

USE GAL DEVICES FOR NEW DESIGNS

FINAL

COM'L: H-25

PALCE29M16H-25

Lattice Semiconductor

24-Pin EE CMOS Programmable Array Logic

DISTINCTIVE CHARACTERISTICS

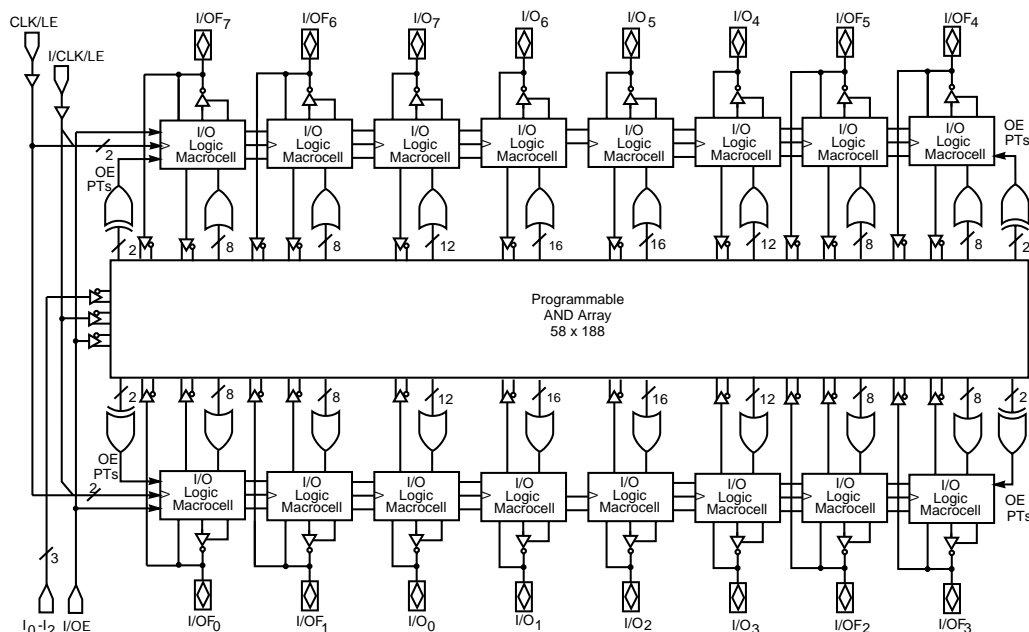
- High-performance semicustom logic replacement; Electrically Erasable (EE) technology allows reprogrammability
- 16 bidirectional user-programmable I/O logic macrocells for Combinatorial/Registered/Latched operation
- Output Enable controlled by a pin or product terms
- Varied product term distribution for increased design flexibility
- Programmable clock selection with two clocks/latch enables (LEs) and LOW/HIGH clock/LE polarity
- Register/Latch Preload permits full logic verification
- High speed ($t_{PD} = 25$ ns, $f_{MAX} = 33$ MHz and f_{MAX} internal = 50 MHz)
- Full-function AC and DC testing at the factory for high programming and functional yields and high reliability
- 24-Pin 300 mil SKINNYDIP and 28-pin plastic leaded chip carrier packages
- Extensive third-party software and programmer support through FusionPLD partners

GENERAL DESCRIPTION

The PALCE29M16 is a high-speed, EE CMOS Programmable Array Logic (PAL) device designed for general logic replacement in TTL or CMOS digital systems. It offers high speed, low power consumption, high programming yield, fast programming and excellent reliability. PAL devices combine the flexibility of custom

logic with the off-the-shelf availability of standard products, providing major advantages over other semicustom solutions such as gate arrays and standard cells, including reduced development time and low up-front development cost.

BLOCK DIAGRAM



08740G-1

GENERAL DESCRIPTION (continued)

The PALCE29M16 uses the familiar sum-of-products (AND-OR) structure, allowing users to customize logic functions by programming the device for specific applications. It provides up to 29 array inputs and 16 outputs. It incorporates our unique input/output logic macro-cell which provides flexible input/output structure and polarity, flexible feedback selection, multiple Output Enable choices, and a programmable clocking scheme. The macrocells can be individually programmed as combinatorial, registered, or latched with active-HIGH or active-LOW polarity. The flexibility of the logic macro-cells permits the system designer to tailor the device to particular application requirements.

Increased logic power has been built into the PALCE29M16 by providing a varied number of logic product terms per output. Eight outputs have 8 product

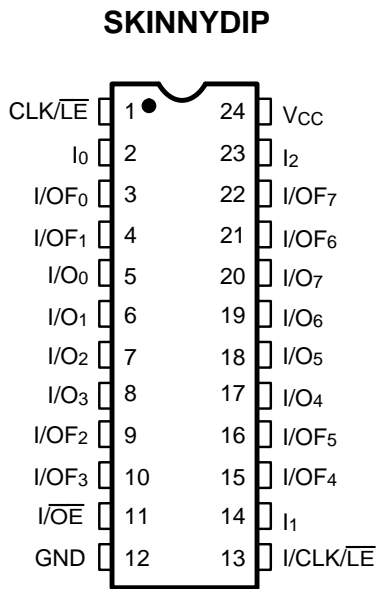
terms each, four outputs have 12 product terms each, and the other four outputs have 16 product terms each. This varied product-term distribution allows complex functions to be implemented in a single PAL device. Each output can be dynamically controlled by a common Output Enable pin or Output Enable product terms per bank of four outputs. Each output can also be permanently enabled or disabled.

System operation has been enhanced by the addition of common asynchronous-Preset and Reset product terms and a power-up Reset feature. The PALCE29M16 also incorporates Preload and Observability functions which permit full logic verification of the design.

The PALCE29M16 is offered in the space-saving 300-mil SKINNYDIP package as well as the plastic leaded chip carrier package.

CONNECTION DIAGRAMS

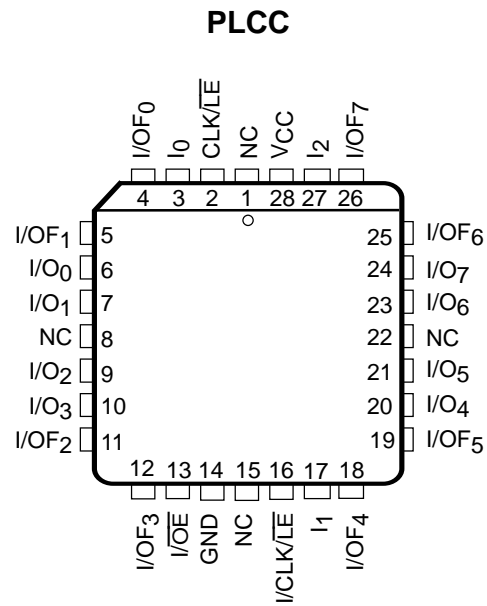
Top View



08740G-2

Note:

Pin 1 is marked for orientation.



08740G-3

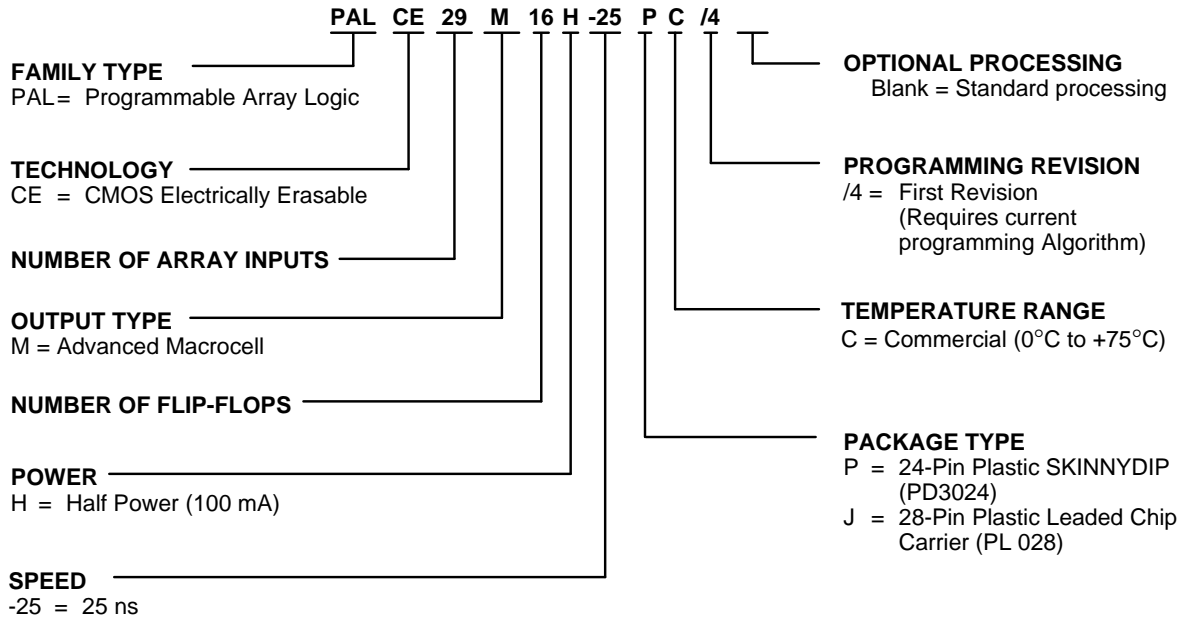
PIN DESIGNATIONS

- CLK/ \overline{LE} = Clock/Latch Enable
- GND = Ground
- I = Input
- I/CLK/ \overline{LE} = Input or Clock/Latch Enable
- I/O = Input/Output
- I/O_F = Input/Output with Dual Feedback
- NC = No Connection
- V_{CC} = Supply Voltage

ORDERING INFORMATION

Commercial Products

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		
PALCE29M16H-25	PC, JC	/4

Valid Combinations

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

FUNCTIONAL DESCRIPTION

Inputs

The PALCE29M16 has 29 inputs to drive each product term (up to 58 inputs with both TRUE and complement versions available to the AND array) as shown in the block diagram in Figure 1. Of these 29 inputs, 3 are dedicated inputs, 16 are from 8 I/O logic macrocells with two feedbacks, 8 are from other I/O logic macrocells with single feedback, one is the $\overline{I/OE}$ input and one is the $\overline{I/CLK/LE}$ input.

Initially the AND-array gates are disconnected from all the inputs. This condition represents a logical TRUE for the AND array. By selectively programming the EE cells, the AND array may be connected to either the TRUE input or the complement input. When both the TRUE and complement inputs are connected, a logical FALSE results at the output of the AND gate.

Product Terms

The degree of programmability and complexity of a PAL device is determined by the number of connections that form the programmable-AND and OR gates. Each programmable-AND gate is called a product term. The PALCE29M16 has 188 product terms; 176 of these product terms provide logic capability and 12 are architectural or control product terms. Among the 12 control product terms, two are for common Asynchronous-Preset and Reset, one is for Observability, and one is for Preload. The other eight are common Output Enable product terms. The Output Enable of each bank of four macrocells can be programmed to be controlled by a common Output Enable pin or two AND/XOR product terms. It may be also permanently enabled or permanently disabled.

Each product term on the PALCE29M16 consists of a 58-input AND gate. The outputs of these AND gates are

connected to a fixed-OR plane. Product terms are allocated to OR gates in a varied distribution across the device ranging from 8 to 16 wide, with an average of 11 logic product terms per output. An increased number of product terms per output allows more complex functions to be implemented in a single PAL device. This flexibility aids in implementing functions such as counters, exclusive-OR functions, or complex state machines, where different states require different numbers of product terms.

Common asynchronous-Preset and Reset product terms are connected to all Registered or Latched I/Os.

When the asynchronous-Preset product term is asserted (HIGH) all the registers and latches will immediately be loaded with a HIGH, independent of the clock. When the asynchronous-Reset product term is asserted (HIGH) all the registers and latches will be immediately loaded with a LOW, independent of the clock. The actual output state will depend on the macrocell polarity selection. The latches must be in latched mode (not transparent mode) for the Reset, Preset, Preload, and power-up Reset modes to be meaningful.

Input/Output Logic Macrocells

The I/O logic macrocell allows the user the flexibility of defining the architecture of each input or output on an individual basis. It also provides the capability of using the associated pin either as an input or an output.

The PALCE29M16 has 16 macrocells, one for each I/O pin. Each I/O macrocell can be programmed for combinatorial, registered or latched operation (see Figure 2). Combinatorial output is desired when the PAL device is used to replace combinatorial glue logic. Registers and Latches are used in synchronous logic applications.

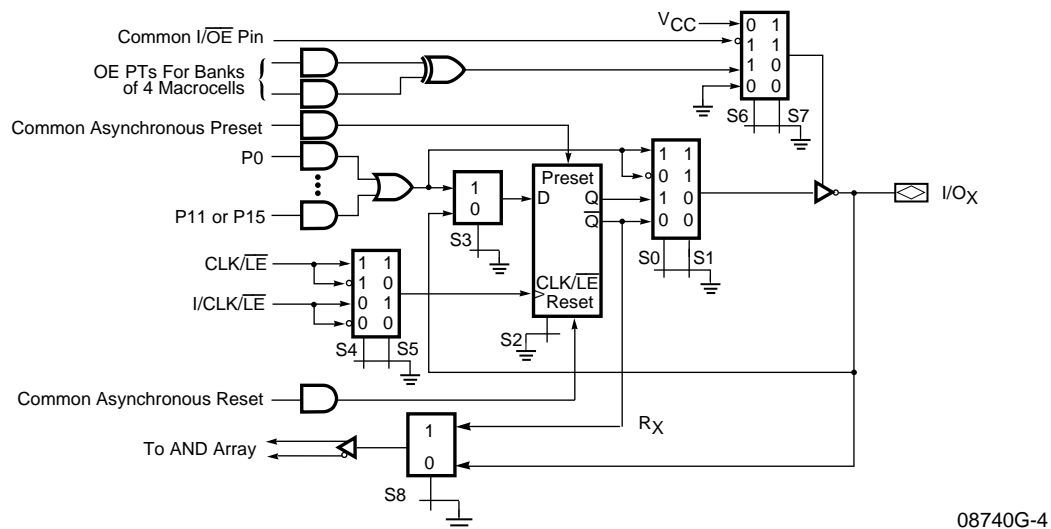


Figure 2a. PALCE29M16 Macrocell (Single Feedback)

The output polarity for each macrocell in each of the three modes of operation is user-selectable, allowing complete flexibility of the macrocell configuration.

Eight of the macrocells (I/OF₀–I/OF₇) have two independent feedback paths to the AND array (see Figure 2b). The first is a dedicated I/O pin feedback to the AND array for combinatorial input. The second path consists of a direct register/latch feedback to the array. If the pin is used as a dedicated input using the first feedback path, the register/latch feedback path is still available to the AND array. This path provides the capability of using the register/latch as a buried state register/latch. The other eight macrocells have a single feedback path to the AND array. This feedback is user-selectable as either an I/O pin or a register/latch feedback (see Figure 2a).

Each macrocell can provide true input/output capability. The user can select each macrocell register/latch to be driven by either the signal generated by the AND-OR array or the I/O pin. When the I/O pin is selected as the input, the feedback path provides the register/latch input to the array. When used as an input, each macrocell is also user-programmable for registered, latched, or combinatorial input.

The PALCE29M16H has a dedicated CLK/ \overline{LE} pin and an I/CLK/ \overline{LE} pin. All macrocells have a programmable switch to choose between these two pins as the clock or latch enable signal. These signals are clock signals for macrocells configured as registers and latch enable signals for macrocells configured as latches. The polarity of these CLK/ \overline{LE} signals is also individually programmable. Thus different registers or latches can be driven by different clocks and clock phases.

The Output-Enable mode of each of the macrocells can be selected by the user. The I/O pin can be configured as an output pin (permanently enabled) or as an input pin (permanently disabled). It can also be configured as

a dynamic I/O controlled by the Output Enable pin or by two AND-XOR product terms which are available for each bank of four I/O Logic Macrocells.

I/O Logic Macrocell Configuration

Our unique I/O macrocell offers major benefits through its versatile, programmable input/output cell structure, multiple clock choices, flexible Output Enable and feedback selection. Eight I/O macrocells with single feedback contain 9 EE cells, while the other eight macrocells contain 8 EE cells for programming the input/output functions (see Table 1).

EE cell S₁ controls whether the macrocell will be combinatorial or registered/latched. S₀ controls the output polarity (active-HIGH or active-LOW). S₂ determines whether the storage element is a register or a latch. S₃ allows the use of the macrocell as an input register/latch or as an output register/latch. It selects the direction of the data path through the register/latch. If connected to the usual AND-OR array output, the register/latch is an output connected to the I/O pin. If connected to the I/O pin, the register/latch becomes an input register/latch to the AND array using the feedback data path.

Programmable EE cells S₄ and S₅ allow the user to select one of the four CLK/ \overline{LE} signals for each macrocell. S₆ and S₇ are used to control Output Enable as pin controlled, two-product-term-controlled, permanently enabled or permanently disabled. S₈ controls a feedback multiplexer for the macrocells with a single feedback path only.

Using the programmable EE cells S₀–S₈ various input and output configurations can be selected. Some of the possible configuration options are shown in Figure 3.

In the unprogrammed state (charged, disconnected), an architectural cell is said to have a value of “1”; in the programmed state (discharged, connected to GND), an architectural cell is said to have a value of “0.”

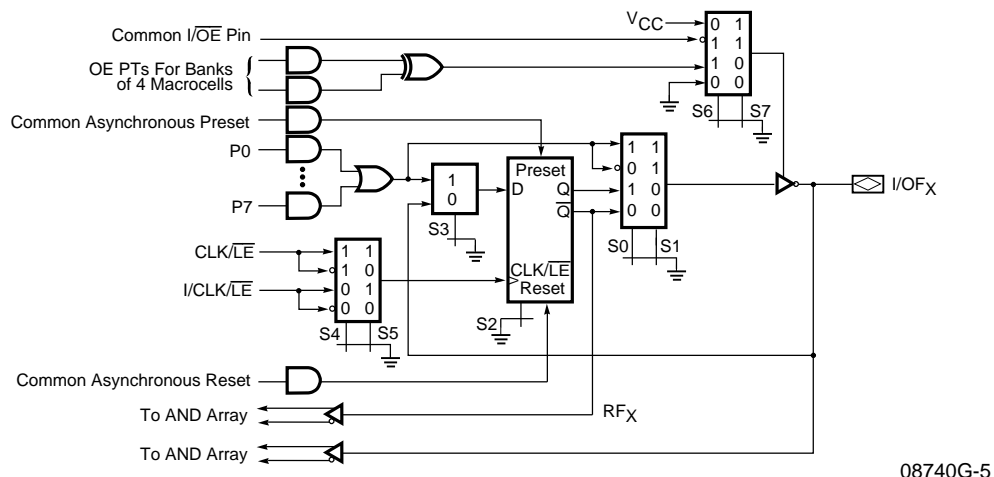


Figure 2b. PALCE29M16 Macrocell (Dual Feedback)

Table 1a. PALCE29M16 I/O Logic Macrocell Architecture Selections

S ₃	I/O Cell
1	Output Cell
0	Input Cell

S ₂	Storage Element
1	Register
0	Latch

S ₁	Output Type
1	Combinatorial
0	Register/Latch

S ₀	Output Polarity
1	Active LOW
0	Active HIGH

S ₈	Feedback*
1	Register/Latch
0	I/O

**Applies to macrocells with single feedback only.*

Table 1b. PALCE29M16 I/O Logic Macrocell Clock Polarity and Output Enable Selections

S ₄	S ₅	Clock Edge/Latch Enable Level
1	1	CLK/ $\overline{\text{LE}}$ pin positive-going edge, active-LOW LE
1	0	CLK/ $\overline{\text{LE}}$ pin negative-going edge, active-HIGH LE
0	1	I/CLK/ $\overline{\text{LE}}$ pin positive-going edge, active-LOW LE
0	0	I/CLK/ $\overline{\text{LE}}$ pin negative-going edge, active-HIGH LE

S ₆	S ₇	Output Buffer Control
1	1	Pin-Controlled Three-State Enable
1	0	XOR PT-Controlled Three-State Enable
0	1	Permanently Enabled (Output only)
0	0	Permanently Disabled (Input only)

Notes:

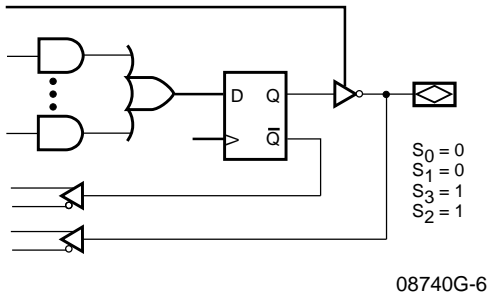
1 = Erased State (charged or disconnected).

0 = Programmed State (discharged or connected).

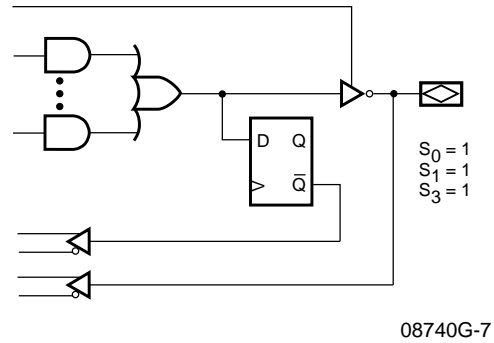
*Active-LOW LE means that data is stored when the $\overline{\text{LE}}$ pin is HIGH, and the latch is transparent when the $\overline{\text{LE}}$ pin is LOW. Active-HIGH LE means the opposite.

SOME POSSIBLE CONFIGURATIONS OF THE INPUT/OUTPUT LOGIC MACROCELL

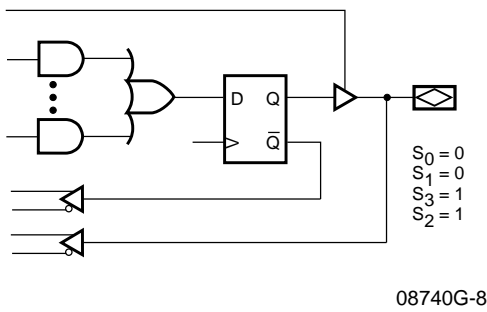
(For other useful configurations, please refer to the macrocell diagrams in Figure 2. All macrocell architecture cells are independently programmable).



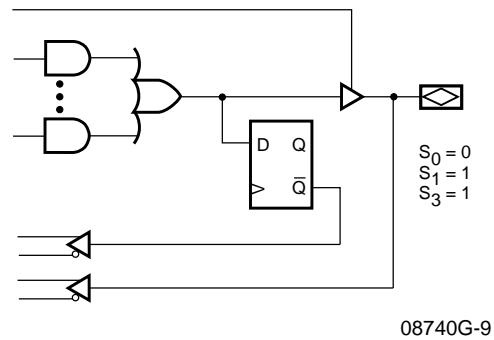
Output Registered/Active Low



Output Combinatorial/Active Low

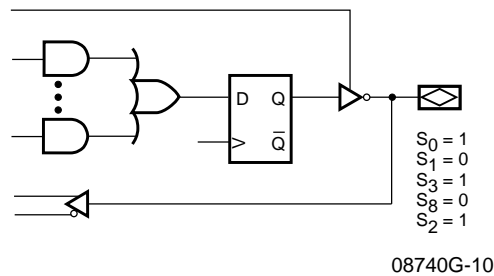


Output Registered/Active High

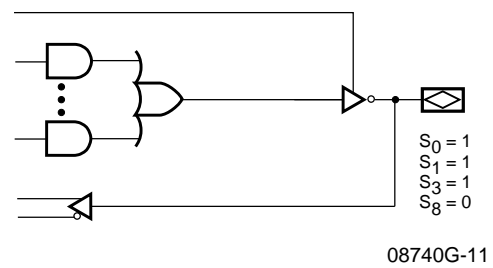


Output Combinatorial/Active High

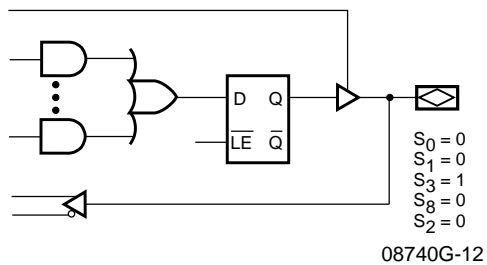
Figure 3a. Dual Feedback Macrocells



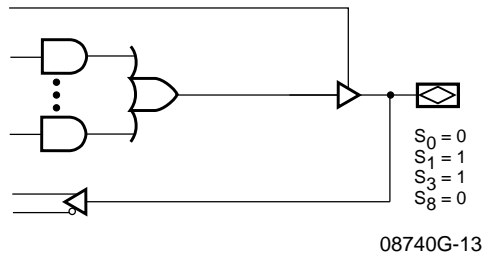
Output Registered/Active Low, I/O Feedback



Output Combinatorial/Active Low, I/O Feedback



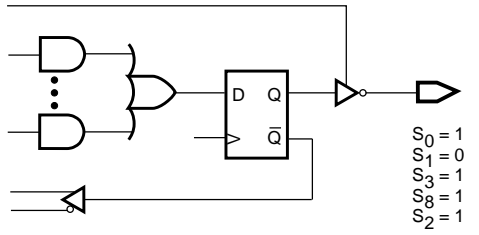
Output Latched/Active High, I/O Feedback



Output Combinatorial/Active High, I/O Feedback

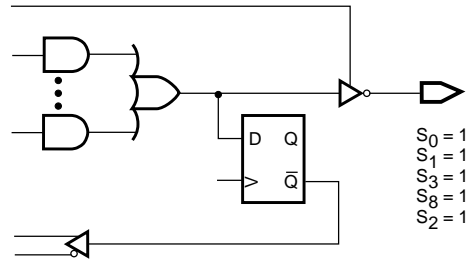
Figure 3b. Single Feedback Macrocells

POSSIBLE CONFIGURATIONS OF THE INPUT/OUTPUT LOGIC MACROCELL



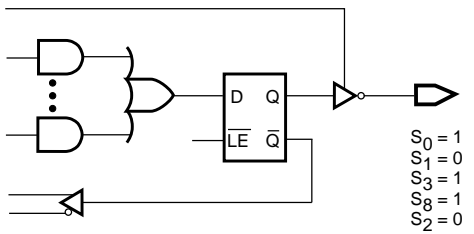
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**Output Registered/Active Low,
Register Feedback**



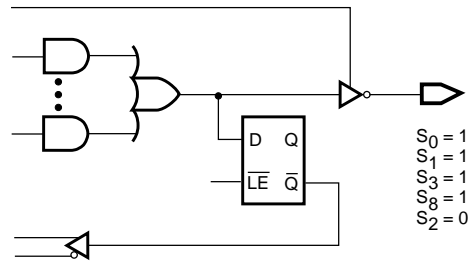
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**Output Combinatorial/Active Low,
Register Feedback**



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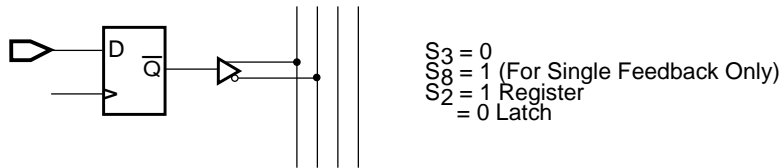
**Output Latched/Active Low,
Latched Feedback**



08740G-17

**Output Combinatorial/Active Low,
Latched Feedback**

Figure 3b. Single Feedback Macrocells (continued)



Programmable-AND Array

08740G-18

Input Registered/Latched

Figure 3c. All Macrocells

Power-Up Reset

All flip-flops power up to a logic LOW for predictable system initialization. The outputs of the PALCE29M16 depend on whether they are selected as registered or combinatorial. If registered is selected, the output will be LOW if programmed as active LOW and HIGH if programmed as active HIGH. If combinatorial is selected, the output will be a function of the logic.

Preload

To simplify testing, the PALCE29M16 is designed with preload circuitry that provides an easy method for testing logical functionality. Both product-term-controlled and supervoltage-enabled preload modes are available. The TTL-level preload product term can be useful during debugging, where supervoltages may not be available.

Preload allows any arbitrary state value to be loaded into the registers/latches of the device. A typical functional-test sequence would be to verify all possible state transitions for the device being tested. This requires the ability to set the state registers into an arbitrary “present state” value and to set the device’s inputs into an arbitrary “present input” value. Once this is done, the state machine is clocked into a new state, or “next state,” which can be checked to validate the transition from the “present state.” In this way any transition can be checked.

Since preload can provide the capability to go directly to any desired arbitrary state, test sequences may be greatly shortened. Also, all possible states can be tested, thus greatly reducing test time and development costs and guaranteeing proper in-system operation.

Observability

The output register/latch observability product term, when asserted, suppresses the combinatorial output data from appearing on the I/O pin and allows the observation of the contents of the register/latch on the output

pin for each of the logic macrocells. This unique feature allows for easy debugging and tracing of the buried state machines. In addition, a capability of supervoltage observability is also provided.

Security Cell

A security cell is provided on each device to prevent unauthorized copying of the user’s proprietary logic design. Once programmed, the security cell disables the programming, verification, preload, and the observability modes. The only way to erase the protection cell is by erasing the entire array and architecture cells, in which case no proprietary design can be copied. (This cell should be programmed only after the rest of the device has been completely programmed and verified.)

Programming and Erasing

The PALCE29M16 can be programmed on standard logic programmers. It may also be erased to reset a previously configured device back to its virgin state. Erasure is automatically performed by the programming hardware. No special erasure operation is required.

Quality and Testability

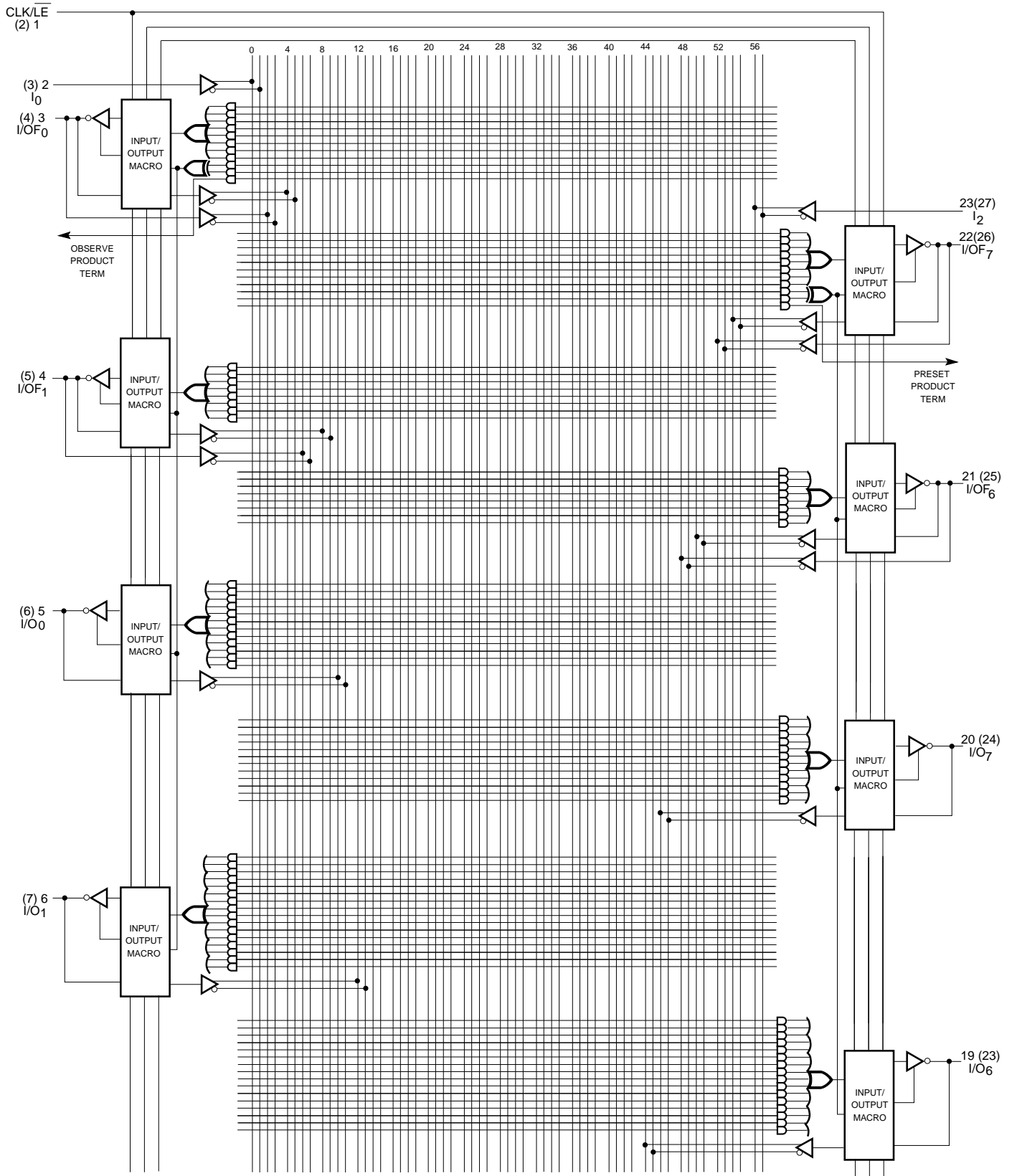
The PALCE29M16 offers a very high level of built-in quality. The erasability of the device provides a direct means of verifying performance of all the AC and DC parameters. In addition, this verifies complete programmability and functionality of the device to yield the highest programming yield and post-programming functional yield in the industry.

Technology

The high-speed PALCE29M16 is fabricated with our advanced electrically-erasable (EE) CMOS process. The array connections are formed with proven EE cells. Inputs and outputs are designed to be compatible with TTL devices. This technology provides strong input-clamp diodes, output slew-rate control, and a grounded substrate for clean switching.

LOGIC DIAGRAM

DIP (PLCC) Pinouts

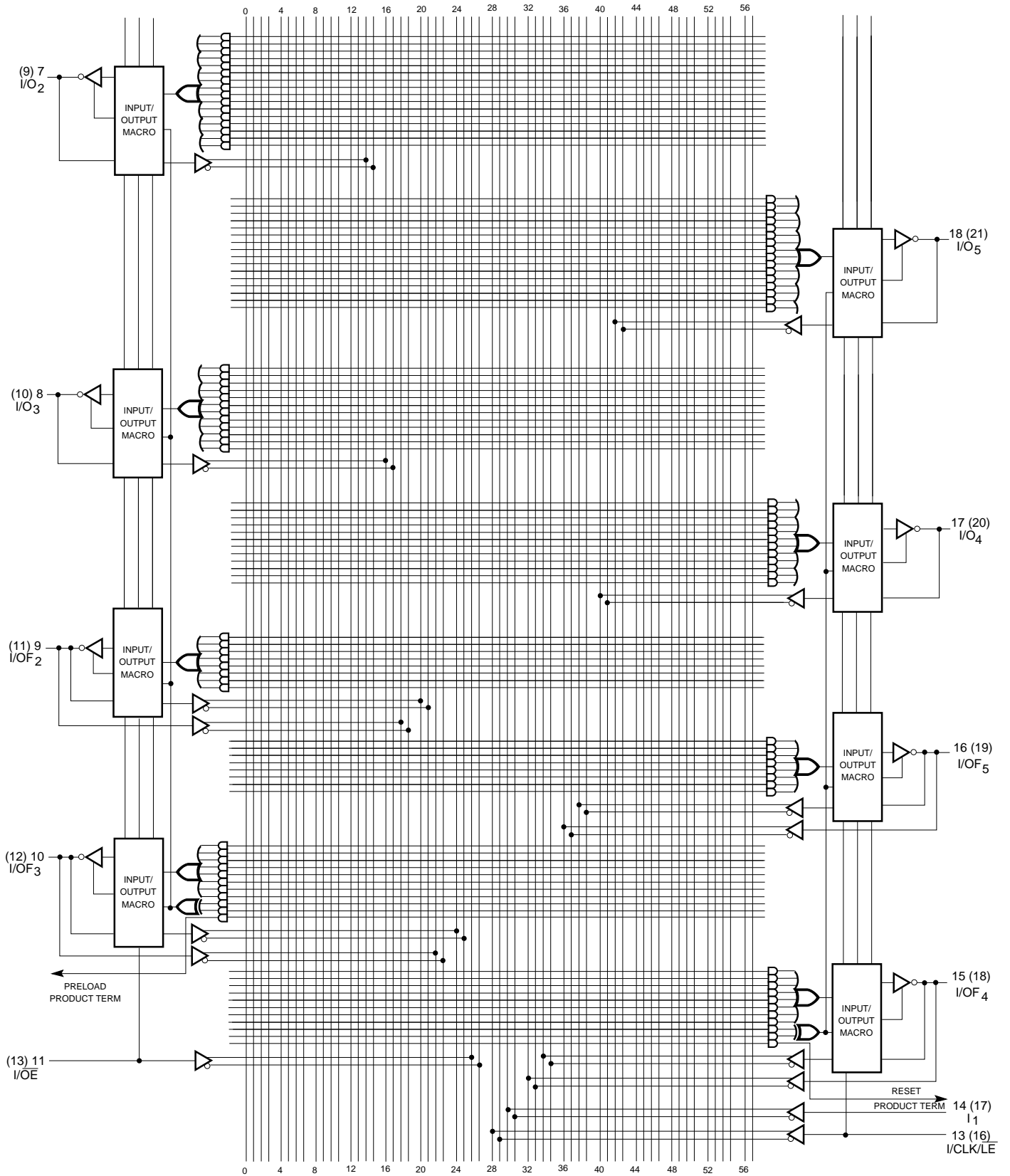


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LOGIC DIAGRAM

DIP (PLCC) Pinouts



08740G-19
(concluded)

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 $+75^\circ\text{C}$)	100 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 75°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 unless otherwise specified

Parameter Symbol	Parameter Description	Test Conditions	Min	Max	Unit
V_{OH}	Output HIGH Voltage	$I_{OH} = -2$ mA $V_{IN} = V_{IH}$ or V_{IL} $V_{CC} = \text{Min}$	2.4		V
V_{OL}	Output LOW Voltage	$I_{OL} = 8$ mA $V_{IN} = V_{IH}$ or V_{IL}		0.5	V
		$I_{OL} = 4$ mA $V_{CC} = \text{Min}$		0.33	
		$I_{OL} = 20$ μA		0.1	
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 Leakage Current	$V_{IN} = 5.5$ V, $V_{CC} = \text{Max}$ (Note 2)		10	μA
I_{IL}	Input LOW Leakage Current	$V_{IN} = 0$ V, $V_{CC} = \text{Max}$ (Note 2)		-10	μA
I_{OZH}	Off-State Output Leakage Current HIGH	$V_{OUT} = 5.5$ V, $V_{CC} = \text{Max}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 2)		10	μA
I_{OZL}	Off-State Output Leakage Current LOW	$V_{OUT} = 5.5$ V, $V_{CC} = \text{Max}$ $V_{IN} = V_{IH}$ or V_{IL} (Note 2)		-10	μA
I_{SC}	Output Short-Circuit Current	$V_{OUT} = 0.5$ V, $V_{CC} = \text{Max}$ (Note 3)	-30	-130	mA
I_{CC}	Supply Current	$V_{IN} = 0$ V, Outputs Open ($I_{OUT} = 0$ mA) $V_{CC} = \text{Max}$		100	mA

Notes:

- These are absolute values with respect to device ground all overshoots due to system and/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.

CAPACITANCE (Note 1)

Parameter Symbol	Parameter Description	Test Conditions		Typ	Unit
C _{IN}	Input Capacitance	V _{IN} = 0 V	V _{CC} = 5.0 V, T _A = 25°C, f = 1 MHz	5	pF
C _{OUT}	Output Capacitance	V _{OUT} = 0 V		8	pF

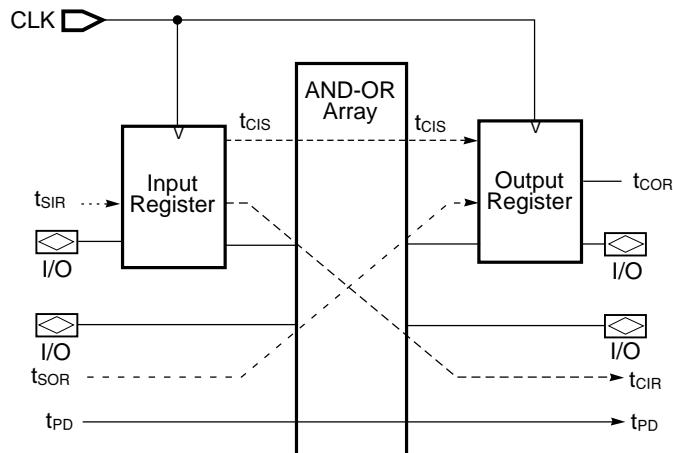
Note:

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.

SWITCHING CHARACTERISTICS

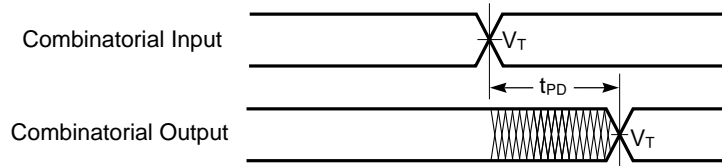
Registered Operation

Parameter Symbol	Parameter Description	Min	Max	Unit
Combinatorial Output				
t _{PD}	Input or I/O Pin to Combinatorial Output		25	ns
Output Register				
t _{SOR}	Input or I/O Pin to Output Register Setup	15		ns
t _{COR}	Output Register Clock to Output		15	ns
t _{HOR}	Data Hold Time for Output Register	0		ns
Input Register				
t _{SIR}	I/O Pin to Input Register Setup	2		ns
t _{CIR}	Register Feedback Clock to Combinatorial Output		28	ns
t _{HIR}	Data Hold Time for Input Register	6		ns
Clock and Frequency				
t _{CIS}	Register Feedback to Output Register/Latch Setup	20		ns
f _{MAX}	Maximum Frequency 1/(t _{SOR} + t _{COR})	33.3		MHz
f _{MAXI}	Maximum Internal Frequency 1/t _{CIS}	50		MHz
t _{CWH}	Pin Clock Width HIGH	8		ns
t _{CWL}	Pin Clock Width LOW	8		ns



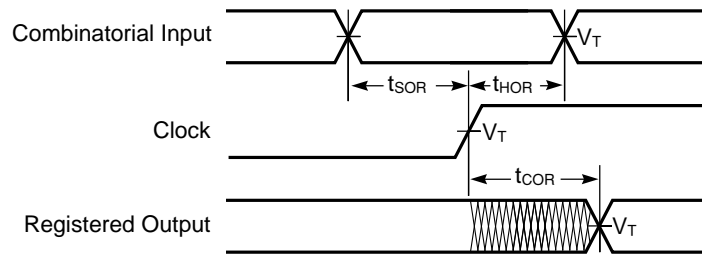
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SWITCHING WAVEFORMS



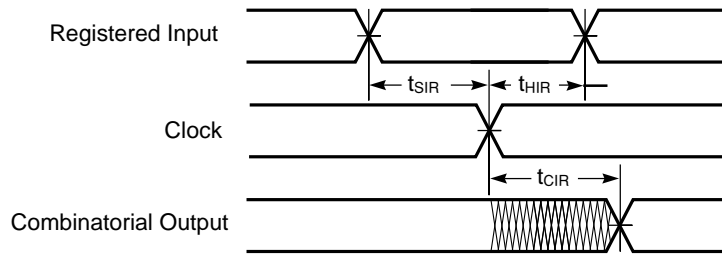
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Combinatorial Output



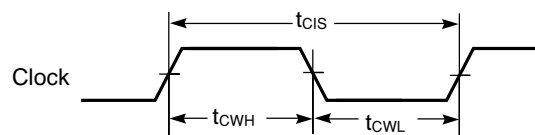
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Output Register



08740G-23

Input Register



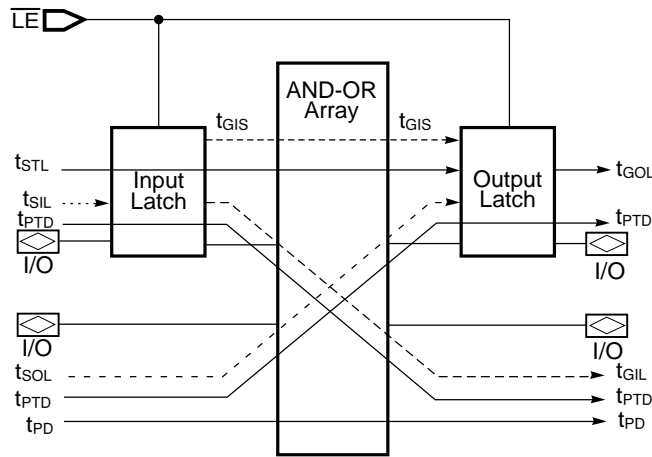
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Clock Width

SWITCHING CHARACTERISTICS

Latched Operation

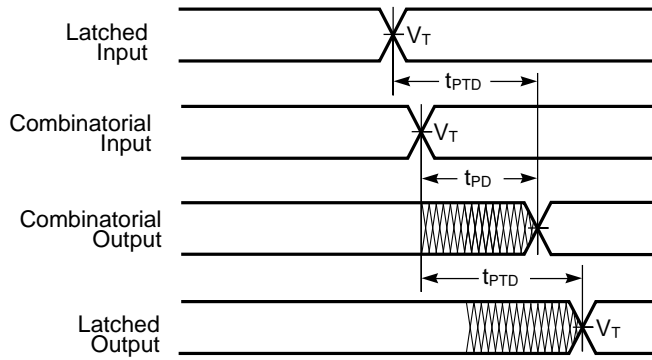
Parameter Symbol	Parameter Description	Min	Max	Unit
Combinatorial Output				
t _{PD}	Input or I/O Pin to Combinatorial Output		25	ns
t _{PTD}	Input or I/O Pin to Output via One Transparent Latch		28	ns
Output Latch				
t _{SOL}	Input or I/O Pin to Output Latch Setup	15		ns
t _{GOL}	Latch Enable to Output Through Transparent Output Latch		15	ns
t _{HOL}	Data Hold Time for Output Latch	0		ns
t _{STL}	Input or I/O Pin to Output Latch Setup via Transparent Input Latch	18		ns
Input Latch				
t _{SIL}	I/O Pin to Input Latch Setup	2		ns
t _{GIL}	Latch Feedback, Latch Enable Transparent Mode to Combinatorial Output		28	ns
t _{HIL}	Data Hold Time for Input Latch	6		ns
Latch Enable				
t _{GIS}	Latch Feedback to Output Register/Latch Setup	20		ns
t _{GWH}	Pin Enable Width HIGH	8		ns
t _{GWL}	Pin Enable Width LOW	8		ns



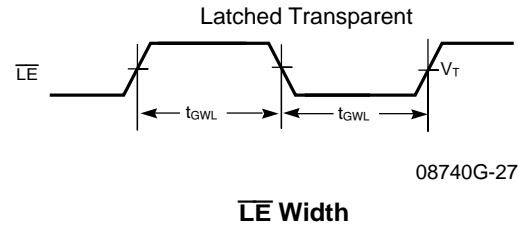
08740G-25

Input/Output Latch Specs

SWITCHING WAVEFORMS

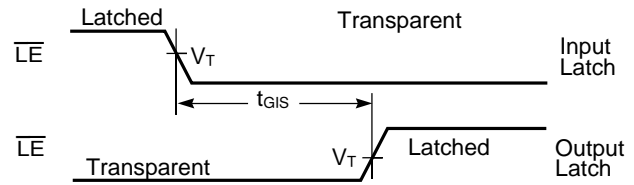


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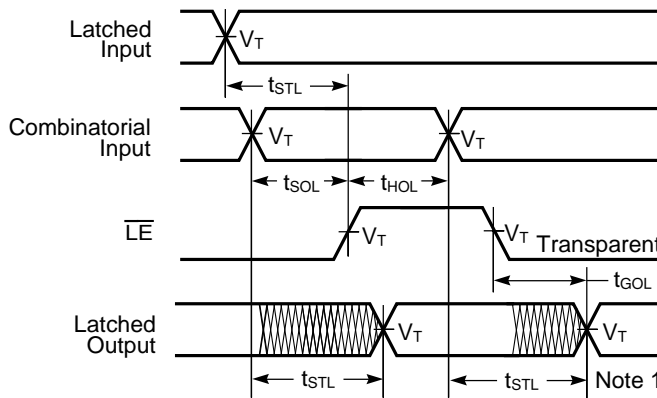
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Latch (Transparent Mode)



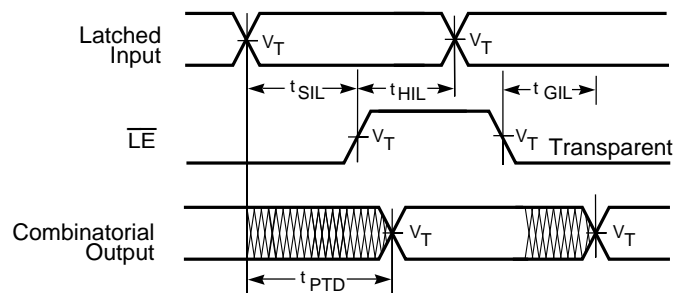
08740G-29

Input and Output Latch Relationship



08740G-28

Output Latch



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Input Latch

Note:

1. If the combinatorial input changes while \overline{LE} is in the latched mode and \overline{LE} goes into the transparent mode after t_{PTD} ns has elapsed, the corresponding latched output will change t_{GOL} ns after \overline{LE} goes into the transparent mode. If the combinatorial input change while \overline{LE} is in the latched mode and \overline{LE} goes into the transparent mode before t_{PTD} ns has elapsed, the corresponding latched output will change at the later of the following— t_{PTD} ns after the combinatorial input changes or t_{GOL} ns after \overline{LE} goes into the latched mode.

SWITCHING CHARACTERISTICS

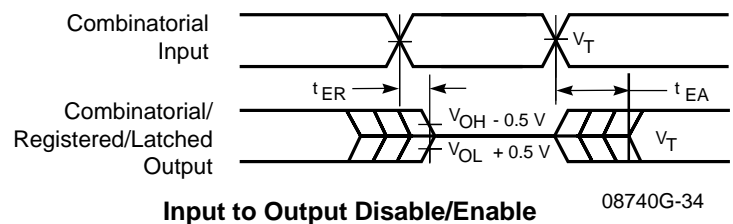
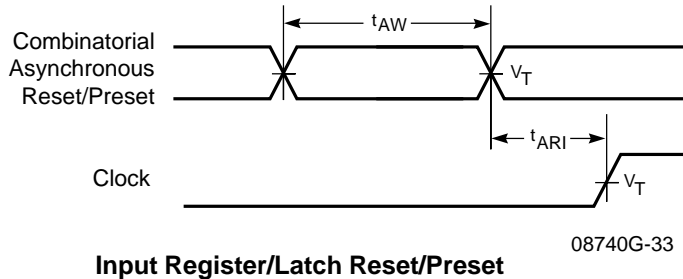
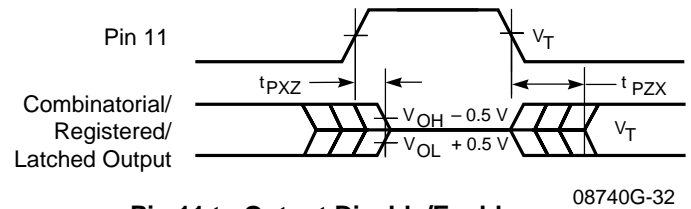
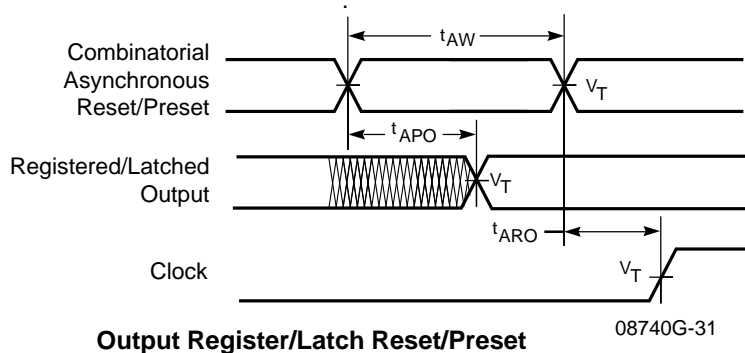
Reset/Preset, Enable

Parameter Symbol	Parameter Description	Min	Max	Unit
Combinatorial Output				
tAPO	Input or I/O Pin to Output Register/Latch Reset/Preset		30	ns
tAW	Asynchronous Reset/Preset Pulse Width	15		ns
tARO	Asynchronous Reset/Preset to Output Register/Latch Recovery	15		ns
tARI	Asynchronous Reset/Preset to Input Register/Latch Recovery	12		ns
Output Enable Operation				
tPZX	I/ \overline{OE} Pin to Output Enable		20	ns
tPXZ	I/ \overline{OE} Pin to Output Disable (Note 1)		20	ns
tEA	Input or I/O to Output Enable via PT		25	ns
tER	Input or I/O to Output Disable via PT (Note 1)		25	ns

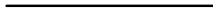


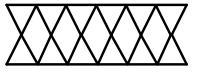
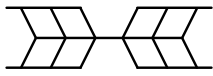
Note:

1. Output disable times do not include test load RC time constants.

SWITCHING WAVEFORMS

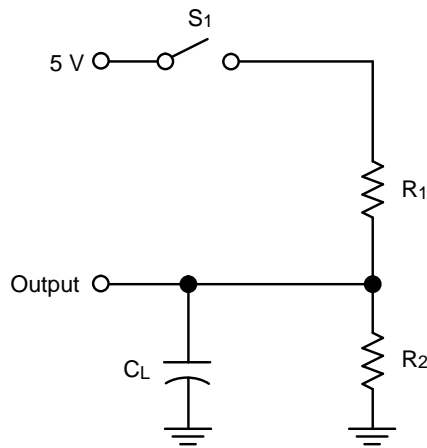


KEY TO SWITCHING WAVEFORMS

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

SWITCHING TEST CIRCUIT



08740G-35

Specification	Switch S ₁	C _L	R ₁	R ₂	Measured Output Value
t _{PD} , t _{CO} , t _{GOL}	Closed	35 pF	470 Ω	390 Ω	1.5 V
t _{EA} , t _{PZX}	Z→H: open Z→L: closed				1.5 V
t _{ER} , t _{PXZ}	H→Z: open L→Z: closed	5 pF			H→Z: V _{OH} - 0.5 V L→Z: V _{OL} + 0.5 V

PRELOAD

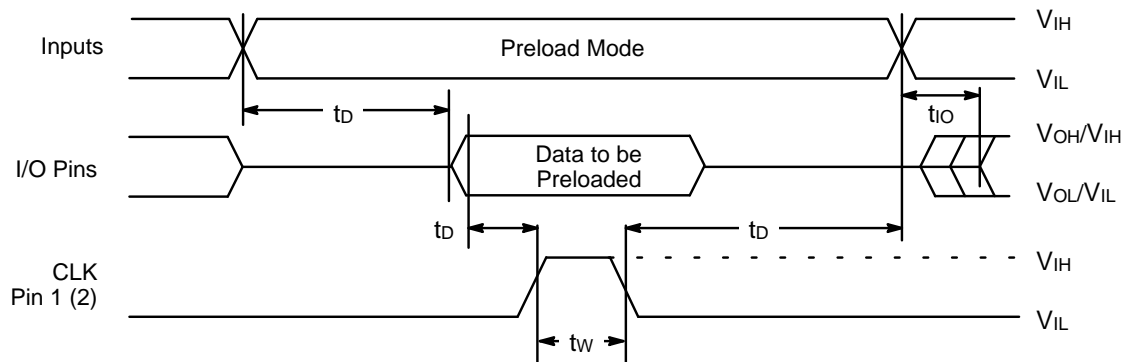
The PALCE29M16 has the capability for product-term Preload. When the global-preload product term is true, the PALCE29M16 will enter the preload mode. This feature aids functional testing by allowing direct setting of register states. The procedure for Preload is as follows:

- Set the selected input pins to the user selected preload condition.
- Apply the desired register value to the I/O pins. This sets Q of the register. The value seen on the I/O pin, after Preload, will depend on whether the macrocell is active high or active low.

- Pulse the clock pin (pin 1).
- Remove the inputs to the I/O pins.
- Remove the Preload condition.
- Verify V_{OL}/V_{OH} for all output pins as per programmed pattern.

Because the Preload command is a product term, any input to the array can be used to set Preload (including I/O pins and registers). Preload itself will change the values of the I/O pins and registers. This will have unpredictable results. Therefore, only dedicated input pins should be used for the Preload command.

Parameter Symbol	Parameter Description	Min	Rec.	Max	Unit
t_D	Delay Time	0.5	1.0	5.0	μs
t_w	Pulse Width	250	500	700	ns
$t_{I/O}$	Valid Output	100		500	ns



Preload Waveform

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OBSERVABILITY

The PALCE29M16 has the capability for product-term Observability. When the global-Observe product term is true, the PALCE29M16 will enter the Observe mode. This feature aids functional testing by allowing direct observation of register states.

When the PALCE29M16 is in the Observe mode, the output buffer is enabled and the I/O pin value will be Q of the corresponding register. This overrides any \overline{OE} inputs.

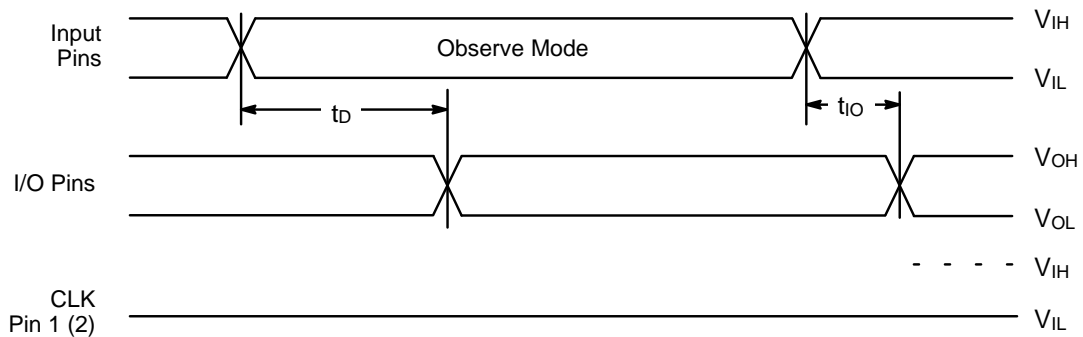
The procedure for Observe is:

- Remove the inputs to all the I/O pins.

- Set the inputs to the user selected Observe configuration.
- The register values will be sent to the corresponding I/O pins.
- Remove the Observe configuration from the selected I/O pins.

Because the Observe command is a product term, any input to the array can be used to set Observe (including I/O pins and registers). If I/O pins are used, the observe mode could cause a value change, which would cause the device to oscillate in and out of the Observe mode. Therefore, only dedicated input pins should be used for the Observe command.

Parameter Symbol	Parameter Description	Min	Rec.	Max	Unit
t_D	Delay Time	0.5	1.0	5.0	μs
$t_{I/O}$	Valid Output	100		500	ns



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Observability Waveform

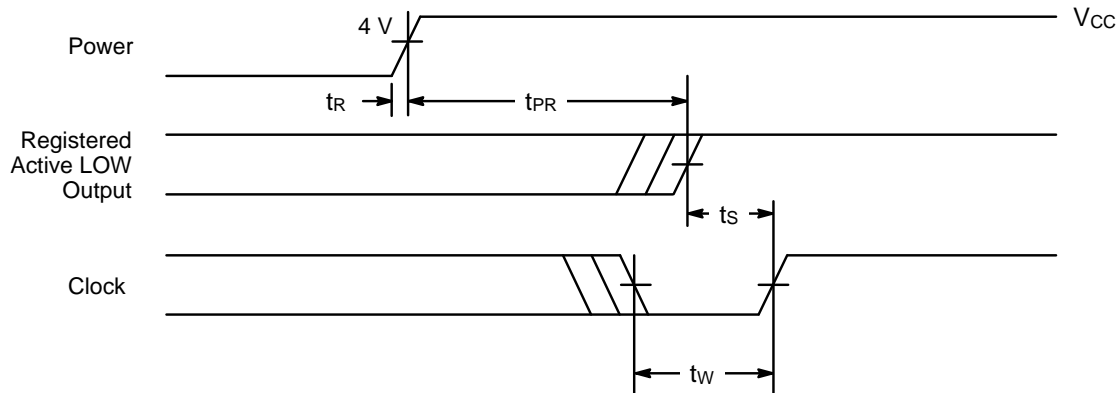
POWER-UP RESET

The registered devices in the PAL Family have been designed with the capability to reset during system power-up. Following power-up, all registers will be reset to LOW. The output state will depend on the polarity of the output buffer. 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

asynchronous 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 ensure a valid power-up reset. These conditions are:

- The V_{CC} rise must be monotonic.
- 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 Description	Min	Max	Unit
t_{PR}	Power-Up Reset Time		10	μs
t_s	Input or Feedback Setup Time	See Switching Characteristics		
t_w	Clock Width			
t_R	V_{CC} Rise Time	500		μs



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Power-Up Reset Waveform

TYPICAL THERMAL CHARACTERISTICS

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

Parameter Symbol	Parameter Description	Typ		Unit	
		SKINNYDIP	PLCC		
θ_{jc}	Thermal Impedance, Junction to Case	17	11	°C/W	
θ_{ja}	Thermal Impedance, Junction to Ambient	63	51	°C/W	
θ_{jma}	Thermal Impedance, Junction to Ambient with Air Flow	200 lfpm air	60	43	°C/W
		400 lfpm air	52	38	°C/W
		600 lfpm air	43	34	°C/W
		800 lfpm air	39	30	°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.