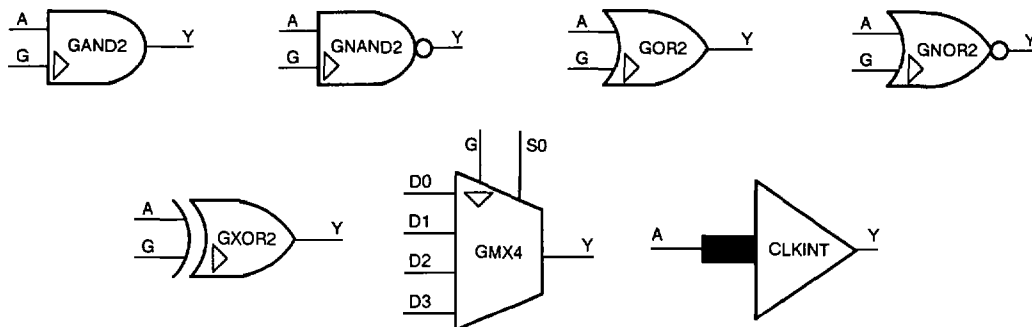
1

(Module Count = 2)



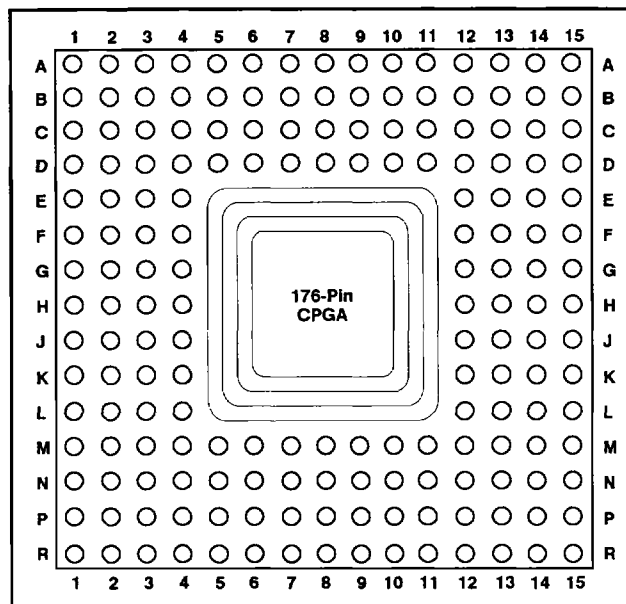
CLKBUF Interface Macros

(Module Count = 1)



▷ Indicates clock input for connection to the global clock networks.

Package Pin Assignments: 176-Pin CPGA (Top View)

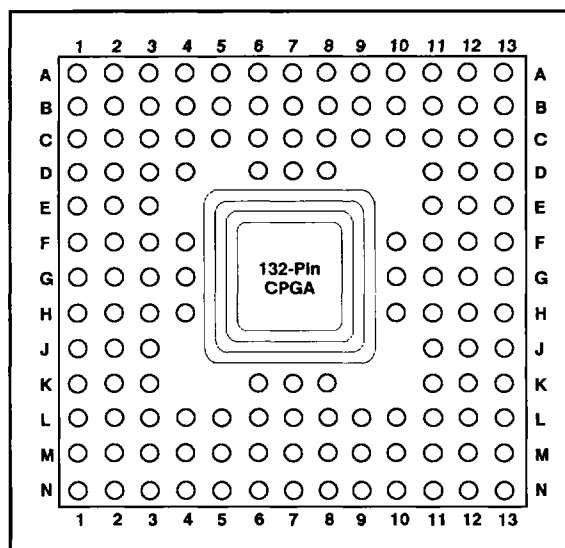


Signal	Pin No.	Location
PRA or I/O	152	C9
PRB or I/O	160	D7
MODE	2	C3
SDI or I/O	135	B14
SDO or I/O	87	P13
DCLK or I/O	175	B3
CLKA or I/O	154	A9
CLKB or I/O	158	B8
GND	1, 8, 18, 23, 33, 38, 45, 57, 67, 77, 89, 101, 106, 111, 121, 126, 133, 145, 156, 165	D4, E4, G4, H4, K4, L4, M4, M6, M8, M10, M12, K12, J12, H12, F12, E12, D12, D10, C8, D6
V _{CC}	13, 24, 28, 52, 68, 82, 112, 116, 140, 155, 170	F4, H3, J4, M5, N8, M11, H13, G12, D11, D8, D5
V _{PP}	110	J14
V _{SV}	25, 113	H2, H14
V _{KS}	109	J13

Notes:

- Unused I/O pins are designated as outputs by ALS and are driven low.
- All unassigned pins are available for use as I/Os.
- MODE = GND, except during device programming or debugging.
- V_{PP} = V_{CC}, except during device programming.
- V_{SV} = V_{CC}, except during device programming.
- V_{KS} = GND, except during device programming.

Package Pin Assignments: 132-Pin CPGA (Top View)



1

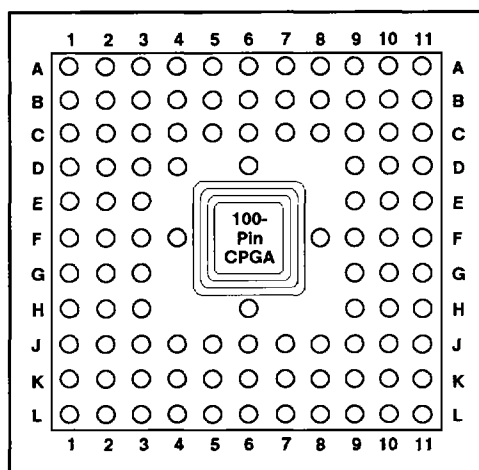
Signal	Pin No.	Location
PRA or I/O	113	B8
PRB or I/O	121	C6
MODE	2	A1
SDI or I/O	101	B12
SDO or I/O	65	N12
DCCLK or I/O	132	C3
CLKA or I/O	115	B7
CLKB or I/O	119	B6
GND	9, 10, 26, 27, 41, 58, 59, 73, 74, 92, 93, 107, 108, 125, 126	E3, F4, J2, J3, L5, M9, L9, K12, J11, E12, E11, C9, B9, B5, C5
V _{CC}	18, 19, 49, 50, 83, 84, 116, 117	G3, G2, L7, K7, G10, G11, D7, C7
V _{PP}	82	G13
V _{SV}	17, 85	G4, G12
V _{KS}	81	H13

Notes:

1. Unused I/O pins are designated as outputs by ALS and are driven low.
2. All unassigned pins are available for use as I/Os.
3. MODE = GND, except during device programming or debugging.

4. V_{PP} = V_{CC}, except during device programming.
5. V_{SV} = V_{CC}, except during device programming.
6. V_{KS} = GND, except during device programming.

Package Pin Assignments: 100-Pin CPGA (Top View)

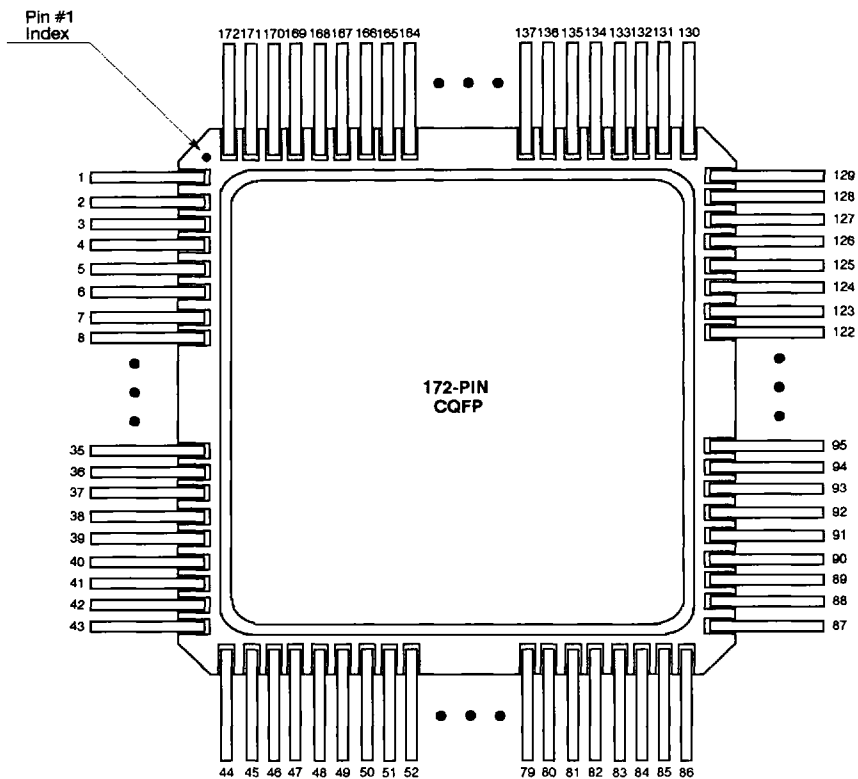


Signal	Pin No.	Location
PRA or I/O	85	A7
PRB or I/O	92	A4
MODE	2	C2
SDI or I/O	77	C8
SDO or I/O	50	J9
DCLK or I/O	100	C3
CLKA or I/O	87	C6
CLKB or I/O	90	D6
GND	7, 20, 32, 44, 55, 70, 82, 94	E3, G3, J5, J7, G9, D10, C7, C5
V _{CC}	15, 38, 64, 88	F3, K6, F9, B6
V _{PP}	63	F10
V _{SV}	14, 65	G1, E11
V _{KS}	62	F11

Notes:

1. All unassigned pins are available for use as I/Os.
2. Unused I/O pins are designated as outputs by ALS and driven low.
3. MODE = GND, except during device programming or debugging.
4. V_{PP} = V_{CC}, except during device programming.
5. V_{SV} = V_{CC}, except during device programming.
6. V_{KS} = GND, except during device programming.

Package Pin Assignments: 172-Pin CQFP (Top View)

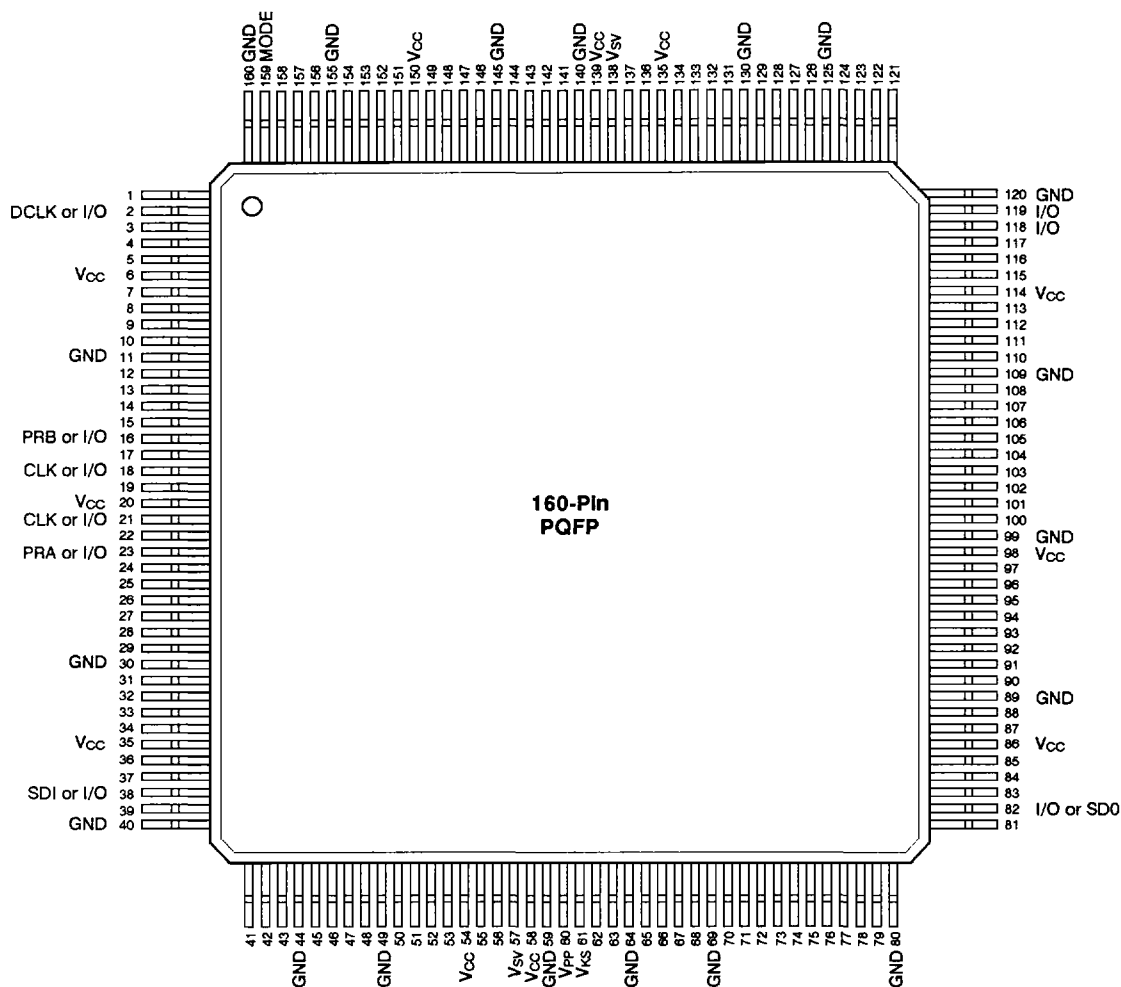


Signal	Pin Number
MODE	1
GND	7, 17, 22, 32, 37, 55, 65, 75, 98, 103, 108, 118, 123, 141, 152, 161
V _{CC}	12, 23, 27, 50, 66, 80, 109, 113, 136, 151, 166
V _{SV}	24, 110
V _{KS}	106
V _{PP}	107
SDO or I/O	85
SDI or I/O	131
PRA or I/O	148
PRB or I/O	156
CLKA or I/O	150
CLKB or I/O	154
DCLK or I/O	171

Notes:

1. V_{PP} must be terminated to V_{CC}, except during device programming.
2. MODE must be terminated to circuit ground, except during device programming or debugging.
3. Unused I/O pins are designated as outputs by ALS and are driven low.
4. All unassigned pins are available for use as I/Os.

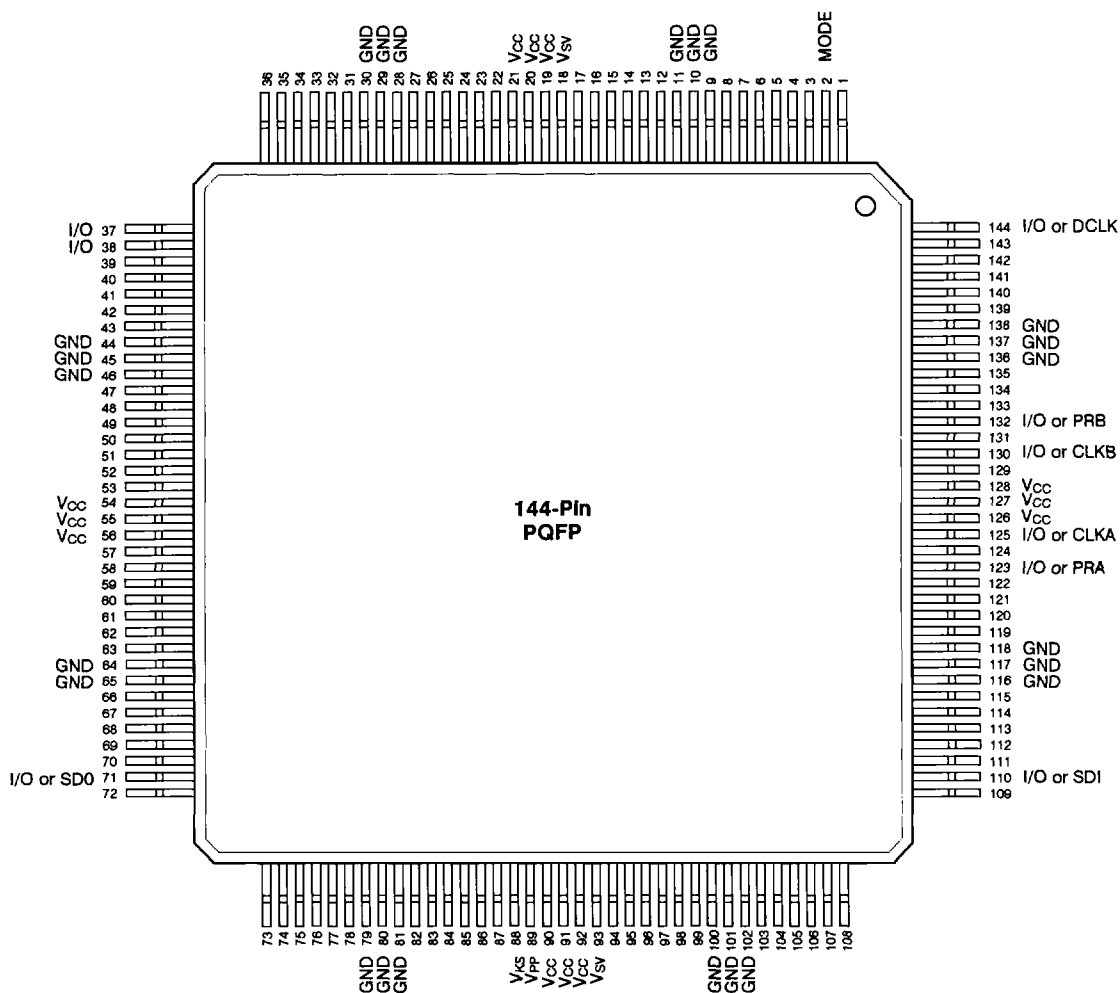
Package Pin Assignments: 160-Pin PQFP (Top View)



Notes:

1. Unused I/O pins are designated as outputs by ALS and are driven low.
2. All unassigned pins are available for use as I/Os.
3. MODE = GND, except during device programming or debugging.
4. $V_{PP} = V_{CC}$, except during device programming.
5. $V_{SV} = V_{CC}$, except during device programming.
6. $V_{KS} = GND$, except during device programming.

Package Pin Assignments: 144-Pin PQFP (Top View)

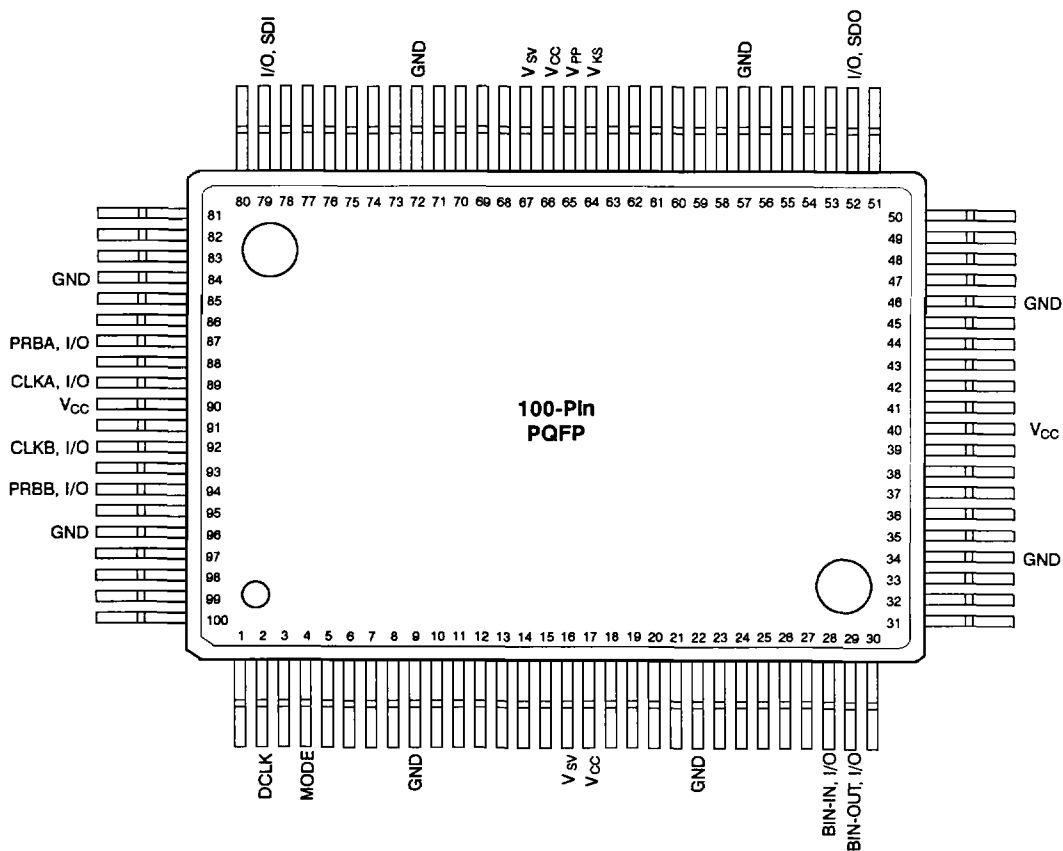


1

Notes:

- Unused I/O pins are designated as outputs by ALS and are driven low.
- All unassigned pins are available for use as I/Os.
- MODE = GND, except during device programming or debugging.
- $V_{PP} = V_{CC}$, except during device programming.
- $V_{SV} = V_{CC}$, except during device programming.
- $V_{KS} = GND$, except during device programming.

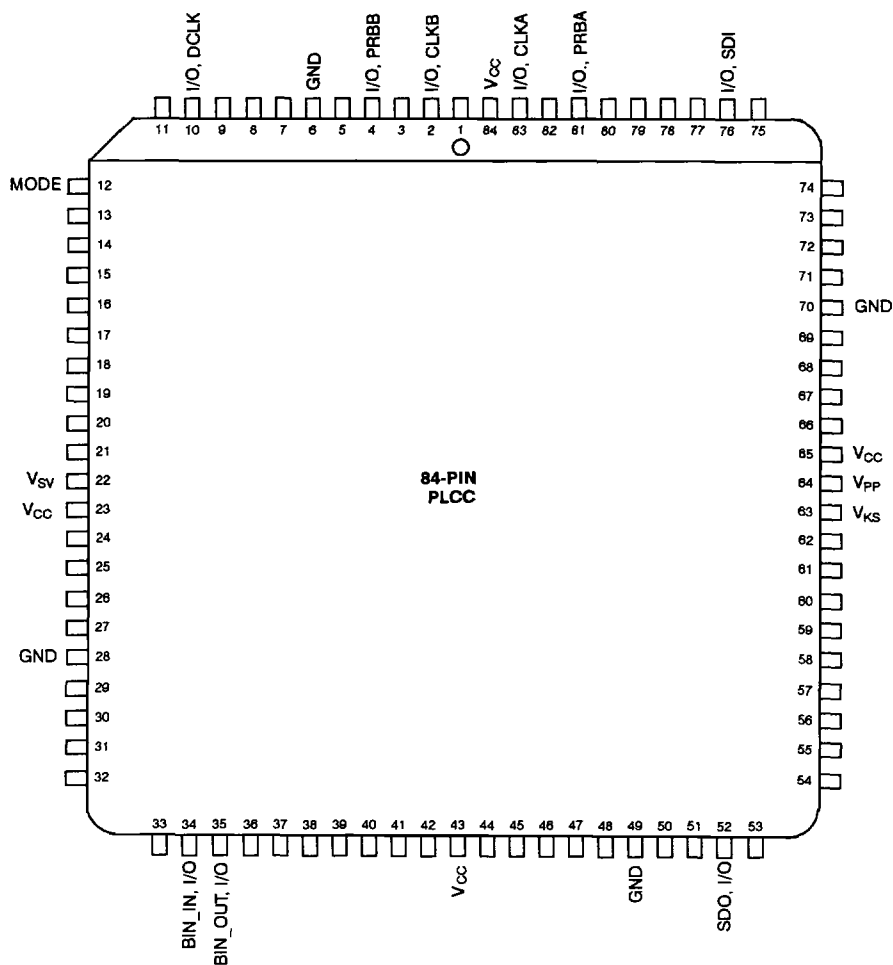
Package Pin Assignments: 100-Pin PQFP (Top View)



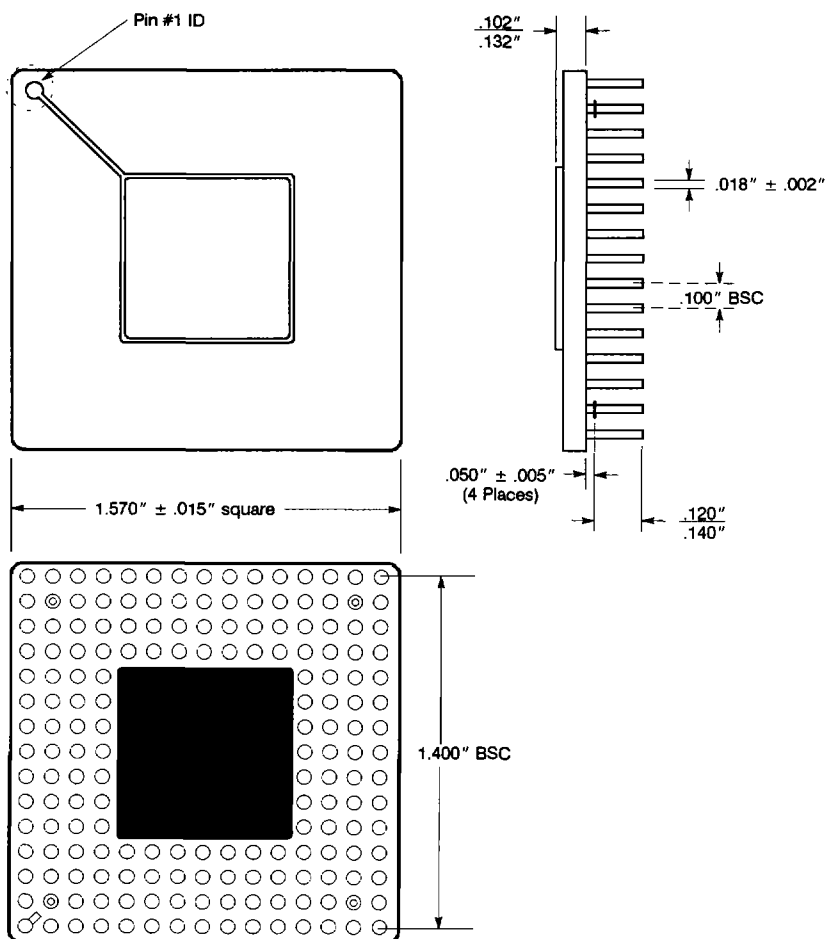
Notes:

1. V_{PP} must be terminated to V_{CC} , except during device programming.
2. $MODE$ must be terminated to circuit ground, except during device programming or debugging.
3. Unused I/O pins are designated as outputs by ALS and are driven low.
4. All unassigned pins are available for use as I/Os.

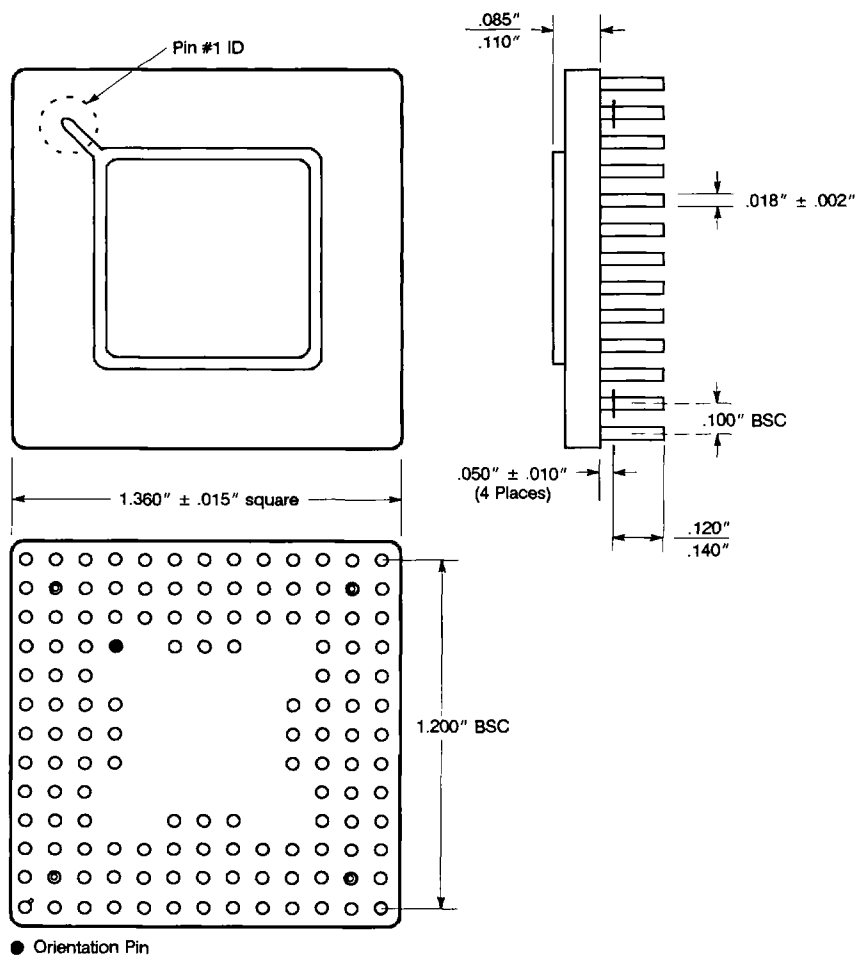
Package Pin Assignments: 84-Pin PLCC (Top View)



Package Mechanical Details: 176-Pin CPGA

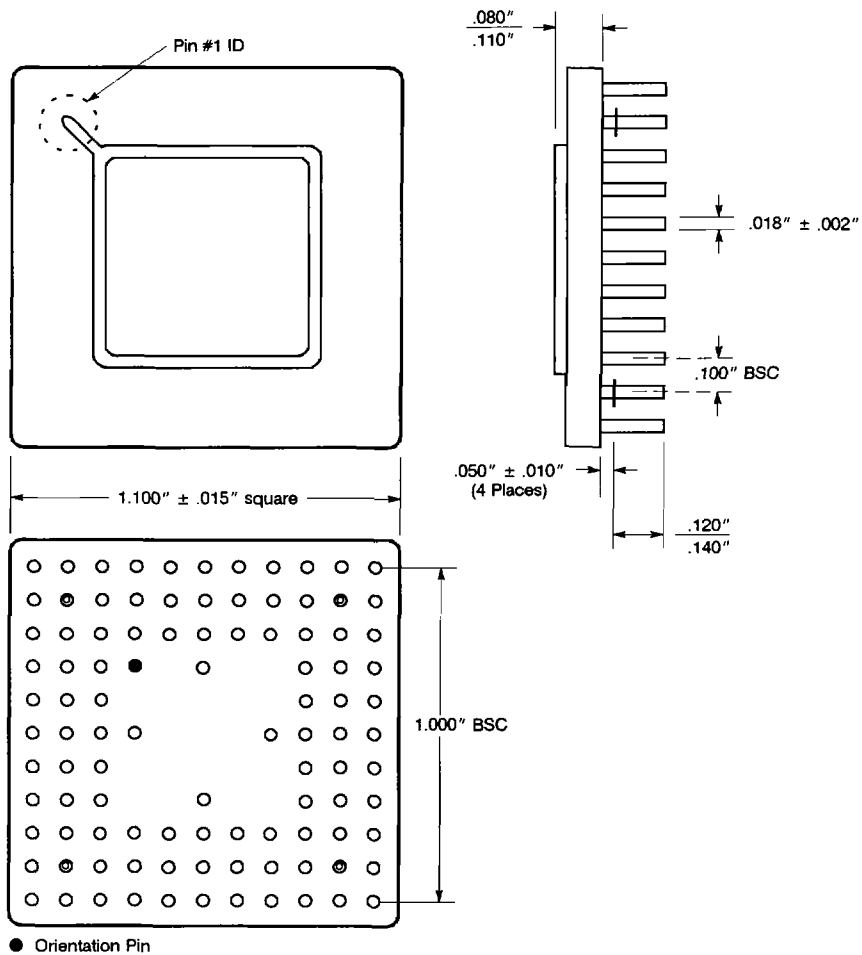


Package Mechanical Details: 132-Pin CPGA

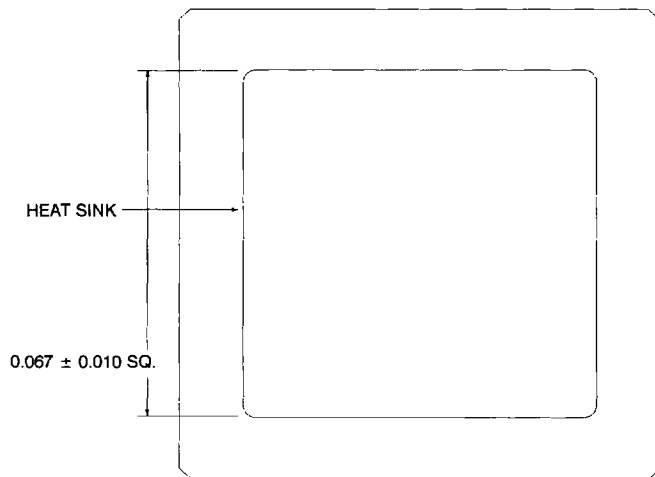
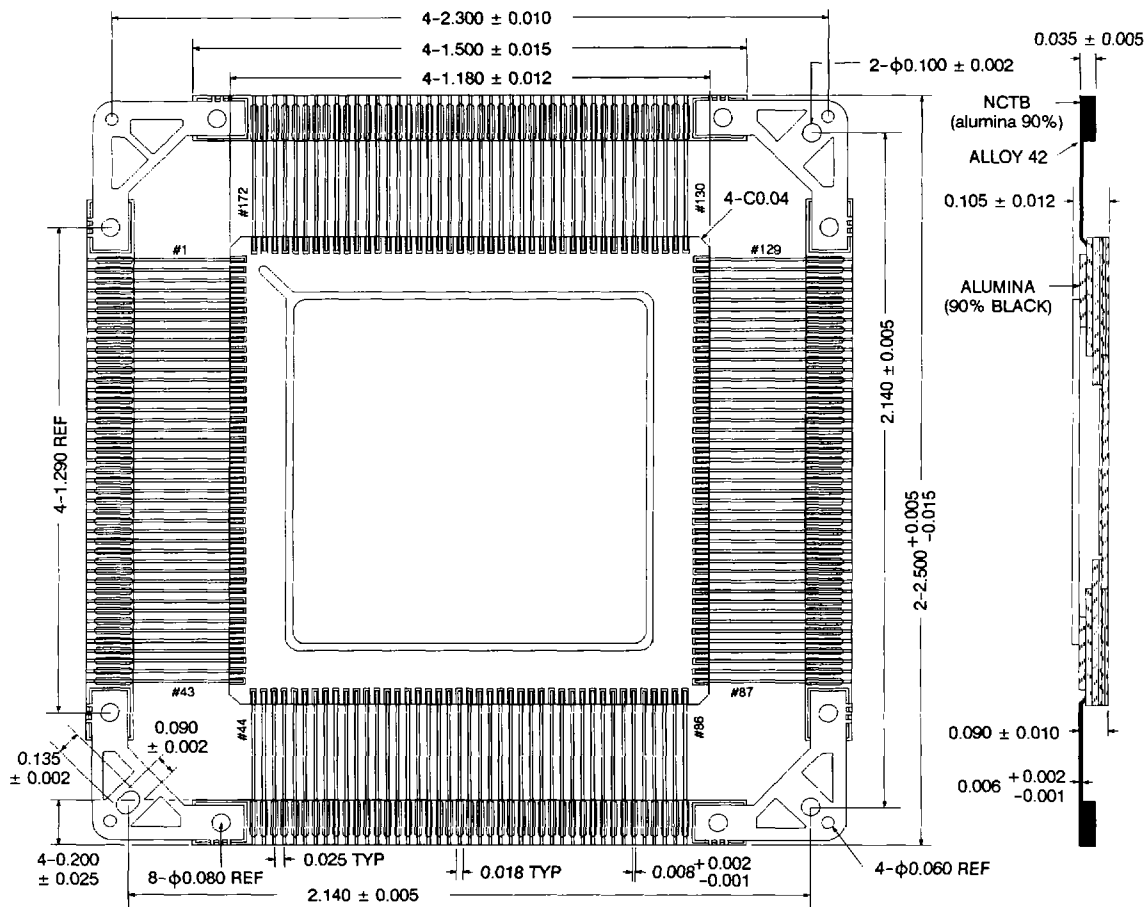


1

Package Mechanical Details: 100-Pin CPGA



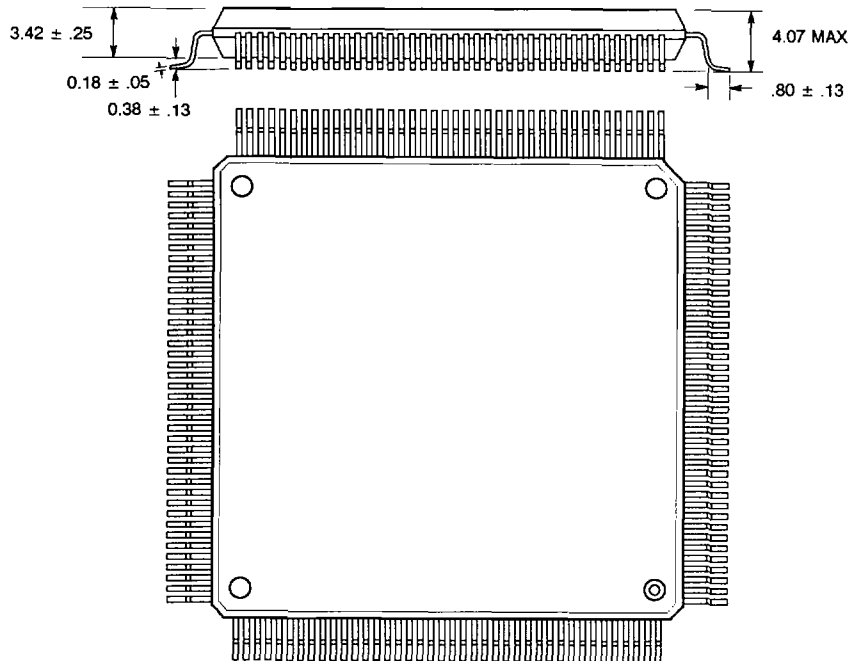
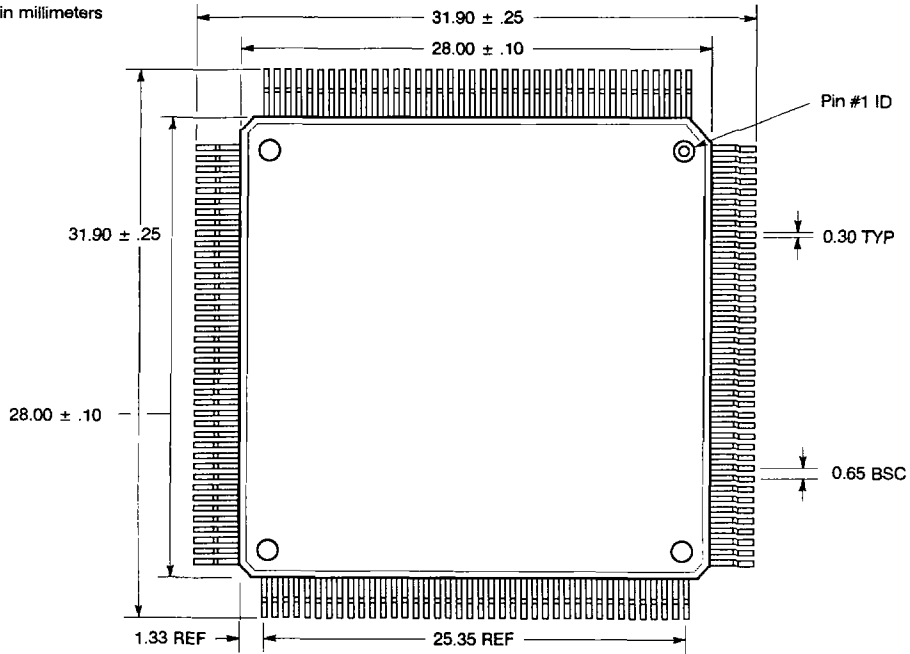
Package Mechanical Details: 172-Pin CQFP

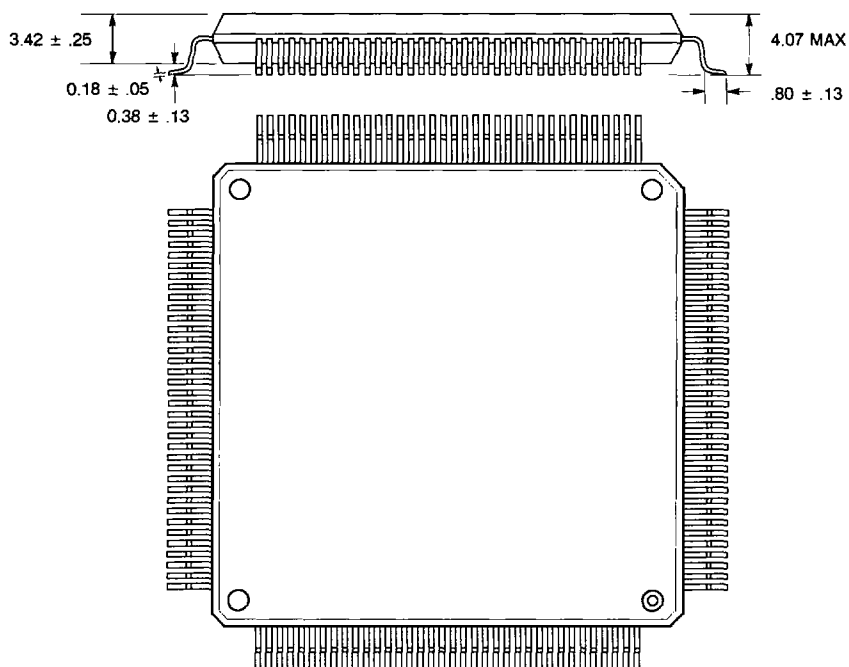
**Notes:**

1. All exposed metallized areas and leads are gold plated 100 microinches (2.5 μ m) min. thickness over 80 to 350 microinches 2.0 to 8.9 μ m thickness of nickel.
2. Seal ring area is connected to GNDa.
3. Die attach pad is connected to GNDa.
4. GNDQ (4 PLS) is connected to GNDa.
5. Tolerances unless otherwise specified: $\pm 1\%$ N.L.T. ± 0.005 .

Package Mechanical Details: 160-Pin PQFP

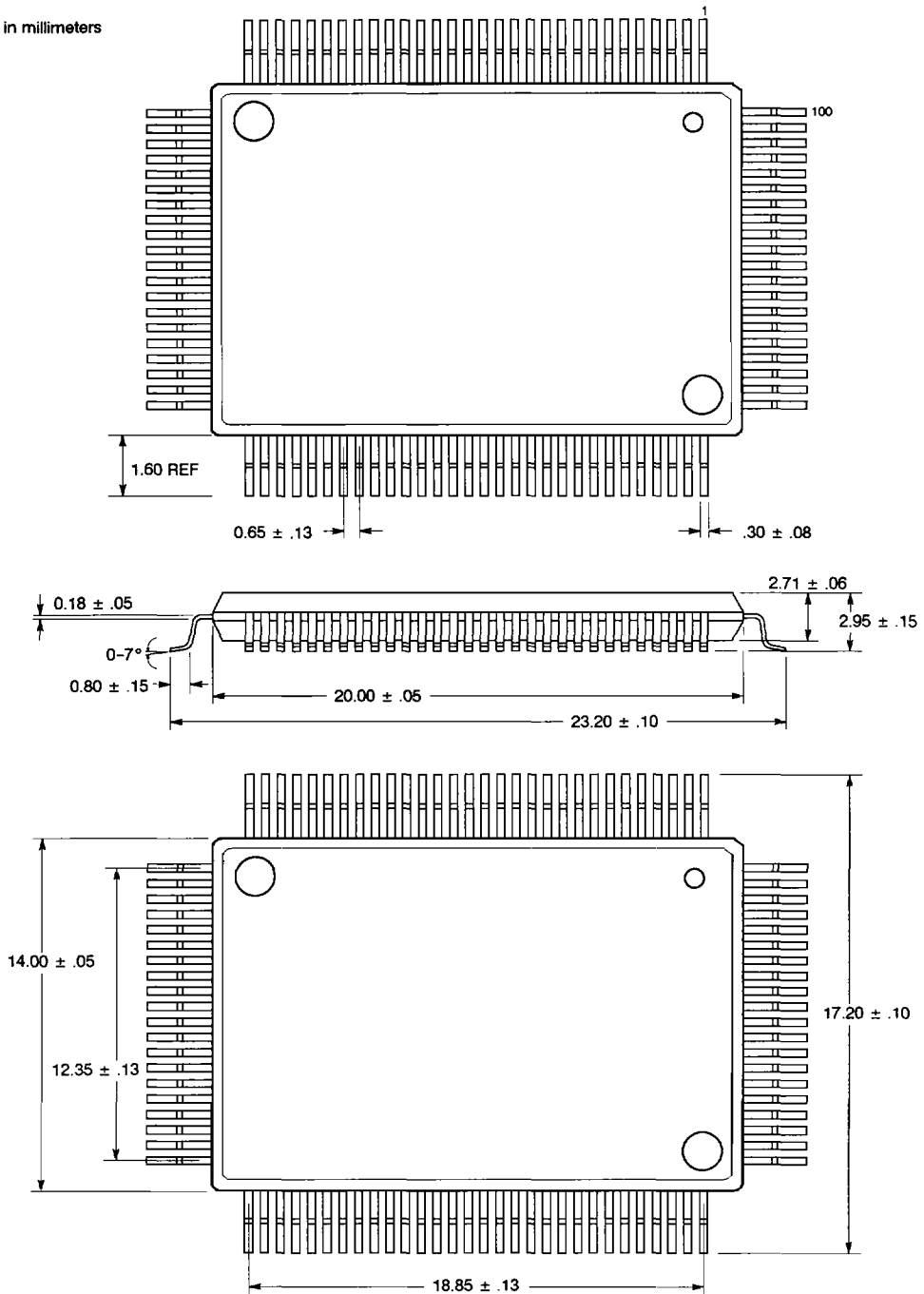
Dimensions in millimeters



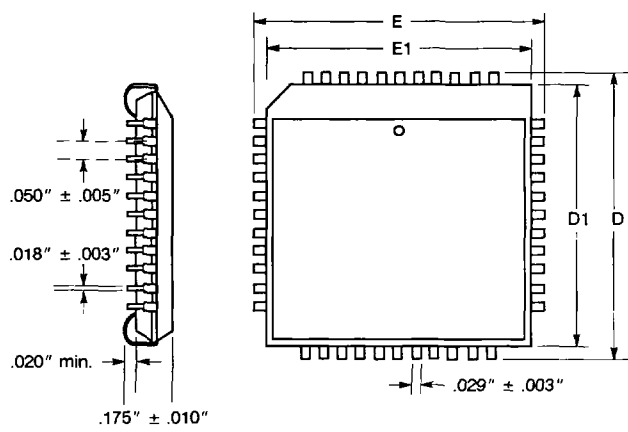


Package Mechanical Details: 100-Pin PQFP

Dimensions in millimeters



Package Mechanical Details: 84-Pin PLCC



Lead Count	D, E	D1, E1
44	$.690" \pm .005"$	$.655" \pm .005"$
68	$.990" \pm .005"$	$.955" \pm .005"$
84	$1.190" \pm .005"$	$1.155" \pm .005"$