



## MACH 5 CPLD Family Fifth Generation MACH Architecture

### FEATURES

- ◆ **High logic densities and I/Os for increased logic integration**
  - 128 to 512 macrocell densities
  - 68 to 256 I/Os
- ◆ **Wide selection of density and I/O combinations to support most application needs**
  - 6 macrocell density options
  - 7 I/O options
  - Up to 4 I/O options per macrocell density
  - Up to 5 density & I/O options for each package
- ◆ **Performance features to fit system needs**
  - 5.5 ns  $t_{PD}$  Commercial, 7.5 ns  $t_{PD}$  Industrial
  - 182 MHz  $f_{CNT}$
  - Four programmable power/speed settings per block
- ◆ **Flexible architecture facilitates logic design**
  - Multiple levels of switch matrices allow for performance-based routing
  - 100% routability and pin-out retention
  - Synchronous and asynchronous clocking, including dual-edge clocking
  - Asynchronous product- or sum-term set or reset
  - 16 to 64 output enables
  - Functions of up to 32 product terms
- ◆ **Advanced capabilities for easy system integration**
  - 3.3-V & 5-V JEDEC-compliant operations
  - IEEE 1149.1 compliant for boundary scan testing
  - 3.3-V & 5-V in-system programmable via IEEE 1149.1 Boundary Scan Test Access Port
  - PCI compliant (-5/-6/-7/-10/-12 speed grades)
  - Safe for mixed supply voltage system design
  - Bus-Friendly™ Inputs & I/Os
  - Individual output slew rate control
  - Hot socketing
  - Programmable security bit
- ◆ **Advanced E<sup>2</sup>CMOS process provides high performance, cost effective solutions**
- ◆ **Supported by ispDesignEXPERT™ software for rapid logic development**
  - Supports HDL design methodologies with results optimized for MACH 5 devices
  - Flexibility to adapt to user requirements
  - Software partnerships that ensure customer success
- ◆ **Lattice and Third-party hardware programming support**
  - LatticePRO™ software for in-system programmability support on PCs and Automated Equipment
  - Programming support on all major programmers including Data I/O, BP Microsystem and System General

**Table 1. MACH 5 Device Features <sup>1</sup>**

Feature	M5-128/1 M5LV-128		M5-192/1	M5-256/1 M5LV-256		M5-320 M5LV-320		M5-384 M5LV-384	
Supply Voltage (V)	5	3.3	5	5	3.3	5	3.3	5	3.3
Macrocells	128	128	192	256	256	320	320	384	384
Maximum User I/O Pins	120	120	120	160	160	192	192	160	192
t <sub>PD</sub> (ns)	5.5	5.5	5.5	5.5	5.5	6.5 <sup>2</sup>	6.5 <sup>2</sup>	6.5 <sup>2</sup>	6.5 <sup>2</sup>
t <sub>SS</sub> (ns)	3.0	3.0	3.0	3.0	3.0	3.0 <sup>2</sup>	3.0 <sup>2</sup>	3.0 <sup>2</sup>	3.0 <sup>2</sup>
t <sub>COS</sub> (ns)	4.5	4.5	4.5	4.5	4.5	5.0 <sup>2</sup>	5.0 <sup>2</sup>	5.0 <sup>2</sup>	5.0 <sup>2</sup>
f <sub>CNT</sub> (MHz)	182	182	182	182	182	167 <sup>2</sup>	167 <sup>2</sup>	167 <sup>2</sup>	167 <sup>2</sup>
Typical Static Power (mA)	35	35	45	55	55	70	70	75	75
IEEE 1149.1 Boundary Scan Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PCI-Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Note:**

1. "M5-xxx" is for 5-V devices. "M5LV-xxx" is for 3.3-V devices.
2. Preliminary specifications for new 6.5ns (Tpd) speed grade. 7.5ns speed grade in production now.

**GENERAL DESCRIPTION**

The MACH<sup>®</sup> 5 family consists of a broad range of high-density and high-I/O Complex Programmable Logic Devices (CPLDs). The fifth-generation MACH architecture yields fast performance at high CPLD densities, low power, and supports additional features such as in-system programmability, Boundary Scan testability, and advanced clocking options (Table 1). The MACH 5 family offers 5-V (M5-xxx) and 3.3-V (M5LV-xxx) operation.

Manufactured in state-of-the-art ISO 9000 qualified fabrication facilities on E<sup>2</sup>CMOS process technologies, MACH 5 devices are available with pin-to-pin delays as fast as 5.5 ns (Table 1). 5.5, 6.5, 7.5, 10, and 12-ns devices are compliant with the *PCI Local Bus Specification*.



**Table 2. MACH 5 Speed Grades**

Device	Speed Grade <sup>1</sup>					
	-5	-6	-7	-10	-12	-15
M5-128 <sup>2</sup>			C	C, I	C, I	C, I
M5-128/1	C		C, I	C, I	C, I	C, I
M5LV-128	C		C, I	C, I	C, I	I
M5-192/1	C		C, I	C, I	C, I	C, I
M5-256 <sup>2</sup>			C	C, I	C, I	C, I
M5-256/1	C		C, I	C, I	C, I	C, I
M5LV-256	C		C, I	C, I	C, I	I
M5-320		C	C, I	C, I	C, I	C, I
M5LV-320		C	C, I	C, I	C, I	C, I
M5-384		C <sup>3</sup>	C, I <sup>3</sup>	C, I	C, I	C, I
M5LV-384		C <sup>3</sup>	C, I <sup>3</sup>	C, I	C, I	C, I
M5-512		C <sup>3</sup>	C, I <sup>3</sup>	C, I	C, I	C, I
M5LV-512		C <sup>3</sup>	C, I <sup>3</sup>	C, I	C, I	C, I

**Note:**

1. C = Commercial grade, I = Industrial grade
2. /1 version recommended for new designs
3. Preliminary specifications

With Lattice’s unique hierarchical architecture, the MACH 5 family provides densities up to 500,000 macrocells to support full system logic integration. Extensive routing resources ensure performance retention as well as high utilization. It is ideal for PAL<sup>®</sup> block device integration and a wide range of other applications including high-speed computing, low-power applications, communications, and embedded control. At each macrocell density point, Lattice offers several I/O and package options to meet a wide range of design needs (Table 3).

**Table 3. MACH 5 Package and I/O Options<sup>1</sup>**

Supply Voltage	M5-128/1 M5LV-128		M5-192/1	M5-256/1 M5LV-256		M5-320 M5LV-320		M5-384 M5LV-384		M5-512
	5	3.3	5	5	3.3	5	3.3	5	3.3	5
100-pin TQFP	68	68, 74	68	68	68*, 74					
100-pin PQFP	68	68*	68*	68*	68					
144-pin TQFP		104			104					
144-pin PQFP	104	104*	104*	104*	104*					
160-pin PQFP	120	120	120	120	120	120*	120	120*	120	120
208-pin PQFP				160	160	160	160	160	160	160
240-pin PQFP						184*	184*	184*	184*	184
256-ball BGA						192	192*	192*	192*	192
352-ball BGA										256

**Note:**

1. The I/O options indicated with a “\*” are obsolete, please contact factory for more information.

Advanced power management options allow designers to incrementally reduce power while maintaining the level of performance needed for today's complex designs. I/O safety features allow for mixed-voltage design, and both the 3.3-V and the 5-V device versions are in-system programmable through an IEEE 1149.1 Test Access Port (TAP) interface.

## FUNCTIONAL DESCRIPTION

The MACH 5 architecture consists of PAL blocks connected by two levels of interconnect. The **block interconnect** provides routing among 4 PAL blocks. This grouping of PAL blocks joined by block interconnect is called a **segment**. The second level of interconnect, the **segment interconnect**, ties all of the segments together. The only logic difference between any two MACH 5 devices is the number of segments. Therefore, once a designer is familiar with one device, consistent performance can be expected across the entire family. All devices have four I/Os available which can also be used as logic inputs.

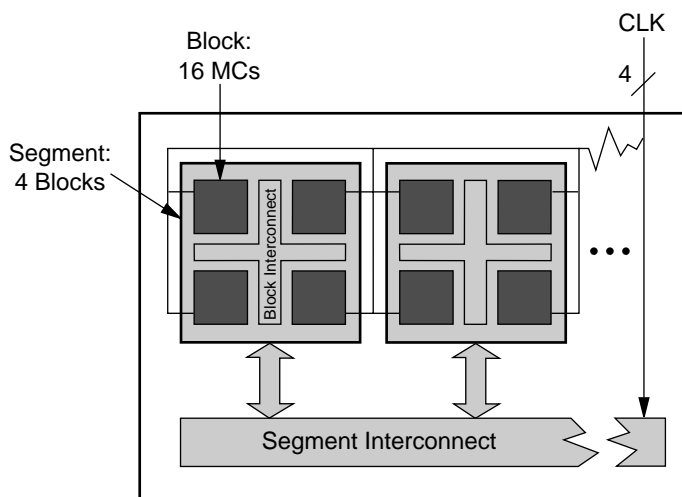


Figure 1. MACH 5 Block Diagram

The MACH 5 PAL blocks consist of the elements listed below (Figure 2). While each PAL block resembles an independent PAL device, it has superior control and logic generation capabilities.

- ◆ I/O cells
- ◆ Product-term array and Logic Allocator
- ◆ Macrocells
- ◆ Register control generator
- ◆ Output enable generator

### I/O Cells

The I/Os associated with each PAL block have a path directly back to that PAL block called **feedback**. If the I/O is used in another PAL block, the **interconnect feeder** assigns a **block interconnect** line to that signal. The interconnect feeder acts as an input switch matrix. The block and segment interconnects provide connections between any two signals in a device. The **block feeder** provides connections between the block interconnect lines and local feedback lines to the PAL block inputs.

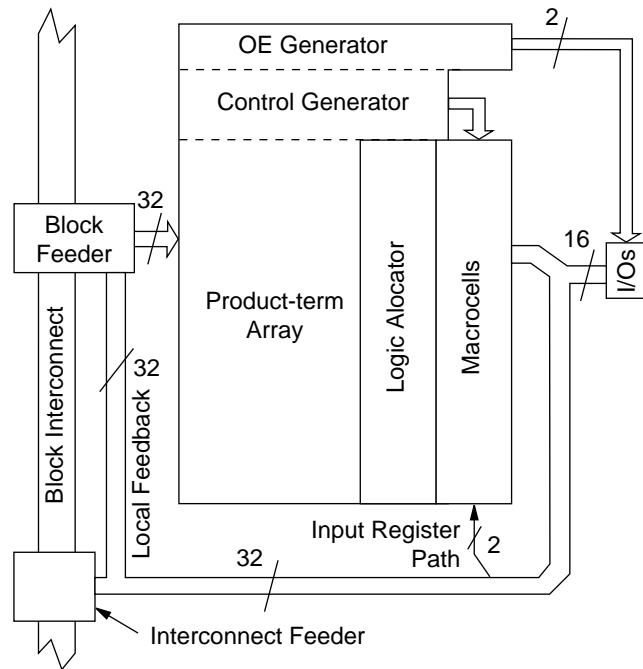


Figure 2. PAL Block Structure

### Product-Term Array and Logic Allocator

The product-term array uses the same sum-of-products architecture as PAL devices and has 32 inputs (plus their complements) and 64 product terms arranged in 16 **clusters**. A cluster is an of-products function with either 3 or 4 product terms.

**Logic allocators** assign the clusters to macrocells. Each macrocell can accept up to eight or three or four product terms, but a given cluster can only be steered to one macrocell (Typically only three product terms in a cluster are steered, the fourth can be used as an input to a gate for separate logic generation and/or polarity control).

The **wide logic allocator** is comprised of all 16 of the individual logic allocators and acts as a switch matrix by reassigning logic to macrocells to retain pinout as designs change. The allocation scheme in the MACH 5 device allows for the implementation of large equations (32 product terms) with only one pass through the logic array.

Table 4. Product Term Steering Options for PT Clusters and Macrocells

Macrocell	Available Clusters	Macrocell	Available Clusters
M <sub>0</sub>	C <sub>0</sub> , C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub>	M <sub>8</sub>	C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub> , C <sub>8</sub> , C <sub>9</sub> , C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub>
M <sub>1</sub>	C <sub>0</sub> , C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub>	M <sub>9</sub>	C <sub>6</sub> , C <sub>7</sub> , C <sub>8</sub> , C <sub>9</sub> , C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub>
M <sub>2</sub>	C <sub>0</sub> , C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub> , C <sub>6</sub>	M <sub>10</sub>	C <sub>7</sub> , C <sub>8</sub> , C <sub>9</sub> , C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub> , C <sub>14</sub>
M <sub>3</sub>	C <sub>0</sub> , C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub>	M <sub>11</sub>	C <sub>8</sub> , C <sub>9</sub> , C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub> , C <sub>14</sub> , C <sub>15</sub>
M <sub>4</sub>	C <sub>0</sub> , C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub>	M <sub>12</sub>	C <sub>8</sub> , C <sub>9</sub> , C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub> , C <sub>14</sub> , C <sub>15</sub>
M <sub>5</sub>	C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub> , C <sub>8</sub>	M <sub>13</sub>	C <sub>9</sub> , C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub> , C <sub>14</sub> , C <sub>15</sub>
M <sub>6</sub>	C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub> , C <sub>8</sub> , C <sub>9</sub>	M <sub>14</sub>	C <sub>10</sub> , C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub> , C <sub>14</sub> , C <sub>15</sub>
M <sub>7</sub>	C <sub>3</sub> , C <sub>4</sub> , C <sub>5</sub> , C <sub>6</sub> , C <sub>7</sub> , C <sub>8</sub> , C <sub>9</sub> , C <sub>10</sub>	M <sub>15</sub>	C <sub>11</sub> , C <sub>12</sub> , C <sub>13</sub> , C <sub>14</sub> , C <sub>15</sub>

## Macrocells

The macrocells for MACH 5 devices consist of a storage element which can be configured for combinatorial, registered or latched operation (Figure 3). The D-type flip-flops can be configured for T-type, J-K, or S-R operation through the use of the XOR gate associated with each macrocell.

Each PAL block has the capability to provide two input registers by using macrocells 0 and 15. In order to use this option, these macrocells must be accessed via the I/O pins associated with macrocells 3 and 12, respectively. Once the macrocell is used as an input register, it cannot be used for logic, so its clusters can be re-directed through the logic allocator to another macrocell. The I/O pins associated with macrocells 0 and 15 can still be used as input pins. Although the I/O pins for macrocells 3 and 12 are used to connect to the input registers, these macrocells can still be used as “buried” macrocells to drive device logic via the matrix.

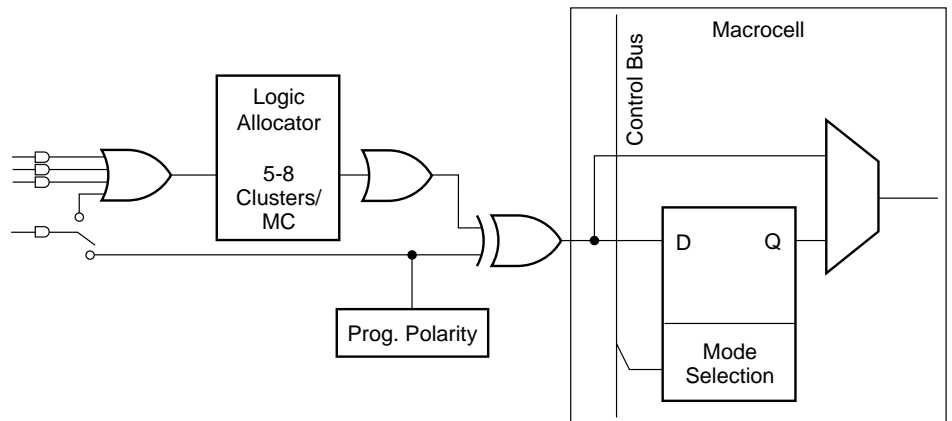


Figure 3. Macrocell Diagram

## Control Generator

The control generator provides four configurable clock lines and three configurable set/reset lines for each macrocell in a PAL block. Any of the four clock lines and any of the three set/reset lines can be independently selected by any flip-flop within a block. The clock lines can be configured to provide synchronous global (pin) clocks and asynchronous product term clocks, sum term clocks, and latch enables (Figure 4). Three of the four global clocks, as well as two product-term clocks and one sum-term clock, are available per PAL block. Positive or negative edge clocking is available as well as advanced clocking features such as **complementary** and **biphase** clocking. Complementary clocking provides two clock lines exactly 180 degrees out of phase, and is used in applications such as fast data paths. A biphase clock line clocks flip-flops on both the positive and negative edges of the clock. The configuration options for the four clock lines per PAL block are as follows:

### Clock Line 0 Options

- ◆ Global clock (0, 1, 2, or 3) with positive or negative edge clock enable
- ◆ Product-term clock ( $A*B*C$ )
- ◆ Sum-term clock ( $A+B+C$ )



### Clock Line 1 Options

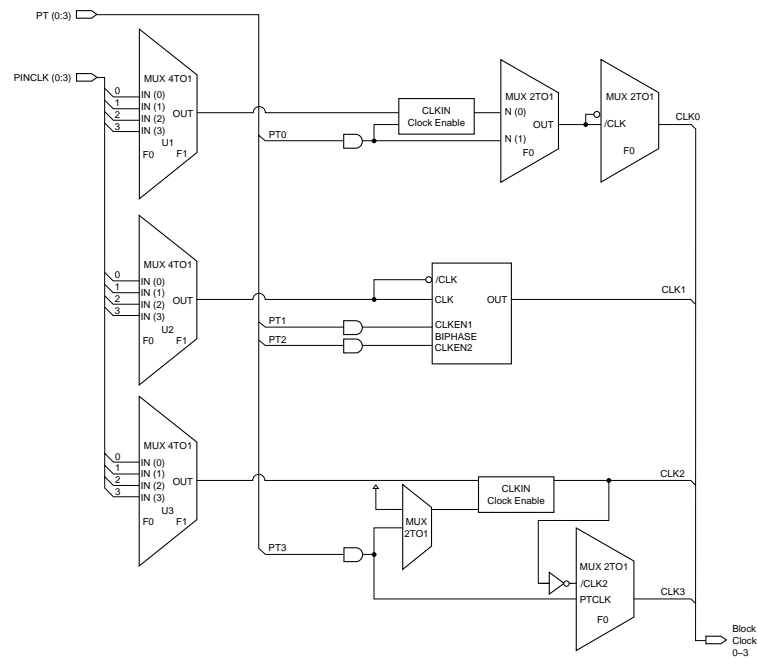
- ◆ Global clock (0, 1, 2, or 3) with positive edge clock enable
- ◆ Global clock (0, 1, 2, or 3) with negative edge clock enable
- ◆ Global clock (0, 1, 2, or 3) with positive and negative edge clock enable (biphase)

### Clock Line 2 Options

- ◆ Global clock (0, 1, 2, or 3) with clock enable

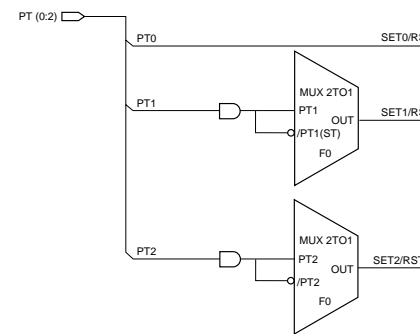
### Clock Line 3 Options

- ◆ Complement of clock line 2 (same clock enable)
- ◆ Product-term clock (if clock line 2 does not use clock enable)



20446G-004

Figure 4. Clock Generator



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Figure 5. Set/Reset Generator

The set/reset generation portion of the control generator (Figure 5) creates three set/reset lines for the PAL block. Each macrocell can choose one of these three lines or choose no set/reset. All three lines can be configured for product term set/reset and two of the three lines can be configured as sum term set/reset and one of the lines can be configured as product-term latch enable. While the set/reset signals are generated in the control generator, whether a signal sets or resets a flip-flop is determined within the individual macrocell. The same signal can set one flip-flop and reset another. PT2 or /PT2 can also be used as a latch enable for macrocells configured as latches.

## OE Generator

There is one output enable (OE) generator per PAL block that generates two product-term output enables. Each I/O cell is simply an output buffer. Each I/O cell within the PAL block can choose to be permanently enabled, permanently disabled, or choose one of the two product-term output enables per PAL block (Figure 6).

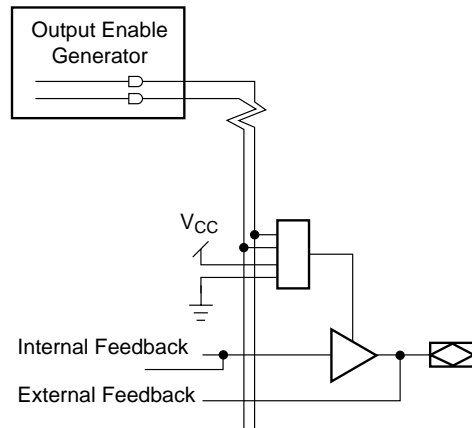


Figure 6. Output Enable Generator and I/O Cell





## MACH 5 TIMING MODEL

The primary focus of the MACH 5 timing model is to accurately represent the timing in a device, and at the same time, be easy to understand. This model accurately describes a combinatorial and registered paths through the device, making a distinction between **internal feedback** and **external feedback**. A signal uses internal feedback when it is fed back into the switch matrix or block without having to go through the output buffer. The input register specifications are also reported as internal feedback. When a signal is fed back into the switch matrix after going through the output buffer, it is using external feedback.

The parameter,  $t_{BUF}$ , is defined as the time it takes to go through the output buffer to the I/O pad. If a signal goes to the internal feedback rather than to the I/O pad, the parameter designation is followed by an "i". By adding  $t_{BUF}$  to this internal parameter, the external parameter is formed. For example,  $t_{PD} = t_{PDi} + t_{BUF}$ . A diagram representing the modularized MACH 5 timing model is shown in Figure 7. Refer to the Technical Note entitled *MACH 5 Timing and High Speed* for a more detailed discussion about the timing parameters.

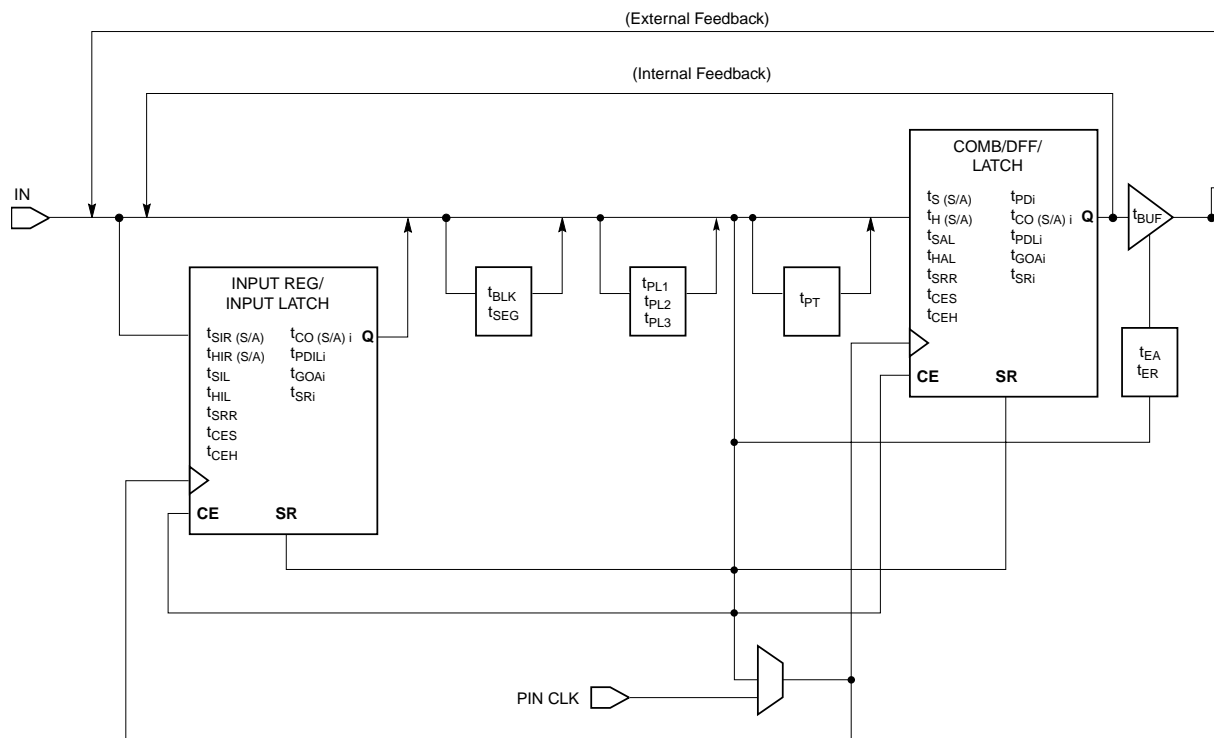


Figure 7. MACH 5 Timing Model

## MULTIPLE I/O AND DENSITY OPTIONS

The MACH 5 family offers six macrocell densities in a number of I/O options. This allows you to choose a device close to their logic density and I/O requirements, thus minimizing cost. In the same package type, every density has the same pin-out. With proper design consideration, design can be moved to a higher or lower density part as required.

## IEEE 1149.1 - COMPLIANT BOUNDARY SCAN TESTABILITY

Most MACH 5 devices have boundary scan registers and are compliant to the IEEE 1149.1 standard. This allows functional testing of the circuit board on which the device is mounted through a boundary scan path that can access all critical logic nodes. Internal registers are linked internally, allowing test data to be shifted in and loaded directly onto test nodes, or test node data to be captured and shifted out for verification. In addition, these devices can be linked into a board-level scan path for more complete board-level testing.

## IEEE 1149.1 - COMPLIANT IN-SYSTEM PROGRAMMING

Programming devices in-system provides a number of significant benefits including: rapid prototyping, lower inventory levels, higher quality, and the ability to make in-field modifications. All MACH 5 devices provide in-system programming (ISP) capability through their IEEE 1149.1-compliant Boundary Scan Test Access Port. By using the IEEE 1149.1-compliant Boundary Scan Test Access Port as the communication interface through which ISP is achieved, customers benefit from a standard, well-defined interface.

MACH 5 devices can be programmed across the commercial temperature and voltage range. LatticePRO, a PC-based LatticePRO software facilitates in-system programming of MACH 5 devices. LatticePRO software takes the JEDEC file output produced by design implementation software, along with information about the Boundary Scan chain, and creates a set of vectors that are used to drive the Boundary Scan chain. LatticePRO software can use these vectors to drive a Boundary Scan chain via the parallel port of a PC. Alternatively, LatticePRO software can output files in a format understood by common automated test equipment. This equipment can then be used to program MACH 5 devices during the testing of a circuit board.

## PCI COMPLIANT

MACH 5 devices in the -5/-6/-7/-10/-12 speed grades are compliant with the *PCI Local Bus Specification* version 2.1, published by the PCI Special Interest Group (SIG). The 5-V devices are fully PCI-compliant. The 3.3-V devices are mostly compliant but do not meet the PCI compliance requirement to clamp the inputs as they rise above  $V_{CC}$  because of their 5-V input tolerant feature. MACH 5 devices provide the speed, drive, density, output enables and I/Os for the most complex designs.



## SAFE FOR MIXED SUPPLY VOLTAGE SYSTEM DESIGNS <sup>1</sup>

Both the 3.3-V and 5-V  $V_{CC}$  MACH 5 devices are safe for mixed supply voltage system designs. The 5-V devices will not overdrive 3.3-V devices above the output voltage of 3.3 V, while the 3.3-V devices will accept inputs from other 3.3-V devices. The 3.3-V devices will accept inputs up to 5.5 V. Both 3.3-V and 5-V versions have the same high-speed performance and provide easy-to-use voltage design capability.

**Note:**

1. Excludes original M5-128, M5-192, and M5-256 while M5-128/1, M3-192/1 and M5-256/1 are supported. Please refer to Application Note titled "Hot Socketing and Mixed Supply Design with MACH 4 and MACH 5 Devices".

## BUS-FRIENDLY INPUTS AND I/OS

All MACH 5 devices have inputs and I/Os which feature the Bus-Friendly circuitry incorporating two inverters in series which loop back to the input. This double inversion weakly holds the input at its last driven logic state. While it is a good design practice to tie unused pins to a known state, the Bus-Friendly input structure pulls pins away from the input threshold voltage where they can cause high-frequency switching. At power-up, the Bus-Friendly latches are reset to a logic "1." For the circuit diagram, please refer to the document entitled *MACH Endurance Characteristics* on the Lattice Data Book CD-ROM or Lattice web site.

## POWER MANAGEMENT

There are 4 power/speed options in each MACH 5 PAL block (Table 5). The speed and power tradeoff can be tailored for each design. The signal speed paths in the lower-power PAL blocks will be slower than those in the higher-power PAL blocks. This feature allows speed critical paths to run at maximum frequency while the rest of the signal paths operate in a lower-power mode. In large designs, there may be several different speed requirements for different portions of the design.

**Table 5. Power Levels**

High Speed/High Power	100% Power
Medium High Speed/Medium High Power	67% Power
Medium Low Speed/Medium Low Power	40% Power
Low Speed/Low Power	20% Power

## PROGRAMMABLE SLEW RATE

Each MACH 5 device I/O has an individually programmable output slew rate control. The output can be individually configured for the higher speed transition (3 V/ns) or for the slower noise transition (1 V/ns). For high-speed designs with long, unterminated traces, the slower slew rate will introduce fewer reflections, less noise, and keep ground bounce to a minimum. For designs with short traces or well terminated lines, the fast slew rate can be used to achieve the maximum signal speed. The slew rate is adjusted independent of power.

## POWER-UP RESET/SET

All flip-flops power up to a known state for predictable system initialization. If a macrocell is configured to SET on a signal from the control generator, then that macrocell will be SET on device power-up. If a macrocell is configured to RESET on a signal from the control generator and is not configured for set/reset, then that macrocell will RESET on power-up. To guarantee

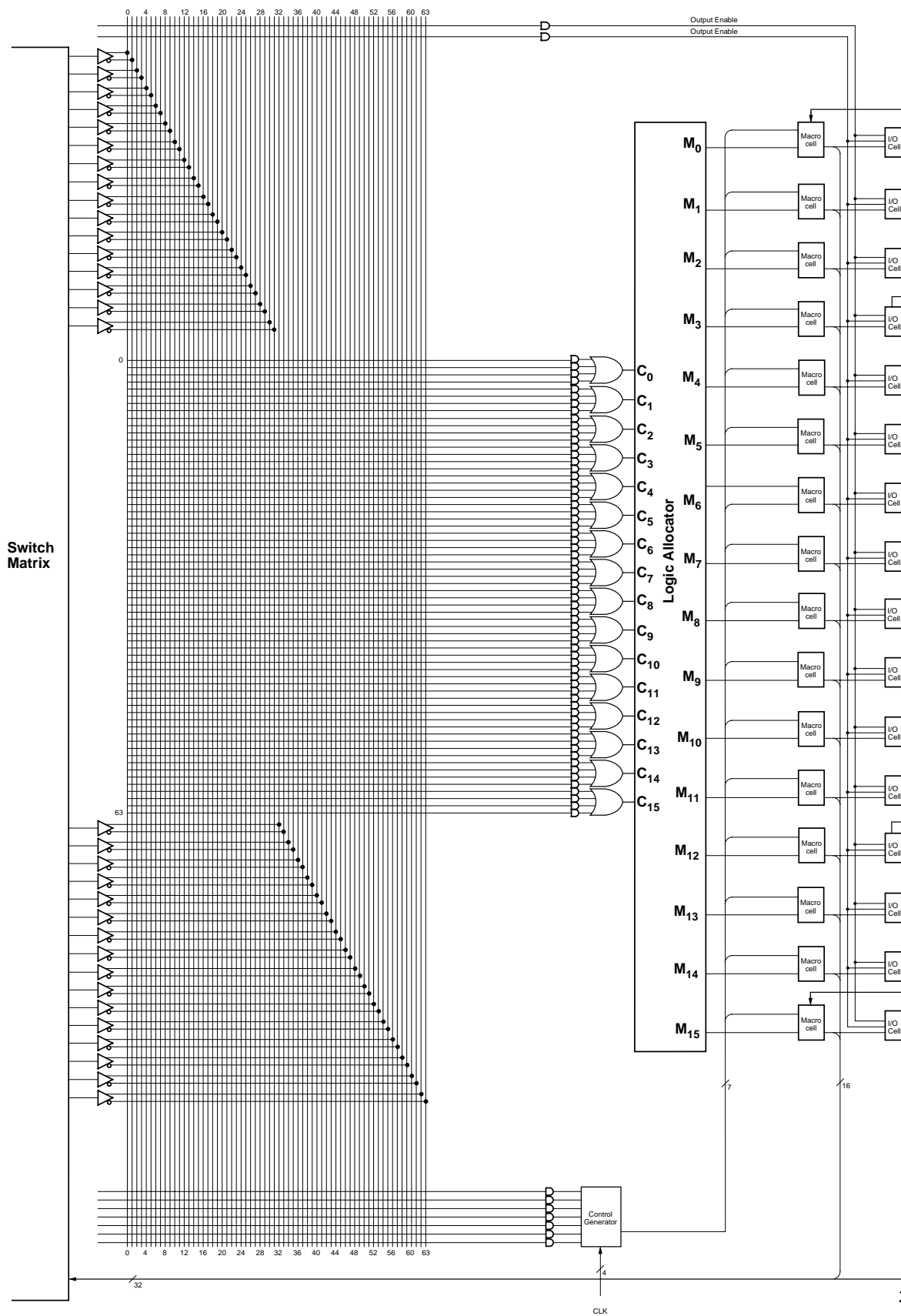
initialization values, the  $V_{CC}$  rise must be monotonic and the clock must be inactive until delay time has elapsed.

## SECURITY BIT

A programmable security bit is provided on the MACH 5 devices as a deterrent to unauthorized copying of the array configuration patterns. Once programmed, this bit defeats readback of the programmed pattern by a device programmer, securing proprietary designs from competitors. Programming and verification are also defeated by the security bit. The bit can only be reset by erasing the entire device.

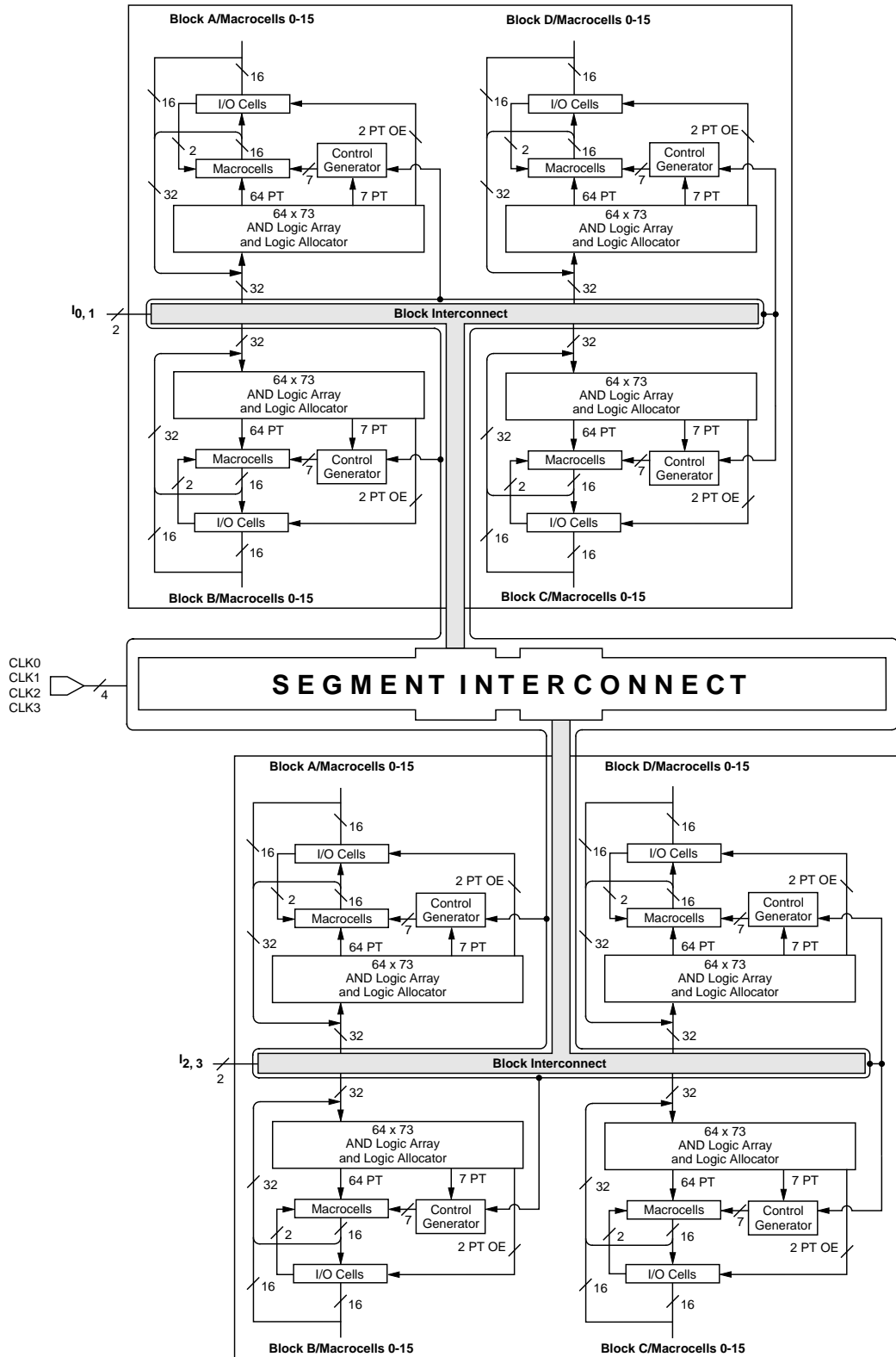


# MACH 5 PAL BLOCK



## BLOCK DIAGRAM — M5(LV)-128/XXX

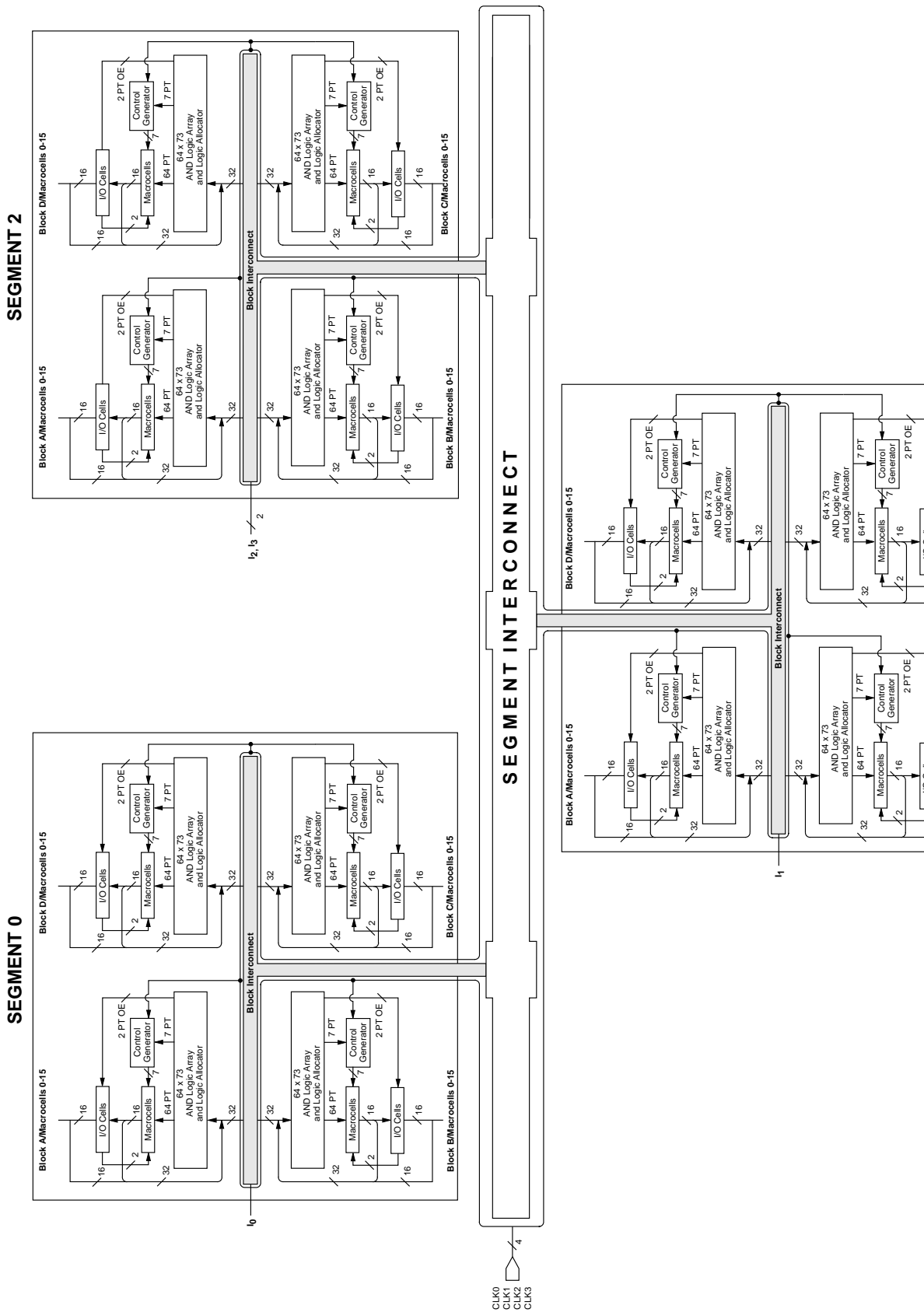
### SEGMENT 0



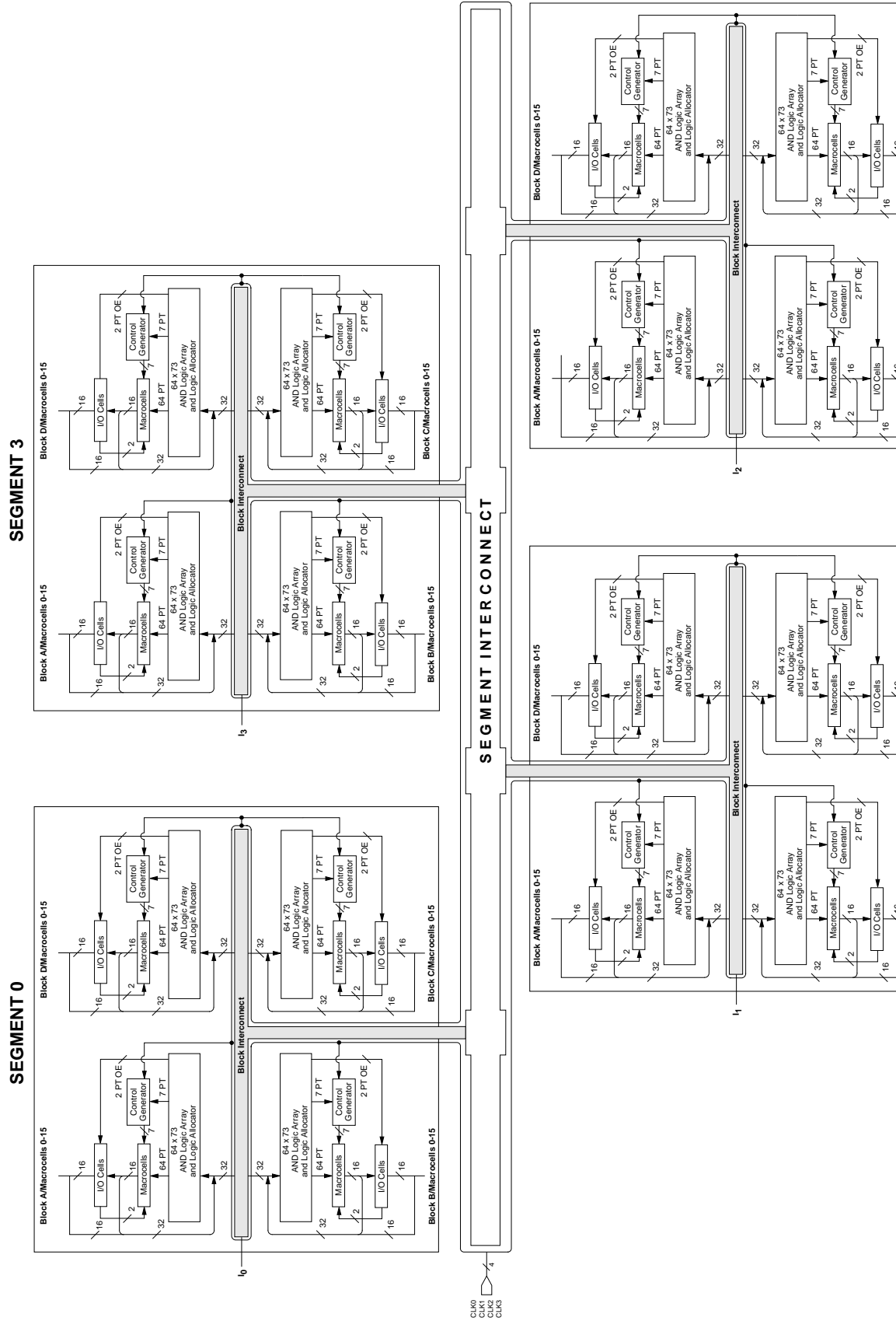
### SEGMENT 1



# BLOCK DIAGRAM — M5-192/XXX



# BLOCK DIAGRAM — M5(LV)-256/XXX

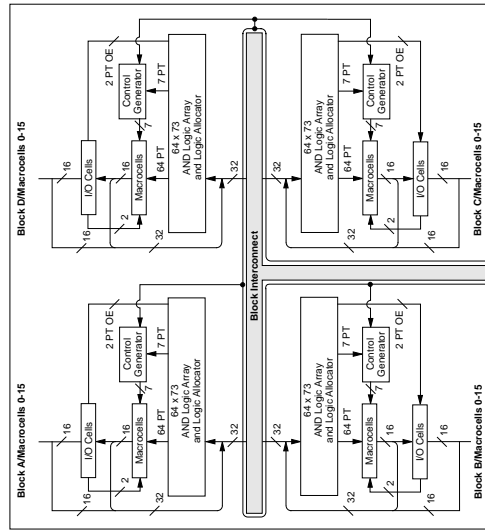




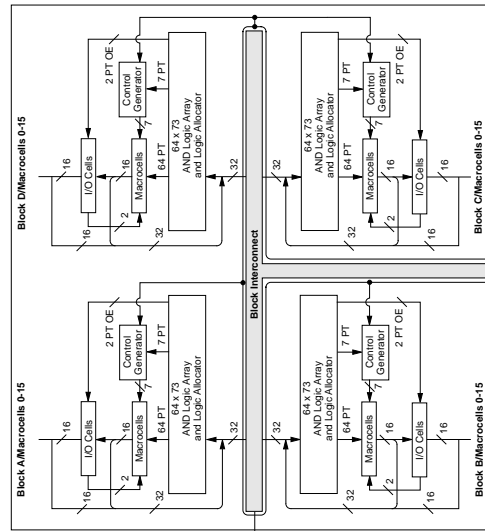


# BLOCK DIAGRAM — M5(LV)-320/XXX

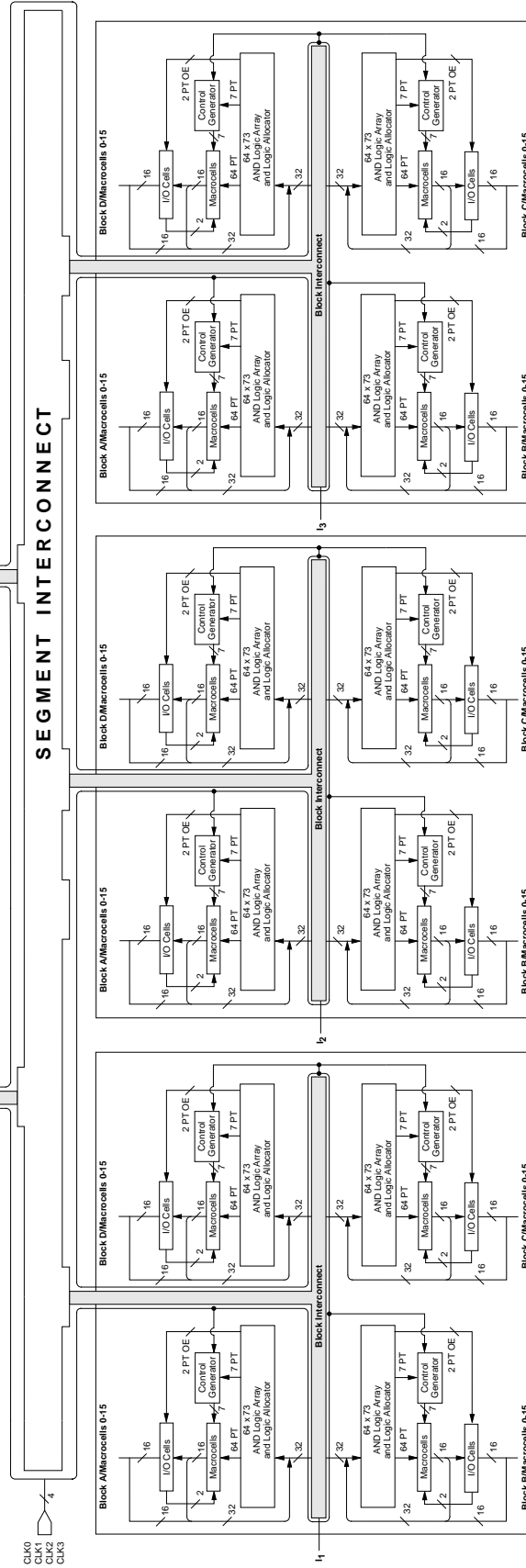
## SEGMENT 4



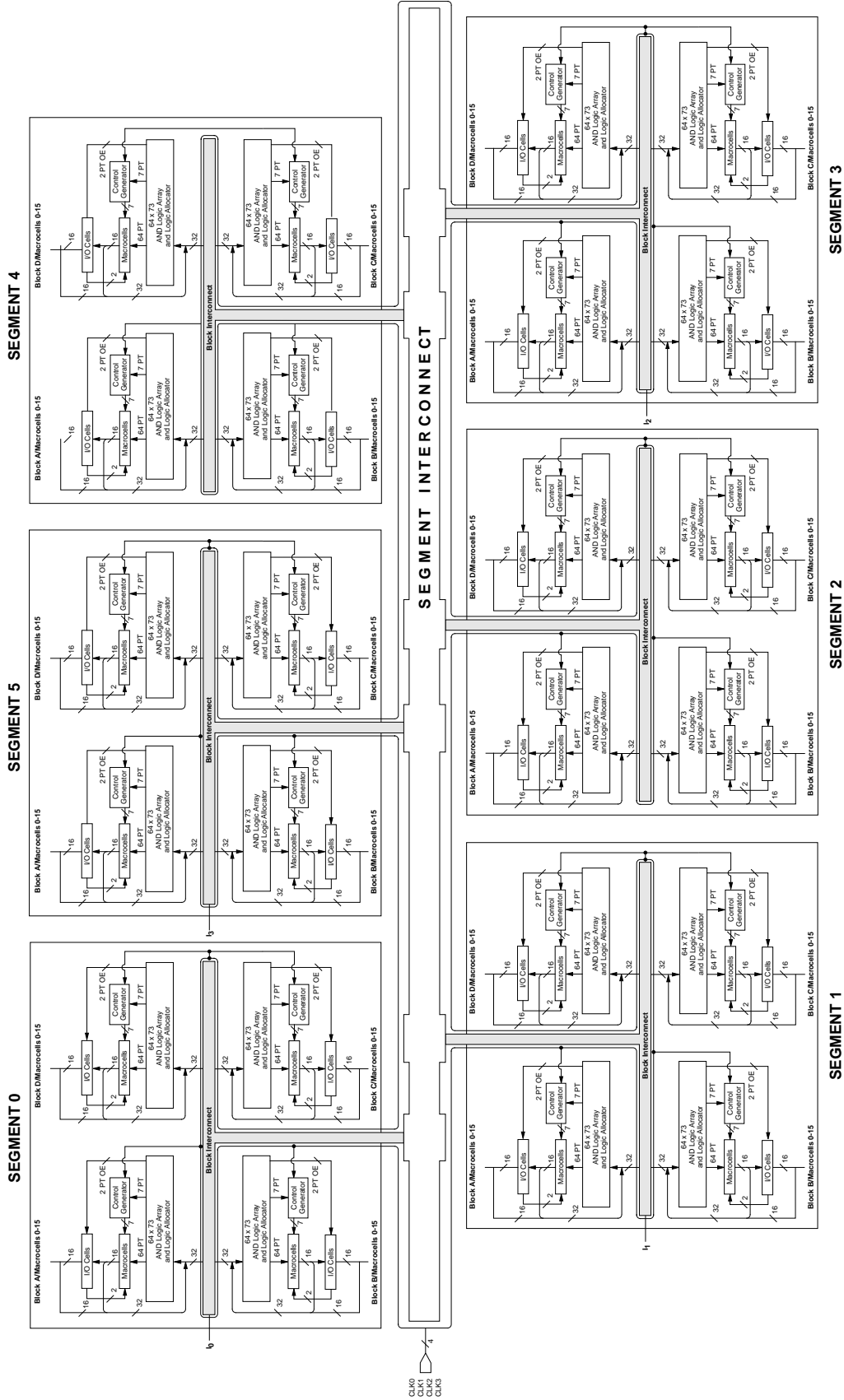
## SEGMENT 0



## SEGMENT INTERCONNECT



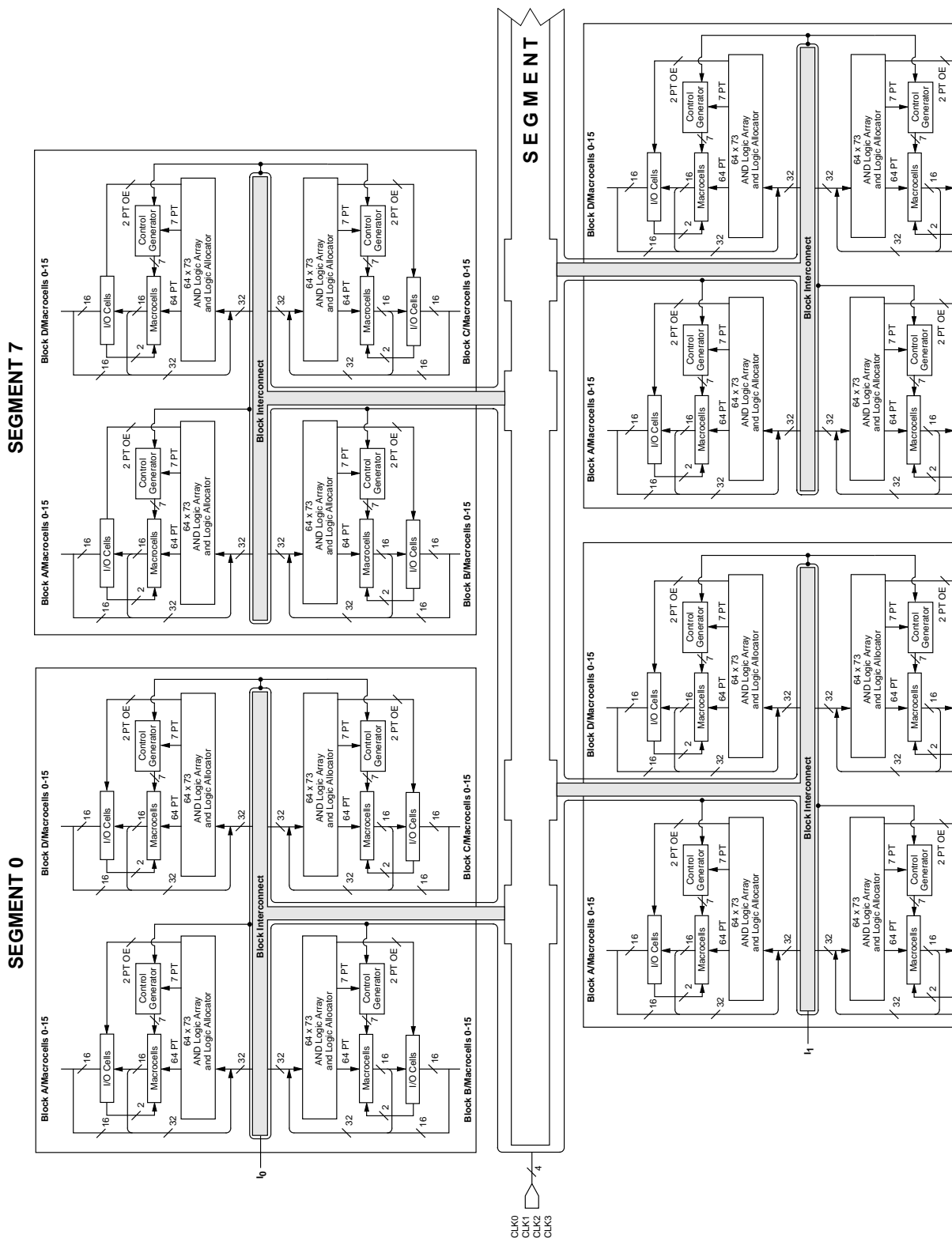
# BLOCK DIAGRAM — M5(LV)-384/XXX





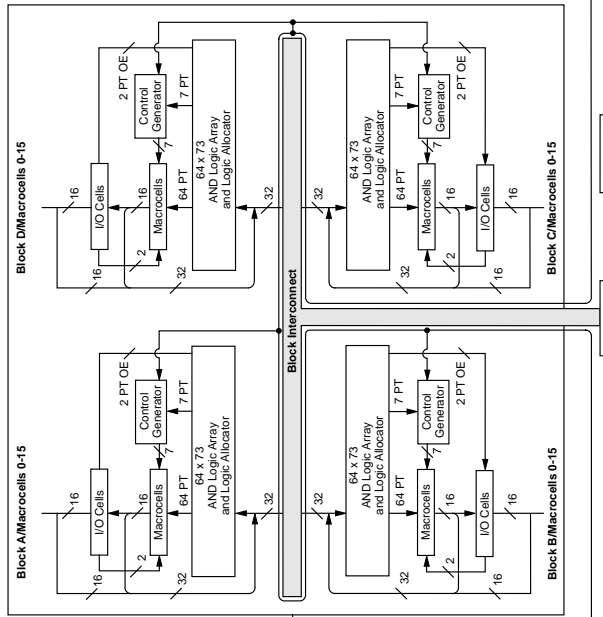
# BLOCK DIAGRAM — M5(LV)-512/XXX

Continued

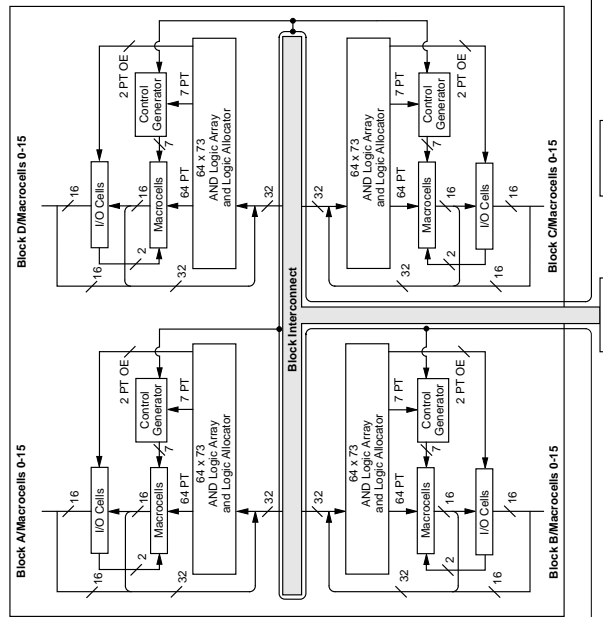


# BLOCK DIAGRAM — M5(LV)-512/XXX

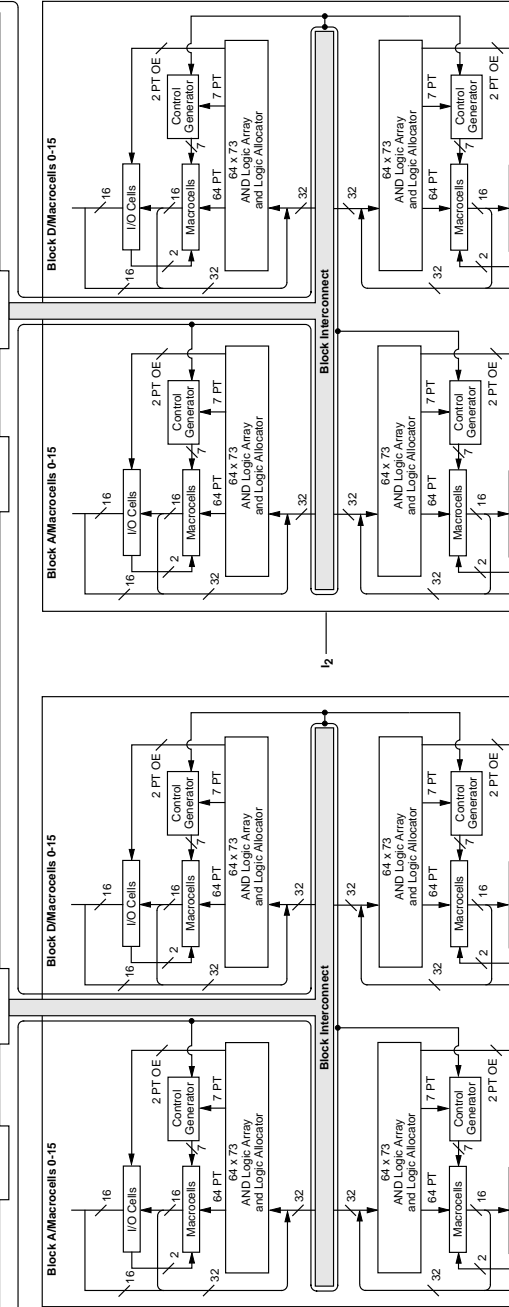
## SEGMENT 5



## SEGMENT 6



## INTERCONNECT



Continued



## ABSOLUTE MAXIMUM RATINGS

### M5

Storage Temperature . . . . .	-65°C to +150°C
Device Junction Temperature (Note 1) . . . . .	+130°C or +150°C
Supply Voltage with Respect to Ground . . . . .	-0.5 V to +7.0 V
DC Input Voltage . . . . .	-0.5 V to 5.5 V
Static Discharge Voltage . . . . .	2000 V
Latchup Current (-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.*

## OPERATING RANGES

### Commercial (C) Devices

Ambient Temperature (T <sub>A</sub> ) Operating in Free Air . . . . .	0 to +70
Supply Voltage (V <sub>CC</sub> ) with Respect to Ground . . . . .	+4.75 V

### Industrial (I) Devices

Ambient Temperature (T <sub>A</sub> ) Operating in Free Air . . . . .	-40 to +125
Supply Voltage (V <sub>CC</sub> ) with Respect to Ground . . . . .	+4.5 V

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

## 5-V DC CHARACTERISTICS OVER OPERATING RANGES

Parameter Symbol	Parameter Description	Test Description	Min	Typ	Max
V <sub>OH</sub>	Output HIGH Voltage (For M5-128/1, M5-192/1, M5-256/1, M5-320, M5-384, M5-512 Devices)	I <sub>OH</sub> = -3.2 mA, V <sub>CC</sub> = Min, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	2.4		
		I <sub>OH</sub> = 0 mA, V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>			
	Output HIGH Voltage (For M5-128, M5-192, M5-256 Devices)	I <sub>OH</sub> = -3.2 mA, V <sub>CC</sub> = Min, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	2.4		
		I <sub>OH</sub> = -2.5 mA, V <sub>CC</sub> = 5.25 V, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>			
V <sub>OL</sub>	Output LOW Voltage (Note 2)	I <sub>OL</sub> = +16 mA, V <sub>CC</sub> = Min, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>			0
V <sub>IH</sub>	Input HIGH Voltage	Guaranteed Input Logical HIGH Voltage for all Inputs (Note 3)	2.0		
V <sub>IL</sub>	Input LOW Voltage	Guaranteed Input Logical LOW Voltage for all Inputs (Note 3)			0
I <sub>IH</sub>	Input HIGH Leakage Current	V <sub>IN</sub> = 5.25, V <sub>CC</sub> = Max (Note 4)			
I <sub>IL</sub>	Input LOW Leakage Current	V <sub>IN</sub> = 0, V <sub>CC</sub> = Max (Note 4)			
I <sub>OZH</sub>	Off-State Output Leakage Current HIGH	V <sub>OUT</sub> = 5.25, V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> (Note 4)			
I <sub>OZL</sub>	Off-State Output Leakage Current LOW	V <sub>OUT</sub> = 0, V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> (Note 4)			
I <sub>SC</sub>	Output Short-Circuit Current	V <sub>OUT</sub> = 0.5 V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> (Note 5)	-30		

**Note:**

- 150° for M5-128, M5-192 and M5-256 devices. 130° for M5-128/1, M5-192/1, M5-256/1, M5-320, M5-384 and M5-512 devices.
- Total I<sub>OL</sub> between ground pins should not exceed 64 mA.
- These are absolute values with respect to device ground, and all overshoots due to system and/or tester noise are included.
- I/O pin leakage is the worst case of I<sub>IL</sub> and I<sub>OZL</sub> or I<sub>IH</sub> and I<sub>OZH</sub>.
- Not more than one output should be shorted at a time. Duration of the short-circuit should not exceed one second.

## ABSOLUTE MAXIMUM RATINGS

### M5LV

Storage Temperature . . . . .	-65°C to +150°C
Device Junction Temperature . . . . .	+130°C
Supply Voltage with Respect to Ground . . . . .	-0.5 V to +4.5 V
DC Input Voltage . . . . .	-0.5 V to 5.5 V
Static Discharge Voltage . . . . .	2000 V
Latchup Current (-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.*

## OPERATING RANGES

### Commercial (C) Devices

Ambient Temperature (T <sub>A</sub> ) Operating in Free Air . . . . .	0
Supply Voltage (V <sub>CC</sub> ) with Respect to Ground . . . . .	+3.0

### Industrial (I) Devices

Ambient Temperature (T <sub>A</sub> ) Operating in Free Air . . . . .	-40
Supply Voltage (V <sub>CC</sub> ) with Respect to Ground . . . . .	+3.0

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

## 3.3-V DC CHARACTERISTICS OVER OPERATING RANGES

Parameter Symbol	Parameter Description	Test Description		Min	Max
V <sub>OH</sub>	Output HIGH Voltage	V <sub>CC</sub> = Min	I <sub>OH</sub> = -100 μA	V <sub>CC</sub> - 0.2	
		V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OH</sub> = 3.2 mA	2.4	
V <sub>OL</sub>	Output LOW Voltage	V <sub>CC</sub> = Min	I <sub>OL</sub> = 100 μA		0.2
		V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub>	I <sub>OL</sub> = 16 mA (Note 1)		0.5
V <sub>IH</sub>	Input HIGH Voltage	V <sub>OUT</sub> ≥ V <sub>OH</sub> Min or V <sub>OUT</sub> ≤ V <sub>OL</sub> Max (Note 2)		2.0	5.5
V <sub>IL</sub>	Input LOW Voltage	V <sub>OUT</sub> ≥ V <sub>OH</sub> Min or V <sub>OUT</sub> ≤ V <sub>OL</sub> Max (Note 2)		-0.3	0.8
I <sub>IH</sub>	Input HIGH Leakage Current	V <sub>IN</sub> = 3.6, V <sub>CC</sub> = Max (Note 3)			10
I <sub>IL</sub>	Input LOW Leakage Current	V <sub>IN</sub> = 0, V <sub>CC</sub> = Max (Note 3)			-10
I <sub>OZH</sub>	Off-State Output Leakage Current HIGH	V <sub>OUT</sub> = 3.6, V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> (Note 3)			10
I <sub>OZL</sub>	Off-State Output Leakage Current LOW	V <sub>OUT</sub> = 0, V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> (Note 3)			-10
I <sub>sc</sub>	Output Short-Circuit Current	V <sub>OUT</sub> = 0.5 V <sub>CC</sub> = Max, V <sub>IN</sub> = V <sub>IH</sub> or V <sub>IL</sub> (Note 4)		-15	-16

### Notes:

1. Total I<sub>OL</sub> between ground pins should not exceed 64 mA.
2. These are absolute values with respect to device ground, and all overshoots due to system and/or tester noise are included.
3. I/O pin leakage is the worst case of I<sub>IL</sub> and I<sub>OZL</sub> or I<sub>IH</sub> and I<sub>OZH</sub>.
4. Not more than one output should be shorted at one time. Duration of the short-circuit should not exceed one second.



## M5(LV) TIMING PARAMETERS OVER OPERATING RANGES<sup>1</sup>

		-5		-6		-7		-10		-12		-15		Min
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
<b>Combinatorial Delay:</b>														
$t_{PDI}$	Internal combinatorial propagation delay		3.5		4.5		5.5		8.0		10.0		13.0	
$t_{PD}$	Combinatorial propagation delay		5.5		6.5		7.5		10.0		12.0		15.0	
<b>Registered Delays:</b>														
$t_{SS}$	Synchronous clock setup time	3.0		3.0		4.0		5.0		6.0		8.0		10.0
$t_{SA}$	Asynchronous clock setup time	3.0		3.0		4.0		5.0		6.0		7.0		8.0
$t_{HS}$	Synchronous clock hold time	0.0		0.0		0.0		0.0		0.0		0.0		0.0
$t_{HA}$	Asynchronous clock hold time	3.0		3.0		4.0		5.0		6.0		7.0		8.0
$t_{COSi}$	Synchronous clock to internal output		2.5		3.0		4.0		5.0		6.0		8.0	
$t_{COS}$	Synchronous clock to output		4.5		5.0		6.0		7.0		8.0		10.0	
$t_{COAi}$	Asynchronous clock to internal output		6.0		6.0		8.0		10.0		13.0		15.0	
$t_{COA}$	Asynchronous clock to output		8.0		8.0		10.0		12.0		15.0		17.0	
<b>Latched Delays:</b>														
$t_{SAL}$	Latch setup time	3.0		4.0		4.0		5.0		6.0		7.0		8.0
$t_{HAL}$	Latch hold time	3.0		3.0		4.0		5.0		6.0		7.0		8.0
$t_{PDLi}$	Transparent latch internal		6.0		7.0		7.0		8.0		9.0		10.0	
$t_{PDL}$	Propagation delay through transparent latch		8.0		9.0		9.0		10.0		11.0		12.0	
$t_{GOAi}$	Gate to internal output		7.0		8.0		8.0		9.0		10.0		11.0	
$t_{GOA}$	Gate to output		9.0		10.0		10.0		11.0		12.0		13.0	
<b>Input Register Delays:</b>														
$t_{SIRS}$	Input register setup time using a synchronous clock	2.0		2.0		2.0		3.0		3.0		3.0		3.0
$t_{SIRA}$	Input register setup time using an asynchronous clock	0.0		0.0		0.0		0.0		0.0		0.0		0.0
$t_{HIRS}$	Input register hold time using a synchronous clock	3.0		3.0		3.0		4.0		4.0		4.0		4.0
$t_{HIRA}$	Input register hold time using an asynchronous clock	6.0		6.0		6.0		7.0		7.0		7.0		7.0
<b>Input Latch Delays:</b>														
$t_{SIL}$	Input latch setup time	2.0		2.0		2.0		3.0		3.0		3.0		3.0
$t_{HIL}$	Input latch hold time	6.0		6.0		6.0		7.0		7.0		7.0		7.0
$t_{PDILi}$	Transparent input latch		5.0		5.0		5.5		6.0		6.0		6.0	
<b>Output Delays:</b>														
$t_{BUF}$	Output buffer delay		2.0		2.0		2.0		2.0		2.0		2.0	
$t_{SIW}$	Slow slew rate delay		2.5		2.5		2.5		2.5		2.5		2.5	
$t_{EA}$	Output enable time		7.5		7.5		9.5		10.0		12.0		15.0	
$t_{ER}$	Output disable time		7.5		7.5		9.5		10.0		12.0		15.0	

## M5(LV) TIMING PARAMETERS OVER OPERATING RANGES<sup>1</sup> (CONTINUED)

		-5		-6		-7		-10		-12		-15		Min
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
<b>Power Delays:</b>														
t <sub>PL1</sub>	Power level 1 delay (Note 2)		4.0 (5.0)		4.0		4.0 (5.0)		4.0 (5.0)		4.0 (5.0)		4.0 (5.0)	
t <sub>PL2</sub>	Power level 2 delay (Note 2)		6.0 (9.0)		6.0		6.0 (9.0)		6.0 (9.0)		6.0 (9.0)		6.0 (9.0)	
t <sub>PL3</sub>	Power level 3 delay (Note 2)		9.0 (17.5)		9.0		9.0 (17.5)		9.0 (17.5)		9.0 (17.5)		9.0 (17.5)	
<b>Additional Cluster Delay:</b>														
t <sub>PT</sub>	Product term cluster delay		0.3		0.3		0.3		0.3		0.3		0.3	
<b>Interconnect Delays:</b>														
t <sub>BLK</sub>	Block interconnect delay		1.5		1.5		1.5		2.0		2.0		2.0	
t <sub>SEG</sub>	Segment interconnect delay		4.5		4.5		5.0		6.0		6.0		6.0	
<b>Reset and Preset Delays:</b>														
t <sub>SRi</sub>	Asynchronous reset or preset to internal register output		6.0		8.0		8.0		10.0		12.0		14.0	
t <sub>SR</sub>	Asynchronous reset or preset to register output		8.0		10.0		10.0		12.0		14.0		16.0	
t <sub>SRR</sub>	Reset and set register recovery time	5.5		7.5		7.5		8.0		9.0		10.0		11.0
t <sub>SRW</sub>	Asynchronous reset or preset width	3.0		4.0		4.0		5.0		6.0		7.0		8.0
<b>Clock Enable Delays:</b>														
t <sub>CES</sub>	Clock enable setup time	4.0		5.0		5.0		6.0		7.0		7.0		8.0
t <sub>CEH</sub>	Clock enable hold time	3.0		4.0		4.0		5.0		6.0		6.0		7.0
<b>Width:</b>														
t <sub>WLS</sub>	Global clock width low (Note 3)	2.5		3.0		3.0		4.0		5.0		6.0		6.0
t <sub>WHS</sub>	Global clock width high (Note 3)	2.5		3.0		3.0		4.0		5.0		6.0		6.0
t <sub>WLA</sub>	Product term clock width low	3.0		4.0		4.0		5.0		6.0		7.0		8.0
t <sub>WHA</sub>	Product term clock width high	3.0		4.0		4.0		5.0		6.0		7.0		8.0
t <sub>GWA</sub>	Gate width low (for low transparent) or high (for high transparent)	3.0		4.0		4.0		5.0		6.0		7.0		8.0
t <sub>WIR</sub>	Input register clock width low or high	3.0		4.0		4.0		5.0		6.0		7.0		8.0





## M5(LV) TIMING PARAMETERS OVER OPERATING RANGES<sup>1</sup> (CONTINUED)

		-5		-6		-7		-10		-12		-15		Min
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
<b>Frequency:</b>														
$f_{MAX}$	External feedback, PAL block level. Min of $1/(t_{WLS} + t_{WHS})$ or $1/(t_{SS} + t_{COS})$	133		125		100		83.3		71.4		55.6		45.5
	Internal feedback, PAL block level. Min of $1/(t_{WLS} + t_{WHS})$ or $1/(t_{SS} + t_{COSi})$	182		167		125		100		83.3		62.5		50.0
	No feedback PAL block level. Min of $1/(t_{WLS} + t_{WHS})$ or $1/(t_{SS} + t_{HS})$	200		167		167		125		100		83.3		83.3
$f_{MAXA}$	External feedback, PAL block level. Min of $1/(t_{WLA} + t_{WHA})$ or $1/(t_{SA} + t_{COA})$	91		91		71.4		58.8		47.6		41.7		35.7
	Internal feedback, PAL block level. Min of $1/(t_{WLA} + t_{WHA})$ or $1/(t_{SA} + t_{COAi})$	111		111		83.3		66.7		52.6		45.5		38.3
	No feedback, PAL block level. Min of $1/(t_{WLA} + t_{WHA})$ or $1/(t_{SA} + t_{HA})$	167		125		125		100		83.3		71.4		62.5
$f_{MAXI}$	Maximum input register frequency $1/(t_{SIRS} + t_{HIRS})$ or $1/(2 \times t_{WICW})$	167		125		125		100		83.3		71.4		62.5

**Notes:**

1. See "MACH Switching Test Circuits" documentation on the Lattice Data Book CD-ROM or Lattice web site.
2. Numbers in parentheses are for M5-128, M5-192, M5-256.
3. If a signal is used as both a clock and a logic array input, then the maximum input frequency applies ( $f_{MAX}/2$ ).

## CAPACITANCE<sup>1</sup>

Parameter Symbol	Parameter Description	Test conditions		Typ
$C_{IN}$	I/CLK pin	$V_{IN} = 2.0\text{ V}$	3.3 V or 5 V, 25° C, 1 MHz	12
$C_{I/O}$	I/O pin	$V_{OUT} = 2.0\text{ V}$	3.3 V or 5 V, 25° C, 1 MHz	10

1. These parameters are not 100% tested, but are calculated at initial characterization and at any time the design is modified. These parameters may be affected.

## $I_{CC}$ vs. FREQUENCY

These curves represent the typical power consumption for a particular device at system frequency. The selected “typical” pattern is a 16-bit up-down counter. This pattern fills the device and exercises every macrocell. Maximum frequency shown uses internal feedback and a D-register. Power/Speed are optimized to obtain the highest counter frequency and the lowest power. The highest frequency (LSBs) is placed in common PAL blocks, which are set to low power. The lowest frequency signals (MSBs) are placed in a common PAL block and set to low power. For a more detailed discussion about MACH 5 power consumption, refer to application note entitled *MACH 5 Power* in the Application Notes section on the Lattice Design CD-ROM or Lattice web site.

## $I_{CC}$ CURVES AT HIGH /LOW POWER MODES

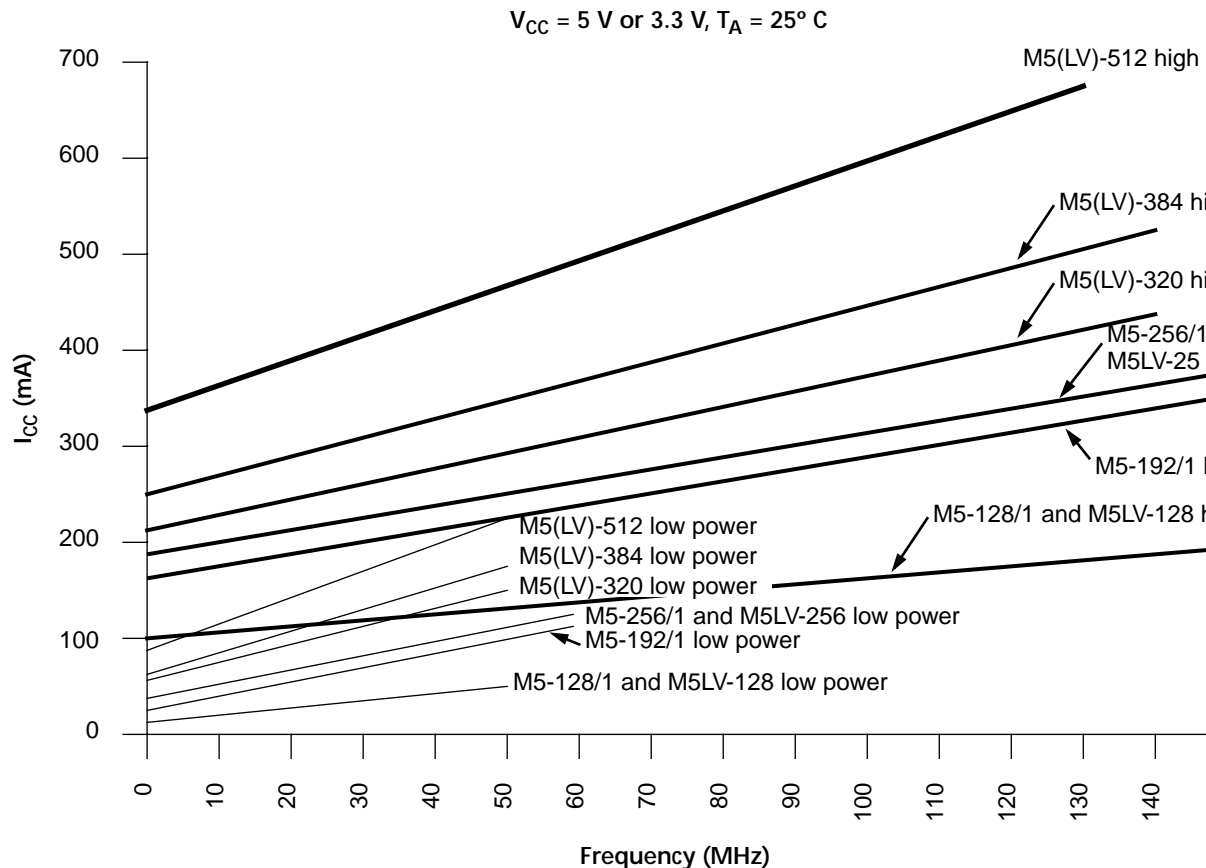


Figure 8.  $I_{CC}$  Curves at High/Low Power Modes

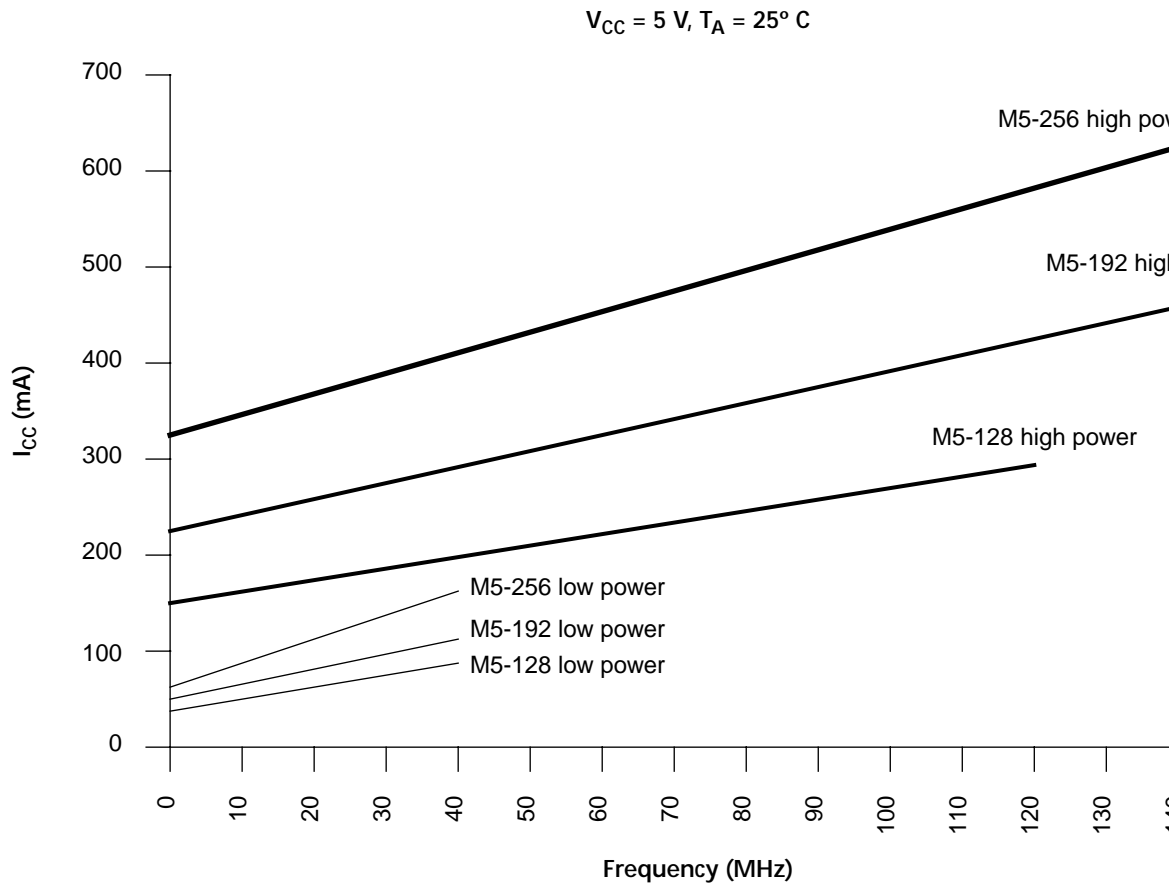
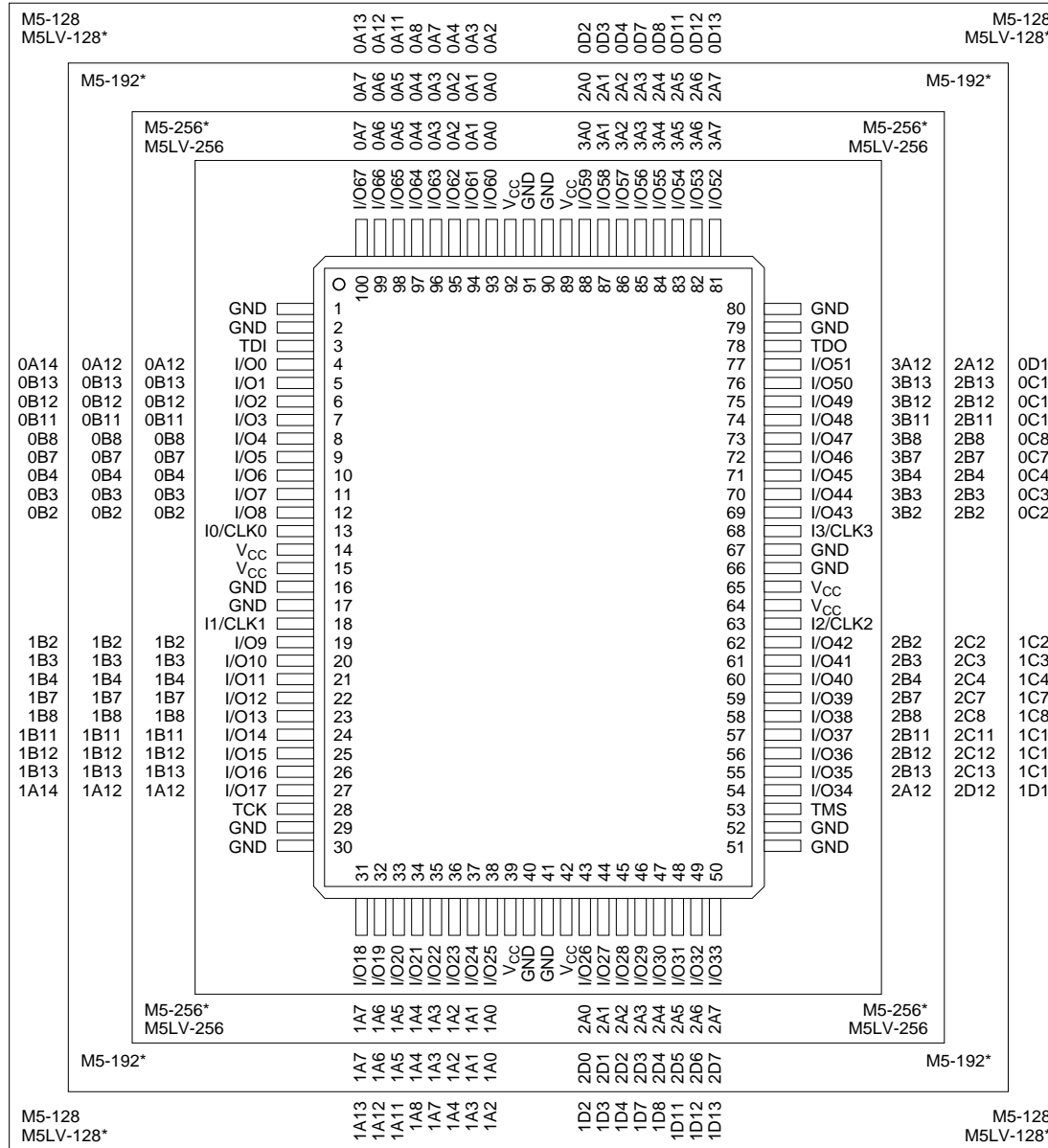


Figure 9.  $I_{CC}$  Curves at High/Low Power Modes

## 100-PIN PQFP CONNECTION DIAGRAM

### Top View

100-Pin PQFP (68 I/O)



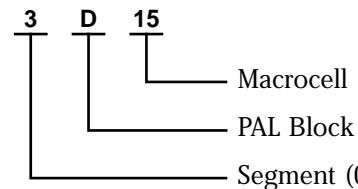
\*Package obsolete, contact factory.

20446G-01

### Pin Designations

CLK = Clock  
GND = Ground  
I = Input  
I/O = Input/Output  
NC = No Connect

V<sub>CC</sub> = Supply Voltage  
TDI = Test Data In  
TCK = Test Clock  
TMS = Test Mode Select  
TDO = Test Data Out

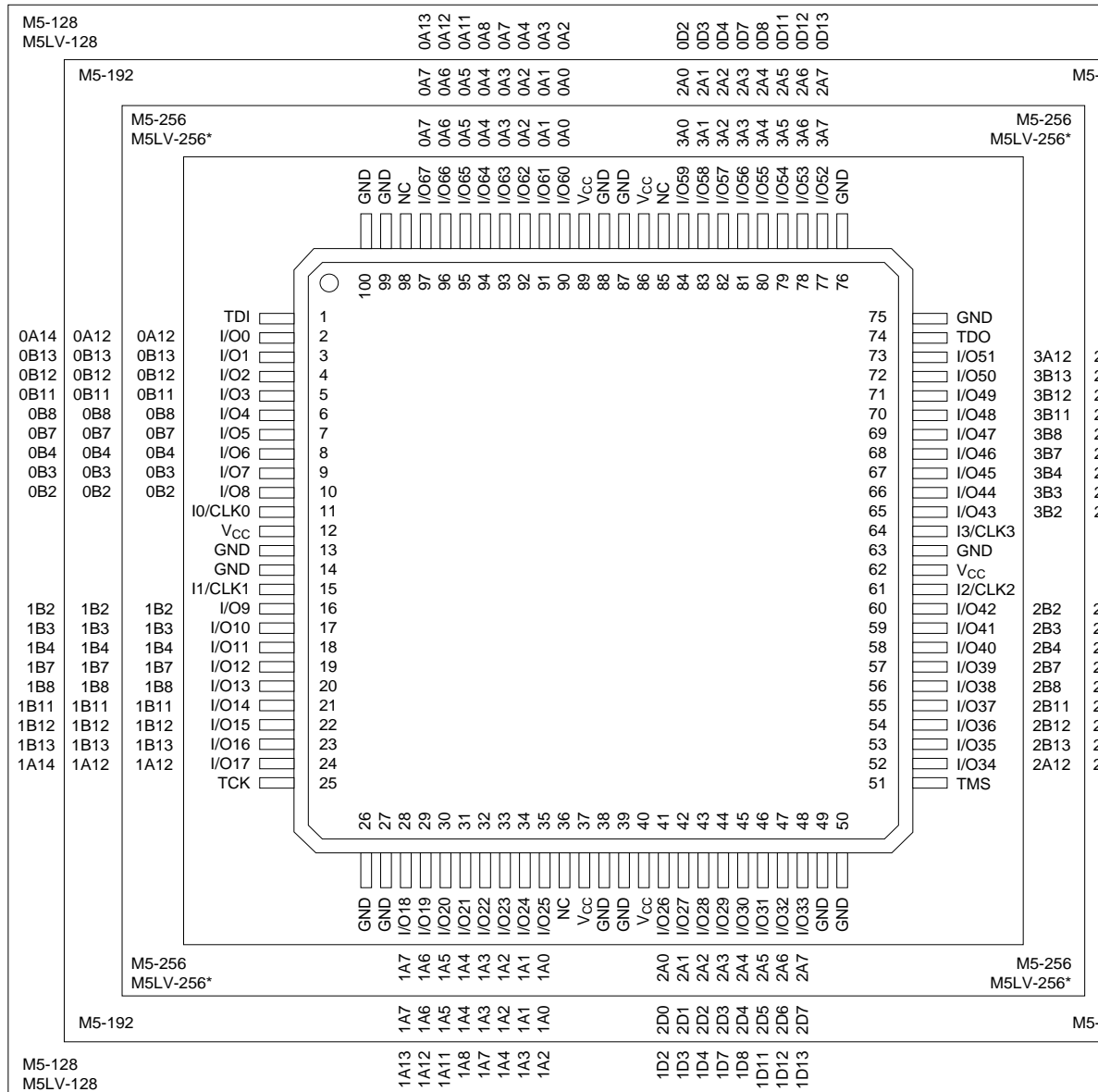




# 100-PIN TQFP CONNECTION DIAGRAM – 68 I/O

Top View

100-Pin TQFP (68 I/O)

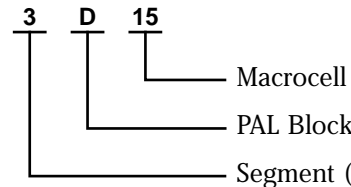


\*Package obsolete, contact factory.

### Pin Designations

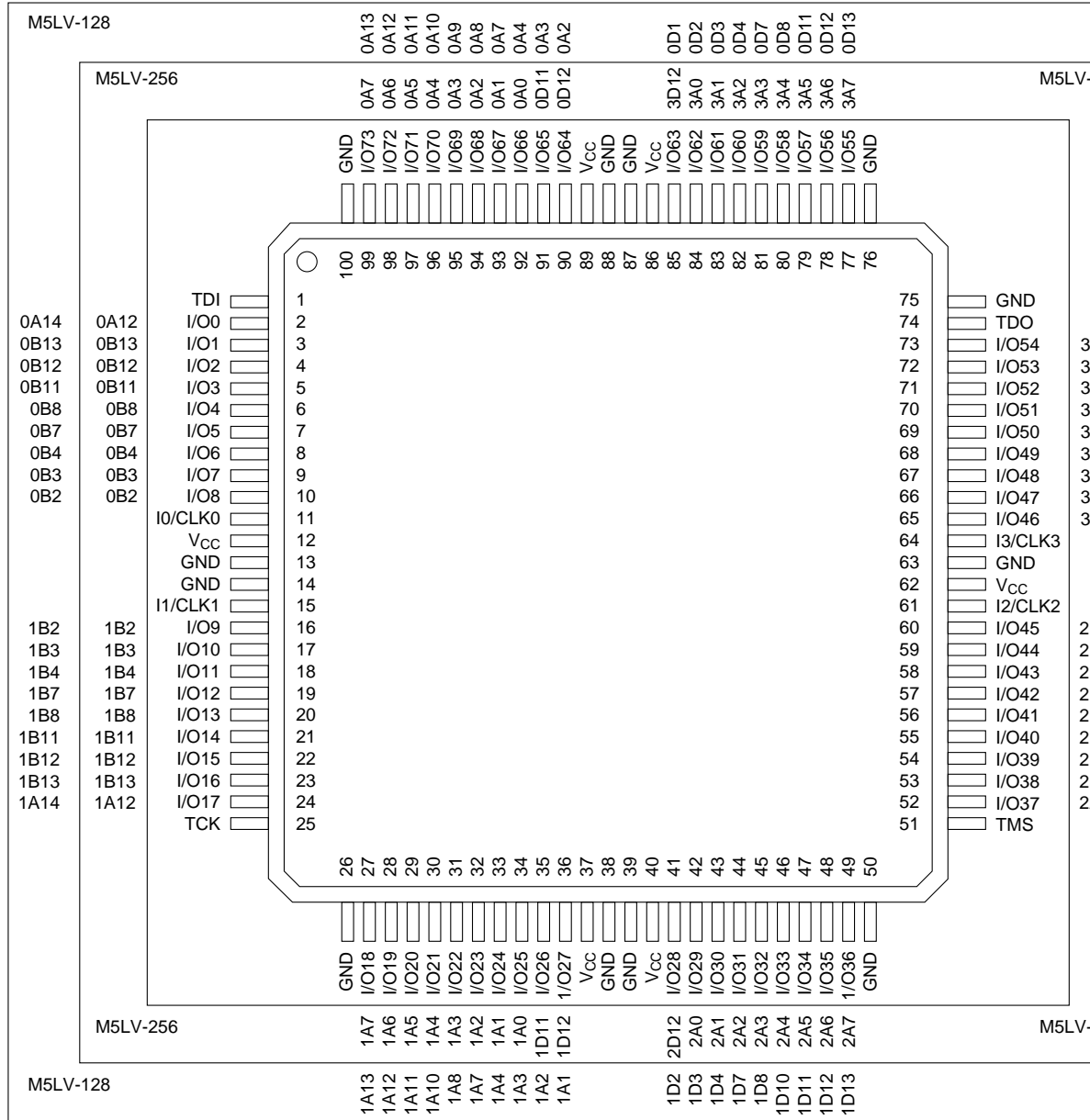
- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect

- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



## 100-PIN TQFP CONNECTION DIAGRAM – 74 I/O Top View

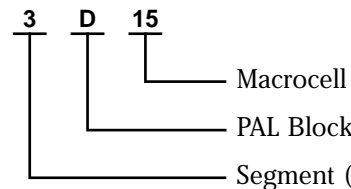
100-Pin TQFP (74 I/O)



### Pin Designations

CLK = Clock  
GND = Ground  
I = Input  
I/O = Input/Output  
NC = No Connect

V<sub>CC</sub> = Supply Voltage  
TDI = Test Data In  
TCK = Test Clock  
TMS = Test Mode Select  
TDO = Test Data Out

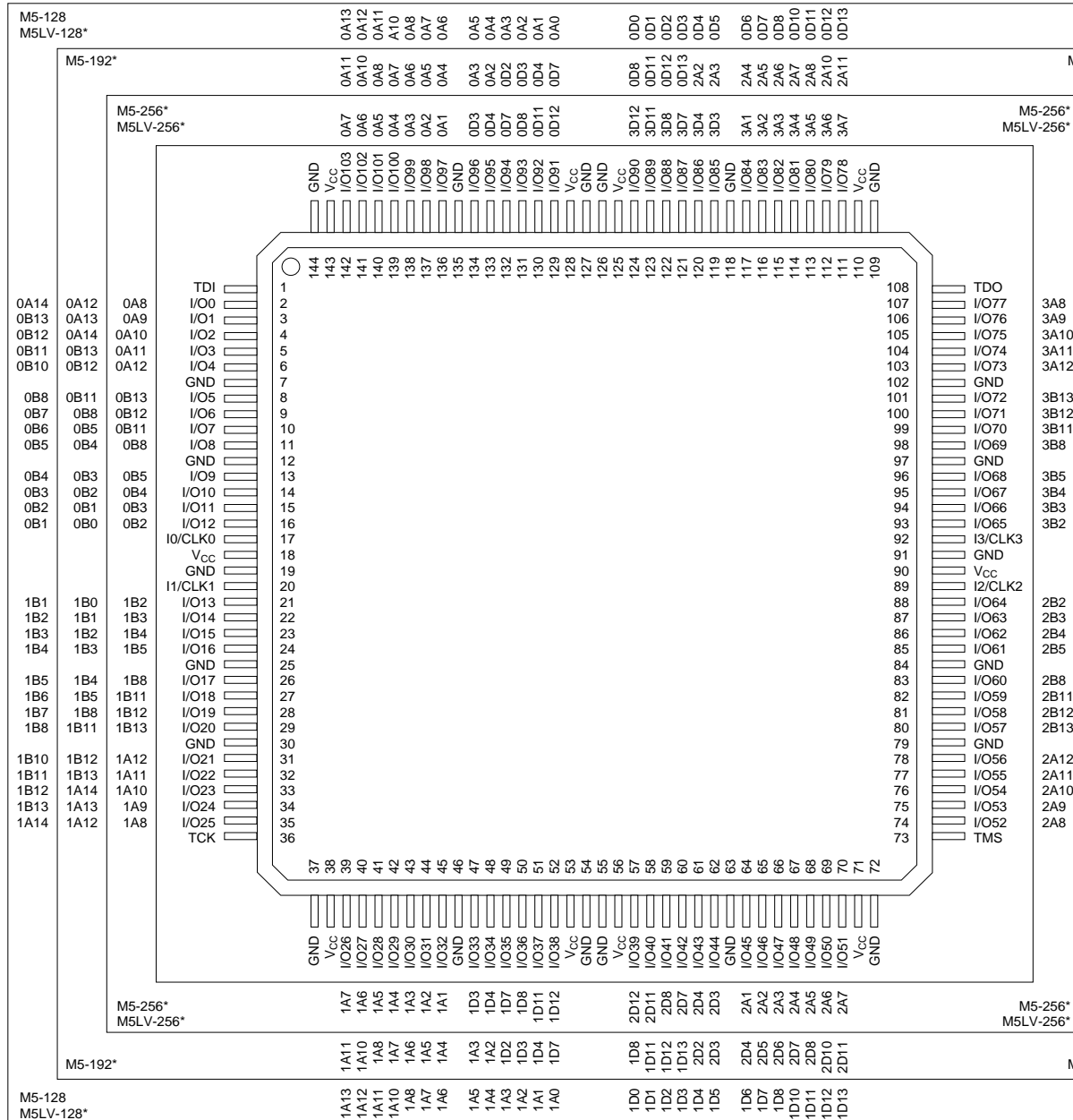




# 144-PIN PQFP CONNECTION DIAGRAM

Top View

144-Pin PQFP

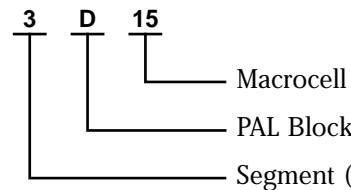


\*Package obsolete, contact factory.

## Pin Designations

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect

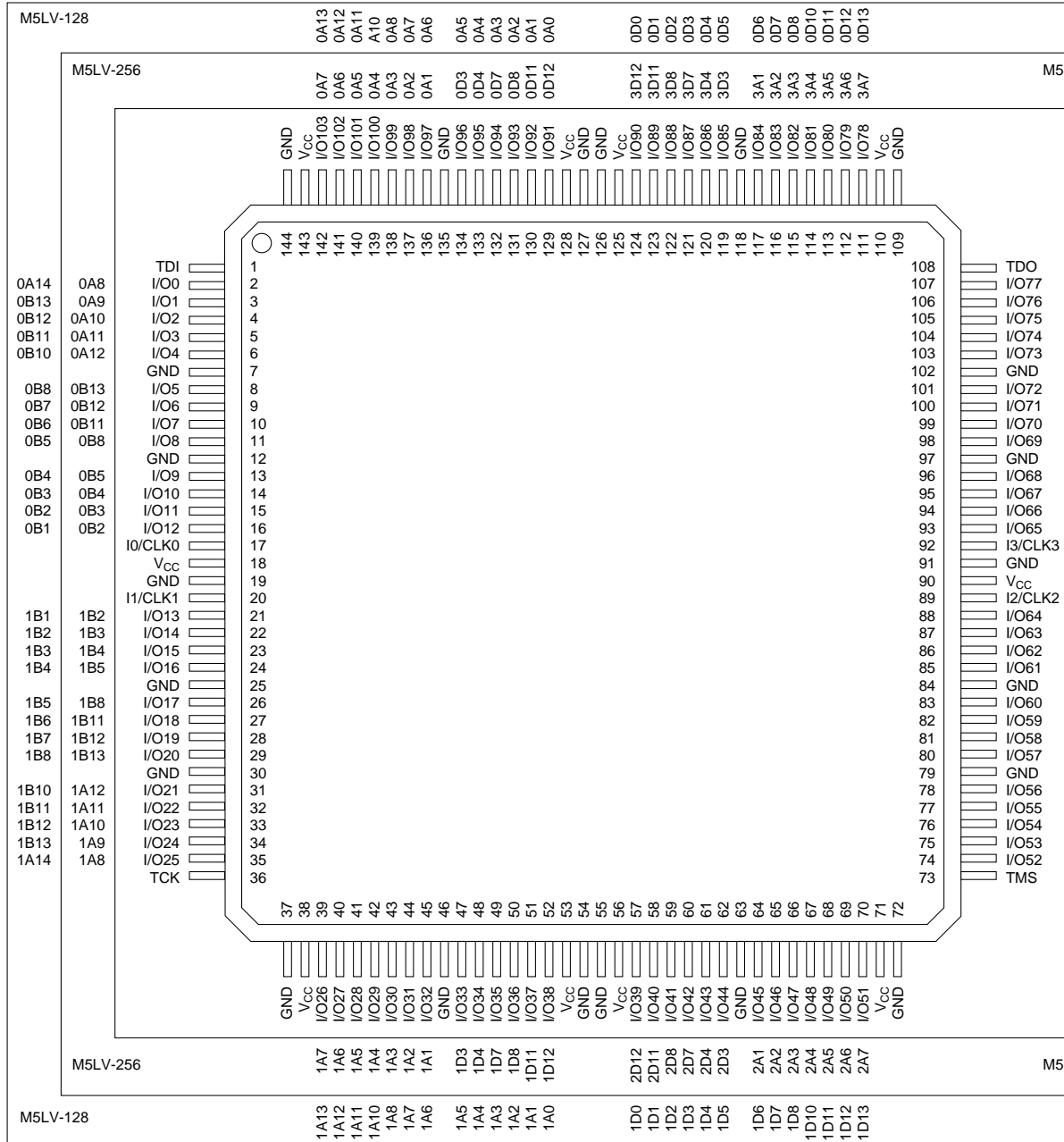
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



# 144-PIN TQFP CONNECTION DIAGRAM

## Top View

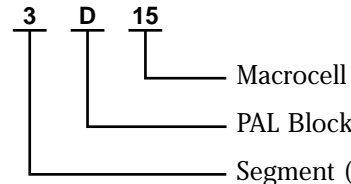
144-Pin TQFP



### Pin Designations

CLK = Clock  
 GND = Ground  
 I = Input  
 I/O = Input/Output  
 NC = No Connect

V<sub>CC</sub> = Supply Voltage  
 TDI = Test Data In  
 TCK = Test Clock  
 TMS = Test Mode Select  
 TDO = Test Data Out



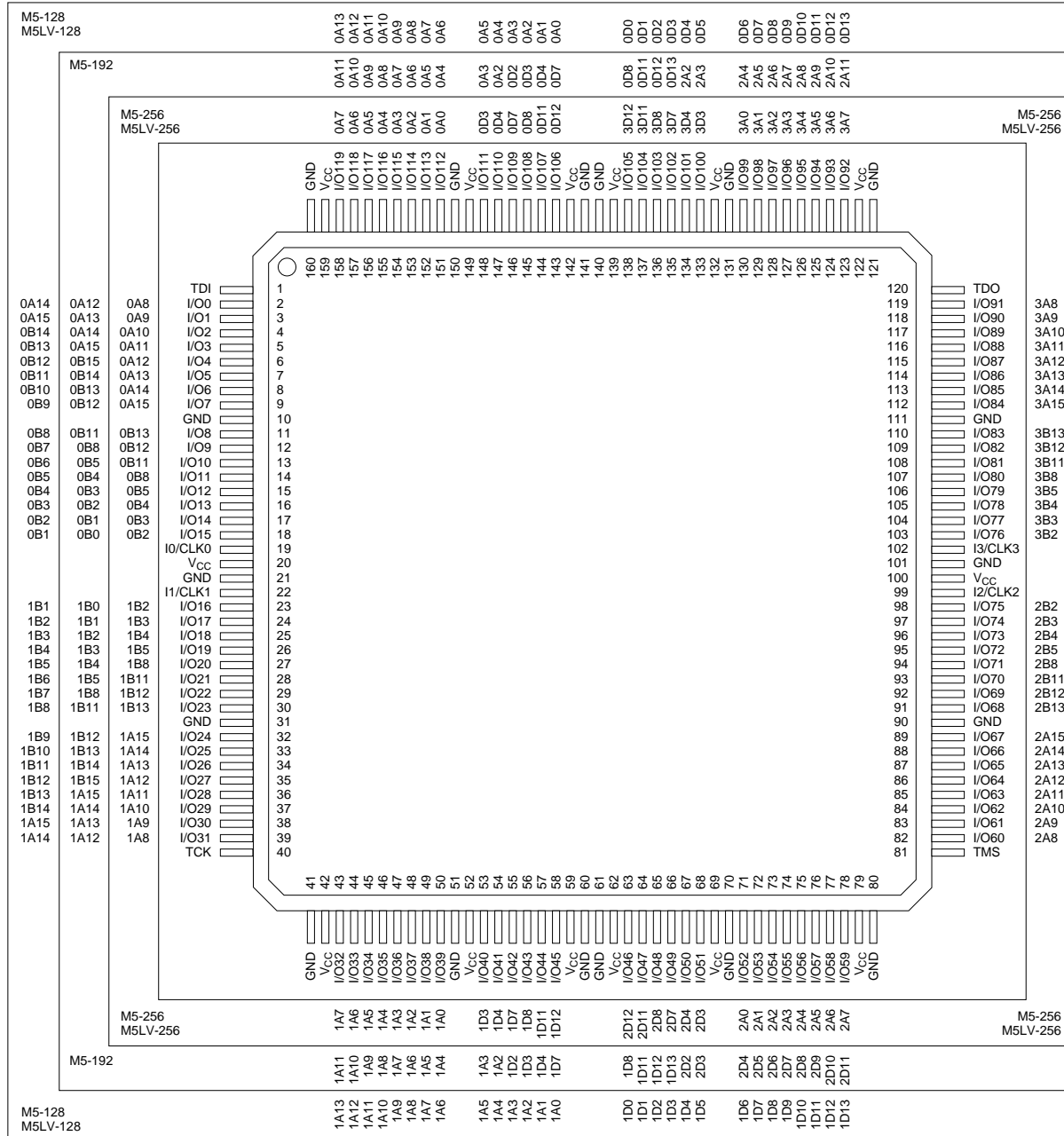




# 160-PIN PQFP CONNECTION DIAGRAM

## Top View

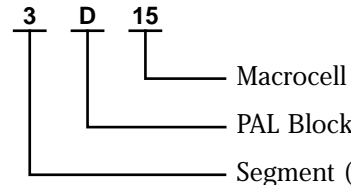
160-Pin PQFP (128, 192, 256 Macrocells)



### Pin Designations

CLK = Clock  
 GND = Ground  
 I = Input  
 I/O = Input/Output  
 NC = No Connect

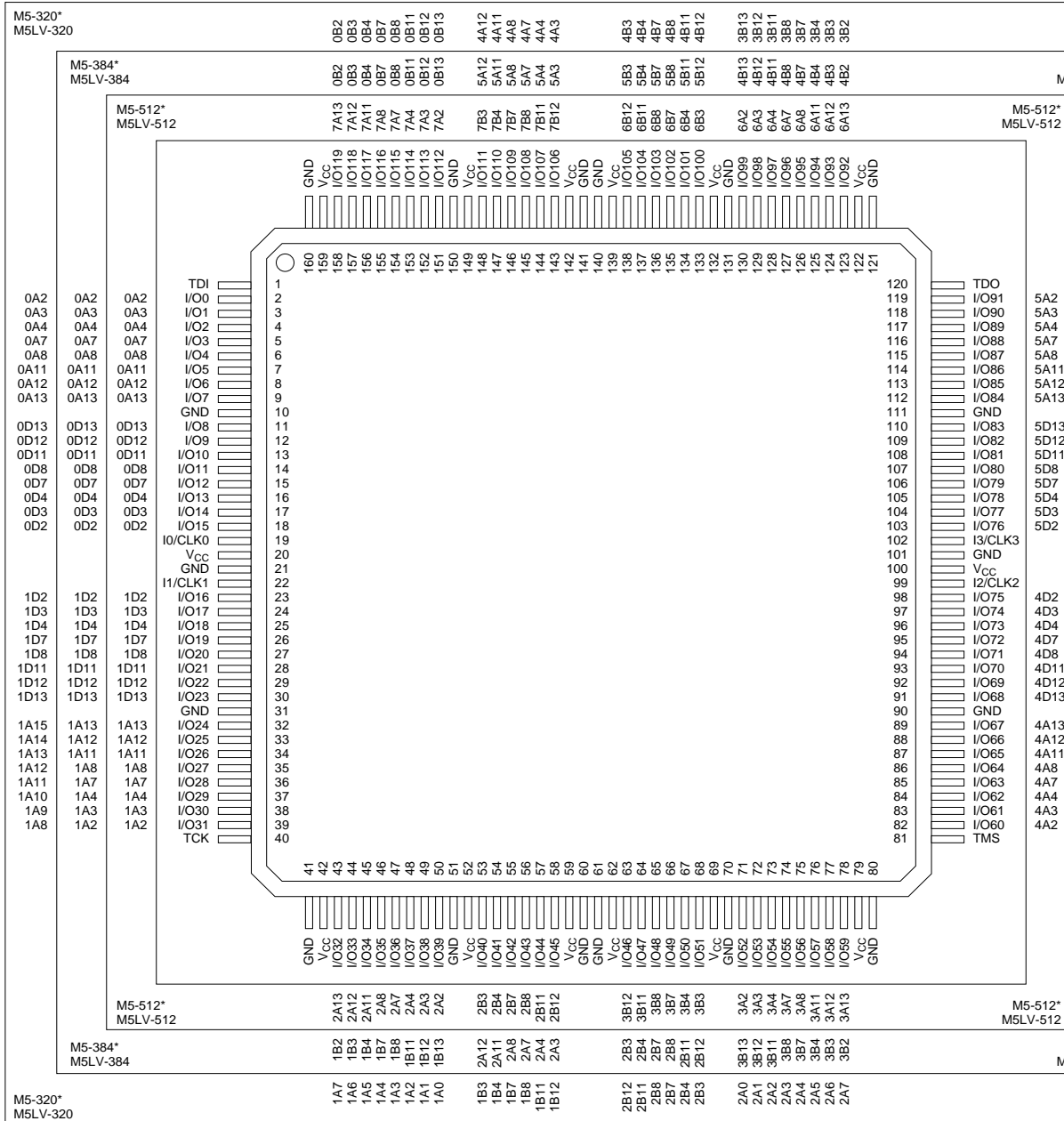
V<sub>CC</sub> = Supply Voltage  
 TDI = Test Data In  
 TCK = Test Clock  
 TMS = Test Mode Select  
 TDO = Test Data Out



# 160-PIN PQFP (WITH INTERNAL HEAT SPREADER) CONNECTION DIAGRAM

## Top View

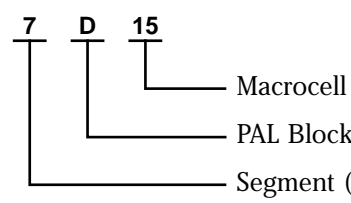
160-Pin PQFP (320, 384, 512 Macrocells)



\*Package obsolete, contact factory.

### Pin Designations

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out

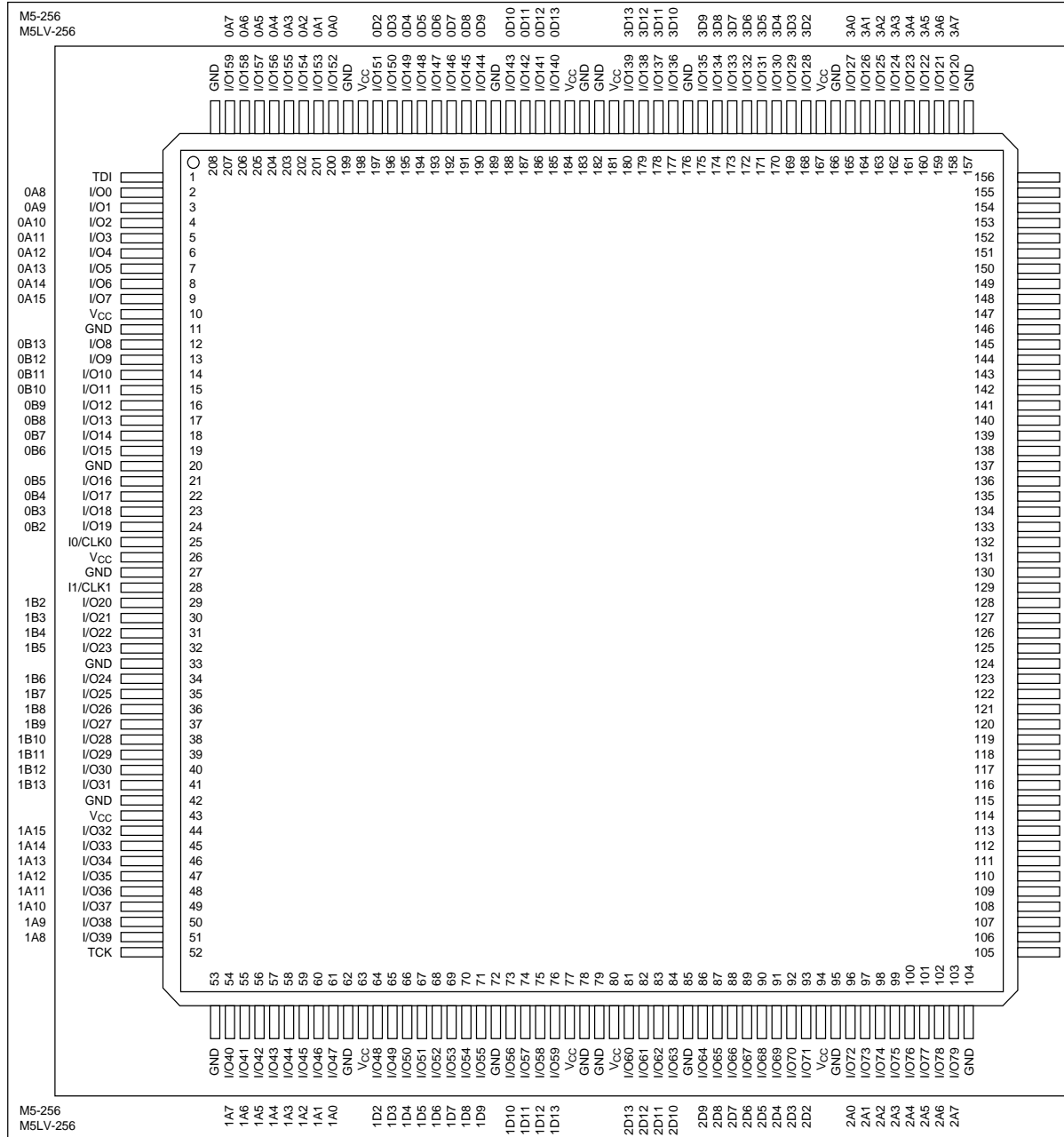




# 208-PIN PQFP CONNECTION DIAGRAM

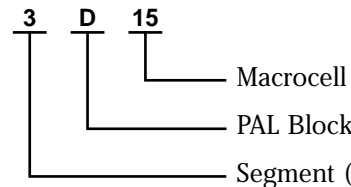
## Top View

208-Pin PQFP (192, 256 Macrocells)



### Pin Designations

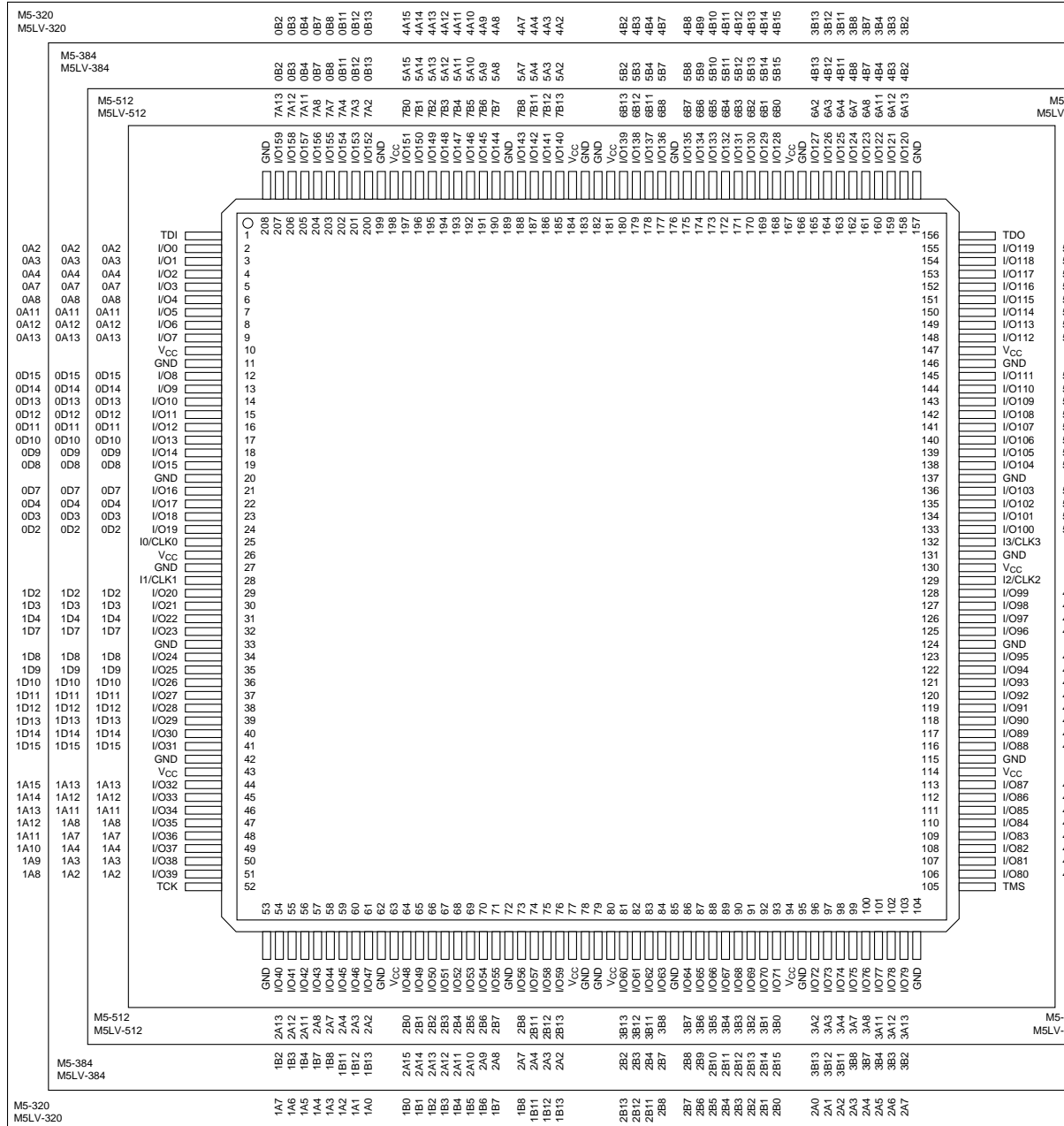
- |                    |                        |
|--------------------|------------------------|
| CLK = Clock        | Vcc = Supply Voltage   |
| GND = Ground       | TDI = Test Data In     |
| I = Input          | TCK = Test Clock       |
| I/O = Input/Output | TMS = Test Mode Select |
| NC = No Connect    | TDO = Test Data Out    |



# 208-PIN PQFP (WITH INTERNAL HEAT SPREADER) CONNECTION DIAGRAM

## Top View

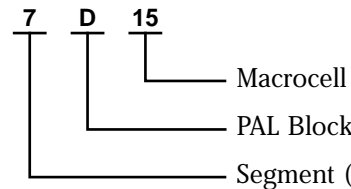
208-Pin PQFP (320, 384, 512 Macrocells)



### Pin Designations

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect

- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out

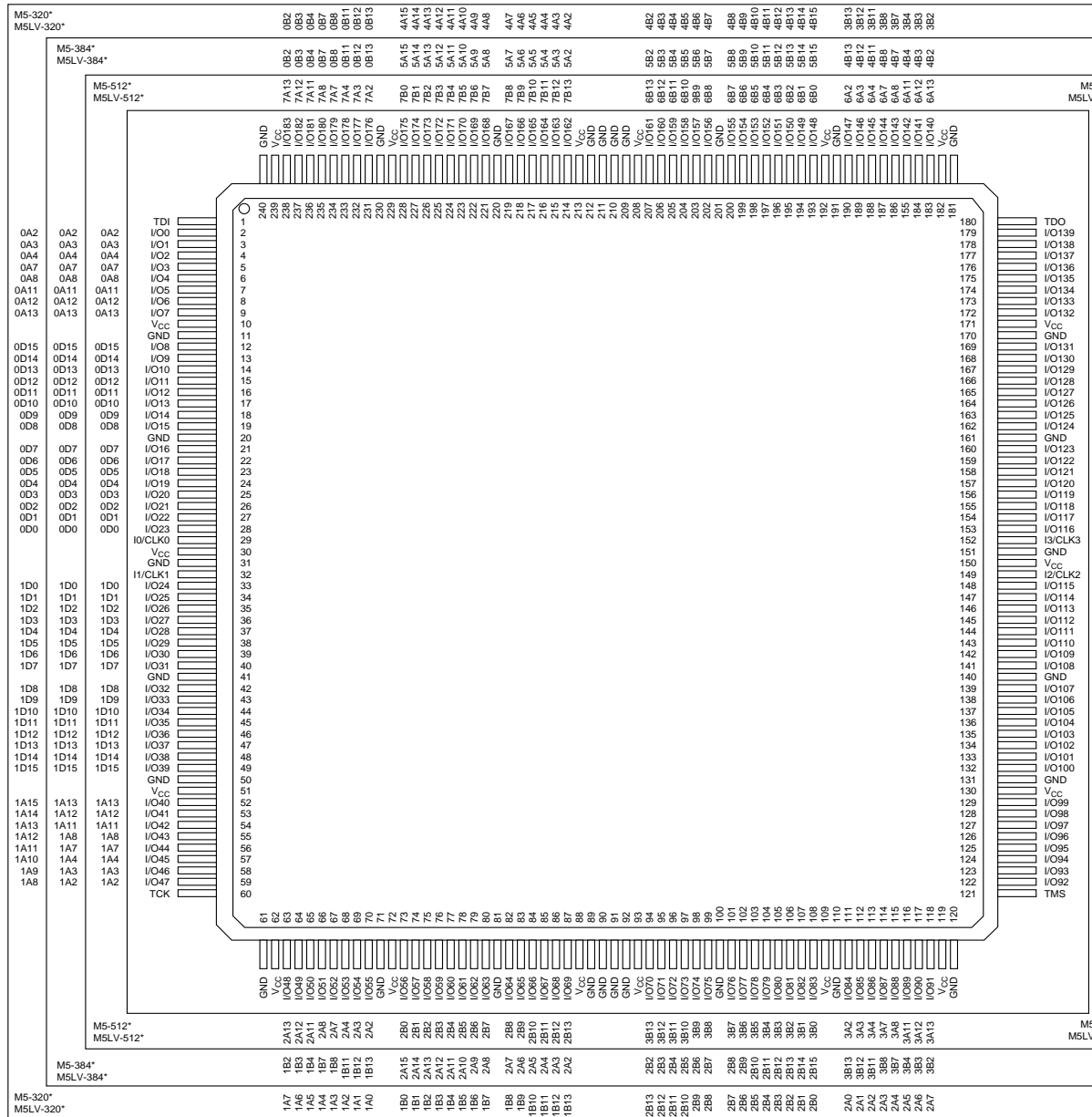




# 240-PIN PQFP CONNECTION DIAGRAM

Top View

240-Pin PQFP

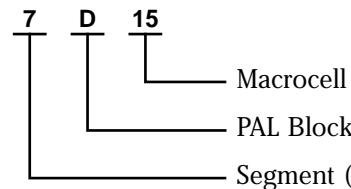


\*Package obsolete, contact factory.

## Pin Designations

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect

- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



## 256-BALL BGA CONNECTION DIAGRAM — M5-320, M5LV-320\*, M5-384\*, M5LV-384\*, M5-512\*, M5LV-512\* Bottom View (I/O Pin-outs)

**256-Ball BGA**

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y	
1	GND	GND	I/O181	I/O182	I/O183	GND	I/O184	GND	I/O185	I/O186	GND	I/O187	GND	I/O188	GND	I/O189	I/O190	I/O191	GND	GND	
2	GND	I/O164	I/O165	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	I/O186	I/O186	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177	I/O178	I/O179	I/O180	
3	GND	I/O148	V <sub>CC</sub>	I/O149	I/O150	I/O151	I/O152	I/O153	I/O154	I/O155	I/O156	I/O157	I/O158	I/O159	I/O160	I/O161	I/O162	V <sub>CC</sub>	I/O163	I/O164	
4	I/O134	I/O135	I/O136	V <sub>CC</sub>	TDO	I/O137	V <sub>CC</sub>	I/O138	I/O139	I/O140	I/O141	I/O142	I/O143	V <sub>CC</sub>	I/O144	TMS	V <sub>CC</sub>	I/O145	I/O146	I/O147	
5	I/O128	I/O129	I/O130	V <sub>CC</sub>													V <sub>CC</sub>	I/O131	I/O132	I/O133	
6	GND	I/O122	I/O123	I/O124													I/O125	I/O126	I/O127	GND	
7	I/O108	I/O109	I/O110	V <sub>CC</sub>													V <sub>CC</sub>	I/O109	I/O110	I/O111	
8	GND	I/O102	I/O103	I/O104													I/O105	I/O106	I/O107	I/O108	
9	GND	I/O96	I/O97	I/O98													I/O99	I/O100	I/O101	GND	
10	GND	I/O90	I/O91	I/O92													I/O83	I/O84	I/O85	GND	
11	GND	I/O84	I/O85	I/O86													I/O87	I/O88	I/O89	GND	
12	GND	I/O76	I/O77	I/O78	I/O79												I/O80	I/O81	I/O82	I/O83	
13	I/O70	I/O71	I/O72	V <sub>CC</sub>													V <sub>CC</sub>	I/O73	I/O74	I/O75	
14	GND	I/O64	I/O65	I/O66													I/O67	I/O68	I/O69	GND	
15	I/O58	I/O59	I/O60	V <sub>CC</sub>													V <sub>CC</sub>	I/O61	I/O62	I/O63	
16	I/O44	I/O45	I/O46	V <sub>CC</sub>	TDI												V <sub>CC</sub>	I/O55	I/O56	I/O57	
17	GND	I/O28	V <sub>CC</sub>	I/O29	I/O30	I/O31	I/O32	I/O33	I/O34	I/O35	I/O36	I/O37	I/O38	I/O39	I/O40	I/O41	V <sub>CC</sub>	V <sub>CC</sub>	I/O43	GND	
18	I/O11	I/O12	I/O13	I/O14	I/O15	I/O16	I/O17	I/O18	I/O19	I/O19	I/O20	I/O21	I/O22	I/O23	I/O24		I/O25	I/O26	I/O27	GND	
19	GND	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	GND
20	GND	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	I/O0	GND

**Pin Designations**

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out

\*Package obsolete, contact factory.



## 256-BALL BGA CONNECTION DIAGRAM — M5-320, M5LV-320\*

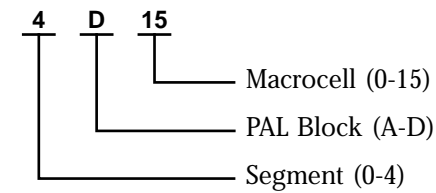
### Bottom View (Macrocell Association)

256-Ball BGA

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y
1	GND	GND	3A11	3D15	3D12	GND	3D7	GND	3D3	3D2	GND	2D2	GND	2D7	GND	2D10	2D13	2D15	GND	GND
2	GND	3B2	3A3	3A8	3A13	3D13	3D9	3D8	3D4	13/CLK3	12/CLK2	2D3	2D4	2D8	2D12	2A15	2A13	2A12	2A9	2A7
3	GND	3B8	V <sub>CC</sub>	3A2	3A4	3A12	3D14	3D10	3D5	3D0	2D0	2D5	2D9	2D14	2A14	2A10	2A8	V <sub>CC</sub>	2A3	GND
4	3B13	3B11	3B3	V <sub>CC</sub>	TDO	3A7	V <sub>CC</sub>	3D11	3D6	3D1	2D1	2D6	2D11	V <sub>CC</sub>	2A11	TMS	V <sub>CC</sub>	2A6	2A2	2A0
5	4B14	4B15	3B4	V <sub>CC</sub>													V <sub>CC</sub>	2A5	2A2	2A0
6	GND	4B11	3B12	3B7													2A4	2A1	2A2	2A7
7	4B8	4B10	4B13	V <sub>CC</sub>													V <sub>CC</sub>	2B2	2B4	GND
8	4B4	4B6	4B9	4B12													2B3	2B6	2B5	2B1
9	GND	4B3	4B5	4B7													2B8	2B10	2B9	2B11
10	GND	4B0	4B1	4B2													2B13	2B14	2B12	GND
11	GND	4A0	4A1	4A2													1B13	1B14	1B15	GND
12	GND	4A3	4A5	4A7													1B8	1B10	1B12	GND
13	4A4	4A6	4A9	4A12													1B3	1B6	1B9	1B11
14	4A8	4A10	4A13	V <sub>CC</sub>													V <sub>CC</sub>	1B2	1B5	1B7
15	GND	4A11	0B12	0B7													1A4	1A1	1B4	GND
16	4A14	4A15	0B4	V <sub>CC</sub>													V <sub>CC</sub>	1A5	1B0	1B1
17	0B13	0B11	0B3	V <sub>CC</sub>	TDI												V <sub>CC</sub>	1A6	1A2	1A0
18	GND	0B8	V <sub>CC</sub>	0A2	0A4	0A7											1A8	V <sub>CC</sub>	1A3	GND
19	0B2	0A3	0A8	0A11	0A13	0D12	0D8	0D4	0D3	10/CLK0	11/CLK1	1D8	1D7	1D13	1A11		1A12	1A9	1A7	GND
20	GND	GND	0D15	0D13	0D10	GND	0D7	GND	0D2	GND	1D2	1D3	GND	GND	1D12	1D15	1A13	GND	1A7	GND

**Pin Designations**

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



\*Package obsolete, contact factory.

## 256-BALL BGA CONNECTION DIAGRAM — M5-384\*, M5LV-384\*

### Bottom View (Macrocell Association)

256-Ball BGA

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y
1	GND	GND	4A11	4D15	4D12	GND	4D7	GND	4D3	4D2	GND	3D2	GND	3D7	GND	3D10	3D13	3D15	GND	GND
2	GND	4B2	4A3	4A8	4A13	4D13	4D9	4D8	4D4	13/CLK3	12/CLK2	3D3	3D4	3D8	3D12	3A13	3A11	3A8	3A3	3B2
3	GND	4B8	V <sub>CC</sub>	4A2	4A4	4A12	4D14	4D10	4D5	4D0	3D0	3D5	3D9	3D14	3A12	3A4	3A2	V <sub>CC</sub>	3B8	GND
4	4B13	4B11	4B3	V <sub>CC</sub>	TDO	4A7	V <sub>CC</sub>	4D11	4D6	4D1	3D1	3D6	3D11	V <sub>CC</sub>	3A7	TMS	V <sub>CC</sub>	3B3	3B11	3B13
5	5B14	5B15	4B4	V <sub>CC</sub>													V <sub>CC</sub>	3B4	2B15	2B14
6	GND	5B11	4B12	4B7													V <sub>CC</sub>	3B12	2B11	GND
7	5B8	5B10	5B13	V <sub>CC</sub>													V <sub>CC</sub>	2B13	2B10	2B8
8	5B4	5B6	5B9	5B12													2B12	2B9	2B6	2B4
9	GND	5B3	5B5	5B7													2B7	2B5	2B3	GND
10	GND	5B0	5B1	5B2													2B2	2B1	2B0	GND
11	GND	5A0	5A1	5A2													2A2	2A1	2A0	GND
12	GND	5A3	5A5	5A7													2A7	2A5	2A3	GND
13	5A4	5A6	5A9	5A12													2A12	2A9	2A6	2A4
14	5A8	5A10	5A13	V <sub>CC</sub>													V <sub>CC</sub>	2A13	2A10	2A8
15	GND	5A11	0B12	0B7													1B7	1B12	2A11	GND
16	5A14	5A15	0B4	V <sub>CC</sub>													V <sub>CC</sub>	1B4	2A15	2A14
17	0B13	0B11	0B3	V <sub>CC</sub>	TDI	0A7	V <sub>CC</sub>	0D11	0D6	0D1	1D1	1D6	1D11	V <sub>CC</sub>	1A7	TCK	V <sub>CC</sub>	1B3	1B11	1B13
18	GND	0B8	V <sub>CC</sub>	0A2	0A4	0A12	0D14	0D9	0D5	0D0	1D2	1D3	1D8	1D14	1A12	1A4	1A2	V <sub>CC</sub>	1B8	GND
19	0B2	0A3	0A8	0A11	0A13	0D12	0D8	0D4	0D3	10/CLK0	11/CLK1	1D4	1D9	1D13	1A13	1A8	1A8	1A3	1B2	GND
20	GND	GND	0D15	0D13	0D10	GND	0D7	GND	0D2	GND	1D5	GND	1D7	GND	1D12	1D15	1A11	GND	GND	GND

**Pin Designations**

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out

5 — Segment (0-5)  
D — PAL Block (A-D)  
15 — Macrocell (0-15)

\*Package obsolete, contact factory.





## 256-BALL BGA CONNECTION DIAGRAM — M5-512\*, M5LV-512\*

### Bottom View (Macrocell Association)

256-Ball BGA

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y
1	GND	GND	5A11	5D15	5D12	GND	5D7	GND	5D3	5D2	GND	4D2	GND	4D7	GND	4D10	4D13	4D15	GND	GND
2	GND	6A13	5A3	5A8	5A13	5D13	5D9	5D8	5D4	I <sub>3</sub> CLK <sub>3</sub>	I <sub>2</sub> CLK <sub>2</sub>	4D3	4D4	4D8	4D12	4A13	4A11	4A8	4A3	3A13
3	GND	6A7	V <sub>CC</sub>	5A2	5A4	5A12	5D14	5D10	5D5	5D0	4D0	4D5	4D9	4D14	4A12	4A4	4A2	V <sub>CC</sub>	3A7	GND
4	6A2	6A4	6A12	V <sub>CC</sub>	TDO	5A7	V <sub>CC</sub>	5D11	5D6	5D1	4D1	4D6	4D11	V <sub>CC</sub>	4A7	TMS	V <sub>CC</sub>	3A12	3A4	3A2
5	6B1	6B0	6A11	V <sub>CC</sub>													V <sub>CC</sub>	3A11	3B0	3B1
6	GND	6B4	6A3	6A8													3A8	3A3	3B4	GND
7	6B7	6B5	6B2	V <sub>CC</sub>													V <sub>CC</sub>	3B2	3B5	3B7
8	6B11	6B9	6B6	6B3													3B3	3B6	3B9	3B11
9	GND	6B12	6B10	6B8													3B8	3B10	3B12	GND
10	GND	6B15	6B14	6B13													3B13	3B14	3B15	GND
11	GND	7B15	7B14	7B13													2B13	2B14	2B15	GND
12	GND	7B12	7B10	7B8													2B8	2B10	2B12	GND
13	7B11	7B9	7B6	7B3													2B3	2B6	2B9	2B11
14	7B7	7B5	7B2	V <sub>CC</sub>													V <sub>CC</sub>	2B2	2B5	2B7
15	GND	7B4	7A3	7A8													2A8	2A3	2B4	GND
16	7B1	7B0	7A11	V <sub>CC</sub>													V <sub>CC</sub>	2A11	2B0	2B1
17	7A2	7A4	7A12	V <sub>CC</sub>	TDI	0A7	V <sub>CC</sub>	0D11	0D6	0D1	1D1	1D6	1D11	V <sub>CC</sub>	1A7	TCK	V <sub>CC</sub>	2A12	2A4	2A2
18	GND	7A7	V <sub>CC</sub>	0A2	0A4	0A12	0D14	0D9	0D5	0D0	1D0	1D5	1D10	1D14	1A12		V <sub>CC</sub>	V <sub>CC</sub>	2A7	GND
19	7A13	0A3	0A8	0A11	0A13	0D12	0D8	0D4	0D3	I <sub>0</sub> CLK <sub>0</sub>	I <sub>1</sub> CLK <sub>1</sub>	1D4	1D8	1D9	1A13	1A4	1A8	1A3	2A13	GND
20	GND	GND	0D15	0D13	0D10	GND	0D7	GND	0D2	GND	1D2	1D3	GND	1D7	GND	1D12	1D15	1A11	GND	GND

**Pin Designations**

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out

5      D      15

Macrocell (0-15)

PAL Block (A-D)

Segment (0-5)

\*Package obsolete, contact factory.

## 352-BALL BGA CONNECTION DIAGRAM — M5-512, M5LV-512

### Bottom View (I/O Pin-outs)

352-Ball BGA

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y	AA	AB	AC	AD
1	NC	NC	NC	GND	NC	I/O245	GND	I/O246	I/O247	GND	I/O248	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249	I/O249
2	NC	NC	NC	I/O224	I/O225	I/O226	I/O227	I/O228	I/O229	I/O230	I/O231	I/O232	I/O233	I/O233	I/O234	I/O235	I/O236	I/O237	I/O238	I/O239	I/O240	I/O241	I/O242	I/O243
3	GND	GND	NC	I/O205	I/O206	I/O207	I/O208	I/O209	I/O210	I/O211	I/O212	I/O213	I/O214	I/O214	I/O215	I/O216	I/O217	I/O218	I/O219	I/O219	I/O220	I/O221	I/O222	I/O223
4	NC	I/O188	NC	TDO	I/O189	I/O190	I/O191	V <sub>CC</sub>	I/O192	V <sub>CC</sub>	I/O193	I/O194	I/O195	V <sub>CC</sub>	I/O196	I/O197	I/O198	V <sub>CC</sub>	I/O199	V <sub>CC</sub>	I/O200	I/O201	V <sub>CC</sub>	I/O202
5	GND	I/O183	I/O184	V <sub>CC</sub>																			I/O185	
6	NC	I/O176	I/O177	I/O178																			I/O179	
7	GND	I/O169	I/O170	I/O171																			I/O172	
8	I/O162	I/O163	I/O164	I/O165																			I/O166	
9	I/O156	I/O157	I/O158	I/O159																			V <sub>CC</sub>	
10	GND	I/O150	I/O151	V <sub>CC</sub>																			I/O152	
11	I/O142	I/O143	I/O144	I/O145																			I/O146	
12	I/O134	I/O135	I/O136	I/O137																			I/O138	
13	I/O128	I/O129	I/O130	I/O131																			V <sub>CC</sub>	
14	GND	I/O122	I/O123	V <sub>CC</sub>																			I/O124	
15	I/O114	I/O115	I/O116	I/O117																			I/O118	
16	NC	I/O107	I/O108	I/O109																			I/O110	
17	I/O101	I/O102	I/O103	I/O104																			V <sub>CC</sub>	
18	GND	I/O95	I/O96	V <sub>CC</sub>																			I/O97	
19	I/O87	I/O88	I/O89	I/O90																			I/O91	
20	I/O80	I/O81	I/O82	I/O83																			I/O84	
21	I/O73	I/O74	I/O75	I/O76																			I/O77	
22	GND	I/O68	I/O69	I/O70																			V <sub>CC</sub>	
23	I/O51	I/O52	I/O53	V <sub>CC</sub>																			I/O71	
24	NC	NC	TDI	I/O32	I/O33	I/O34	I/O35	I/O36	I/O37	I/O38	I/O39	I/O40	I/O41	I/O42	I/O43	I/O44	I/O45	I/O46	I/O47	I/O48	I/O49		TCK	
25	GND	GND	I/O11	I/O12	I/O13	I/O14	I/O15	I/O16	I/O17	I/O18	I/O19	I/O20	I/O21	I/O22	I/O23	I/O24	I/O25	I/O26	I/O27	I/O28	I/O29		I/O50	
26	NC	NC	I/O0	I/O0	NC	GND	I/O1	I/O2	GND	I/O3	I/O4	I/O5	GND	I/O6	I/O7	GND	I/O8	I/O9	GND	I/O10	NC		NC	

#### Pin Designations

- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out

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## 352-BALL BGA CONNECTION DIAGRAM — M5-512, M5LV-512

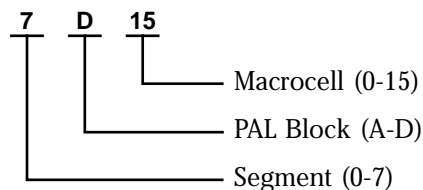
### Bottom View (I/O Pin-outs)

352-Ball BGA

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y	AA	AB	AC	AD
1	NC	NC	NC	GND	NC	5A12	GND	5D15	5D11	GND	5D6	5D3	I3/CLK3	GND	4D1	4D5	4D9	GND	4D15	4A13	GND	NC	4A6	GND
2	NC	NC	NC	5A2	5A5	5A9	5A14	5A15	5D13	5D10	5D8	5D4	5D0	4D0	4D2	4D6	4D10	4D13	4A15	4A12	4A9	4A8	4A3	4A1
3	GND	GND	NC	5A1	5A4	5A7	5A8	5A10	5A13	5D14	5D9	5D5	5D1	I2/CLK2	4D4	4D7	4D11	4D14	4A14	4A10	4A7	4A5	4A2	TMS
4	NC	6A14	NC	TDO	5A0	5A3	5A6	V <sub>CC</sub>	5A11	V <sub>CC</sub>	5D12	5D7	5D2	V <sub>CC</sub>	4D3	4D8	4D12	V <sub>CC</sub>	4A11	V <sub>CC</sub>	4A4	4A0	V <sub>CC</sub>	3A15
5	GND	6A12	6A13	V <sub>CC</sub>																				
6	NC	6A9	6A10	6A15																			3A14	3A11
7	GND	6A6	6A8	6A11																			3A6	3A1
8	6A1	6A4	6A5	6A7																			3A2	3A4
9	6B1	6A0	6A2	6A3																			V <sub>CC</sub>	3B1
10	GND	6B2	6B0	V <sub>CC</sub>																			3B3	3B4
11	6B6	6B5	6B4	6B3																			3B7	3B8
12	6B10	6B9	6B8	6B7																			3B11	3B2
13	6B14	6B13	6B12	6B11																			V <sub>CC</sub>	2B15
14	GND	7B15	7B15	V <sub>CC</sub>																			2B11	2B12
15	7B14	7B13	7B12	7B11																			2B7	2B8
16	NC	7B10	7B9	7B8																			2B3	2B4
17	7B7	7B6	7B5	7B4																			V <sub>CC</sub>	2B0
18	GND	7B3	7B2	V <sub>CC</sub>																			2A3	2A2
19	7B1	7B0	7A1	7A4																			2A7	2A5
20	7A0	7A2	7A3	7A8																			2A11	2A8
21	7A5	7A6	7A7	7A12																			2A15	2A10
22	GND	7A9	7A11	7A15																			V <sub>CC</sub>	2A13
23	7A10	7A13	7A14	V <sub>CC</sub>	0A0	0A4	V <sub>CC</sub>	0A11	V <sub>CC</sub>	0D12	0D8	0D3	V <sub>CC</sub>	1D2	1D7	1D12	V <sub>CC</sub>	1A11	V <sub>CC</sub>	1A6	1A3	1A0	TCK	NC
24	NC	NC	TDI	0A2	0A5	0A7	0A10	0A14	0D14	0D11	0D7	0D4	I0/CLK0	1D1	1D5	1D9	1A13	1A10	1A8	1A7	1A4	1A1	1A1	NC
25	GND	GND	0A1	0A3	0A8	0A9	0A12	0A15	0D13	0D10	0D6	0D2	0D0	1D0	1D4	1D8	1D14	1A15	1A14	1A9	1A5	1A2	NC	NC
26	NC	NC	GND	0A6	NC	GND	0A13	0D15	GND	0D9	0D5	0D1	GND	I1/CLK1	1D3	1D6	GND	1D11	GND	1A12	NC	NC	NC	NC

#### Pin Designations

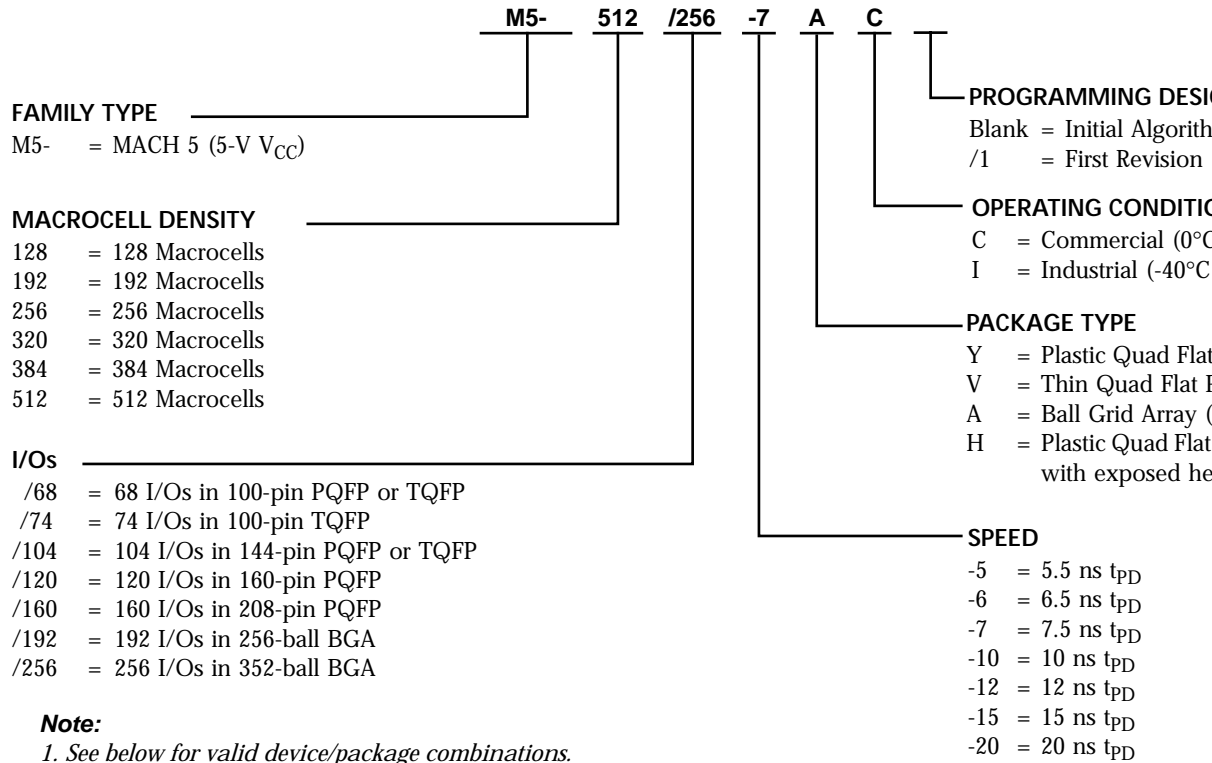
- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V<sub>CC</sub> = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



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## 5V M5 ORDERING INFORMATION<sup>1,2</sup>

Lattice standard products are available in several packages and operating ranges. The order number (Valid Combination) is defined by a combination of the elements below.



**Note:**

- See below for valid device/package combinations.
- M5-128/1, M5-192/1 and M5-256/1 recommended for new designs.

Valid Combinations		
M5-128/68	Commercial: -5, -7, -10, -12, -15 Industrial: -7, -10, -12, -15, -20	YC, VC, YI, VI
M5-128/104		YC, YI
M5-128/120		YC, YI
M5-192/68		YC*, VC, YI*, VI
M5-192/104		YC*, YI*
M5-192/120		YC, YI
M5-256/68		YC*, VC, YI*, VI
M5-256/104		YC*, YI*
M5-256/120		YC, YI
M5-256/160		YC, YI

\*Package obsolete, contact factory.

\*\* Contact Factory for availability.

**Device Marking**

Actual device marking differs from the ordering part number (OPN). All MACH devices are dual-marked with both Commercial and Industrial grades. The Industrial grade is slower, i.e., M5-512/256-7AC-10AI.

Valid Combinations		
M5-320/120	Commercial: -6, -7, -10, -12, -15 Industrial: -7, -10, -12, -15, -20	H
M5-320/160		HC, Y
M5-320/184		H
M5-320/192		A
M5-384/120		H
M5-384/160		HC, Y
M5-384/184		H
M5-384/192		A
M5-512/120		H
M5-512/160		HC, Y
M5-512/184	H	
M5-512/192	A	
M5-512/256	A	

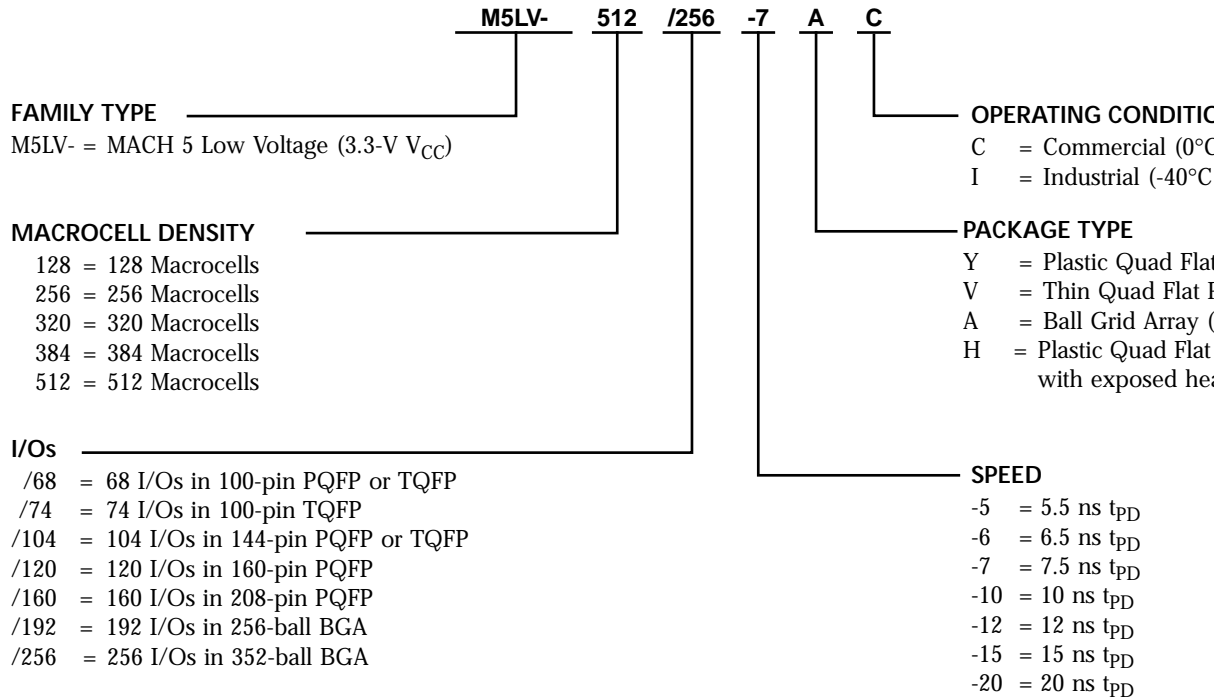
**Valid Combinations**

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



### 3.3V M5LV ORDERING INFORMATION<sup>1</sup>

Lattice standard products are available in several packages and operating ranges. The order number (Valid Combination) is defined by a combination of the elements below.



**Note:**

1. See below for valid device/package combinations.

Valid Combinations		
M5LV-128/68	Commercial: -5, -7, -10, -12  Industrial: -7, -10, -12, -15	YC*, VC, YI*, VI
M5LV-128/74		VC, VI
M5LV-128/104		YC*, VC, YI*, VI
M5LV-128/120		YC, YI
M5LV-256/68		YC, VC*, YI, VI*
M5LV-256/74		VC, VI
M5LV-256/104		YC*, VC, YI*, VI
M5LV-256/120		YC, YI
M5LV-256/160		YC, YI

\*Package obsolete, contact factory.

\*\* Contact Factory for availability.

**Device Marking**

Actual device marking differs from the ordering part number (OPN). All MACH devices are dual-marked with both Commercial and Industrial grades. The Industrial grade is slower, i.e., M5LV-512/256-7AC-10AI.

Valid Combinations		
M5LV-320/120	Commercial: -6, -7, -10, -12, -15  Industrial: -10, -12, -15, -20	HC, Y
M5LV-320/160		HC, Y
M5LV-320/184		F
M5LV-320/192		A
M5LV-384/120		HC, Y
M5LV-384/160		HC, Y
M5LV-384/184		F
M5LV-384/192		A
M5LV-512/120		HC, Y
M5LV-512/160		HC, Y
M5LV-512/184		F
M5LV-512/192		A
M5LV-512/256		

**Valid Combinations**

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



