Lattice Semiconductor

MACH120-12/15

High-Performance EE CMOS Programmable Logic

DISTINCTIVE CHARACTERISTICS

- 68 Pins in PLCC
- 48 Macrocells
- 12 ns t_{PD} Commercial, 18 ns t_{PD} Industrial
- 77 MHz f_{CNT} Commercial
- 48 I/Os; 4 dedicated inputs; 4 dedicated inputs/clocks
- 48 Outputs
- 48 Flip-flops; 4 clock choices
- 4 "PALCE26V12" blocks
- SpeedLocking™ for guaranteed fixed timing
- Pin-compatible with the MACH221

GENERAL DESCRIPTION

The MACH120 is a member of the high-performance EE CMOS MACH® 1 family. This device has approximately five times the logic macrocell capability of the popular PALCE22V10 without loss of speed.

The MACH120 consists of four PAL® blocks interconnected by a programmable switch matrix. The 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.

The MACH120 macrocell provides either registered or combinatorial outputs with programmable polarity. If a registered configuration is chosen, the register can be configured as D-type or T-type to help reduce the number of product terms. The register type decision can be made by the designer or by the software. All macrocells can be connected to an I/O cell. If a buried macrocell is desired, the internal feedback path from the macrocell can be used, which frees up the I/O pin for use as an input.

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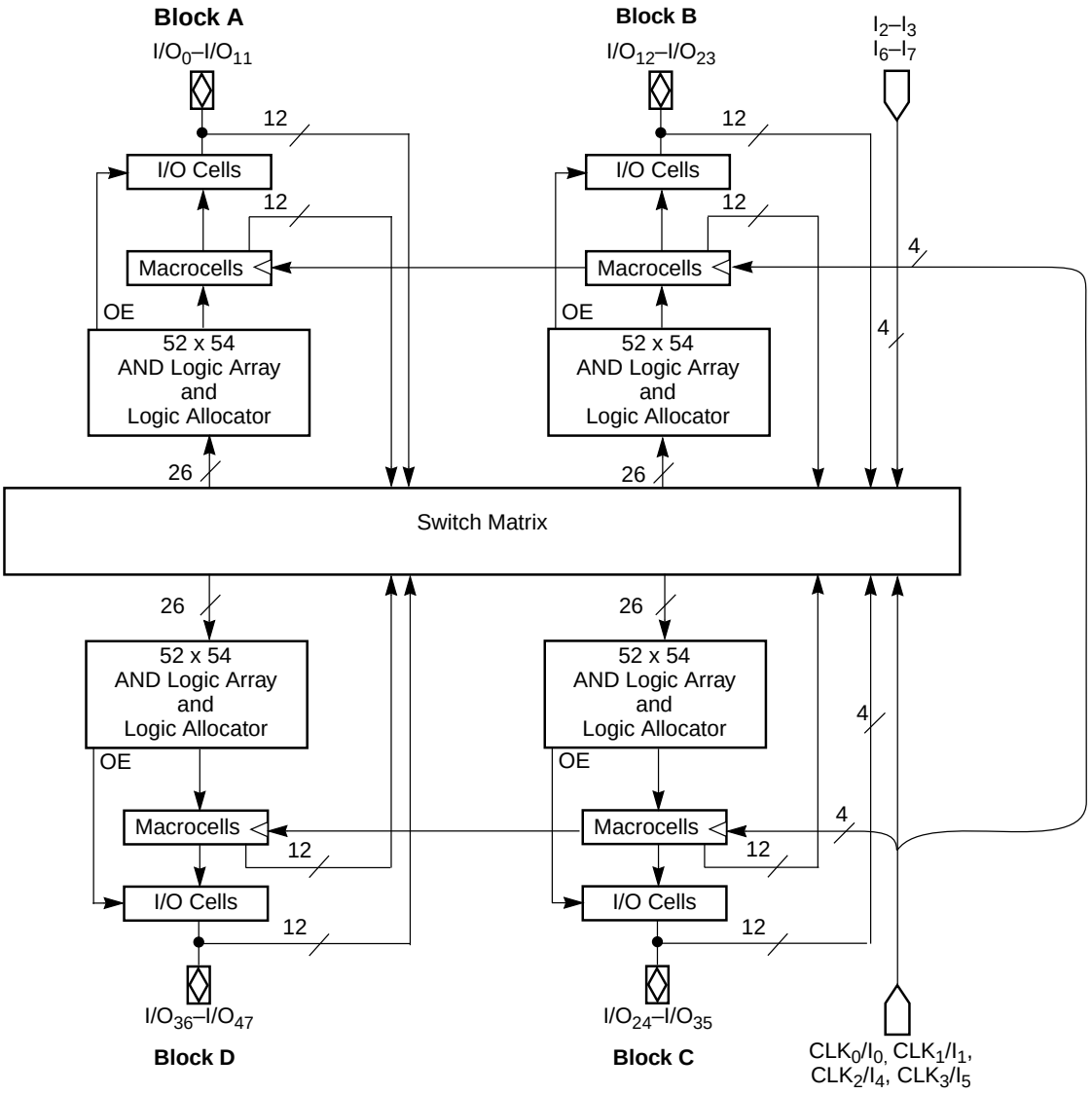
Amendment/**0** Issue Date: **November 1997**

BLOCK DIAGRAM



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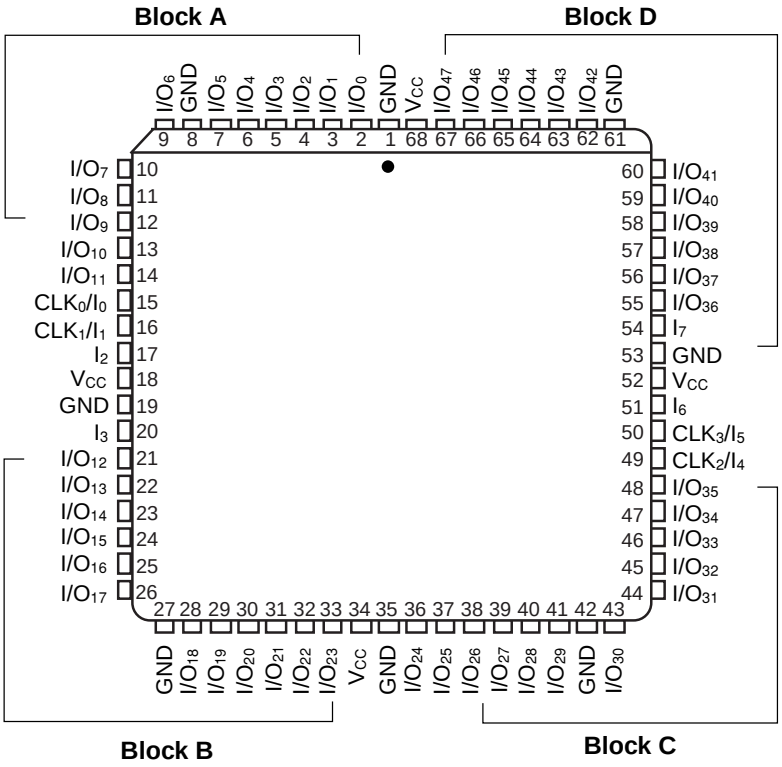
CONNECTION DIAGRAM

Top View

PLCC



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Note:
Pin-compatible with the MACH220 and MACH221.

PIN DESIGNATIONS

CLK/I = Clock or Input

GND = Ground

I = Input

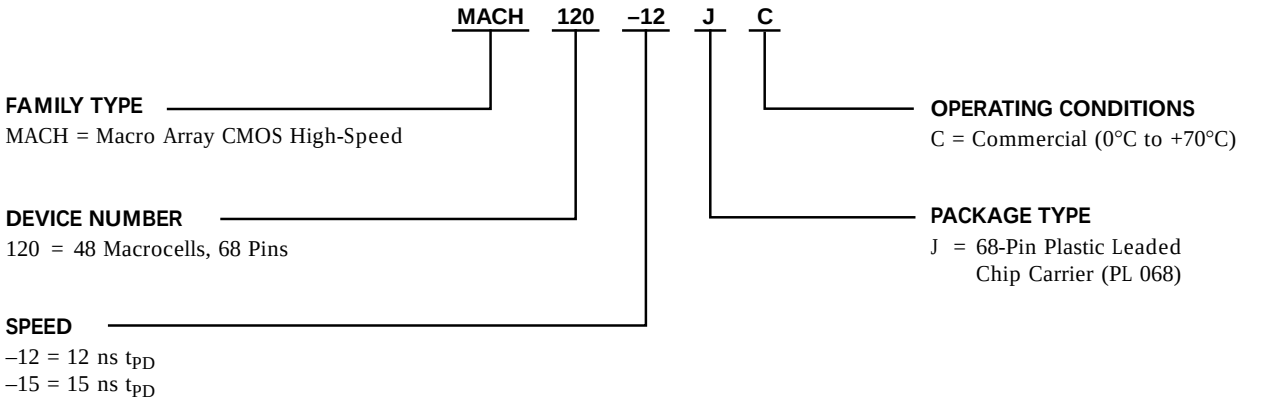
I/O = Input/Output

VCC = Supply Voltage

ORDERING INFORMATION

Commercial Products

Vantis 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	
MACH120-12	JC
MACH120-15	

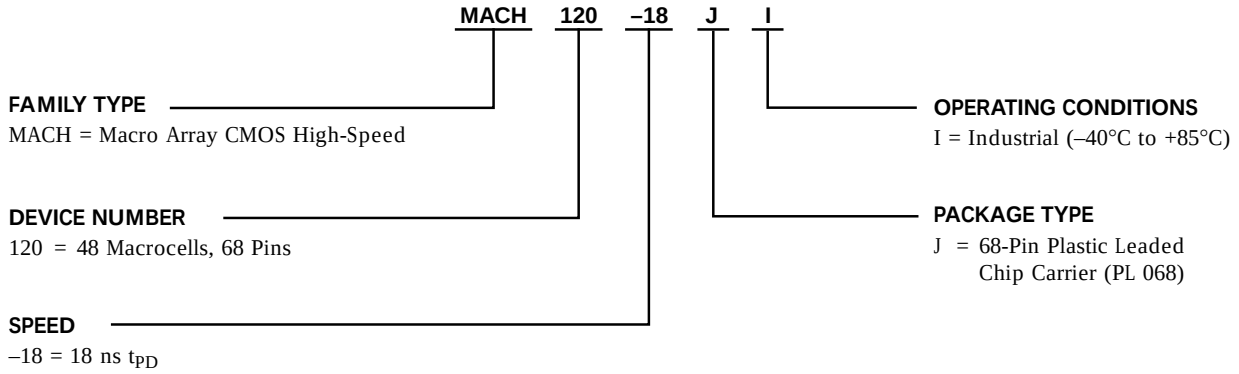
Valid Combinations

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

ORDERING INFORMATION

Industrial Products

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



Valid Combinations	
MACH120-18	JI

Valid Combinations

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

FUNCTIONAL DESCRIPTION

The MACH120 consists of four PAL blocks connected by a switch matrix. There are 48 I/O pins and 4 dedicated input pins feeding the switch matrix. These signals are distributed to the four PAL blocks for efficient design implementation. There are 4 clock pins that can also be used as dedicated inputs.

The PAL Blocks

Each PAL block in the MACH120 (Figure 1) contains a 48-product-term logic array, a logic allocator, 12 macrocells and 12 I/O cells. The switch matrix feeds each PAL block with 26 inputs. This makes the PAL block look effectively like an independent “PALCE26V12”.

There are four additional output enable product terms in each PAL block. For purposes of output enable, the 12 I/O cells are divided into 2 banks of 6 macrocells. Each bank is allocated two of the output enable product terms.

An asynchronous reset product term and an asynchronous preset product term are provided for flip-flop initialization. All flip-flops within the PAL block are initialized together.

The Switch Matrix

The MACH120 switch matrix is fed by the inputs and feedback signals from the PAL blocks. Each PAL block provides 12 internal feedback signals and 12 I/O feedback signals. The switch matrix distributes these signals back to the PAL blocks in an efficient manner that also provides for high performance. The design software automatically configures the switch matrix when fitting a design into the device.

The Product-Term Array

The MACH120 product-term array consists of 48 product terms for logic use, and 6 special-purpose product terms. Four of the special-purpose product terms provide programmable output enable, one provides asynchronous reset, and one provides asynchronous preset. Two of the output enable product terms are used for the first six I/O cells; the other two control the last six macrocells.

The Logic Allocator

The logic allocator in the MACH120 takes the 48 logic product terms and allocates them to the 12 macrocells as needed. Each macrocell can be driven by up to 12 product terms. The design software automatically configures the logic allocator when fitting the design into the device.

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

Output Macrocell	Available Clusters	Output Macrocell	Available Clusters
M_0	C_0, C_1	M_6	C_5, C_6, C_7
M_1	C_0, C_1, C_2	M_7	C_6, C_7, C_8
M_2	C_1, C_2, C_3	M_8	C_7, C_8, C_9
M_3	C_2, C_3, C_4	M_9	C_8, C_9, C_{10}
M_4	C_3, C_4, C_5	M_{10}	C_9, C_{10}, C_{11}
M_5	C_4, C_5, C_6	M_{11}	C_{10}, C_{11}

The Macrocell

The MACH120 macrocells can be configured as either registered or combinatorial, with programmable polarity. The macrocell provides internal feedback whether configured as registered or combinatorial. The flip-flops can be configured as D-type or T-type, allowing for product-term optimization.

The flip-flops can individually select one of four global clock pins, which are also available as logic inputs. The registers are clocked on the LOW-to-HIGH transition of the clock signal. The flip-flops can also be asynchronously initialized with the common asynchronous reset and preset product terms.

The I/O Cell

The I/O cell in the MACH120 consists of a three-state output buffer. The three-state buffer can be configured in one of three ways: always enabled, always disabled, or controlled by a product term. If product term control is chosen, one of two product terms may be used to provide the control. The two product terms that are available are common to six I/O cells. Within each PAL block, two product terms are available for selection by the first six three-state outputs; two other product terms are available for selection by the last six three-state outputs.

These choices make it possible to use the macrocell as an output, an input, a bidirectional pin, or a three-state output for use in driving a bus.

SpeedLocking for Guaranteed Fixed Timing

The unique MACH 1 architecture is designed for high performance—a metric that is met in both raw speed, but even more importantly, *guaranteed fixed speed*. Using the design of the central switch matrix, the MACH 120 product offers the SpeedLocking feature, which allows a stable fixed pin-to-pin delay, independent of logic paths, routing resources and design refits for up to 16 product terms per output. Other non-Vantis CPLDs incur serious timing delays as product terms expand beyond their typical 4 or 5 product term limits. Speed *and* SpeedLocking combine for continuous, high performance required in today's demanding designs

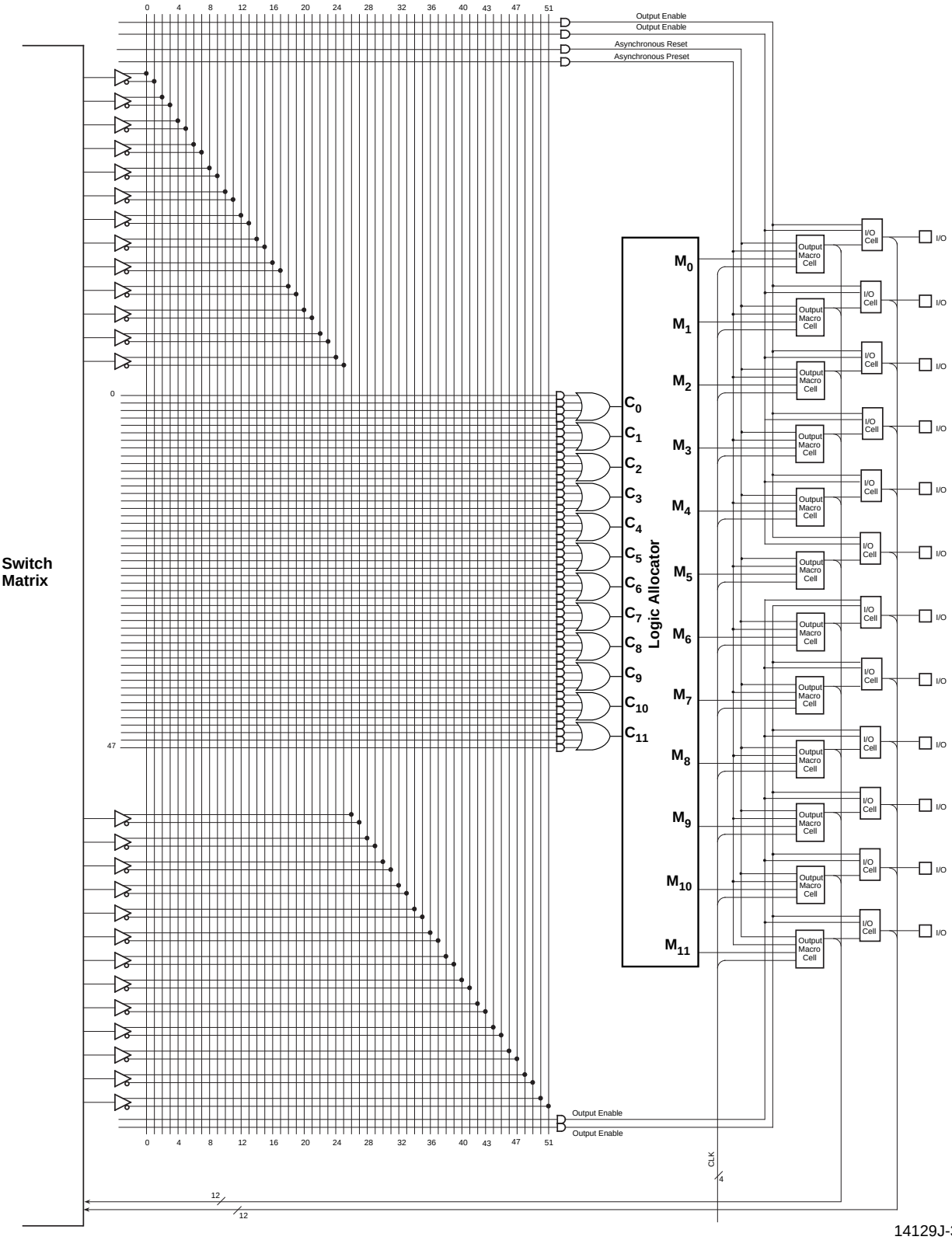


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Figure 1. MACH120 PAL Block

ABSOLUTE MAXIMUM RATINGS

Storage Temperature . . . . . -65°C to +150°C

Ambient Temperature
With Power Applied . . . . . .-55°C to +125°C

Device Junction Temperature . . . . . +150°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°C to 70°C) . . . . . 200 mA

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.

OPERATING RANGES

Commercial (C) Devices

Ambient 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.

DC CHARACTERISTICS over COMMERCIAL operating ranges

Parameter Symbol	Parameter Description	Test Conditions	Min	Typ	Max	Unit
V_{OH}	Output HIGH Voltage	I_{OH} = -3.2 mA, V_{CC} = Min V_{IN} = V_{IH} or V_{IL}	2.4			V
V_{OL}	Output LOW Voltage	I_{OL} = 16 mA, V_{CC} = Min V_{IN} = V_{IH} or V_{IL}			0.5	V
V_{IH}	Input HIGH Voltage	Guaranteed Input Logical HIGH Voltage for all Inputs (Note 1)	2.0			V
V_{IL}	Input LOW Voltage	Guaranteed Input Logical LOW Voltage for all Inputs (Note 1)			0.8	V
I_{IH}	Input HIGH Current	V_{IN} = 5.25 V, V_{CC} = Max (Note 2)			10	µA
I_{IL}	Input LOW Current	V_{IN} = 0 V, V_{CC} = Max (Note 2)			-10	µA
I_{OZH}	Off-State Output Leakage Current HIGH	V_{OUT} = 5.25 V, V_{CC} = Max V_{IN} = V_{IH} or V_{IL} (Note 2)			10	µA
I_{OZL}	Off-State Output Leakage Current LOW	V_{OUT} = 0 V, V_{CC} = Max V_{IN} = V_{IH} or V_{IL} (Note 2)			-10	µA
I_{SC}	Output Short-Circuit Current	V_{OUT} = 0.5 V, V_{CC} = Max (Note 3)	-30		-130	mA
I_{CC}	Supply Current (Typical)	V_{CC} = 5 V, T_A=25°C, f = 25 MHz (Note 4)		85		mA

Notes:

1. *These are absolute values with respect to device ground and all overshoots due to system and/or tester noise are included.*
2. *I/O pin leakage is the worst case of I_{IL} and I_{OZL} (or I_{IH} and I_{OZH}).*
3. *Not more than one output should be shorted at a time. 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.*
4. *Measured with a 12-bit up/down counter pattern. This pattern is programmed in each PAL block and capable of being loaded, enabled, and reset.*

CAPACITANCE (Note 1)

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°C f = 1 MHz	6	pF
C_{OUT}	Output Capacitance	V_{OUT} = 2.0 V		8	pF

SWITCHING CHARACTERISTICS over COMMERCIAL operating ranges (Note 2)

Parameter Symbol	Parameter Description			-12		-15		Unit
				Min	Max	Min	Max	
t_{PD}	Input, I/O, or Feedback to Combinatorial Output				12		15	ns
t_S	Setup Time from Input, I/O, or Feedback to Clock		D-type	7		10		ns
			T-type	8		11		ns
t_H	Hold Time			0		0		ns
t_{CO}	Clock to Output				8		10	ns
t_{WL}	CLock Width		LOW	6		6		ns
t_{WH}			HIGH	6		6		ns
f_{MAX}	Maximum Frequency (Note 1)	External Feedback	D-type	66.7		50		MHz
			T-type	62.5		47.6		MHz
		Internal Feedback (f_{CNT})	D-type	76.9		66.6		MHz
			T-type	71.4		55.5		MHz
		No Feedback		83.3		83.3		MHz
t_{AR}	Asynchronous Reset to Registered Output				16		20	ns
t_{ARW}	Asynchronous Reset Width (Note 1)			12		15		ns
t_{ARR}	Asynchronous Reset Recovery Time (Note 1)			8		10		ns
t_{AP}	Asynchronous Preset to Registered Output				16		20	ns
t_{APW}	Asynchronous Preset Width (Note 1)			12		15		ns
t_{APR}	Asynchronous Preset Recovery Time (Note 1)			8		10		ns
t_{EA}	Input, I/O, or Feedback to Output Enable				12		15	ns
t_{ER}	Input, I/O, or Feedback to Output Disable				12		15	ns

Notes:

1. *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.*
2. *See Switching Test Circuit, for test conditions.*

ABSOLUTE MAXIMUM RATINGS

Storage Temperature . . . . . -65°C to +150°C

Ambient Temperature
With Power Applied . . . . . -55°C to +125°C

Device Junction Temperature . . . . . +150°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 = -40°C to +85°C) . . . . . 200 mA

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.

INDUSTRIAL OPERATING RANGES

Industrial (I) Devices

Ambient Temperature (T_A)
Operating in Free Air . . . . . -40°C to +85°C

Supply Voltage (V_{CC})
with Respect to Ground . . . . . +4.5 V to +5.5 V

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

DC CHARACTERISTICS over INDUSTRIAL operating ranges

Parameter Symbol	Parameter Description	Test Conditions	Min	Typ	Max	Unit
V_{OH}	Output HIGH Voltage	I_{OH} = -3.2 mA, V_{CC} = Min V_{IN} = V_{IH} or V_{IL}	2.4			V
V_{OL}	Output LOW Voltage	I_{OL} = 16 mA, V_{CC} = Min V_{IN} = V_{IH} or V_{IL}			0.5	V
V_{IH}	Input HIGH Voltage	Guaranteed Input Logical HIGH Voltage for all Inputs (Note 1)	2.0			V
V_{IL}	Input LOW Voltage	Guaranteed Input Logical LOW Voltage for all Inputs (Note 1)			0.8	V
I_{IH}	Input HIGH Current	V_{IN} = 5.25 V, V_{CC} = Max (Note 2)			10	µA
I_{IL}	Input LOW Current	V_{IN} = 0 V, V_{CC} = Max (Note 2)			-10	µA
I_{OZH}	Off-State Output Leakage Current HIGH	V_{OUT} = 5.25 V, V_{CC} = Max V_{IN} = V_{IH} or V_{IL} (Note 2)			10	µA
I_{OZL}	Off-State Output Leakage Current LOW	V_{OUT} = 0 V, V_{CC} = Max V_{IN} = V_{IH} or V_{IL} (Note 2)			-10	µA
I_{SC}	Output Short-Circuit Current	V_{OUT} = 0.5 V, V_{CC} = Max (Note 3)	-30		-130	mA
I_{CC}	Supply Current (Typical)	V_{CC} = 5 V, T_A = 25°C, f = 25 MHz (Note 4)		85		mA

Notes:

1. *These are absolute values with respect to device ground and all overshoots due to system and/or tester noise are included.*
2. *I/O pin leakage is the worst case of I_{IL} and I_{OZL} (or I_{IH} and I_{OZH}).*
3. *Not more than one output should be shorted at a time. 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.*
4. *Measured with a 12-bit up/down counter pattern. This pattern is programmed in each PAL block and is capable of being loaded, enabled, and reset.*

CAPACITANCE (Note 1)

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°C, f = 1 MHz	6	pF
C_{OUT}	Output Capacitance	V_{OUT} = 2.0 V		8	pF

SWITCHING CHARACTERISTICS over INDUSTRIAL operating ranges (Note 2)

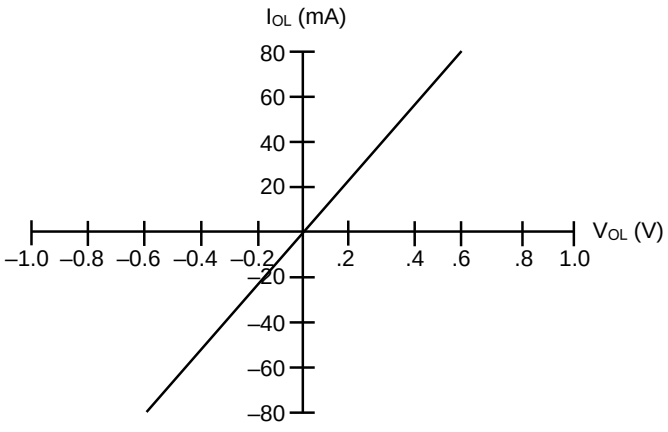
Parameter Symbol	Parameter Description				-18 Min	-18 Max	Unit
t_{PD}	Input, I/O, or Feedback to Combinatorial Output (Note 3)					18	ns
t_S	Setup Time from Input, I/O, or Feedback			D-type	12		ns
				T-type	13.5		ns
t_H	Hold Time				0		ns
t_{CO}	Clock to Output (Note 3)					12	ns
t_{WL}	Clock Width			LOW	7.5		ns
t_{WH}				HIGH	7.5		ns
f_{MAX}	Maximum Frequency (Note 1)	External Feedback	$1/(t_S + t_{CO})$	D-type	40		MHz
				T-type	38		MHz
		Internal Feedback (f_{CNT})		D-type	53		MHz
				T-type	44		MHz
		No Feedback	$1/(t_{WL} + t_{WH})$		66.5		MHz
t_{AR}	Asynchronous Reset to Registered Output					24	ns
t_{ARW}	Asynchronous Reset Width (Note 1)				18		ns
t_{ARR}	Asynchronous Reset Recovery Time (Note 1)				12		ns
t_{AP}	Asynchronous Preset to Registered Output					24	ns
t_{APW}	Asynchronous Preset Width (Note 1)				18		ns
t_{APR}	Asynchronous Preset Recovery Time (Note 1)				12		ns
t_{EA}	Input, I/O, or Feedback to Output Enable (Note 3)					18	ns
t_{ER}	Input, I/O, or Feedback to Output Disable (Note 3)					18	ns

Notes:

1. *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.*
2. *See Switching Test Circuit, for test conditions.*
3. *Parameters measured with 24 outputs switching.*

TYPICAL CURRENT vs. VOLTAGE (I-V) CHARACTERISTICS

V_{CC} = 5.0 V, T_A = 25°C



Output, LOW

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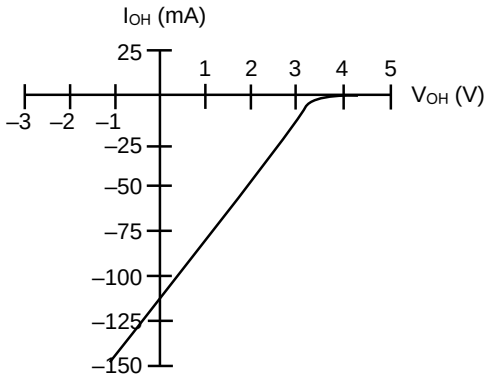

Output, HIGH

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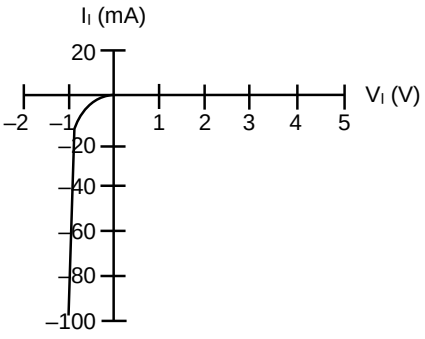
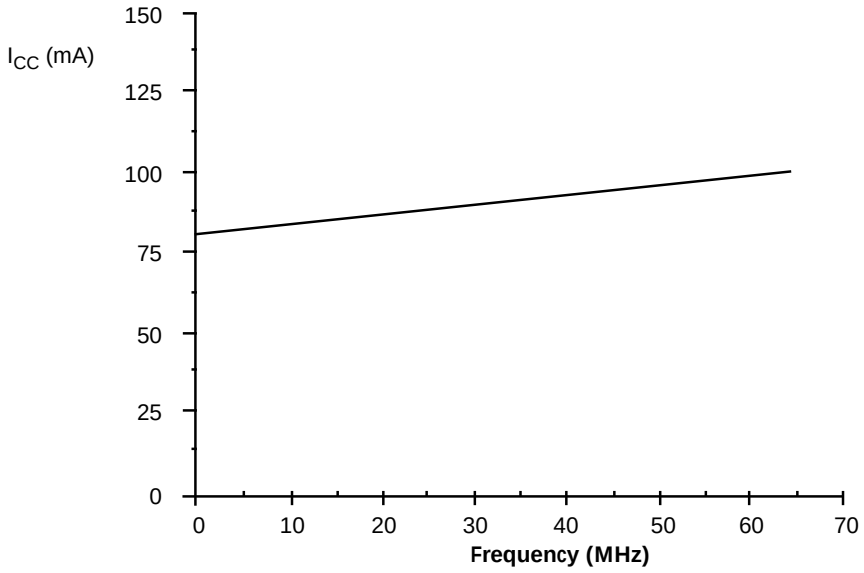


Input

14129J-6

TYPICAL I_{CC} CHARACTERISTICS

V_{CC} = 5 V, T_A = 25°C



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The selected "typical" pattern is a 12-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 CHARACTERISTICS

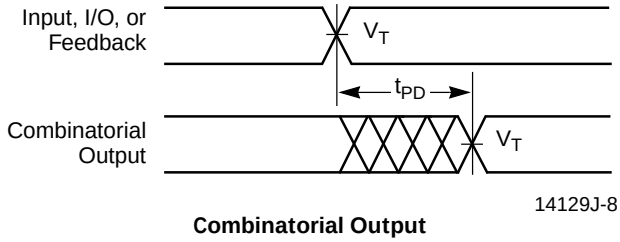
Measured at 25°C ambient. These parameters are not tested.

Parameter Symbol	Parameter Description		Typ PLCC	Unit
θ_{jc}	Thermal impedance, junction to case		13	°C/W
θ_{ja}	Thermal impedance, junction to ambient		37	°C/W
θ_{jma}	Thermal impedance, junction to ambient with air flow	200 lfpm air	33	°C/W
		400 lfpm air	30	°C/W
		600 lfpm air	28	°C/W
		800 lfpm air	25	°C/W

Plastic θjc Considerations

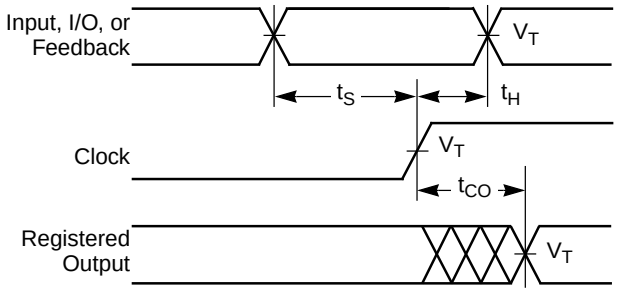
The data listed for plastic θjc are for reference only and are not recommended for use in calculating junction temperatures. The heat-flow paths in plastic-encapsulated devices are complex, making the θjc measurement relative to a specific location on the package surface. Tests indicate this measurement reference point is directly below the die-attach area on the bottom center of the package. Furthermore, θjc 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. The thermal measurements are taken with components on a six-layer printed circuit board.

SWITCHING WAVEFORMS



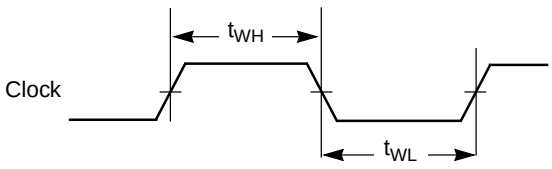
14129J-8

Combinatorial Output



14129J-9

Registered Output



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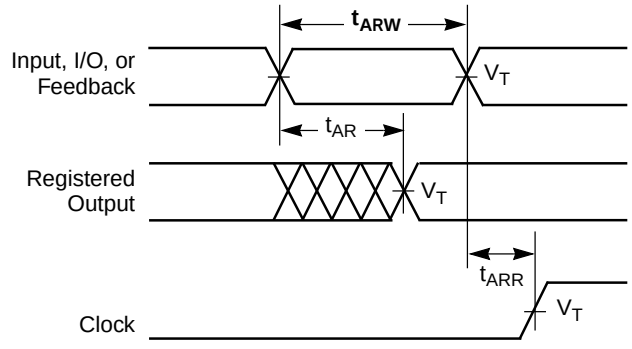
Clock Width

Notes:

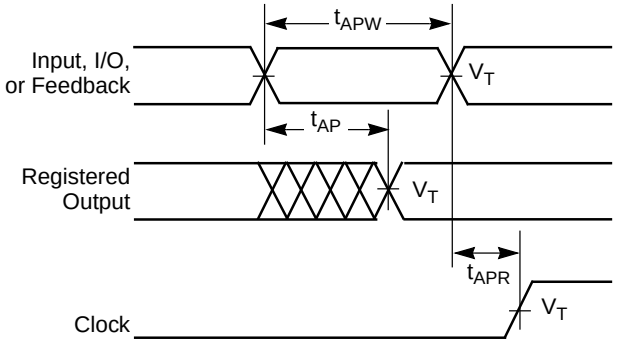
1. *V_T = 1.5 V.*
2. *Input pulse amplitude 0 V to 3.0 V.*
3. *Input rise and fall times 2 ns–4 ns typical.*

SWITCHING WAVEFORMS



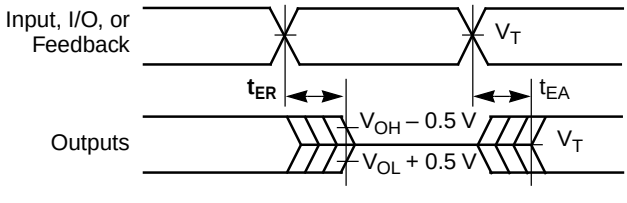
14129J-11

Asynchronous Reset



14129J-12

Asynchronous Preset



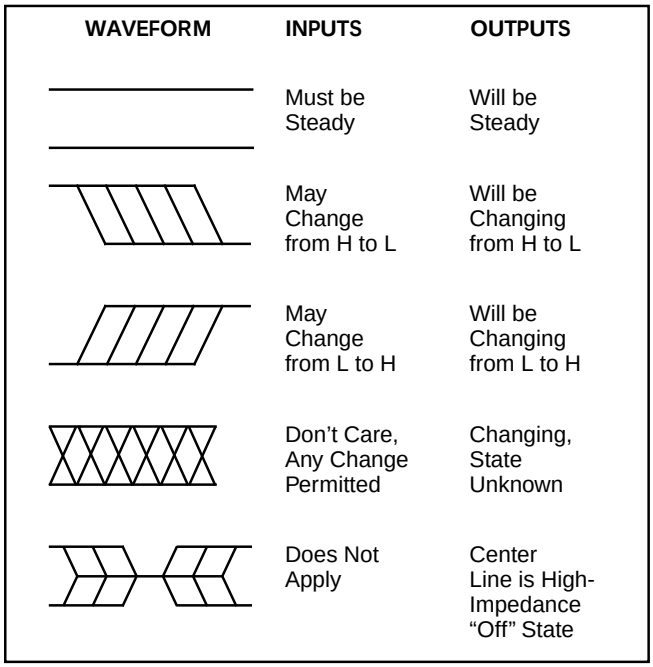
14129J-13

Output Disable/Enable

Notes:

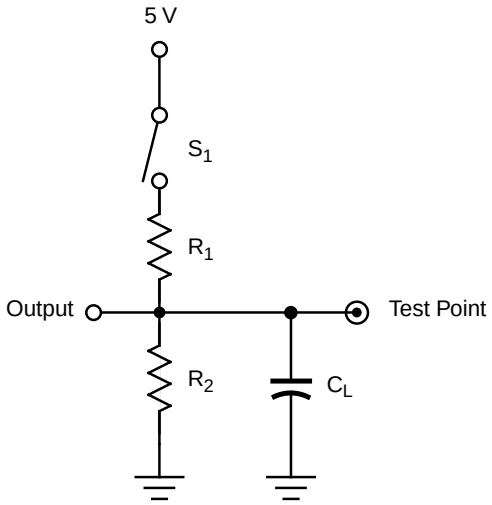
1. *V_T = 1.5 V.*
2. *Input pulse amplitude 0 V to 3.0 V.*
3. *Input rise and fall times 2 ns–4 ns typical.*

KEY TO SWITCHING WAVEFORMS



KS000010-PAL

SWITCHING TEST CIRCUIT



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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				
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.

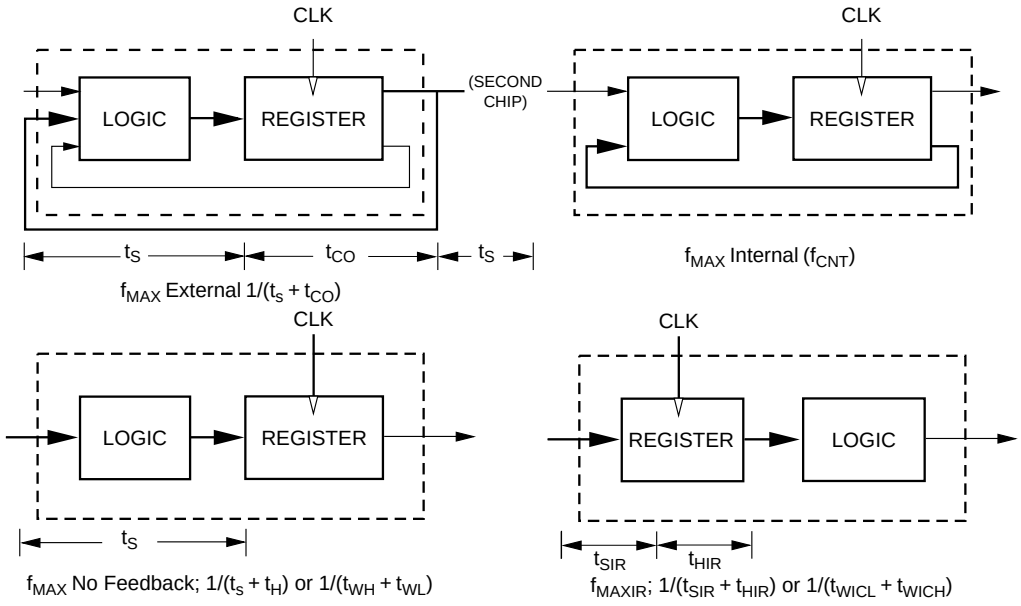
The first type of design is a state machine with feedback signals sent off-chip. This external feedback could go back to the device inputs, or to a second device in a multi-chip state machine. The slowest path defining the period is the sum of the clock-to-output time and the input setup time for the 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 use in the same path, the overall frequency will be limited by t_{ICS}.

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



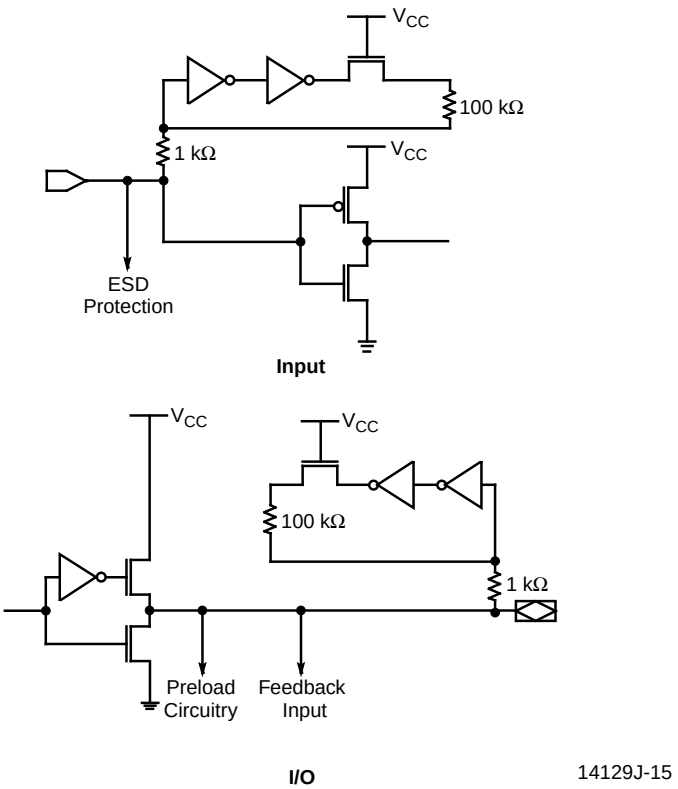
ENDURANCE CHARACTERISTICS

The MACH families are manufactured using Vantis' 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		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



Input

I/O

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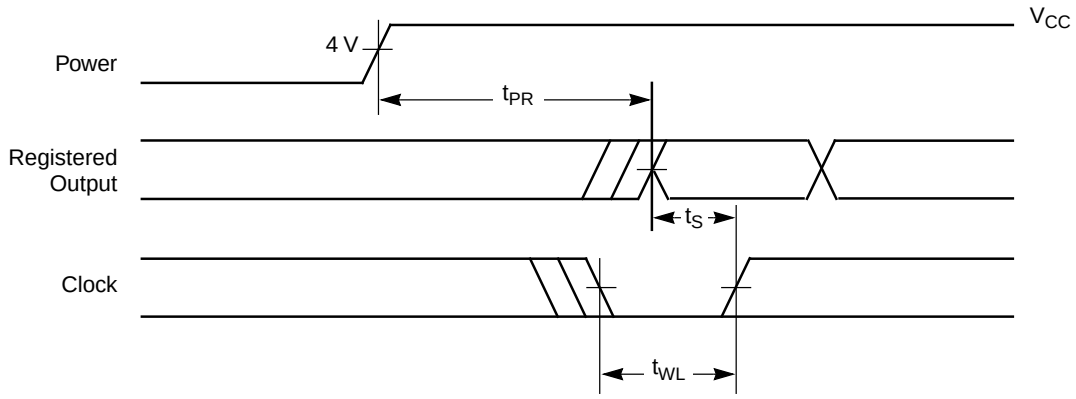
POWER-UP RESET

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		



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Power-Up Reset Waveform