



MACH465-12/15/20

High-Density EE CMOS Programmable Logic

DISTINCTIVE CHARACTERISTICS

- 208 pins in PQFP
- JTAG, 5-V, in-circuit programmable
- IEEE 1149.1 JTAG testing capability
- 256 macrocells
- 12 ns t_{PD}
- 83.3 MHz f_{CNT}
- 146 Inputs with pull-up resistors
- 128 Outputs
- 384 flip-flops
 - 256 Macrocell flip-flops
 - 128 Input flip-flops
- Up to 20 product terms per function, with XOR
- Flexible clocking
 - Four global clock pins with selectable edges
 - Asynchronous mode available for each macrocell
- 16 “PAL34V16” blocks
- Input and output switch matrices for high routability
- Fixed, predictable, deterministic delays
- Zero-hold-time input register option
- Peripheral Component Interconnect (PCI) compliant

GENERAL DESCRIPTION

The MACH465 is a member of AMD's high-performance EE CMOS MACH 4 family. This device has approximately 25 times the macrocell capability of the popular PAL22V10, with significant density and functional features that the PAL22V10 does not provide.

The MACH465 consists of 16 PAL blocks interconnected by a programmable central switch matrix. The central switch matrix connects the PAL blocks to each other and to all input pins, providing a high degree of connectivity between the fully-connected PAL blocks. This allows designs to be placed and routed efficiently. Routability is further enhanced by an input switch matrix and an output switch matrix. The input switch matrix provides input signals with alternative paths into the central switch matrix; the output switch matrix provides flexibility in assigning macrocells to I/O pins.

The MACH465 has macrocells that can be configured as synchronous or asynchronous. This allows designers to implement both synchronous and asynchronous logic

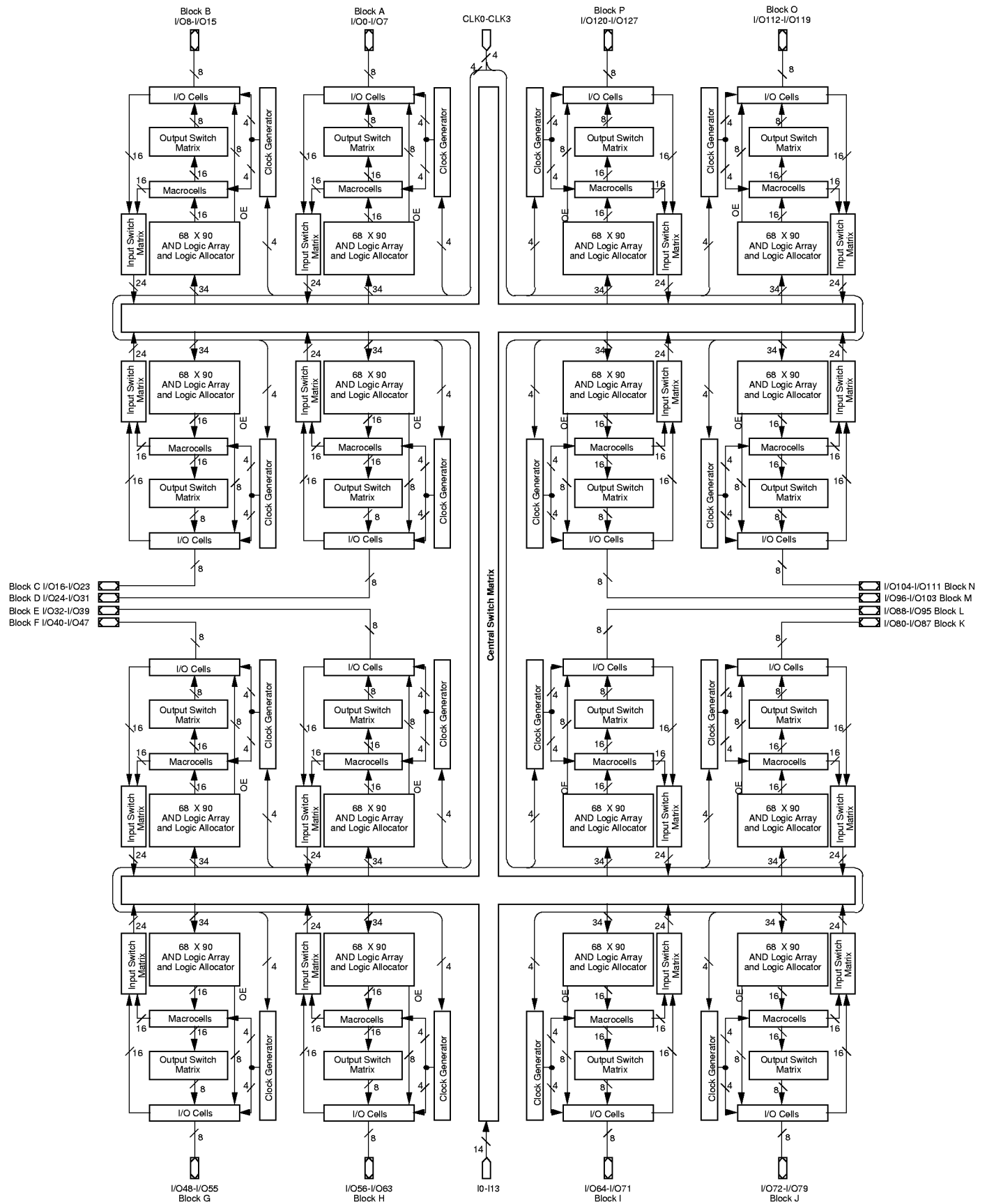
together on the same device. The two types of design can be mixed in any proportion, since the selection on each macrocell affects only that macrocell.

Up to 20 product terms per function can be assigned. It is possible to allocate some product terms away from a macrocell without losing the use of that macrocell for logic generation.

The MACH465 macrocell provides either registered or combinatorial outputs with programmable polarity. If a registered configuration is chosen, the register can be configured as D-type, T-type, J-K, or S-R to help reduce the number of product terms used. The flip-flop can also be configured as a latch. The register type decision can be made by the designer or by the software.

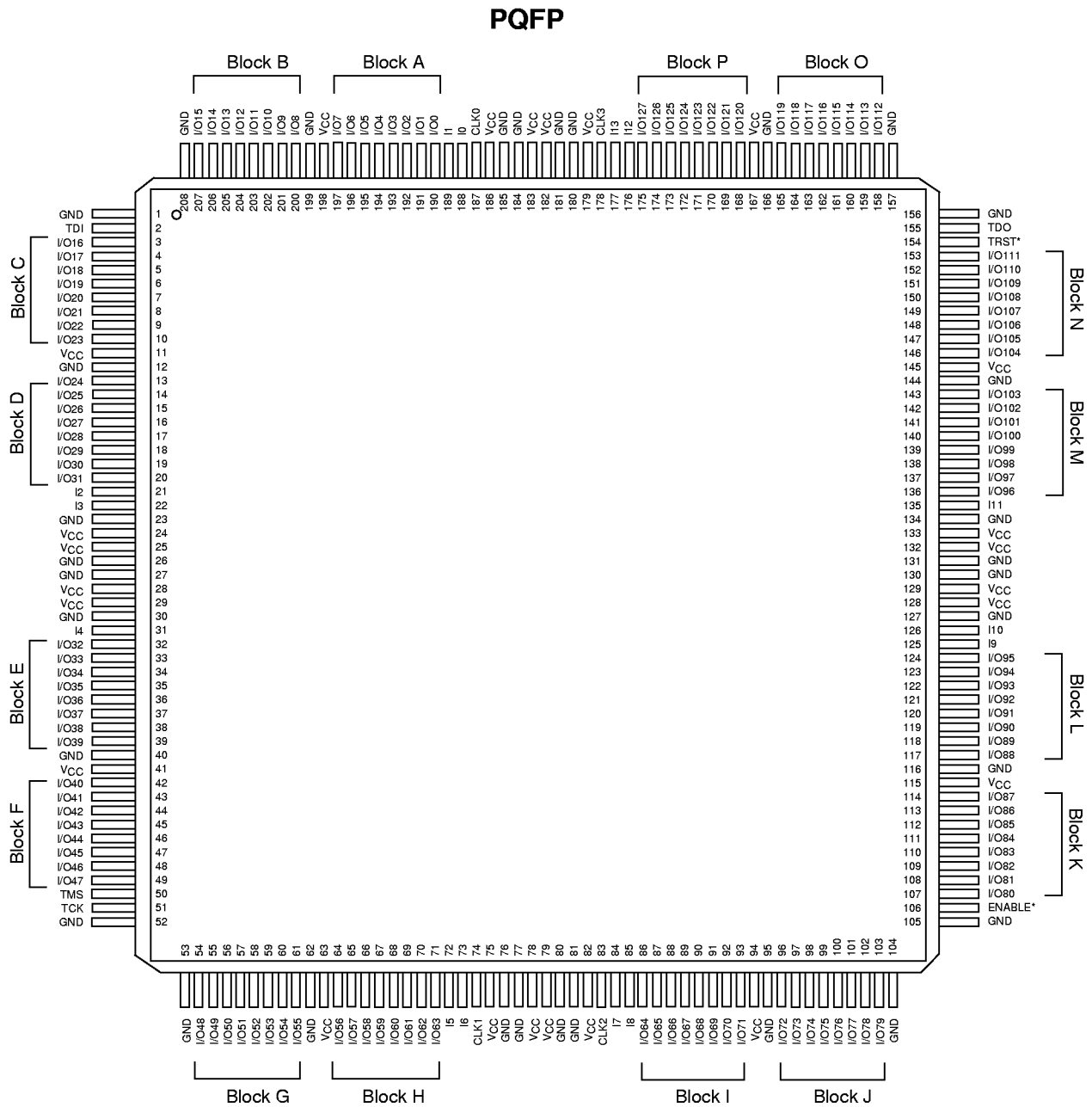
All macrocells can be connected to an I/O cell through the output switch matrix. The output switch matrix makes it possible to make significant design changes while minimizing the risk of pinout changes.

BLOCK DIAGRAM



CONNECTION DIAGRAM

Top View



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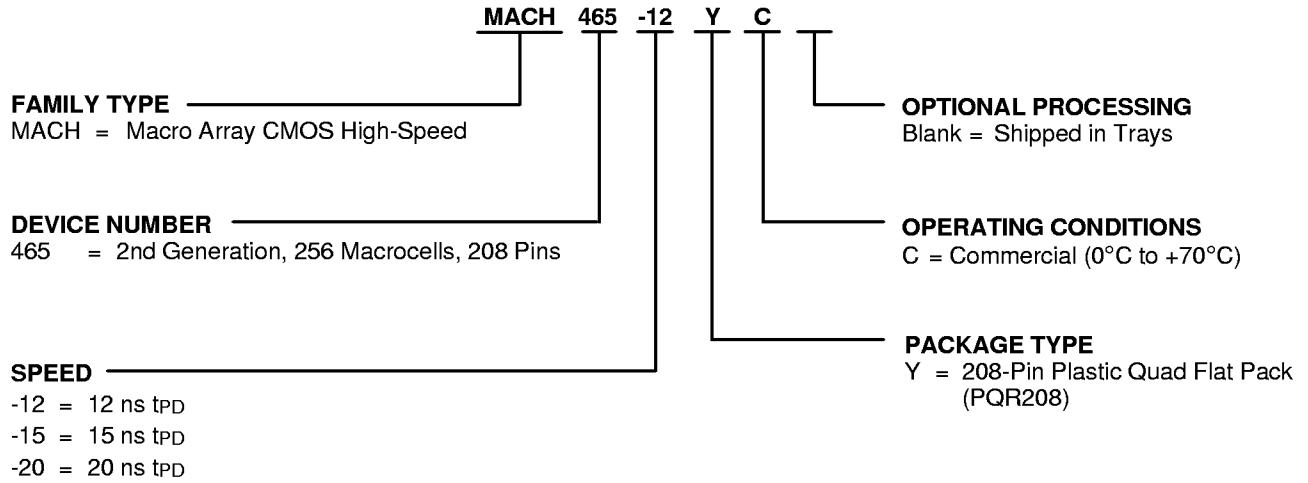
PIN DESIGNATIONS

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- V_{cc} = Supply Voltage

ORDERING INFORMATION

Commercial Products

AMD programmable logic products for commercial applications are available with several ordering options. The order number (Valid Combination) is formed by a combination of:



Valid Combinations	
MACH465-12	YC
MACH465-15	
MACH465-20	

Valid Combinations

The Valid Combinations table lists configurations planned to be supported in volume for this device. Consult the local AMD sales office to confirm availability of specific valid combinations and to check on newly released combinations.

FUNCTIONAL DESCRIPTION

The MACH465 consists of sixteen PAL blocks connected by a central switch matrix. There are 128 I/O pins and 14 dedicated input pins feeding the central switch matrix. These signals are distributed to the sixteen PAL blocks for efficient design implementation. There are also 4 global clock pins.

All inputs and I/O pins have built-in pull-up resistors. While it is always good design practice to tie unused pins high, the pull-up resistors provide design security and stability in the event that unused pins are left disconnected.

The PAL Blocks

Each PAL block in the MACH465 (Figure 1) contains a clock generator, a 90-product-term logic array, a logic allocator, 16 macrocells, an output switch matrix, 8 I/O cells, and an input switch matrix. The central switch matrix feeds each PAL block with 34 inputs. This makes the PAL block look effectively like an independent “PAL34V16”.

In addition to the logic product terms, individual output enable product terms and two PAL block initialization product term are provided. Each I/O pin can be individually enabled. All flip-flops that are in the synchronous mode within a PAL block are initialized together by either of the PAL block initialization product terms.

The Central Switch Matrix and Input Switch Matrix

The MACH465 central switch matrix is fed by the input switch matrices in each PAL block. Each PAL block provides 16 internal feedback signals, 8 registered input signals, and 8 I/O pin signals to the input switch matrix. Of these 32 signals, 24 decoded signals are provided to the central switch matrix by the input switch matrix. The central switch matrix distributes these signals back to the PAL blocks in a very efficient manner that provides for high performance. The design software automatically configures the input and central switch matrices when fitting a design into the device.

The Clock Generator

Each PAL block has a clock generator that can generate four clock signals for use throughout the PAL block.

These four signals are available to all macrocells and I/O cells in the PAL block, whether in synchronous or asynchronous mode. The clock generator chooses the four signals from the eight possible signals given by the true and complement versions of the four global clock pin signals.

The Product-Term Array

The MACH465 product-term array consists of 80 product terms for logic use, eight product terms for output enable use, and two product terms for global PAL block initialization. Each macrocell has a nominal allocation of 5 product terms for logic, although the logic allocator allows for logic redistribution. Each I/O pin has its own individual output enable term. The initialization product terms provide asynchronous reset or preset to synchronous-mode macrocells in the PAL block.

The Logic Allocator

The logic allocator in the MACH465 takes the 80 logic product terms and allocates them to the 16 macrocells as needed. Each macrocell can be driven by up to 20 product terms if in synchronous mode, or 18 product terms if in asynchronous mode. When product terms are routed away from a macrocell, it is possible to route all 5 product terms away, which precludes the use of the macrocell for logic generation; or it is possible to route only 4 product terms away, leaving one for simple function generation. The design software automatically configures the logic allocator when fitting the design into the device.

The logic allocator also provides an exclusive-OR gate. This gate allows generation of combinatorial exclusive-OR logic, such as comparison or addition. It allows registered exclusive-OR functions, such as CRC generation, to be implemented more efficiently. It also makes it possible to emulate all flip-flop types with a D-type flip-flop. Register type emulation is automatically handled by the design software.

Table 1 illustrates which product term clusters are available to each macrocell within a PAL block. Refer to Figure 1 for cluster and macrocell numbers.

Table 1. Logic Allocation

Macrocell	Available Clusters
M0	C0, C1, C2
M1	C0, C1, C2, C3
M2	C1, C2, C3, C4
M3	C2, C3, C4, C5
M4	C3, C4, C5, C6
M5	C4, C5, C6, C7
M6	C5, C6, C7, C8
M7	C6, C7, C8, C9
M8	C7, C8, C9, C10
M9	C8, C9, C10, C11
M10	C9, C10, C11, C12
M11	C10, C11, C12, C13
M12	C11, C12, C13, C14
M13	C12, C13, C14, C15
M14	C13, C14, C15
M15	C14, C15

The Macrocell and Output Switch Matrix

The MACH465 has 16 macrocells, half of which can drive I/O pins; this selection is made by the output switch matrix. Each macrocell can drive one of four I/O cells. The allowed combinations are shown in Table 2. Please refer to Figure 1 for macrocell and I/O pin numbers.

Table 2. Output Switch Matrix Combinations

Macrocell	Routeable to I/O Pins
M0, M1	I/O5, I/O6, I/O7, I/O0
M2, M3	I/O6, I/O7, I/O0, I/O1
M4, M5	I/O7, I/O0, I/O1, I/O2
M6, M7	I/O0, I/O1, I/O2, I/O3
M8, M9	I/O1, I/O2, I/O3, I/O4
M10, M11	I/O2, I/O3, I/O4, I/O5
M12, M13	I/O3, I/O4, I/O5, I/O6
M14, M15	I/O4, I/O5, I/O6, I/O7
I/O Pin	Available Macrocells
I/O0	M0, M1, M2, M3, M4, M5, M6, M7
I/O1	M2, M3, M4, M5, M6, M7, M8, M9
I/O2	M4, M5, M6, M7, M8, M9, M10, M11
I/O3	M6, M7, M8, M9, M10, M11, M12, M13
I/O4	M8, M9, M10, M11, M12, M13, M14, M15
I/O5	M10, M11, M12, M13, M14, M15, M0, M1
I/O6	M12, M13, M14, M15, M0, M1, M2, M3
I/O7	M14, M15, M0, M1, M2, M3, M4, M5

The macrocells can be configured as registered, latched, or combinatorial. In combination with the logic allocator, the registered configuration can be any of the standard flip-flop types. The macrocell provides internal feedback whether configured with or without the flip-flop, and whether or not the macrocell drives an I/O cell.

The flip-flop clock depends on the mode selected for the macrocell. In synchronous mode, any of the PAL block clocks generated by the Clock Generator can be used. In asynchronous mode, the additional choice of either edge of an individual product-term clock is available.

Initialization can be handled as part of a bank of macrocells via the PAL block initialization terms if in synchronous mode, or individually if in asynchronous mode. In synchronous mode, one of the PAL block product terms is available each for preset and reset. The swap function determines which product term drives which function. This allows initialization polarity compatibility with the MACH 1 and 2 series. In asynchronous mode, one product term can be used either to drive reset or preset.

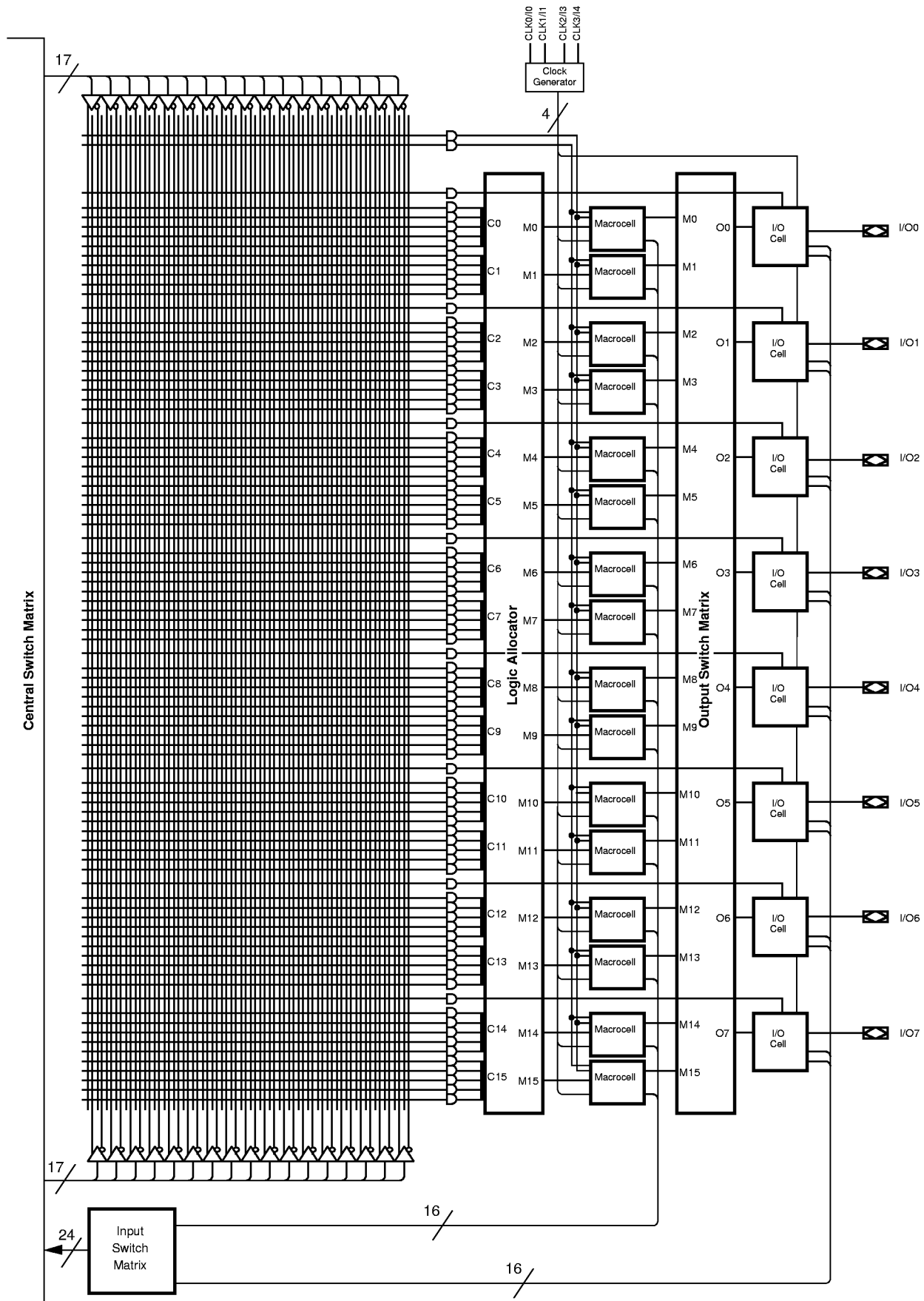
The I/O Cell

The I/O cell in the MACH465 consists of a three-state buffer and an input flip-flop. The I/O cell is driven by one of the macrocells, as selected by the output switch matrix. Each I/O cell can take its input from one of eight macrocells. The three-state buffer is controlled by an individual product term. The direct I/O signal is available to the input switch matrix, and can be used if desired.

JTAG Testing

JTAG is the commonly used acronym for the IEEE Standard 1149.1–1990. The JTAG standard defines and output pins, logic control functions, and instructions. AMD has incorporated this standard into the MACH465 device.

The JTAG standard was developed as a means of providing both board-level and device-level testing. Details on this feature can be found in the application note titled, *Introduction to JTAG and Five-Volt Programming with MACH 3 and 4 Devices*, at the end of this data book.



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Figure 1. MACH465 PAL Block

Five-Volt Programming

Another benefit from the JTAG circuitry that AMD has derived is the ability to use the JTAG port for five-volt programming. This allows the device to be soldered to the board before programming. Once the device is attached, the delicate Plastic Quad Flat Pack, or PQFP, leads are protected from programming and testing operations that could potentially damage them. Programming and verification of the device is done serially which is ideal for on-board programming since it only requires the use of the Test Access Port, along with the additional ENABLE* pin. Programming can also be done in any JTAG chain.

Details on this feature can also be found in the *Introduction to JTAG and Five-Volt Programming with MACH 3 and 4 Devices* application note, at the end of this data book.

Zero-Hold-Time Input Register

The MACH465 device has a zero-hold time (ZHT) fuse. This fuse controls the time delay associated with loading data into all I/O cell registers and latches in the MACH465 device.

When programmed, the ZHT fuse increases the data path setup delays to input storage elements, matching equivalent delays in the clock path. When the fuse is erased, the setup time to the input storage element is minimized.

This feature facilitates doing worst-case designs for which data is loaded from sources which have low (or zero) minimum output propagation delays from clock edges.

ABSOLUTE MAXIMUM RATINGS

Storage Temperature	−65°C to +150°C
Ambient Temperature with Power Applied	−55°C to +125°C
Supply Voltage with Respect to Ground	−0.5 V to +7.0 V
DC Input Voltage	−0.5 V to $V_{CC} + 0.5$ V
DC Output or I/O Pin Voltage	−0.5 V to $V_{CC} + 0.5$ V
Static Discharge Voltage	2001 V
Latchup Current ($T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$)	200 mA

OPERATING RANGES

Commercial (C) Devices

Temperature (T_A) Operating in Free Air	0°C to +70°C
Supply Voltage (V_{CC}) with Respect to Ground	+4.75 V to +5.25 V

Operating ranges define those limits between which the functionality of the device is guaranteed.

Stresses above those listed under Absolute Maximum Ratings may cause permanent device failure. Functionality at or above these limits is not implied. Exposure to Absolute Maximum Ratings for extended periods may affect device reliability. Programming conditions may differ.

DC CHARACTERISTICS over COMMERCIAL operating ranges unless otherwise specified

Parameter Symbol	Parameter Description	Test Conditions	Min	Typ	Max	Unit
V_{OH}	Output HIGH Voltage	$I_{OH} = -3.2$ mA, $V_{CC} = \text{Min}$ $V_{IN} = V_{IH}$ or V_{IL}	2.4			V
V_{OL}	Output LOW Voltage	$I_{OL} = 24$ mA, $V_{CC} = \text{Min}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 1)			0.5	V
V_{IH}	Input HIGH Voltage	Guaranteed Input Logical HIGH Voltage for all Inputs (Note 2)	2.0			V
V_{IL}	Input LOW Voltage	Guaranteed Input Logical LOW Voltage for all Inputs (Note 2)			0.8	V
I_{IH}	Input HIGH Leakage Current	$V_{IN} = 5.25$ V, $V_{CC} = \text{Max}$ (Note 3)			10	μA
I_{IL}	Input LOW Leakage Current	$V_{IN} = 0$ V, $V_{CC} = \text{Max}$ (Note 3)			−100	μA
I_{OZH}	Off-State Output Leakage Current HIGH	$V_{OUT} = 5.25$ V, $V_{CC} = \text{Max}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 3)			−100	μA
I_{OZL}	Off-State Output Leakage Current LOW	$V_{OUT} = 0$ V, $V_{CC} = \text{Max}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 3)			10	μA
I_{SC}	Output Short-Circuit Current	$V_{OUT} = 0.5$ V, $V_{CC} = \text{Max}$ (Note 4)	−30		−160	mA
I_{CC}	Supply Current	$V_{IN} = 0$ V, Outputs Open ($I_{OUT} = 0$ mA), $V_{CC} = 5.0$ V, $f = 25$ MHz $T_A = 25^\circ\text{C}$ (Note 5)		285		mA

CAPACITANCE (Note 6)

Parameter Symbol	Parameter Description	Test Conditions		Typ	Unit
C_{IN}	Input Capacitance	$V_{IN} = 2.0$ V	$V_{CC} = 5.0$ V, $T_A = 25^\circ\text{C}$, $f = 1$ MHz	6	pF
C_{OUT}	Output Capacitance	$V_{OUT} = 2.0$ V		8	pF

Notes:

1. Total I_{OL} for one PAL block should not exceed 128 mA.
2. These are absolute values with respect to device ground and all overshoots due to system or tester noise are included.
3. I/O pin leakage is the worst case of I_{IL} and I_{OZL} (or I_{IH} and I_{OZH}).
4. Not more than one output should be shorted at a time and duration of the short-circuit should not exceed one second. $V_{OUT} = 0.5$ V has been chosen to avoid test problems caused by tester ground degradation.
5. Measured with a 16-bit up/down counter pattern. This pattern is programmed in each PAL block and capable of being loaded, enabled, and reset.
6. These parameters are not 100% tested, but are evaluated at initial characterization and at any time the design is modified where capacitance may be affected.

SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 1)

Parameter Symbol	Parameter Description		-12		Unit
			Min	Max	
t _{PD}	Input, I/O, or Feedback to Combinatorial Output		3	12	ns
t _{SA}		D-type	5		ns
		T-type	6		ns
t _{HA}	Register Data Hold Time Using Product Term Clock		5		ns
t _{COA}	Product Term Clock to Output		4	14	ns
t _{WLA}	Product Term, Clock Width	LOW	8		ns
t _{WHA}		HIGH	8		ns
f _{MAXA}	Maximum Frequency Using Product Term Clock (Note 2)	External Feedback	D-type	52.6	MHz
			T-type	50.0	MHz
		Internal Feedback (f _{CNTA})	D-type	58.8	MHz
			T-type	55.6	MHz
No Feedback (Note 3)			62.5	MHz	
t _{SS}		D-type	7		ns
		T-type	8		ns
t _{HS}	Register Data Hold Time Using Global Clock		0		ns
t _{COS}	Global Clock to Output		2	8	ns
t _{WLS}	Global Clock Width	LOW	6		ns
t _{WHS}		HIGH	6		ns
f _{MAXS}	Maximum Frequency Using Global Clock (Note 2)	External Feedback	D-type	66.7	MHz
			T-type	62.5	MHz
		Internal Feedback (f _{CNTA})	D-type	83.3	MHz
			T-type	76.9	MHz
No Feedback (Note 3)			83.3	MHz	
t _{SLA}	Setup Time from Input, I/O, or Feedback to Product Term Clock		5		ns
t _{HLA}	Latch Data Hold Time Using Product Term Clock		5		ns
t _{GOA}	Product Term Gate to Output			16	ns
t _{GWA}	Product Term Gate Width LOW (for LOW transparent) or HIGH (for HIGH transparent)		6		ns
t _{SLS}	Setup Time from Input, I/O, or Feedback to Global Gate		8		ns
t _{HLS}	Latch Data Hold Time Using Global Gate		0		ns
t _{GOS}	Gate to Output			10	ns
t _{GWS}	Global Gate Width LOW (for LOW transparent) or HIGH (for HIGH transparent)		6		ns
t _{ICO}	Input Register Clock to Combinatorial Output			18	ns

SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 1) (continued)

Parameter Symbol	Parameter Description	-12		Unit
		Min	Max	
t _{ICS}	Input Register Clock to Output Register Setup	D-type	9	ns
		T-type	10	ns
t _{WICL}	Input Register Clock Width	LOW	6	ns
t _{WICH}		HIGH	6	ns
f _{MAXIR}	Maximum Input Register Frequency	1/(t _{WICL} + t _{WICH})		MHz
t _{IGO}	Input Latch Gate to Combinatorial Output		16	ns
t _{IGOL}	Input Latch Gate to Output Through Transparent Output Latch		18	ns
t _{IGSA}	Input Latch Gate to Output Latch Setup Using Product Term Output Latch Gate	4		ns
t _{IGSS}	Input Latch Gate to Output Latch Setup Using Global Output Latch Gate	9		ns
t _{WIGL}	Input Latch Gate Width LOW	6		ns
t _{AR}	Asynchronous Reset to Registered or Latched Output		16	ns
t _{ARW}	Asynchronous Reset Width (Note 2)	12		ns
t _{ARR}	Asynchronous Reset Recovery Time (Note 2)	10		ns
t _{AP}	Asynchronous Preset to Registered or Latched Output		16	ns
t _{APW}	Asynchronous Preset Width (Note 2)	12		ns
t _{APR}	Asynchronous Preset Recovery Time (Note 2)	8		ns
t _{EA}	Input, I/O, or Feedback to Output Enable	2	12	ns
t _{ER}	Input, I/O, or Feedback to Output Disable	2	12	ns
Input Register with Standard-Hold-Time Option				
t _{PDL}	Input, I/O, or Feedback to Output Through Transparent Input Latch		14	ns
t _{SIR}	Input Register Setup Time	2		ns
t _{HIR}	Input Register Hold Time	3		ns
t _{SIL}	Input Latch Setup Time	2		ns
t _{HIL}	Input Latch Hold Time	3		ns
t _{SLLA}	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Product Term Output Gate	4		ns
t _{SLLS}	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Output Gate	9		ns
t _{PDLL}	Input, I/O, or Feedback to Output Through Transparent Input and Output Latches		16	ns

**SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 1)
(continued)**

Parameter Symbol	Parameter Description	-12		Unit
		Min	Max	
Input Register with Zero-Hold-Time Option				
t_{PDL}^1	Input, I/O, or Feedback to Output Through Transparent Input Latch		20	ns
t_{SIR}^1	Input Register Setup Time	6		ns
t_{HIR}^1	Input Register Hold Time	0		ns
t_{SIL}^1	Input Latch Setup Time	6		ns
t_{HIL}^1	Input Latch Hold Time	0		ns
t_{SLLA}^1	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Product Term Output Gate	16		ns
t_{SLLS}^1	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Output Gate	18		ns
t_{PDLL}^1	Input, I/O, or Feedback to Output Through Transparent Input and Output Latches		22	ns

Notes:

1. See Switching Test Circuit in the back of this Data Book for test conditions.
2. These parameters are not 100% tested, but are evaluated at initial characterization and at any time the design is modified where frequency may be affected.
3. This parameter does not apply to flip-flops in the emulated mode since the feedback path is required for emulation.

ABSOLUTE MAXIMUM RATINGS

Storage Temperature	−65°C to +150°C
Ambient Temperature with Power Applied	−55°C to +125°C
Supply Voltage with Respect to Ground	−0.5 V to +7.0 V
DC Input Voltage	−0.5 V to $V_{CC} + 0.5$ V
DC Output or I/O Pin Voltage	−0.5 V to $V_{CC} + 0.5$ V
Static Discharge Voltage	2001 V
Latchup Current ($T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$)	200 mA

OPERATING RANGES

Commercial (C) Devices

Temperature (T_A) Operating in Free Air	0°C to +70°C
Supply Voltage (V_{CC}) with Respect to Ground	+4.75 V to +5.25 V

Operating ranges define those limits between which the functionality of the device is guaranteed.

Stresses above those listed under Absolute Maximum Ratings may cause permanent device failure. Functionality at or above these limits is not implied. Exposure to Absolute Maximum Ratings for extended periods may affect device reliability. Programming conditions may differ.

DC CHARACTERISTICS over COMMERCIAL operating ranges unless otherwise specified

Parameter Symbol	Parameter Description	Test Conditions	Min	Typ	Max	Unit
V_{OH}	Output HIGH Voltage	$I_{OH} = -3.2$ mA, $V_{CC} = \text{Min}$ $V_{IN} = V_{IH}$ or V_{IL}	2.4			V
V_{OL}	Output LOW Voltage	$I_{OL} = 24$ mA, $V_{CC} = \text{Min}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 1)			0.5	V
V_{IH}	Input HIGH Voltage	Guaranteed Input Logical HIGH Voltage for all Inputs (Note 2)	2.0			V
V_{IL}	Input LOW Voltage	Guaranteed Input Logical LOW Voltage for all Inputs (Note 2)			0.8	V
I_{IH}	Input HIGH Leakage Current	$V_{IN} = 5.25$ V, $V_{CC} = \text{Max}$ (Note 3)			10	μA
I_{IL}	Input LOW Leakage Current	$V_{IN} = 0$ V, $V_{CC} = \text{Max}$ (Note 3)			−100	μA
I_{OZH}	Off-State Output Leakage Current HIGH	$V_{OUT} = 5.25$ V, $V_{CC} = \text{Max}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 3)			−100	μA
I_{OZL}	Off-State Output Leakage Current LOW	$V_{OUT} = 0$ V, $V_{CC} = \text{Max}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 3)			10	μA
I_{SC}	Output Short-Circuit Current	$V_{OUT} = 0.5$ V, $V_{CC} = \text{Max}$ (Note 4)	−30		−160	mA
I_{CC}	Supply Current	$V_{IN} = 0$ V, Outputs Open ($I_{OUT} = 0$ mA), $V_{CC} = 5.0$ V, $f = 25$ MHz $T_A = 25^\circ\text{C}$ (Note 5)		285		mA

CAPACITANCE (Note 6)

Parameter Symbol	Parameter Description	Test Conditions		Typ	Unit
C_{IN}	Input Capacitance	$V_{IN} = 2.0$ V	$V_{CC} = 5.0$ V, $T_A = 25^\circ\text{C}$, $f = 1$ MHz	6	pF
C_{OUT}	Output Capacitance	$V_{OUT} = 2.0$ V		8	pF

Notes:

- Total I_{OL} for one PAL block should not exceed 128 mA.
- These are absolute values with respect to device ground and all overshoots due to system or tester noise are included.
- I/O pin leakage is the worst case of I_{IL} and I_{OZL} (or I_{IH} and I_{OZH}).
- Not more than one output should be shorted at a time and duration of the short-circuit should not exceed one second. $V_{OUT} = 0.5$ V has been chosen to avoid test problems caused by tester ground degradation.
- Measured with a 16-bit up/down counter pattern. This pattern is programmed in each PAL block and capable of being loaded, enabled, and reset.
- These parameters are not 100% tested, but are evaluated at initial characterization and at any time the design is modified where capacitance may be affected.

SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 1)

Parameter Symbol	Parameter Description		-15		-20		Unit	
			Min	Max	Min	Max		
t _{PD}	Input, I/O, or Feedback to Combinatorial Output (Note 2)		3	15	3	20	ns	
t _{SA}	Setup Time from Input, I/O, or Feedback to Product Term Clock	D-type	8		10		ns	
		T-type	9		11		ns	
t _{HA}	Register Data Hold Time Using Product Term Clock		8		10		ns	
t _{COA}	Product Term Clock to Output (Note 2)		4	18	4	22	ns	
t _{WLA}	Product Term, Clock Width		LOW	9		12	ns	
t _{WHA}			HIGH	9		12	ns	
f _{MAXA}	Maximum Frequency Using Product Term Clock (Note 3)	External Feedback	1/(t _{SA} + t _{COA})	D-type	38.5		31.2	MHz
			T-type	37		30.3	MHz	
		Internal Feedback (f _{CNTA})	D-type	47.6		37	MHz	
			T-type	45.4		35.7	MHz	
No Feedback (Note 4)	1/(t _{WLA} + t _{WHA})	55.6		41.7	MHz			
t _{SS}	Setup Time from Input, I/O, or Feedback to Global Clock	D-type	10		13		ns	
		T-type	11		14		ns	
t _{HS}	Register Data Hold Time Using Global Clock		0		0		ns	
t _{COS}	Global Clock to Output (Note 2)		2	10	2	12	ns	
t _{WLS}	Global Clock Width		LOW	6		8	ns	
t _{WHS}			HIGH	6		8	ns	
f _{MAXS}	Maximum Frequency Using Global Clock (Note 3)	External Feedback	1/(t _{SS} + t _{COS})	D-type	50		40	MHz
			T-type	47.6		38.5	MHz	
		Internal Feedback (f _{CNTS})	D-type	66.6		50	MHz	
			T-type	62.5		47.6	MHz	
No Feedback (Note 4)	1/(t _{WLS} + t _{WHS})	83.3		62.5	MHz			
t _{SLA}	Setup Time from Input, I/O, or Feedback to Product Term Clock		8		10		ns	
t _{HLA}	Latch Data Hold Time Using Product Term Clock		8		10		ns	
t _{GOA}	Product Term Gate to Output (Note 2)			19		22	ns	
t _{GWA}	Product Term Gate Width LOW (for LOW transparent) or HIGH (for HIGH transparent)		9		12		ns	
t _{SLS}	Setup Time from Input, I/O, or Feedback to Global Gate		10		13		ns	
t _{HLS}	Latch Data Hold Time Using Global Gate		0		0		ns	
t _{GOS}	Gate to Output (Note 2)			11		12	ns	
t _{GWS}	Global Gate Width LOW (for LOW transparent) or HIGH (for HIGH transparent)		6		8		ns	
t _{ICO}	Input Register Clock to Combinatorial Output			20		25	ns	

SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 1) (continued)

Parameter Symbol	Parameter Description		-15		-20		Unit
			Min	Max	Min	Max	
t _{ICS}	Input Register Clock to Output Register Setup		D-type	15		20	ns
			T-type	16		21	ns
t _{WICL}	Input Register Clock Width		LOW	6		8	ns
t _{WICH}			HIGH	6		8	ns
f _{MAXIR}	Maximum Input Register Frequency	1/(t _{WICL} + t _{WICH})	83.3		62.5		MHz
t _{IGO}	Input Latch Gate to Combinatorial Output			20		25	ns
t _{IGOL}	Input Latch Gate to Output Through Transparent Output Latch			22		27	ns
t _{IGSA}	Input Latch Gate to Output Latch Setup Using Product Term Output Latch Gate		14		19		ns
t _{IGSS}	Input Latch Gate to Output Latch Setup Using Global Output Latch Gate		16		21		ns
t _{WIGL}	Input Latch Gate Width LOW		6		8		ns
t _{AR}	Asynchronous Reset to Registered or Latched Output			20		25	ns
t _{ARW}	Asynchronous Reset Width (Note 3)		15		20		ns
t _{ARR}	Asynchronous Reset Recovery Time (Note 3)		15		20		ns
t _{AP}	Asynchronous Preset to Registered or Latched Output			20		25	ns
t _{APW}	Asynchronous Preset Width (Note 3)		15		20		ns
t _{APR}	Asynchronous Preset Recovery Time (Note 3)		15		20		ns
t _{EA}	Input, I/O, or Feedback to Output Enable (Note 2)		2	15	2	20	ns
t _{ER}	Input, I/O, or Feedback to Output Disable (Note 2)		2	15	2	20	ns
Input Register with Standard-Hold-Time Option							
t _{PDL}	Input, I/O, or Feedback to Output Through Transparent Input Latch			17		22	ns
t _{SIR}	Input Register Setup Time		2		2		ns
t _{HIR}	Input Register Hold Time		4		5		ns
t _{SIL}	Input Latch Setup Time		2		2		ns
t _{HIL}	Input Latch Hold Time		4		5		ns
t _{SLLA}	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Product Term Output Gate		10		12		ns
t _{SLLS}	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Output Gate		12		16		ns
t _{PDLL}	Input, I/O, or Feedback to Output Through Transparent Input and Output Latches			19		24	ns

SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 1) (continued)

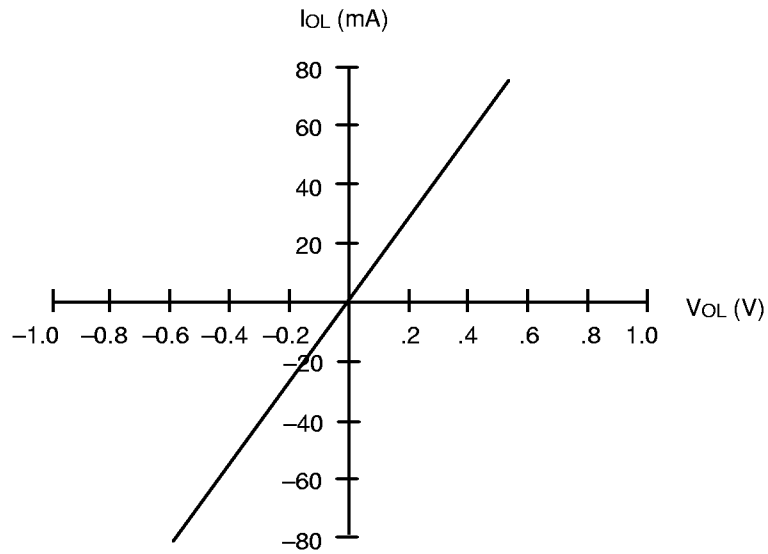
Parameter Symbol	Parameter Description	-15		-20		Unit
		Min	Max	Min	Max	
Input Register with Zero-Hold-Time Option						
t_{PDL}^1	Input, I/O, or Feedback to Output Through Transparent Input Latch		23		30	ns
t_{SIR}^1	Input Register Setup Time	6		8		ns
t_{HIR}^1	Input Register Hold Time	0		0		ns
t_{SIL}^1	Input Latch Setup Time	6		8		ns
t_{HIL}^1	Input Latch Hold Time	0		0		ns
t_{SLLA}^1	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Product Term Output Gate	16		20		ns
t_{SLLS}^1	Setup Time from Input, I/O, or Feedback Through Transparent Input Latch to Output Gate	18		24		ns
t_{PDLL}^1	Input, I/O, or Feedback to Output Through Transparent Input and Output Latches		25		32	ns

Notes:

1. See Switching Test Circuit at the end of this Data Book for test conditions.
2. Parameters measured with 32 outputs switching.
3. These parameters are not 100% tested, but are evaluated at initial characterization and at any time the design is modified where frequency may be affected.
4. This parameter does not apply to flip-flops in the emulated mode since the feedback path is required for emulation.

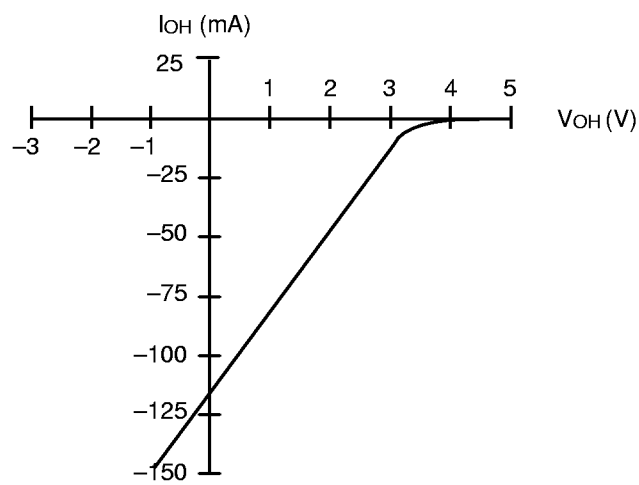
TYPICAL CURRENT VS. VOLTAGE (I-V) CHARACTERISTICS

$V_{CC} = 5.0\text{ V}$, $T_A = 25^\circ\text{C}$



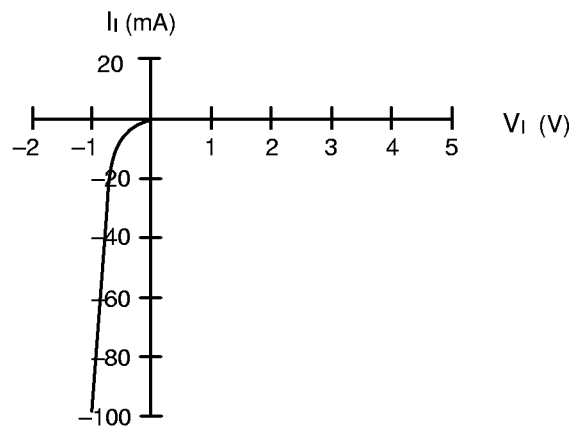
Output, LOW

17470D-4



Output, HIGH

17470D-5

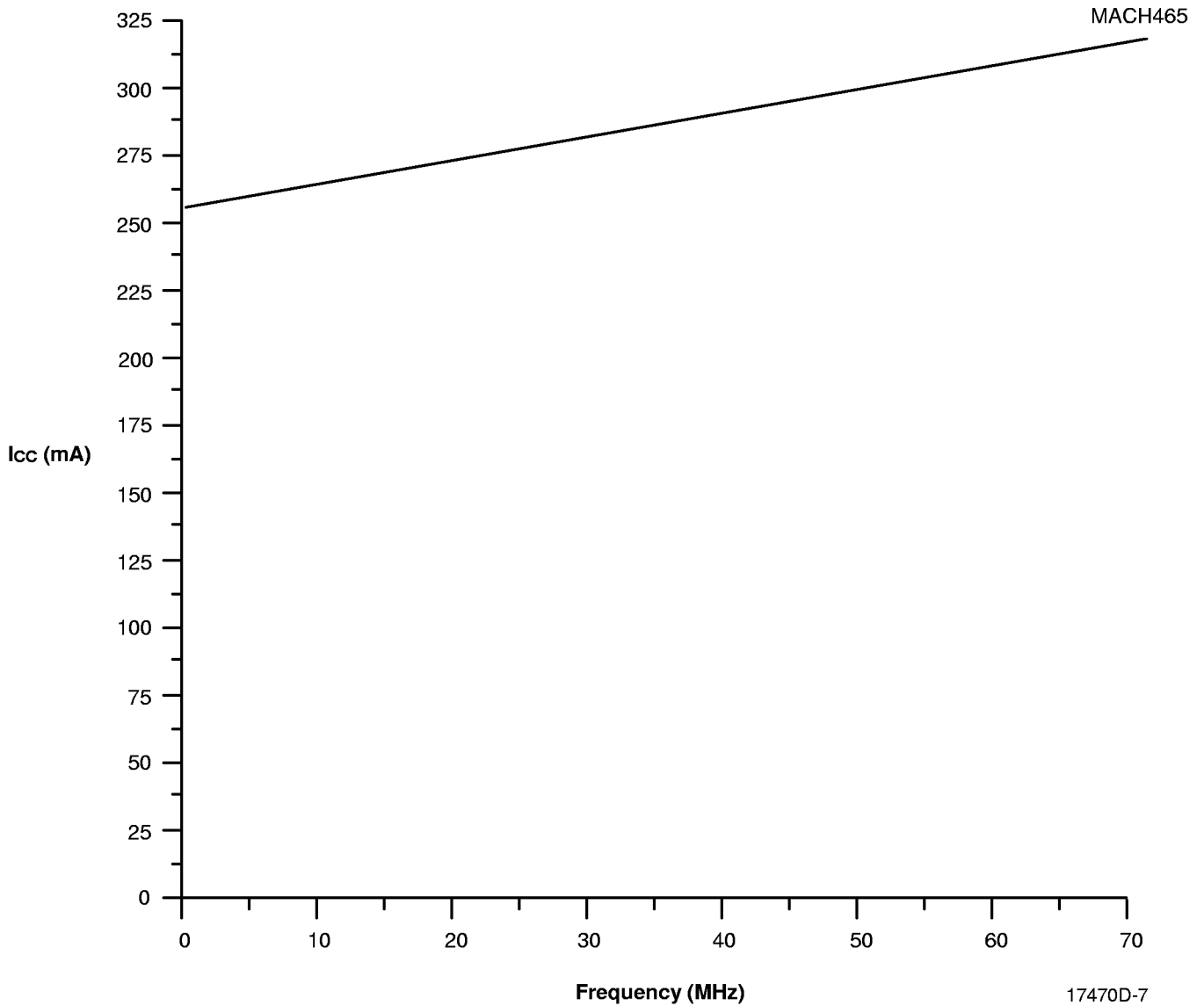


Input

17470D-6

TYPICAL I_{CC} CHARACTERISTICS

V_{CC} = 5 V, T_A = 25°C



The selected "typical" pattern is a 16-bit up/down counter. This pattern is programmed in each PAL block and is capable of being loaded, enabled, and reset.

Maximum frequency shown uses internal feedback and a D-type register.

TYPICAL THERMAL GUIDELINES

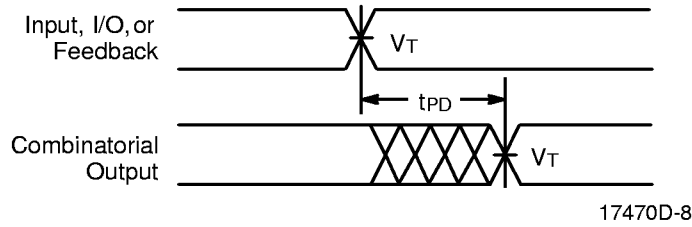
Measured at 25°C ambient. These parameters are not tested.

Parameter Symbol	Parameter Description	Typ	Unit	
		PQFP		
θ_{jc}	Thermal impedance, junction to case	4.7	°C/W	
θ_{ja}	Thermal impedance, junction to ambient	23.2	°C/W	
θ_{jma}	Thermal impedance, junction to ambient with air flow	200 lfpm air	20.6	°C/W
		400 lfpm air	17.7	°C/W
		600 lfpm air	15.1	°C/W
		800 lfpm air	13.8	°C/W

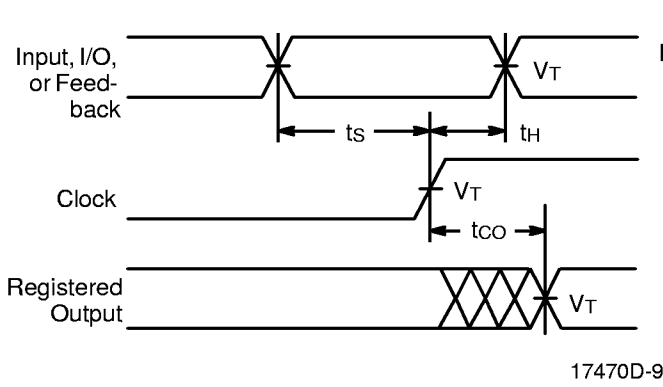
Plastic θ_{jc} Considerations

The data listed for plastic θ_{jc} are for reference only and are not recommended for use in calculating junction temperatures. The heat-flow paths in plastic-encapsulated devices are complex, making the θ_{jc} measurement relative to a specific location on the package surface. Tests indicate this measurement reference point is directly below the die-attach area on the bottom center of the package. Furthermore, θ_{jc} tests on packages are performed in a constant-temperature bath, keeping the package surface at a constant temperature. Therefore, the measurements can only be used in a similar environment.

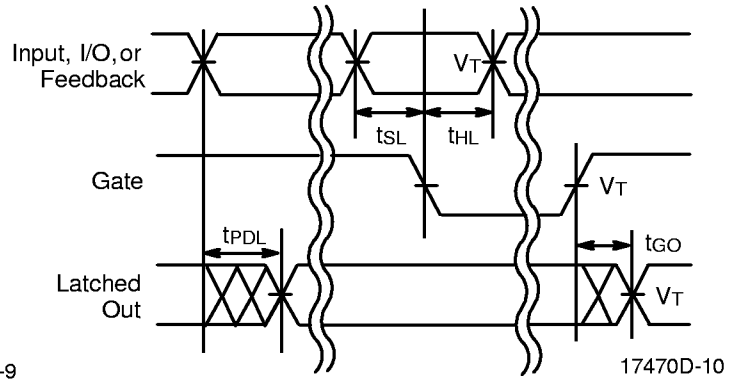
SWITCHING WAVEFORMS



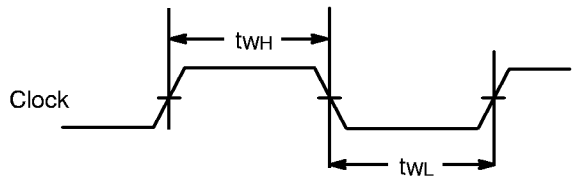
Combinatorial Output



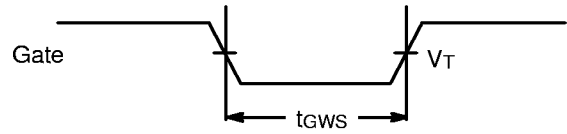
Registered Output



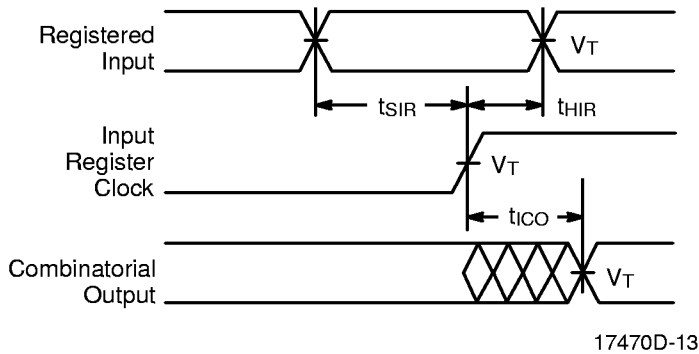
Latched Output (MACH 2, 3, and 4)



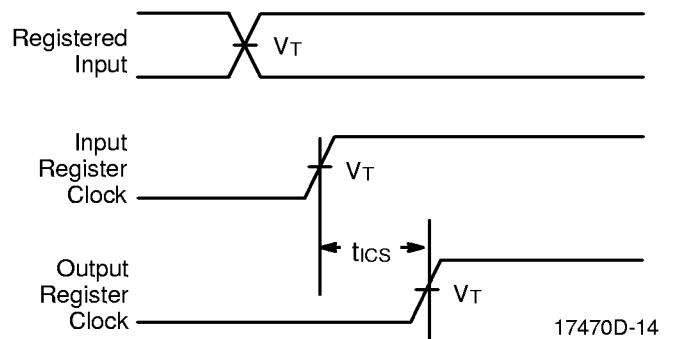
Clock Width



Gate Width (MACH 2, 3, and 4)



Registered Input (MACH 2 and 4)

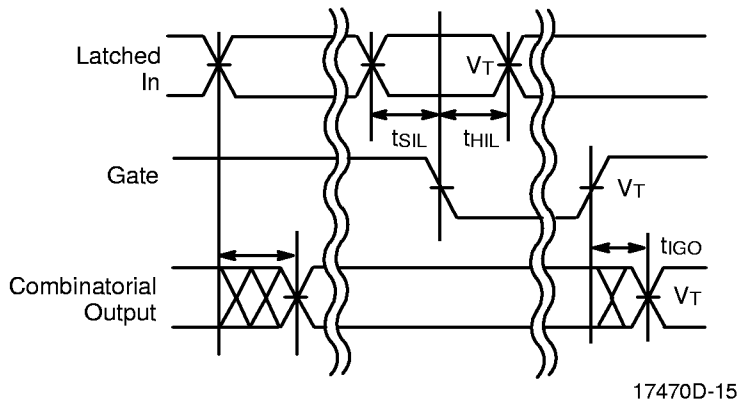


Input Register to Output Register Setup (MACH 2 and 4)

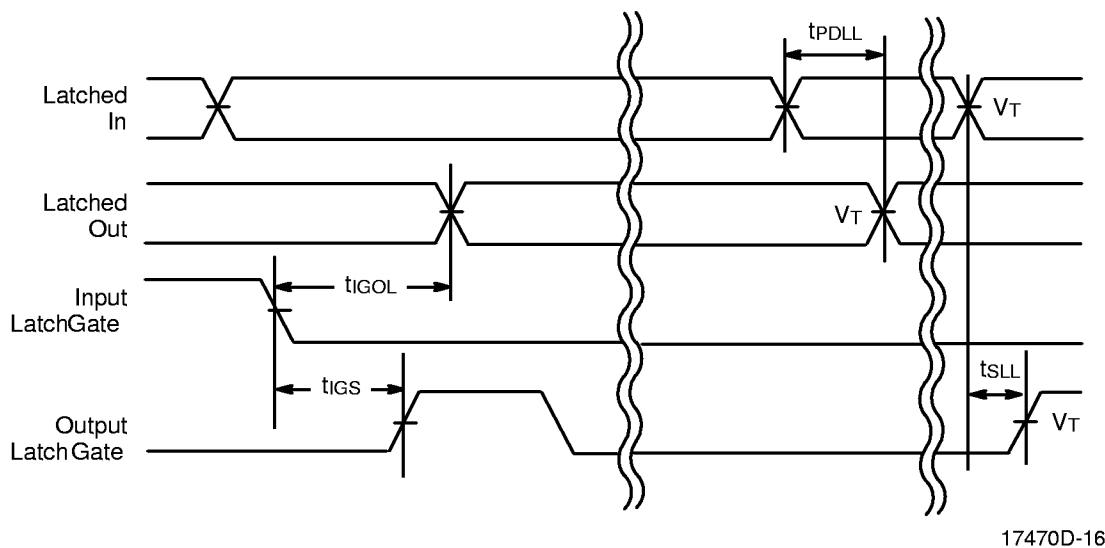
Notes:

1. $V_T = 1.5 V$.
2. Input pulse amplitude 0 V to 3.0 V.
3. Input rise and fall times 2 ns–4 ns typical.

SWITCHINGWAVEFORMS



Latched Input (MACH 2 and 4)

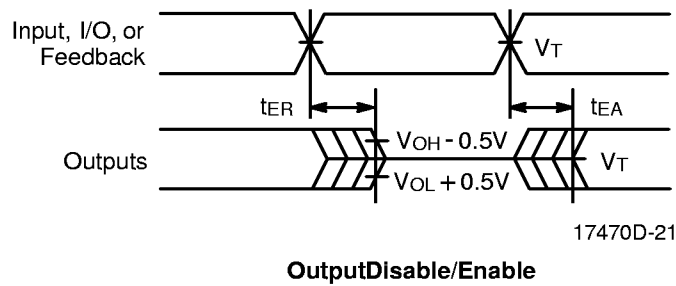
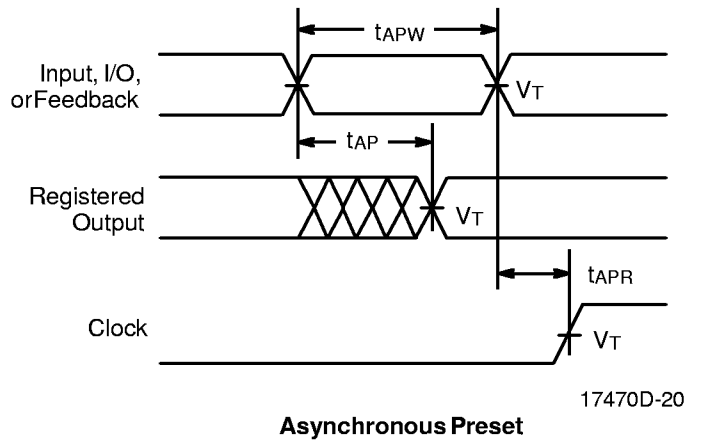
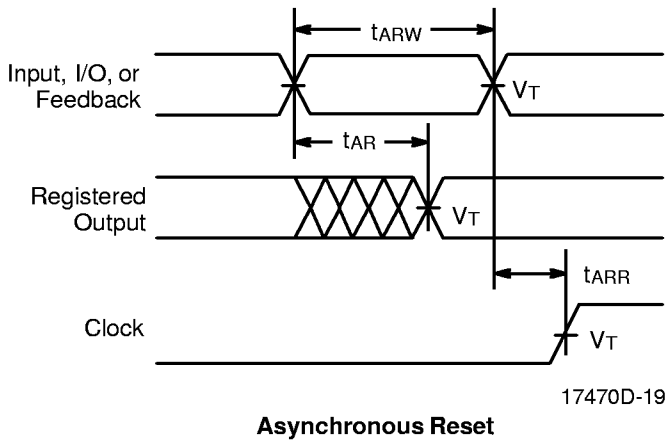
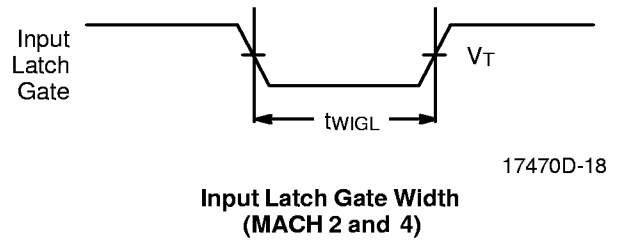
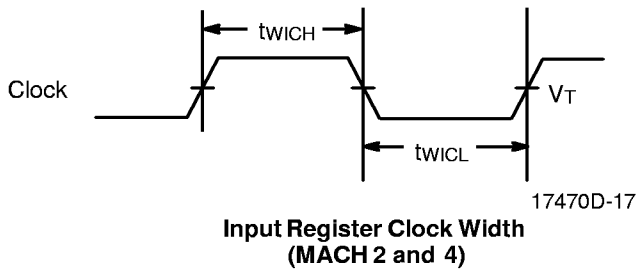


Latched Input and Output (MACH 2, 3, and 4)

Notes:

1. $V_T = 1.5\text{ V}$.
2. Input pulse amplitude 0 V to 3.0 V.
3. Input rise and fall times 2 ns–4 ns typical.

SWITCHING WAVEFORMS



Notes:

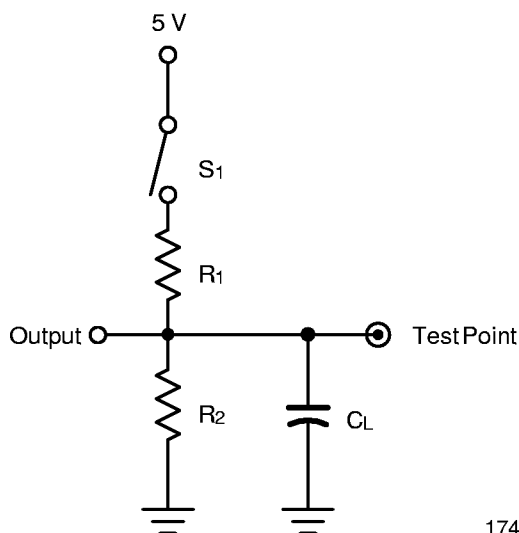
1. $V_T = 1.5 V$.
2. Input pulse amplitude 0 V to 3.0 V.
3. Input rise and fall times 2 ns–4 ns typical.

KEY TO SWITCHING WAVEFORMS

WAVEFORM	INPUTS	OUTPUTS
	Must be Steady	Will be Steady
	May Change from H to L	Will be Changing from H to L
	May Change from L to H	Will be Changing from L to H
	Don't Care, Any Change Permitted	Changing, State Unknown
	Does Not Apply	Center Line is High-Impedance "Off" State

KS000010-PAL

SWITCHING TEST CIRCUIT



17470D-22

Specification	S ₁	C _L	Commercial		Measured Output Value
			R ₁	R ₂	
t _{PD} , t _{CO}	Closed	35 pF	300 Ω	390 Ω	1.5 V
t _{EA}	Z → H: Open Z → L: Closed				1.5 V
t _{ER}	H → Z: Open L → Z: Closed	5 pF			H → Z: V _{OH} - 0.5 V L → Z: V _{OL} + 0.5 V

*Switching several outputs simultaneously should be avoided for accurate measurement.

f_{MAX} PARAMETERS

The parameter f_{MAX} is the maximum clock rate at which the device is guaranteed to operate. Because the flexibility inherent in programmable logic devices offers a choice of clocked flip-flop designs, f_{MAX} is specified for three types of synchronous designs.

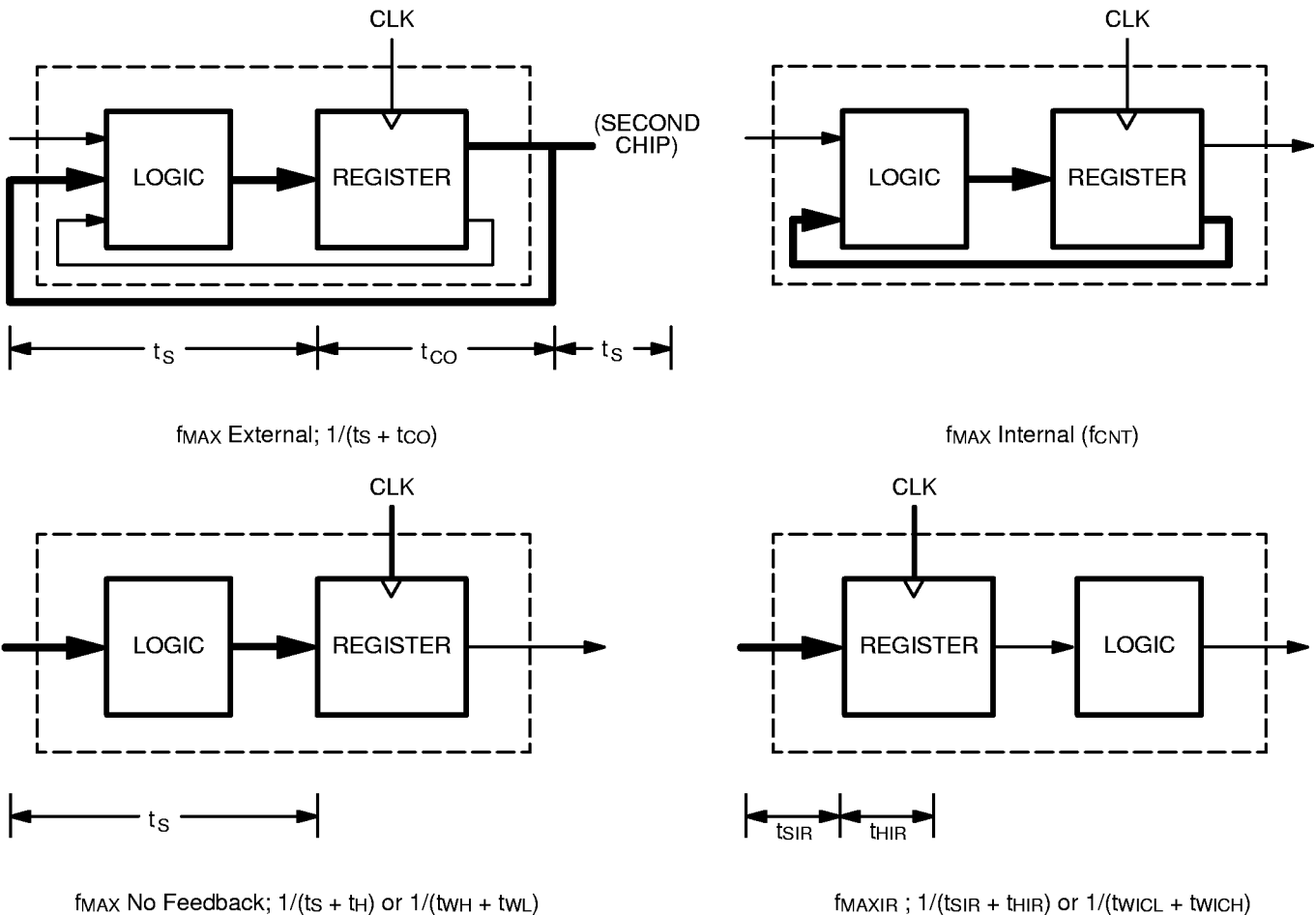
The first type of design is a state machine with feedback signals sent off-chip. This external feedback could go back to the device inputs, or to a second device in a multi-chip state machine. The slowest path defining the period is the sum of the clock-to-output time and the input setup time for the external signals ($t_s + t_{CO}$). The reciprocal, f_{MAX} , is the maximum frequency with external feedback or in conjunction with an equivalent speed device. This f_{MAX} is designated “ f_{MAX} external.”

The second type of design is a single-chip state machine with internal feedback only. In this case, flip-flop inputs are defined by the device inputs and flip-flop outputs. Under these conditions, the period is limited by the internal delay from the flip-flop outputs through the internal feedback and logic to the flip-flop inputs. This f_{MAX} is designated “ f_{MAX} internal”. A simple internal counter is a good example of this type of design; therefore, this parameter is sometimes called “ f_{CNT} .”

The third type of design is a simple data path application. In this case, input data is presented to the flip-flop and clocked through; no feedback is employed. Under these conditions, the period is limited by the sum of the data setup time and the data hold time ($t_s + t_H$). However, a lower limit for the period of each f_{MAX} type is the minimum clock period ($t_{WH} + t_{WL}$). Usually, this minimum clock period determines the period for the third f_{MAX} , designated “ f_{MAX} no feedback.”

For devices with input registers, one additional f_{MAX} parameter is specified: f_{MAXIR} . Because this involves no feedback, it is calculated the same way as f_{MAX} no feedback. The minimum period will be limited either by the sum of the setup and hold times ($t_{SIR} + t_{HIR}$) or the sum of the clock widths ($t_{WICL} + t_{WICH}$). The clock widths are normally the limiting parameters, so that f_{MAXIR} is specified as $1/(t_{WICL} + t_{WICH})$. Note that if both input and output registers are used in the same path, the overall frequency will be limited by t_{CS} .

All frequencies except f_{MAX} internal are calculated from other measured AC parameters. f_{MAX} internal is measured directly.



ENDURANCE CHARACTERISTICS

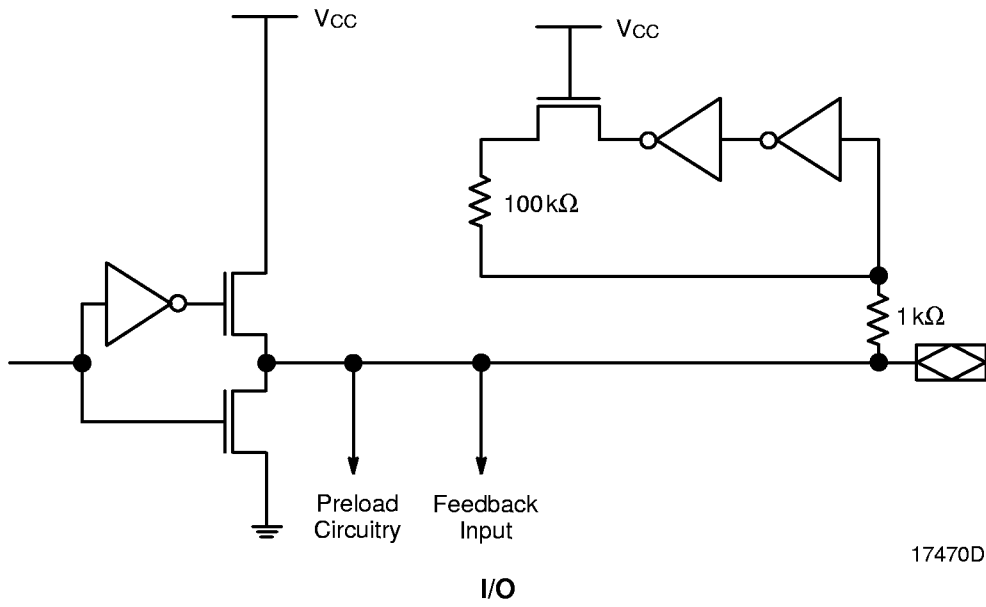
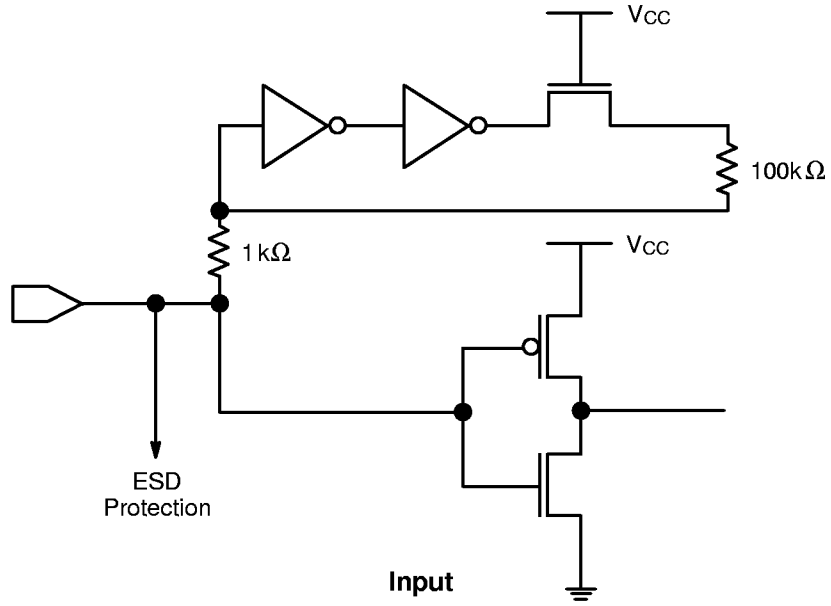
The MACH families are manufactured using AMD's advanced Electrically Erasable process. This technology uses an EE cell to replace the fuse link used in

bipolar parts. As a result, the device can be erased and reprogrammed, a feature which allows 100% testing at the factory.

Endurance Characteristics

Parameter Symbol	Parameter Description	Min	Units	Test Conditions
t _{DR}	Min Pattern Data Retention Time	10	Years	Max Storage Temperature
		20	Years	Max Operating Temperature
N	Max Reprogramming Cycles	100	Cycles	Normal Programming Conditions

INPUT/OUTPUT EQUIVALENT SCHEMATICS



17470D-24

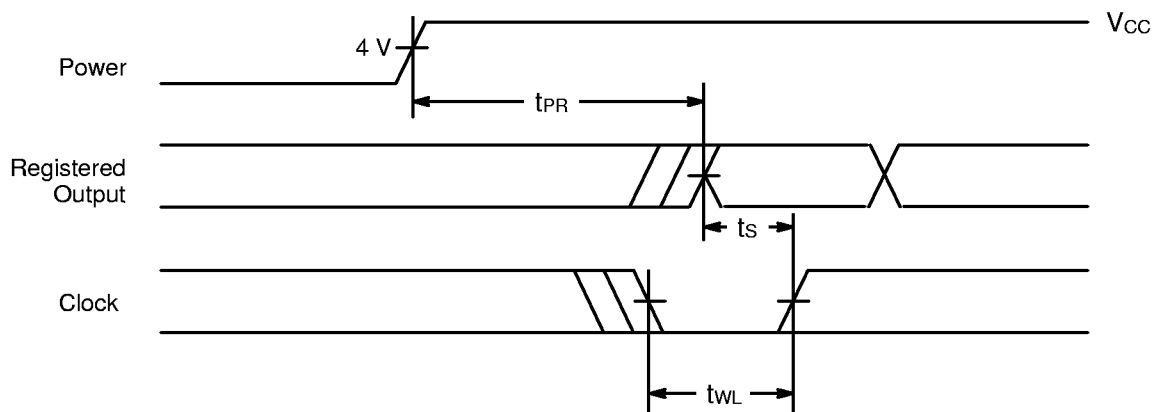
POWER-UP RESET

The MACH devices have been designed with the capability to reset during system power-up. Following power-up, all flip-flops will be reset to LOW. The output state will depend on the logic polarity. This feature provides extra flexibility to the designer and is especially valuable in simplifying state machine initialization. A timing diagram and parameter table are shown below. Due to the synchronous operation of the power-up reset and the

wide range of ways V_{CC} can rise to its steady state, two conditions are required to insure a valid power-up reset. These conditions are:

1. The V_{CC} rise must be monotonic.
2. Following reset, the clock input must not be driven from LOW to HIGH until all applicable input and feedback setup times are met.

Parameter Symbol	Parameter Descriptions	Max	Unit
t_{PR}	Power-Up Reset Time	10	μs
t_s	Input or Feedback Setup Time	See Switching Characteristics	
t_{WL}	Clock Width LOW		



17470D-25

Power-Up Reset Waveform

USING PRELOAD AND OBSERVABILITY

In order to be testable, a circuit must be both controllable and observable. To achieve this, the MACH devices incorporate register preload and observability.

In preload mode, each flip-flop in the MACH device can be loaded from the I/O pins, in order to perform functional testing of complex state machines. Register preload makes it possible to run a series of tests from a known starting state, or to load illegal states and test for proper recovery. This ability to control the MACH device's internal state can shorten test sequences, since it is easier to reach the state of interest.

The observability function makes it possible to see the internal state of the buried registers during test by overriding each register's output enable and activating the output buffer. The values stored in output and buried registers can then be observed on the I/O pins. Without this feature, a thorough functional test would be impossible for any designs with buried registers.

While the implementation of the testability features is fairly straightforward, care must be taken in certain instances to insure valid testing.

One case involves asynchronous reset and preset. If the MACH registers drive asynchronous reset or preset lines and are preloaded in such a way that reset or preset are asserted, the reset or preset may remove the preloaded data. This is illustrated in Figure 2. Care should be taken when planning functional tests, so that states that will cause unexpected resets and presets are not preloaded.

Another case to be aware of arises in testing combinatorial logic. When an output is configured as combinatorial, the observability feature forces the output into registered mode. When this happens, all product terms are forced to zero, which eliminates all combinatorial data. For a straight combinatorial output, the correct value will be restored after the preload or observe function, and there will be no problem. If the function implements a combinatorial latch, however, it relies on feedback to hold the correct value, as shown in Figure 3. As this value may change during the preload or observe operation, you cannot count on the data being correct after the operation. To insure valid testing in these cases, outputs that are combinatorial latches should not be tested immediately following a preload or observe sequence, but should first be restored to a known state.

All MACH 2 devices support both preload and observability.

Contact individual programming vendors in order to verify programmer support.

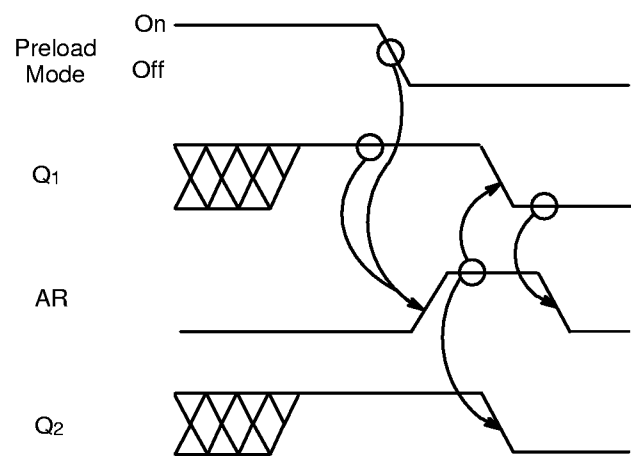
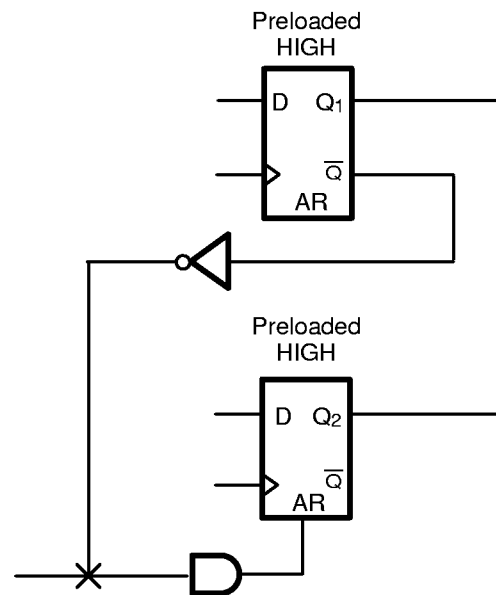


Figure 2. Preload/Reset Conflict

17470D-26

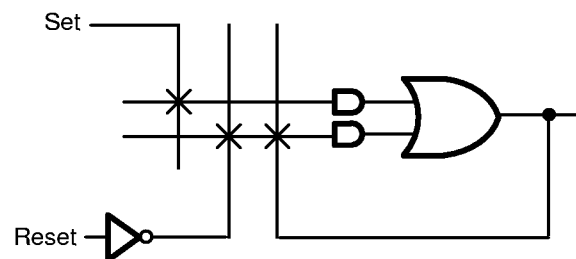


Figure 3. Combinatorial Latch

17470D-27

DEVELOPMENT SYSTEMS (subject to change)

For more information on the products listed below, please consult the AMD FusionPLD Catalog.

MANUFACTURER	SOFTWARE DEVELOPMENT SYSTEMS
Advanced Micro Devices, Inc. P.O. Box 3453, MS 1028 Sunnyvale, CA 94088-3543 (800) 222-9323 or (408) 732-2400	MACHXL [®] Software Ver. 2.0
Advanced Micro Devices, Inc. P.O. Box 3453, MS 1028 Sunnyvale, CA 94088-3543 (800) 222-9323 or (408) 732-2400	Design Center/AMD Software
Advanced Micro Devices, Inc. P.O. Box 3453, MS 1028 Sunnyvale, CA 94088-3543 (800) 222-9323 or (408) 732-2400	AMD-ABEL Software Data I/O MACH Fitters
Advanced Micro Devices, Inc. P.O. Box 3453, MS 1028 Sunnyvale, CA 94088-3543 (800) 222-9323 or (408) 732-2400	PROdeveloper/AMD Software PROsynthesis/AMD Software
Cadence Design Systems 555 River Oaks Pkwy San Jose, CA 95134 (408) 943-1234	ComposerPIC [™] Designer (Requires MACH Fitter) Verilog, LeapFrog, RapidSim Simulators (Models also available from Logic Modeling) Ver. 3.3
Capilano Computing 960 Quayside Dr., Suite 406 New Westminster, B.C. Canada V3M 6G2 (800) 444-9064 or (604) 552-6200	MacABEL [™] Software (Requires SmartPart MACH Fitter)
CINA, Inc. P.O. Box 4872 Mountain View, CA 94040 (415) 940-1723	SmartCAT Circuit Analyzer
Data I/O Corporation 10525 Willows Road N.E. P.O. Box 97046 Redmond, WA 98073-9746 (800) 332-8246 or (206) 881-6444	ABEL [™] -5 Software (Requires MACH Fitter) Synario [™] Software
iNt GmbH Busenstrasse 6 D-8033 Martinsried, Munich, Germany (89) 857-6667	PLDSim 90
ISDATA GmbH Daimlerstr. 51 D7500 Karlsruhe 21 Germany Germany: 0721/7510 87 U.S.: (510) 531-8553	LOG/iC [™] Software (Requires MACH Fitter)
Logic Modeling 19500 NW Gibbs Dr. P.O. Box 310 Beaverton, OR 97075 (503) 690-6900	SmartModel [®] Library
Logical Devices, Inc. 692 S. Military Trail Deerfield Beach, FL 33442 (800) 331-7766 or (305) 428-6868	CUPL [™] Software

DEVELOPMENT SYSTEMS (subject to change) (continued)

MANUFACTURER	SOFTWARE DEVELOPMENT SYSTEMS
Mentor Graphics Corp. 8005 S.W. Boeckman Rd. Wilsonville, OR97070-7777 (800) 547-3000 or (503) 685-7000	PLDSynthesis™ (Requires MACH Fitter) QuickSim Simulator (Models also available from Logic Modeling)
MicroSim Corp. 20 Fairbanks Irvine, CA 92718 (714)770-3022	Design Center Software (Requires MACH Fitter)
MINCIncorporated 6755 Earl Drive, Suite 200 Colorado Springs, CO 80918 (800) 755-FPGA or (719) 590-1155	PLDesigner™-XL Software (Requires MACH Fitter)
OrCAD 3175 N.W. Alclek Dr. Hillsboro, OR 97124 (503)690-9881	Programmable Logic Design Tools386+ Schematic Design Tool386+ Digital Simulation Tools
SUSIE-CAD 10000 Nevada Highway, Suite201 Boulder City, NV 89005 (702)293-2271	SUSIE™Simulator
Teradyne EDA 321 Harrison Ave. Boston, MA02118 (800) 777-2432 or (617) 422-2793	MultiSIM InteractiveSimulator LASAR
Viewlogic Systems, Inc. 293 Boston Post Road West Marlboro, MA01752 (800) 442-4660 or (508) 480-0881	ViewPLD or PROPLD (Requires PROSim Simulator MACH Fitter) ViewSim Simulator (Models for ViewSim also available from Logic Modeling)
MANUFACTURER	TEST GENERATION SYSTEM
Acugen Software, Inc. 427-3 Amherst St., Suite391 Nashua, NH 03063 (603)891-1995	ATGEN™ Test Generation Soft- ware
iNt GmbH Busenstrasse 6 D-8033 Martinsried, Munich, Germany (87)857-6667	PLDCheck 90

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APPROVED PROGRAMMERS (subject to change)

For more information on the products listed below, please consult the AMD Fusion PLD Catalog.

MANUFACTURER	PROGRAMMER CONFIGURATION
Advin Systems, Inc. 1050-L East Duane Ave. Sunnyvale, CA 94086 (408)243-7000	Pilot U84
BPMicrosystems 100 N. Post Oak Rd. Houston, TX 77055-7237 (800) 225-2102 or (713) 688-4600	BP1200
Data I/O Corporation 10525 Willows Road N.E. P.O. Box 97046 Redmond, WA 98073-9746 (800) 332-8246 or (206) 881-6444	UniSite™ Model 3900 AutoSite
Logical Devices Inc./Digelec 692 S. Military Trail Deerfield Beach, FL 33442 (800) 331-7766 or (305) 428-6868	ALLPRO™-88
SMS North America, Inc. 16522 NE 135th Place Redmond, WA 98052 (800)722-4122 or SMS Im Grund 15 D-7988 Vangen Im Allgau, Germany 07522-5018	Sprint/Expert
Stag Microsystems Inc. 1600 Wyatt Dr. Suite 3 Santa Clara, CA 95054 (408)988-1118 or Stag House Martinfield, Welwyn Garden City Herfordshire UK AL7 1JT 707-332148	Stag Quazar
System General 510 S. Park Victoria Dr. Milpitas, CA 95035 (408)263-6667 or 3F, No. 1, Alley 8, Lane 45 Bao Shing Rd., Shin Diau Taipei, Taiwan 2-917-3005	Turpro-1

APPROVED ON-BOARD PROGRAMMERS

MANUFACTURER	PROGRAMMER CONFIGURATION
Corelis, Inc. 12607 Hidden Creek Way, Suite H Cerritos, California 70703 (310)926-6727	JTAG PROG
Advanced Micro Devices P.O. Box 3453, MS-1028 Sunnyvale, CA 94088-3453 (800)222-9323	MACHpro

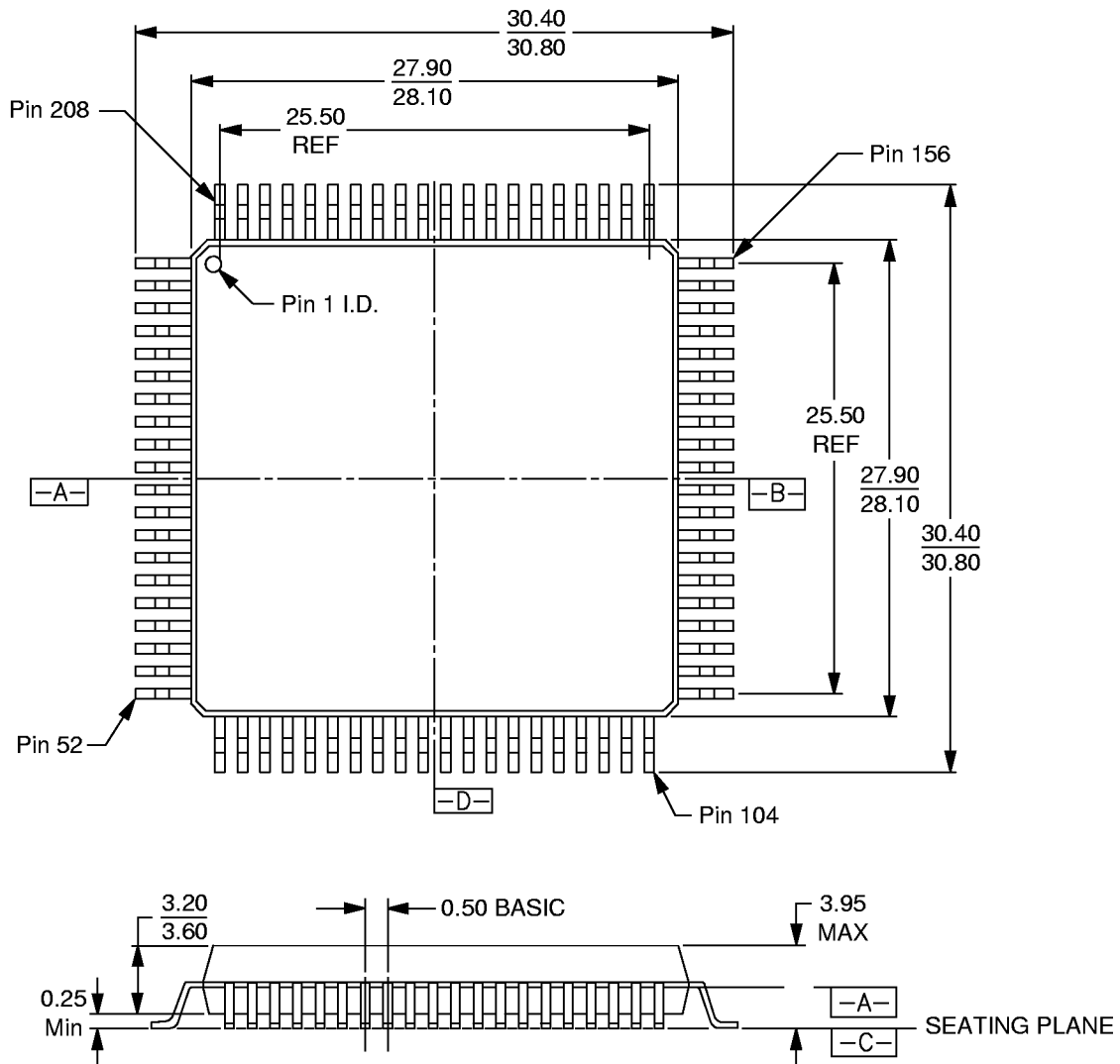
PROGRAMMER SOCKET ADAPTERS (subject to change)

MANUFACTURER	PART NUMBER
EDI Corporation P.O. Box 366 Patterson, CA 95363 (209)892-3270	ContactManufacturer
Emulation Technology 2344 Walsh Ave., Bldg. F Santa Clara, CA 95051 (408)982-0660	ContactManufacturer
Logical Systems Corp. P.O. Box 6184 Syracuse, NY 13217-6184 (315)478-0722	ContactManufacturer
Procon Technologies, Inc. 1333 Lawrence Expwy, Suite 207 Santa Clara, CA 95051 (408)246-4456	ContactManufacturer

PHYSICAL DIMENSIONS*

PQR208

208-Pin Plastic Quad Flat Pack; Trimmed and Formed (measured in millimeters)



16-038-PQR-2
PQR208
DA92
7-20-94 ae

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