
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 E²CMOS process provides high performance, cost effective solutions**

Table 1. MACH 5 Device Features ¹

Feature	M5-128/1 M5LV-128		M5-192/1	M5-256/1 M5LV-256		M5-320 M5LV-320		M5-384 M5LV-384		M5-512 M5LV-512	
	Supply Voltage (V)	5	3.3	5	5	3.3	5	3.3	5	3.3	5
Macrocells	128	128	192	256	256	320	320	384	384	512	512
Maximum User I/O Pins	120	120	120	160	160	192	160	160	160	256	256
t _{PD} (ns)	5.5	5.5	5.5	5.5	5.5	6.5	6.5	6.5	6.5	6.5	6.5
t _{SS} (ns)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
t _{COS} (ns)	4.5	4.5	4.5	4.5	4.5	5.0	5.0	5.0	5.0	5.0	5.0
f _{CNT} (MHz)	182	182	182	182	182	167	167	167	167	167	167
Typical Static Power (mA)	35	35	45	55	55	70	70	75	75	100	100
IEEE 1149.1 Boundary Scan Compliant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PCI-Compliant	Yes	Yes	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.

GENERAL DESCRIPTION

The MACH[®] 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 speeds 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 E²CMOS process technologies, MACH 5 devices are available with pin-to-pin delays as fast as 5.5 ns (Table 2). The 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 ¹						
	-5	-6	-7	-10	-12	-15	-20
M5-128 ²			C	C, I	C, I	C, I	I
M5-128/1	C		C, I	C, I	C, I	C, I	I
M5LV-128	C		C, I	C, I	C, I	I	
M5-192/1	C		C, I	C, I	C, I	C, I	I
M5-256 ²			C	C, I	C, I	C, I	I
M5-256/1	C		C, I	C, I	C, I	C, I	I
M5LV-256	C		C, I	C, I	C, I	I	
M5-320		C	C, I	C, I	C, I	C, I	I
M5LV-320		C	C, I	C, I	C, I	C, I	I
M5-384		C	C, I	C, I	C, I	C, I	I
M5LV-384		C	C, I	C, I	C, I	C, I	I
M5-512		C	C, I	C, I	C, I	C, I	I
M5LV-512		C	C, I	C, I	C, I	C, I	I

Note:

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

With Lattice’s unique hierarchical architecture, the MACH 5 family provides densities up to 512 macrocells to support full system logic integration. Extensive routing resources ensure pinout retention as well as high utilization. It is ideal for PAL[®] 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 ¹

	M5-128/1 M5LV-128		M5-192/1	M5-256/1 M5LV-256		M5-320 M5LV-320		M5-384 M5LV-384		M5-512 M5LV-512	
	5	3.3	5	5	3.3	5	3.3	5	3.3	5	3.3
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*	120
208-pin PQFP				160	160	160	160	160	160	160	160
240-pin PQFP						184*	184*	184*	184*	184*	184*
256-ball BGA						192	192*	192*	192*	192*	192*
352-ball BGA										256	256

Note:

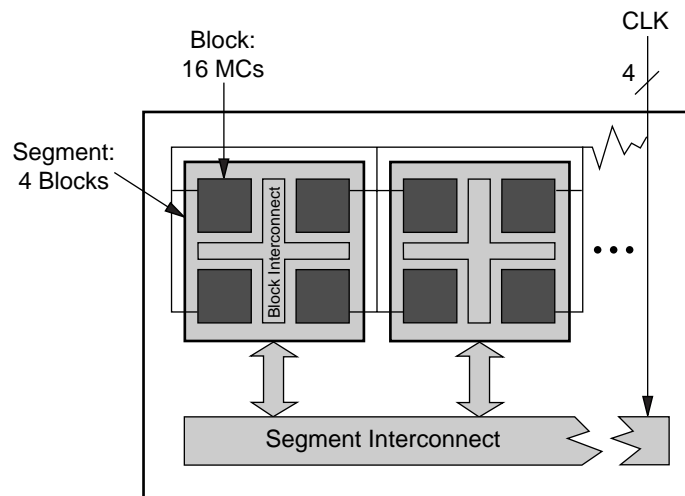
1. The I/O options indicated with a "*" are obsolete, please contact factory for more information.

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 the 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 clock pins available which can also be used as logic inputs.



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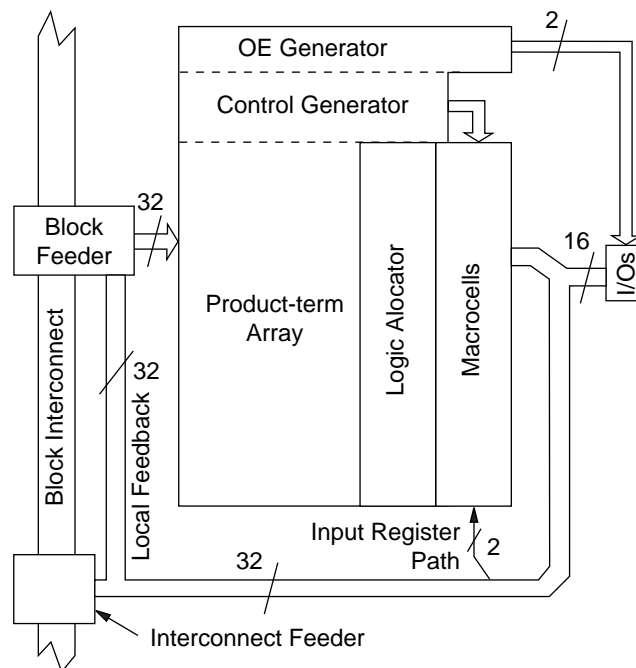
Figure 1. MACH 5 Block Diagram

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 **local 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** assigns block interconnect lines and local feedback lines to the PAL block inputs.



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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 consists of 32 inputs (plus their complements) and 64 product terms arranged in 16 **clusters**. A cluster is a sum-of-products function with either 3 or 4 product terms.

Logic allocators assign the clusters to macrocells. Each macrocell can accept up to eight clusters of three or four product terms, but a given cluster can only be steered to one macrocell (Table 4). If only three product terms in a cluster are steered, the fourth can be used as an input to an XOR 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 an output switch matrix by reassigning logic to macrocells to retain pinout as designs change. The logic allocation scheme in the MACH 5 device allows for the implementation of large equations (up to 32 product terms) with only one pass through the logic array.

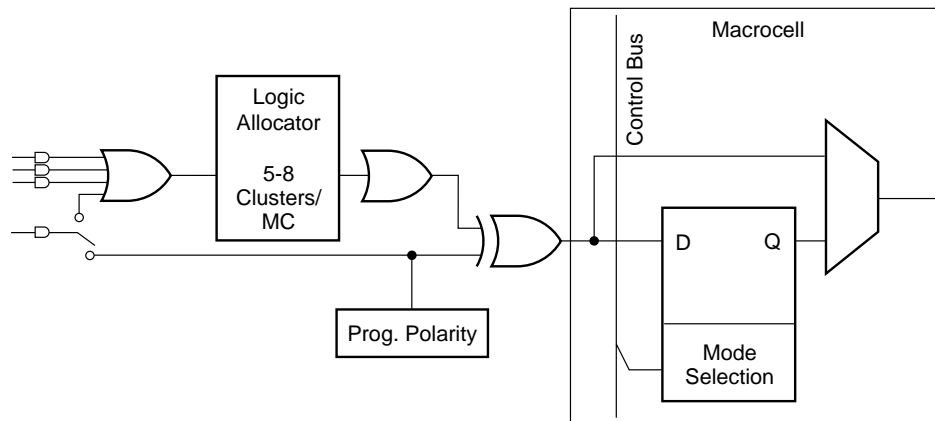
Table 4. Product Term Steering Options for PT Clusters and Macrocells

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

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 as 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.



20446G-003

Figure 3. Macrocell Diagram

Control Generator

The control generator provides four configurable clock lines and three configurable set/reset lines to 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 useful 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

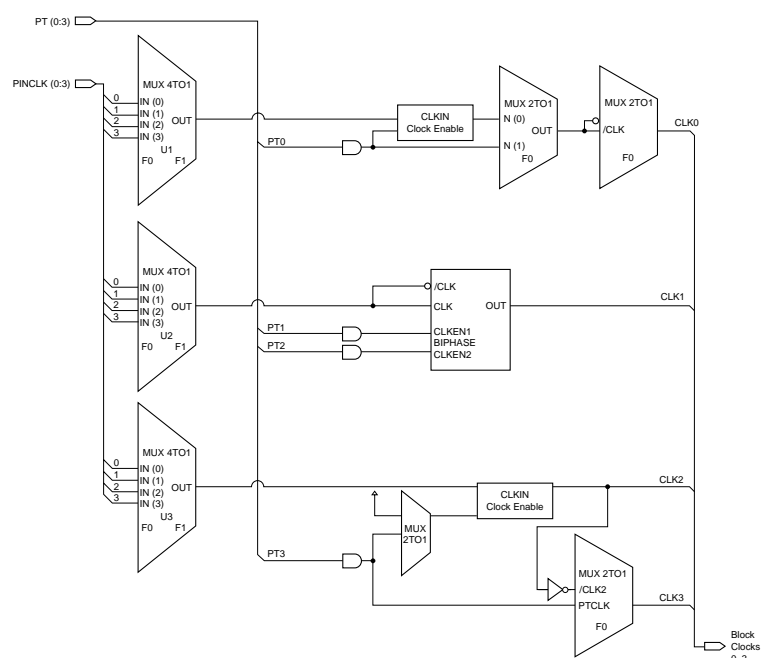
- ◆ Global clock (0, 1, 2, or 3) with positive edge clock enable
- ◆ Global clock (0, 1, 2, or 3) with negative edge clock enable
- ◆ Global clock (0, 1, 2, or 3) with positive and negative edge clock enable (biphase)

Clock Line 2 Options

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

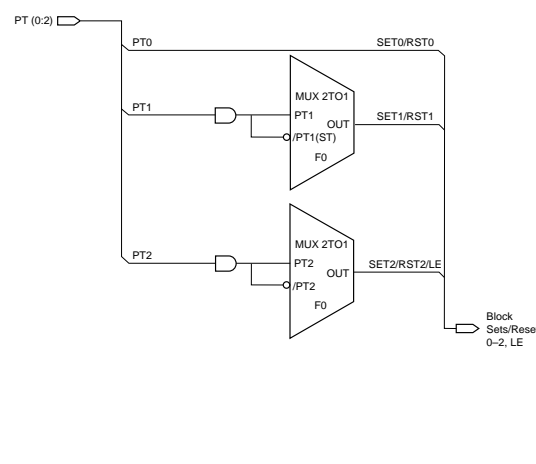
Clock Line 3 Options

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



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Figure 4. Clock Generator



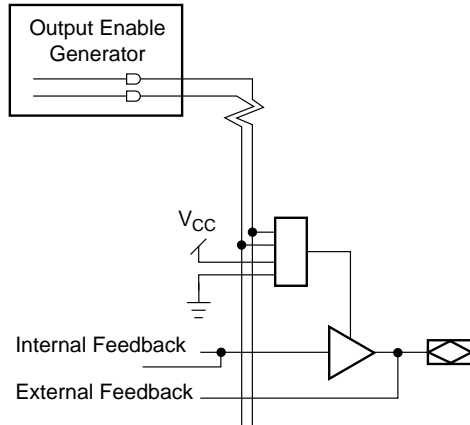
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Figure 5. Set/Reset Generator

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 at all. 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 or sum-term latch enable. While the set/reset signals are generated in the control generator, whether that 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 driven 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).



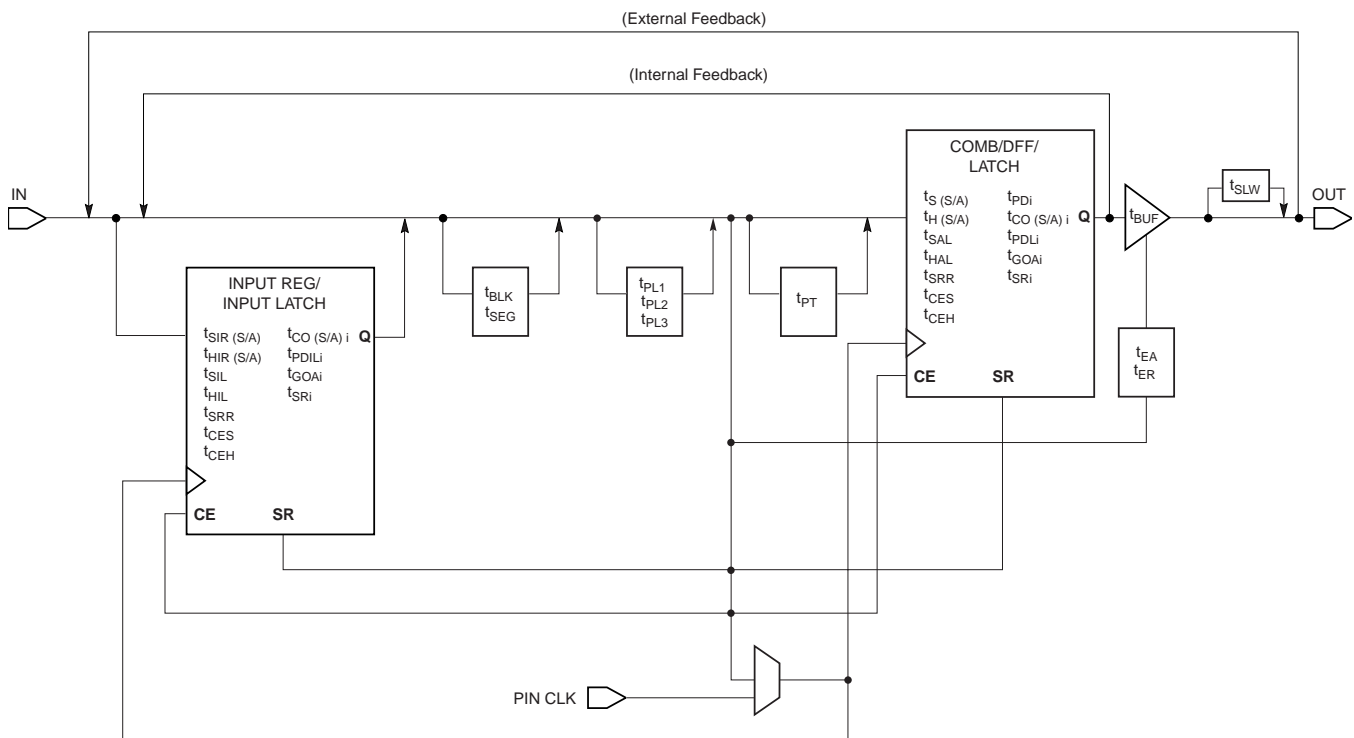
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Figure 6. Output Enable Generator and I/O Cell

MACH 5 TIMING MODEL

The primary focus of the MACH 5 timing model is to accurately represent the timing in a MACH 5 device, and at the same time, be easy to understand. This model accurately describes all 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 having gone 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 designator is followed by an "i". By adding t_{BUF} to this internal parameter, the external parameter is derived. 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 Design* for a more detailed discussion about the timing parameters.



20446G-014

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 designers to choose a device close to their logic density and I/O requirements, thus minimizing costs. For the same package type, every density has the same pin-out. With proper design considerations, a 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 serial 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 serial 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 get the benefit of a standard, well-defined interface.

MACH 5 devices can be programmed across the commercial temperature and voltage range. The 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 formats 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 condition 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 PCI designs.

SAFE FOR MIXED SUPPLY VOLTAGE SYSTEM DESIGNS ¹

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 they accept inputs from other 3.3-V devices. The 3.3-V devices will accept inputs up to 5.5 V. Both the 3.3-V and 5-V versions have the same high-speed performance and provide easy-to-use mixed-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 noise can cause high-frequency switching. At power-up, the Bus-Friendly latches are reset to a logic level "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 bit. Each output can be individually configured for the higher speed transition (3 V/ns) or for the lower noise transition (1 V/ns). For high-speed designs with long, unterminated traces, the slow-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 highest speed. The slew rate is adjusted independent of power.

POWER-UP RESET/SET

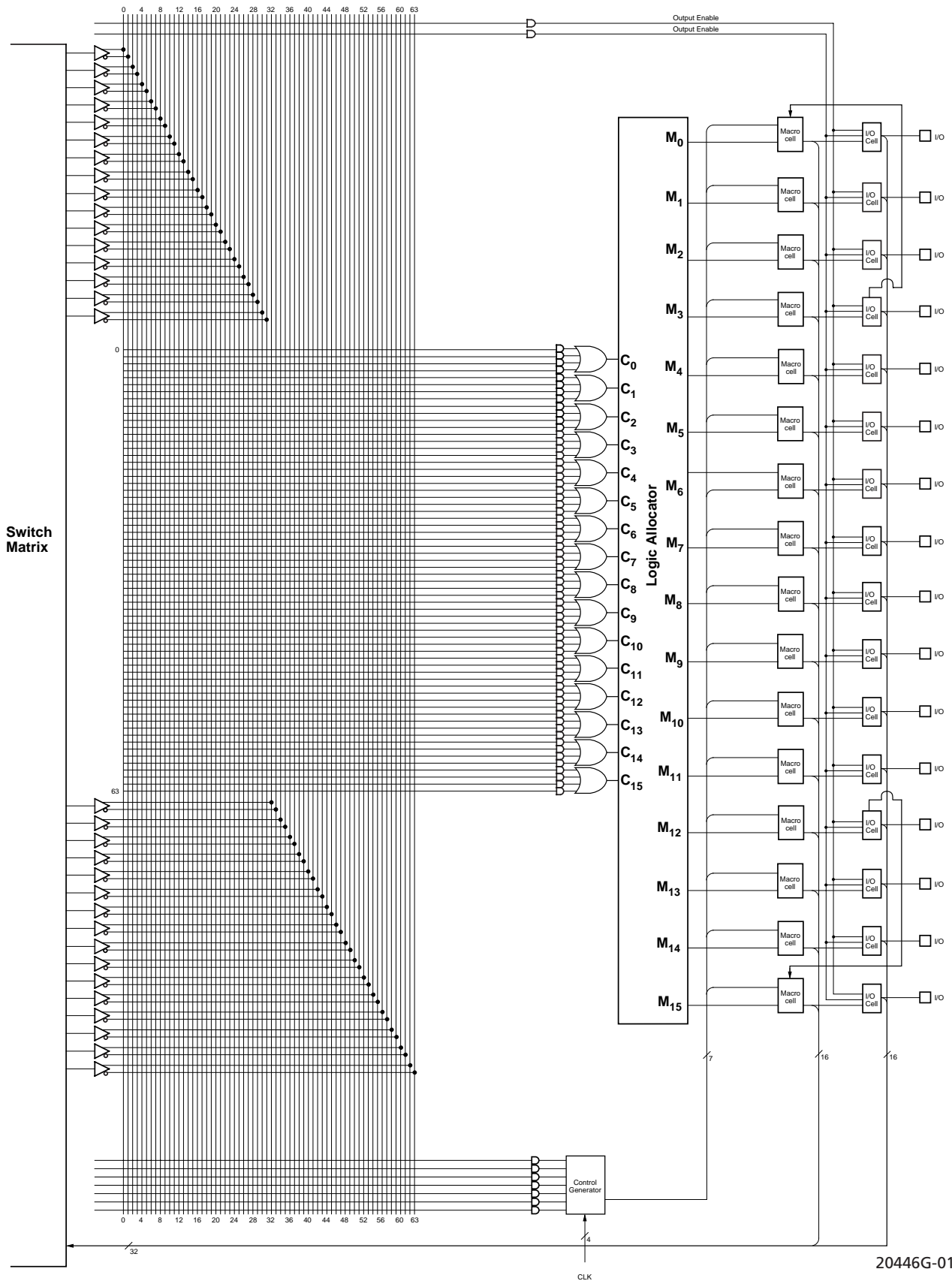
All flip-flops power up to a known state for predictable system initialization. If a macrocell is configured to SET on a signal from the control generator, then that macrocell will be SET during device power-up. If a macrocell is configured to RESET on a signal from the control generator or is not configured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

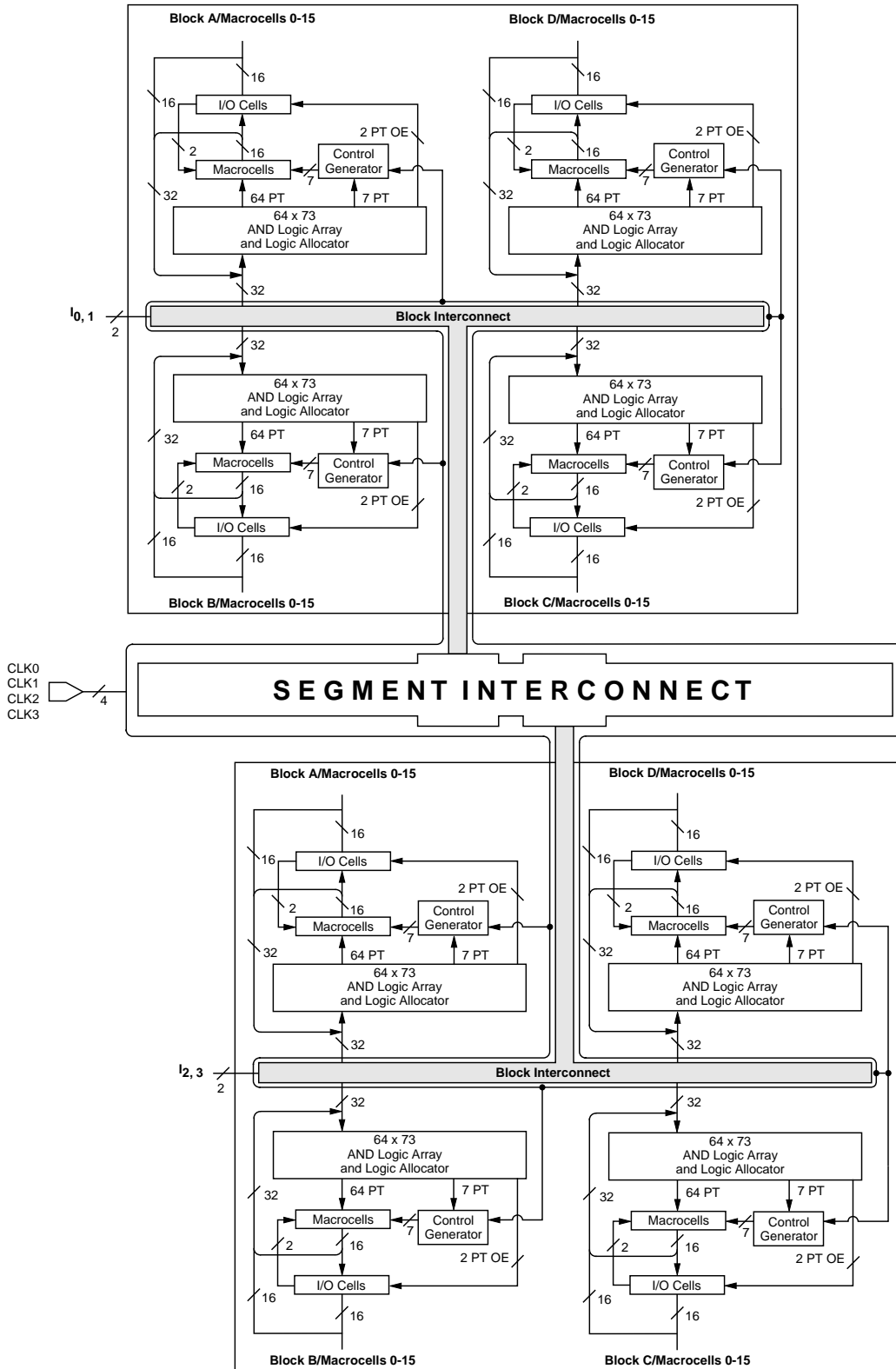
MACH 5 PAL BLOCK



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BLOCK DIAGRAM — M5(LV)-128/XXX

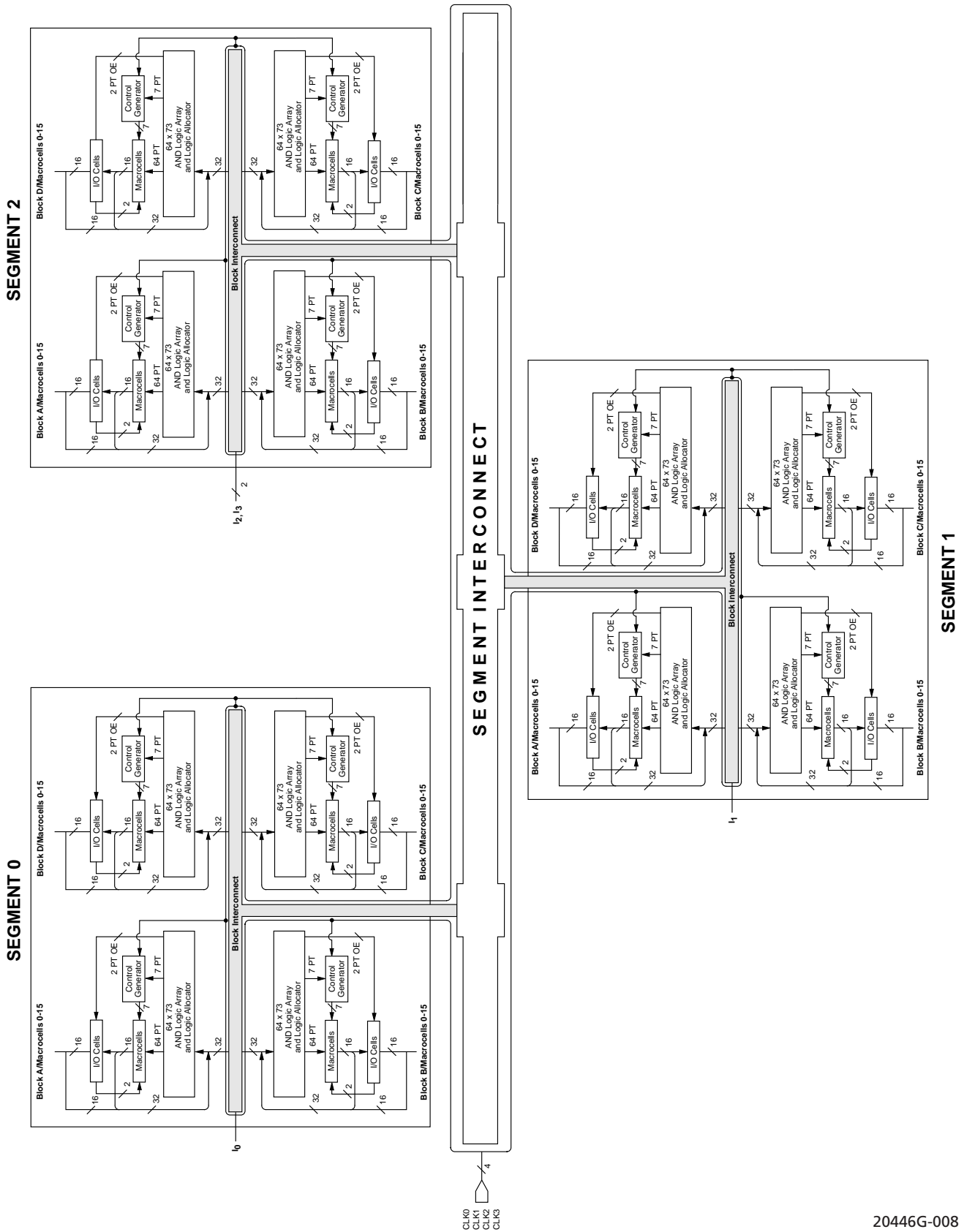
SEGMENT 0



SEGMENT 1

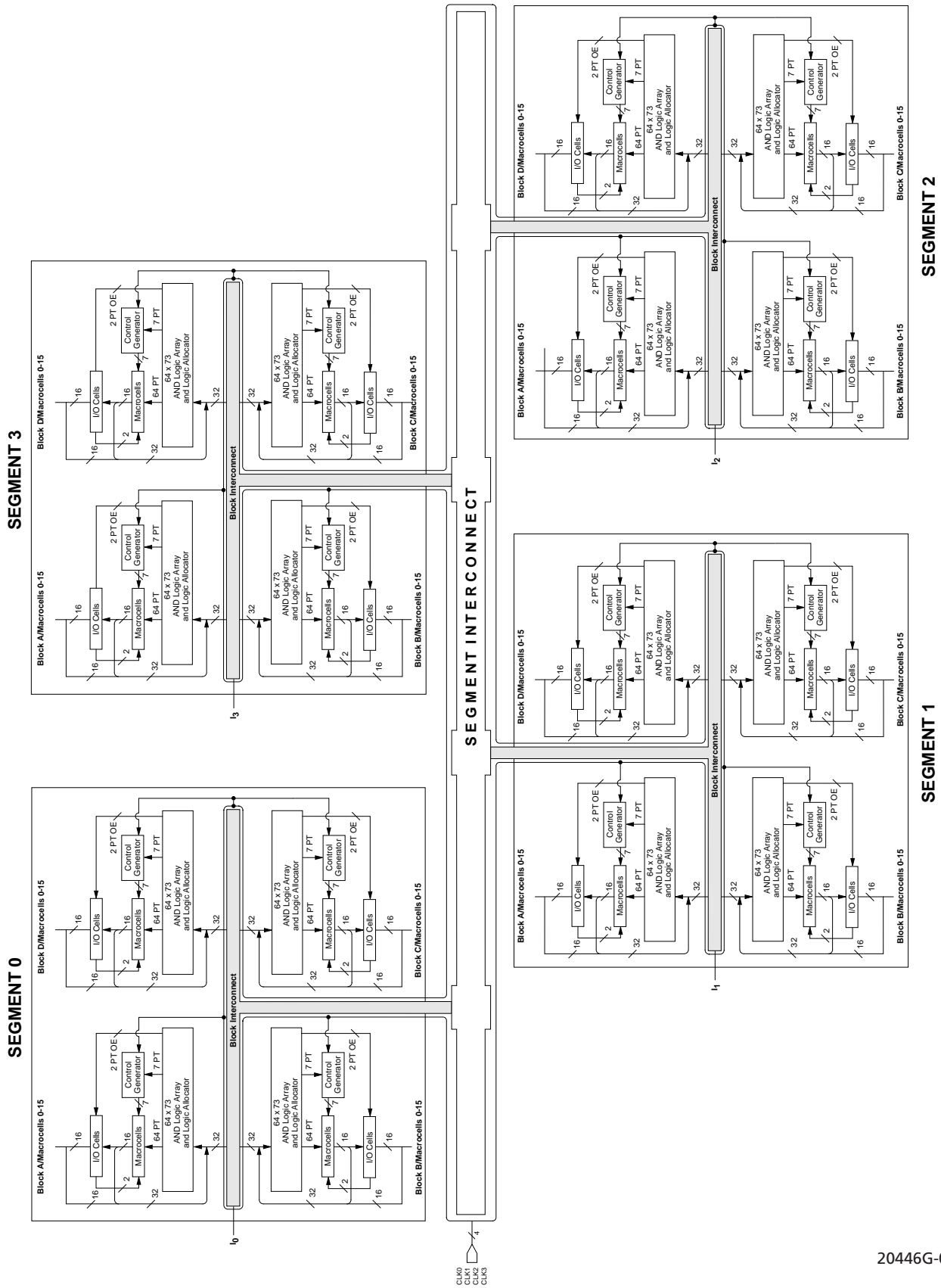
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BLOCK DIAGRAM — M5-192/XXX



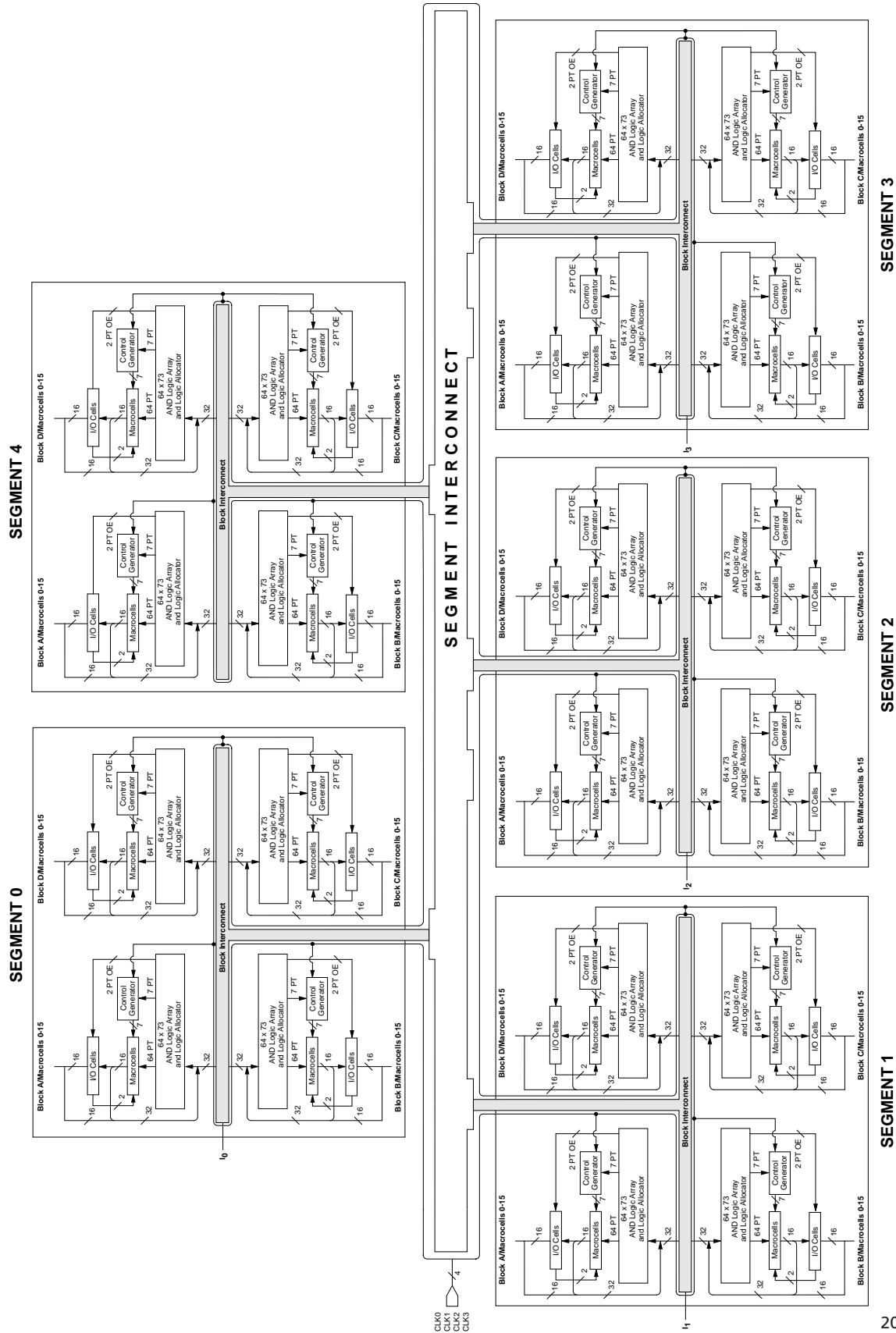
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BLOCK DIAGRAM — M5(LV)-256/XXX



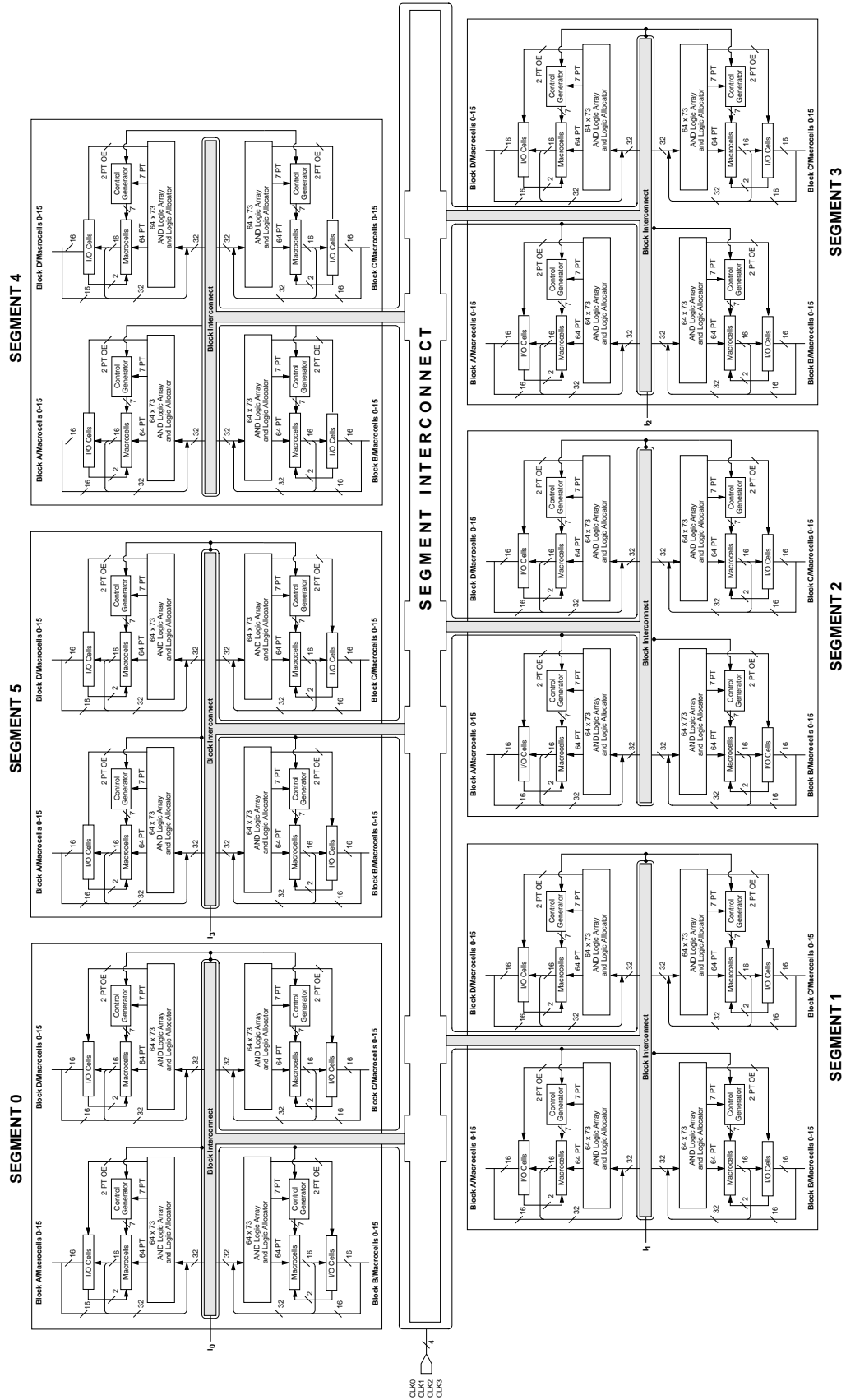
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BLOCK DIAGRAM — M5(LV)-320/XXX



20446G-010

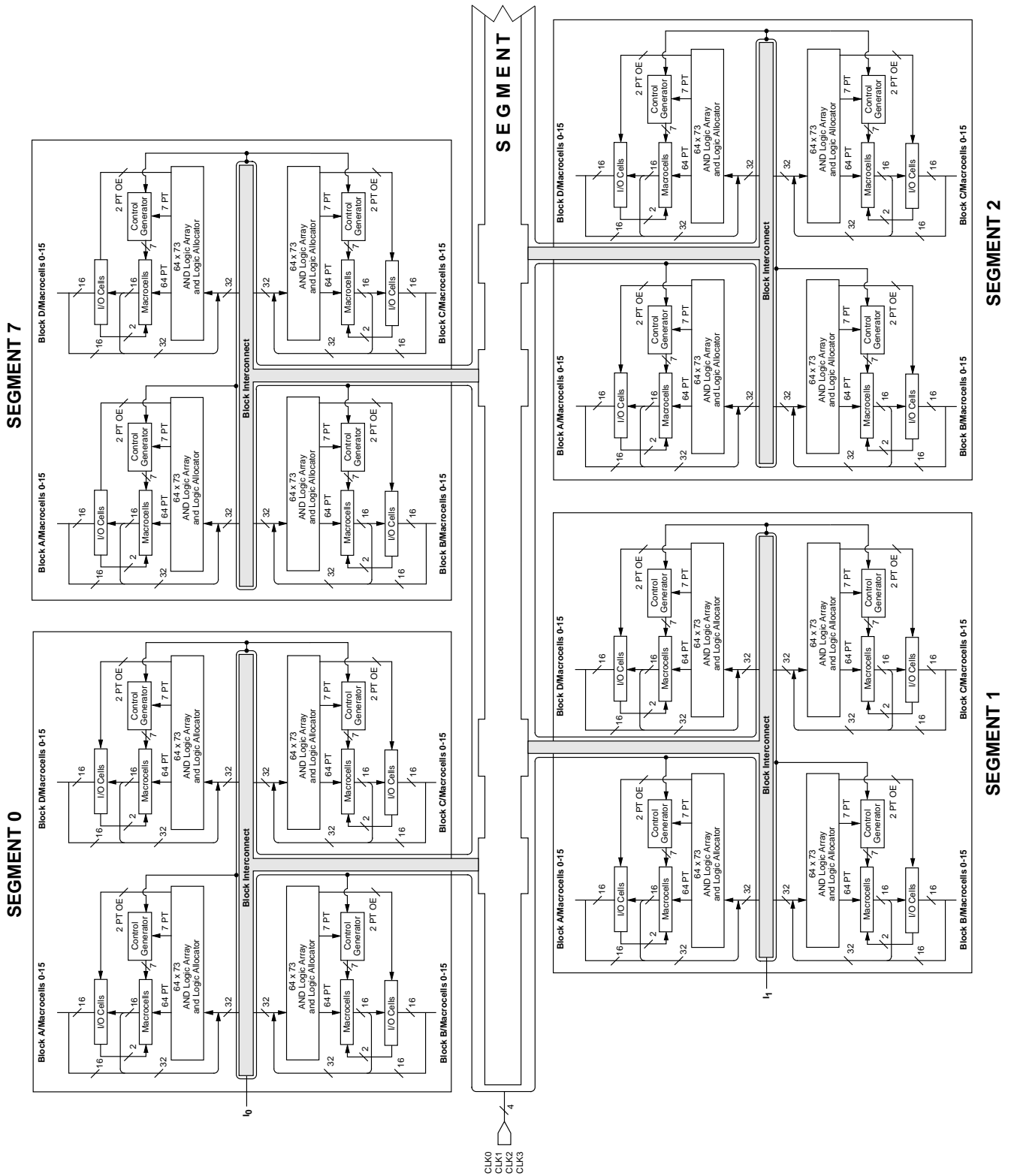
BLOCK DIAGRAM — M5(LV)-384/XXX



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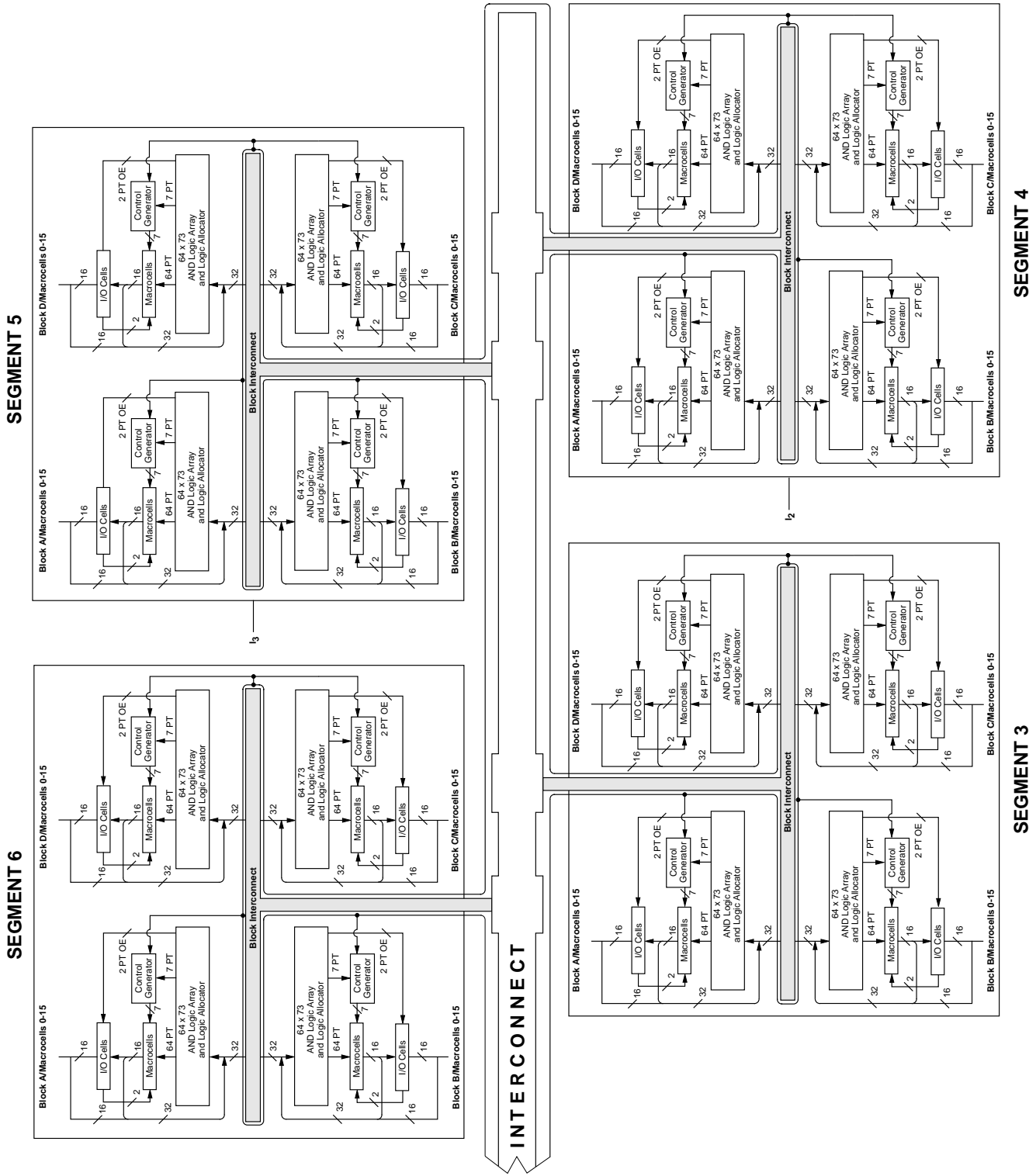
BLOCK DIAGRAM — M5(LV)-512/XXX

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BLOCK DIAGRAM — M5(LV)-512/XXX



Continued

20446G-013

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

Industrial (I) Devices

Ambient Temperature (T_A)	Operating in Free Air	-40°C to +85°C
Supply Voltage (V_{CC}) with Respect to Ground		+4.5 V to +5.5 V

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

5-V DC CHARACTERISTICS OVER OPERATING RANGES

Parameter Symbol	Parameter Description	Test Description	Min	Typ	Max	Unit
V_{OH}	Output HIGH Voltage (For M5-128/1, M5-192/1, M5-256/1, M5-320, M5-384, M5-512 Devices)	$I_{OH} = -3.2$ mA, $V_{CC} = \text{Min}$, $V_{IN} = V_{IH}$ or V_{IL}	2.4			V
		$I_{OH} = -100$ μ A, $V_{CC} = \text{Max}$, $V_{IN} = V_{IH}$ or V_{IL}		3.3	3.6	V
	Output HIGH Voltage (For M5-128, M5-192, M5-256 Devices)	$I_{OH} = -3.2$ mA, $V_{CC} = \text{Min}$, $V_{IN} = V_{IH}$ or V_{IL}	2.4			V
		$I_{OH} = -2.5$ mA, $V_{CC} = 5.25$ V, $V_{IN} = V_{IH}$ or V_{IL}			3.6	V
V_{OL}	Output LOW Voltage (Note 2)	$I_{OL} = +16$ mA, $V_{CC} = \text{Min}$, $V_{IN} = V_{IH}$ or V_{IL}			0.5	V
V_{IH}	Input HIGH Voltage	Guaranteed Input Logical HIGH Voltage for all Inputs (Note 3)	2.0			V
V_{IL}	Input LOW Voltage	Guaranteed Input Logical LOW Voltage for all Inputs (Note 3)			0.8	V
I_{IH}	Input HIGH Leakage Current	$V_{IN} = 5.25$, $V_{CC} = \text{Max}$ (Note 4)			10	μ A
I_{IL}	Input LOW Leakage Current	$V_{IN} = 0$, $V_{CC} = \text{Max}$ (Note 4)			-10	μ A
I_{OZH}	Off-State Output Leakage Current HIGH	$V_{OUT} = 5.25$, $V_{CC} = \text{Max}$, $V_{IN} = V_{IH}$ or V_{IL} (Note 4)			10	μ A
I_{OZL}	Off-State Output Leakage Current LOW	$V_{OUT} = 0$, $V_{CC} = \text{Max}$, $V_{IN} = V_{IH}$ or V_{IL} (Note 4)			-10	μ A
I_{SC}	Output Short-Circuit Current	$V_{OUT} = 0.5 V_{CC} = \text{Max}$, $V_{IN} = V_{IH}$ or V_{IL} (Note 5)	-30		-180	mA

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_{OL} 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_{IL} and I_{OZL} or I_{IH} and I_{OZH} .
- 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_A)	
Operating in Free Air	0°C to +70°C
Supply Voltage (V_{CC}) with Respect to Ground	+3.0 V to +3.6 V

Industrial (I) Devices

Ambient Temperature (T_A)	
Operating in Free Air	-40°C to +85°C
Supply Voltage (V_{CC}) with Respect to Ground	+3.0 V to +3.6 V

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

3.3-V DC CHARACTERISTICS OVER OPERATING RANGES

Parameter Symbol	Parameter Description	Test Description	Min	Max	Unit
V_{OH}	Output HIGH Voltage	$V_{CC} = \text{Min}$ $V_{IN} = V_{IH} \text{ or } V_{IL}$	$I_{OH} = -100 \mu\text{A}$	$V_{CC} - 0.2$	V
			$I_{OH} = 3.2 \text{ mA}$	2.4	V
V_{OL}	Output LOW Voltage	$V_{CC} = \text{Min}$ $V_{IN} = V_{IH} \text{ or } V_{IL}$	$I_{OL} = 100 \mu\text{A}$	0.2	V
			$I_{OL} = 16 \text{ mA (Note 1)}$	0.5	V
V_{IH}	Input HIGH Voltage	$V_{OUT} \geq V_{OH} \text{ Min or } V_{OUT} \leq V_{OL} \text{ Max (Note 2)}$	2.0	5.5	V
V_{IL}	Input LOW Voltage	$V_{OUT} \geq V_{OH} \text{ Min or } V_{OUT} \leq V_{OL} \text{ Max (Note 2)}$	-0.3	0.8	V
I_{IH}	Input HIGH Leakage Current	$V_{IN} = 3.6, V_{CC} = \text{Max (Note 3)}$		10	μA
I_{IL}	Input LOW Leakage Current	$V_{IN} = 0, V_{CC} = \text{Max (Note 3)}$		-10	μA
I_{OZH}	Off-State Output Leakage Current HIGH	$V_{OUT} = 3.6, V_{CC} = \text{Max}, V_{IN} = V_{IH} \text{ or } V_{IL} \text{ (Note 3)}$		10	μA
I_{OZL}	Off-State Output Leakage Current LOW	$V_{OUT} = 0, V_{CC} = \text{Max}, V_{IN} = V_{IH} \text{ or } V_{IL} \text{ (Note 3)}$		-10	μA
I_{SC}	Output Short-Circuit Current	$V_{OUT} = 0.5 V_{CC} = \text{Max}, V_{IN} = V_{IH} \text{ or } V_{IL} \text{ (Note 4)}$	-15	-160	mA

Notes:

1. Total I_{OL} 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_{IL} and I_{OZL} or I_{IH} and I_{OZH} .
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 RANGES¹

		-5		-6		-7		-10		-12		-15		-20		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Combinatorial Delay:																
t_{PDi}	Internal combinatorial propagation delay		3.5		4.5		5.5		8.0		10.0		13.0		18.0	ns
t_{PD}	Combinatorial propagation delay		5.5		6.5		7.5		10.0		12.0		15.0		20.0	ns
Registered Delays:																
t_{SS}	Synchronous clock setup time	3.0		3.0		4.0		5.0		6.0		8.0		10.0		ns
t_{SA}	Asynchronous clock setup time	3.0		3.0		4.0		5.0		6.0		7.0		8.0		ns
t_{HS}	Synchronous clock hold time	0.0		0.0		0.0		0.0		0.0		0.0		0.0		ns
t_{HA}	Asynchronous clock hold time	3.0		3.0		4.0		5.0		6.0		7.0		8.0		ns
t_{COSi}	Synchronous clock to internal output		2.5		3.0		4.0		5.0		6.0		8.0		10.0	ns
t_{COS}	Synchronous clock to output		4.5		5.0		6.0		7.0		8.0		10.0		12.0	ns
t_{COAi}	Asynchronous clock to internal output		6.0		6.0		8.0		10.0		13.0		15.0		18.0	ns
t_{COA}	Asynchronous clock to output		8.0		8.0		10.0		12.0		15.0		17.0		20.0	ns
Latched Delays:																
t_{SAL}	Latch setup time	3.0		4.0		4.0		5.0		6.0		7.0		8.0		ns
t_{HAL}	Latch hold time	3.0		3.0		4.0		5.0		6.0		7.0		8.0		ns
t_{PDLi}	Transparent latch internal		6.0		7.0		7.0		8.0		9.0		10.0		10.0	ns
t_{PDL}	Propagation delay through transparent latch		8.0		9.0		9.0		10.0		11.0		12.0		12.0	ns
t_{GOAi}	Gate to internal output		7.0		8.0		8.0		9.0		10.0		11.0		12.0	ns
t_{GOA}	Gate to output		9.0		10.0		10.0		11.0		12.0		13.0		14.0	ns
Input Register Delays:																
t_{SIRS}	Input register setup time using a synchronous clock	2.0		2.0		2.0		3.0		3.0		3.0		3.0		ns
t_{SIRA}	Input register setup time using an asynchronous clock	0.0		0.0		0.0		0.0		0.0		0.0		0.0		ns
t_{HIRS}	Input register hold time using a synchronous clock	3.0		3.0		3.0		4.0		4.0		4.0		4.0		ns
t_{HIRA}	Input register hold time using an asynchronous clock	6.0		6.0		6.0		7.0		7.0		7.0		7.0		ns
Input Latch Delays:																
t_{SIL}	Input latch setup time	2.0		2.0		2.0		3.0		3.0		3.0		3.0		ns
t_{HIL}	Input latch hold time	6.0		6.0		6.0		7.0		7.0		7.0		7.0		ns
t_{PDILi}	Transparent input latch		5.0		5.0		5.5		6.0		6.0		6.0		6.0	ns
Output Delays:																
t_{BUF}	Output buffer delay		2.0		2.0		2.0		2.0		2.0		2.0		2.0	ns
t_{SLW}	Slow slew rate delay		2.5		2.5		2.5		2.5		2.5		2.5		2.5	ns
t_{EA}	Output enable time		7.5		7.5		9.5		10.0		12.0		15.0		20.0	ns
t_{ER}	Output disable time		7.5		7.5		9.5		10.0		12.0		15.0		20.0	ns

M5(LV) TIMING PARAMETERS OVER OPERATING RANGES¹ (CONTINUED)

		-5		-6		-7		-10		-12		-15		-20		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Power Delays:																
t_{PL1}	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)		4.0 (5.0)	ns
t_{PL2}	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)		6.0 (9.0)	ns
t_{PL3}	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)		9.0 (17.5)	ns
Additional Cluster Delay:																
t_{PT}	Product term cluster delay		0.3		0.3		0.3		0.3		0.3		0.3		0.3	ns
Interconnect Delays:																
t_{BLK}	Block interconnect delay		1.5		1.5		1.5		2.0		2.0		2.0		2.0	ns
t_{SEG}	Segment interconnect delay		4.5		4.5		5.0		6.0		6.0		6.0		6.0	ns
Reset and Preset Delays:																
t_{SRI}	Asynchronous reset or preset to internal register output		6.0		8.0		8.0		10.0		12.0		14.0		16.0	ns
t_{SR}	Asynchronous reset or preset to register output		8.0		10.0		10.0		12.0		14.0		16.0		18.0	ns
t_{SRR}	Reset and set register recovery time	5.5		7.5		7.5		8.0		9.0		10.0		11.0		ns
t_{SRW}	Asynchronous reset or preset width	3.0		4.0		4.0		5.0		6.0		7.0		8.0		ns
Clock Enable Delays:																
t_{CES}	Clock enable setup time	4.0		5.0		5.0		6.0		7.0		7.0		8.0		ns
t_{CEH}	Clock enable hold time	3.0		4.0		4.0		5.0		6.0		6.0		7.0		ns
Width:																
t_{WLS}	Global clock width low (Note 3)	2.5		3.0		3.0		4.0		5.0		6.0		6.0		ns
t_{WHS}	Global clock width high (Note 3)	2.5		3.0		3.0		4.0		5.0		6.0		6.0		ns
t_{WLA}	Product term clock width low	3.0		4.0		4.0		5.0		6.0		7.0		8.0		ns
t_{WHA}	Product term clock width high	3.0		4.0		4.0		5.0		6.0		7.0		8.0		ns
t_{GWA}	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		ns
t_{WIR}	Input register clock width low or high	3.0		4.0		4.0		5.0		6.0		7.0		8.0		ns

M5(LV) TIMING PARAMETERS OVER OPERATING RANGES¹ (CONTINUED)

		-5		-6		-7		-10		-12		-15		-20		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Frequency:																
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		MHz
	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		MHz
	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		MHz
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		MHz
	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		38.5		MHz
	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		MHz
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		MHz

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 ($f_{MAX}/2$).

CAPACITANCE¹

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

1. These parameters are not 100% tested, but are calculated at initial characterization and at any time the design is modified where 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-type 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 high power. The lowest frequency signals (MSBs) are placed in a common PAL block and set to lowest power. For a more detailed discussion about MACH 5 power consumption, refer to the application note entitled *MACH 5 Power* in the Application Notes section on the Lattice Data Book CD-ROM or Lattice web site.

I_{CC} CURVES AT HIGH /LOW POWER MODES

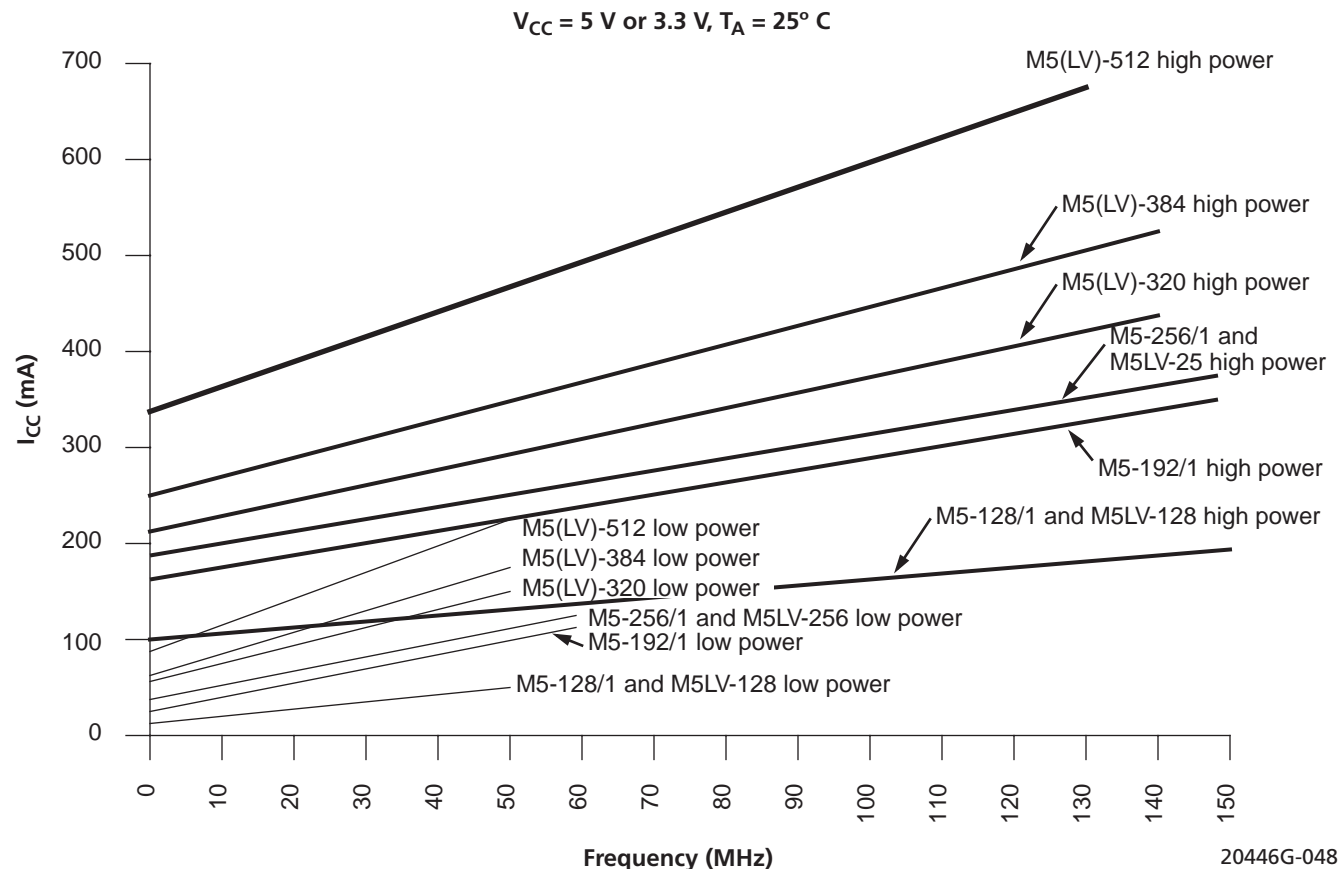


Figure 8. I_{CC} Curves at High/Low Power Modes

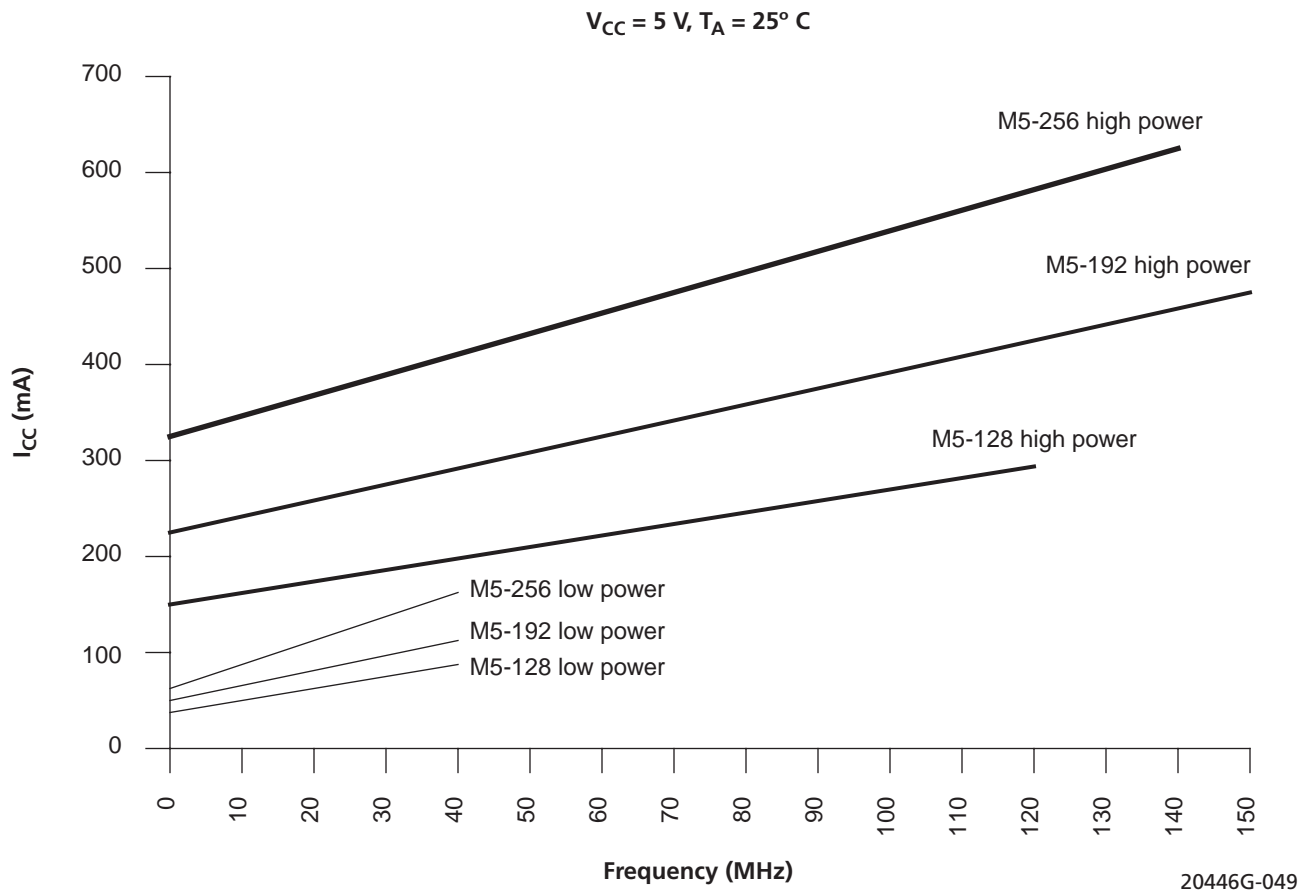
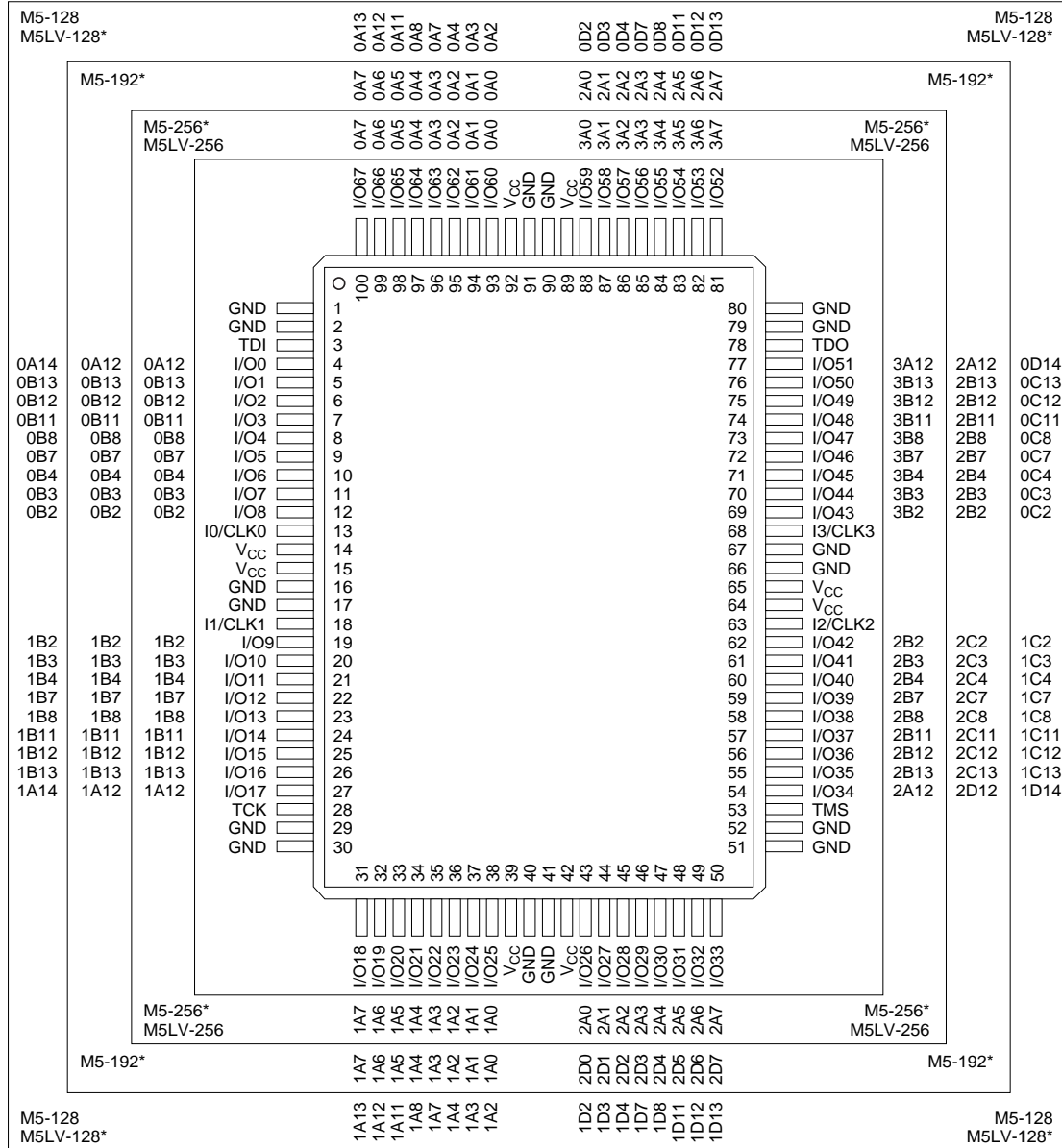


Figure 9. I_{CC} Curves at High/Low Power Modes

100-PIN PQFP CONNECTION DIAGRAM

Top View

100-Pin PQFP (68 I/O)



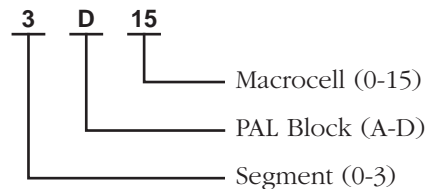
*Package obsolete, contact factory.

20446G-016

Pin Designations

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

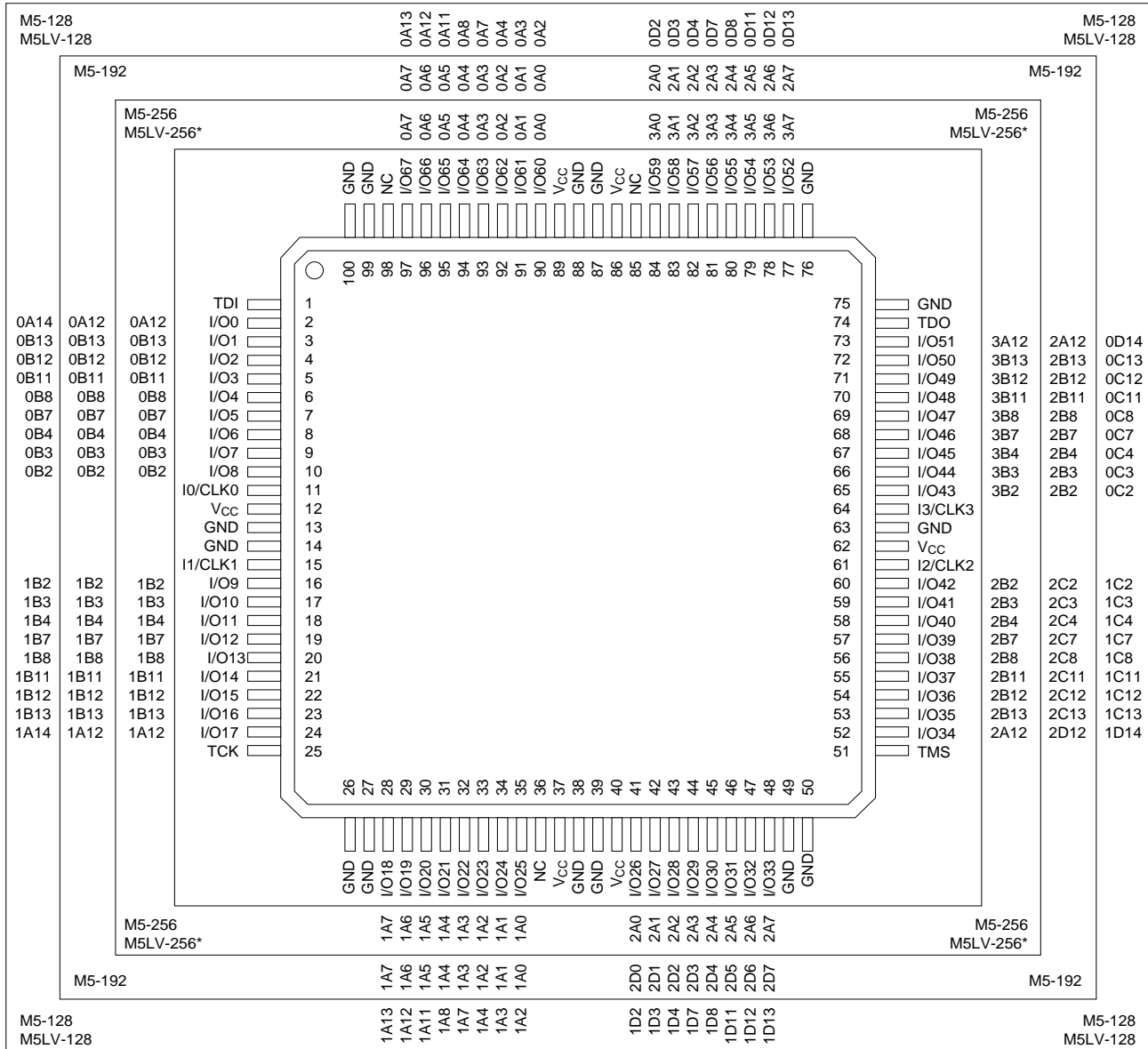
V_{CC} = Supply Voltage
TDI = Test Data In
TCK = Test Clock
TMS = Test Mode Select
TDO = Test Data Out



100-PIN TQFP CONNECTION DIAGRAM – 68 I/O

Top View

100-Pin TQFP (68 I/O)

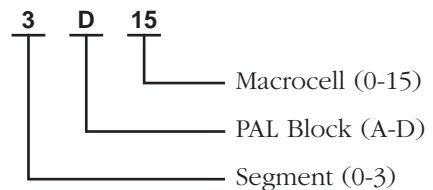


*Package obsolete, contact factory.

20446G-017

Pin Designations

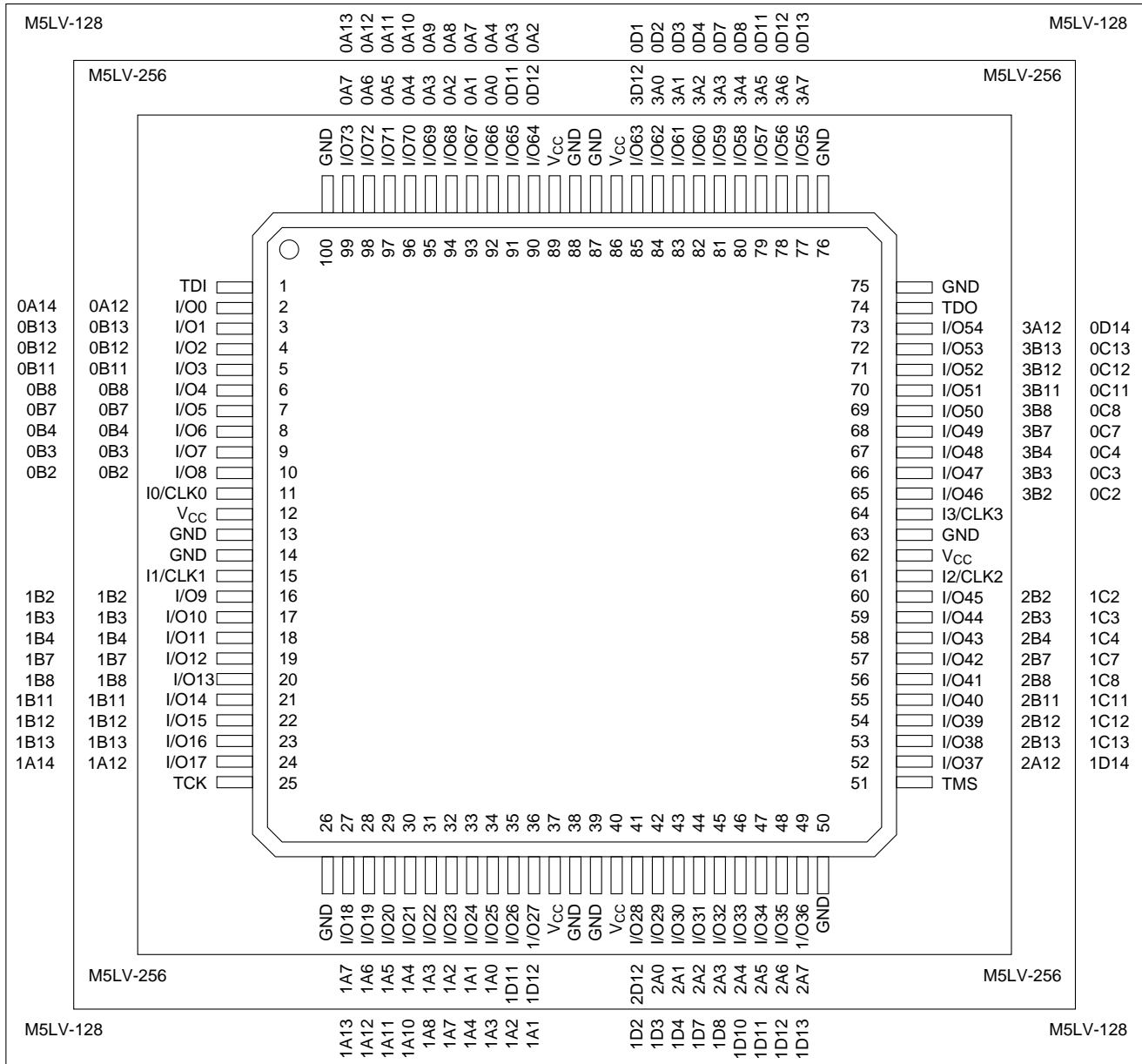
- | | |
|--------------------|----------------------------------|
| CLK = Clock | V _{CC} = Supply Voltage |
| GND = Ground | TDI = Test Data In |
| I = Input | TCK = Test Clock |
| I/O = Input/Output | TMS = Test Mode Select |
| NC = No Connect | TDO = Test Data Out |



100-PIN TQFP CONNECTION DIAGRAM – 74 I/O

Top View

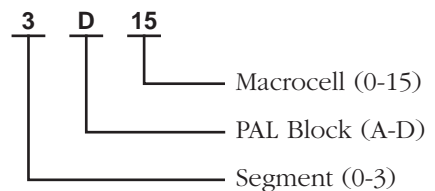
100-Pin TQFP (74 I/O)



20446G-018

Pin Designations

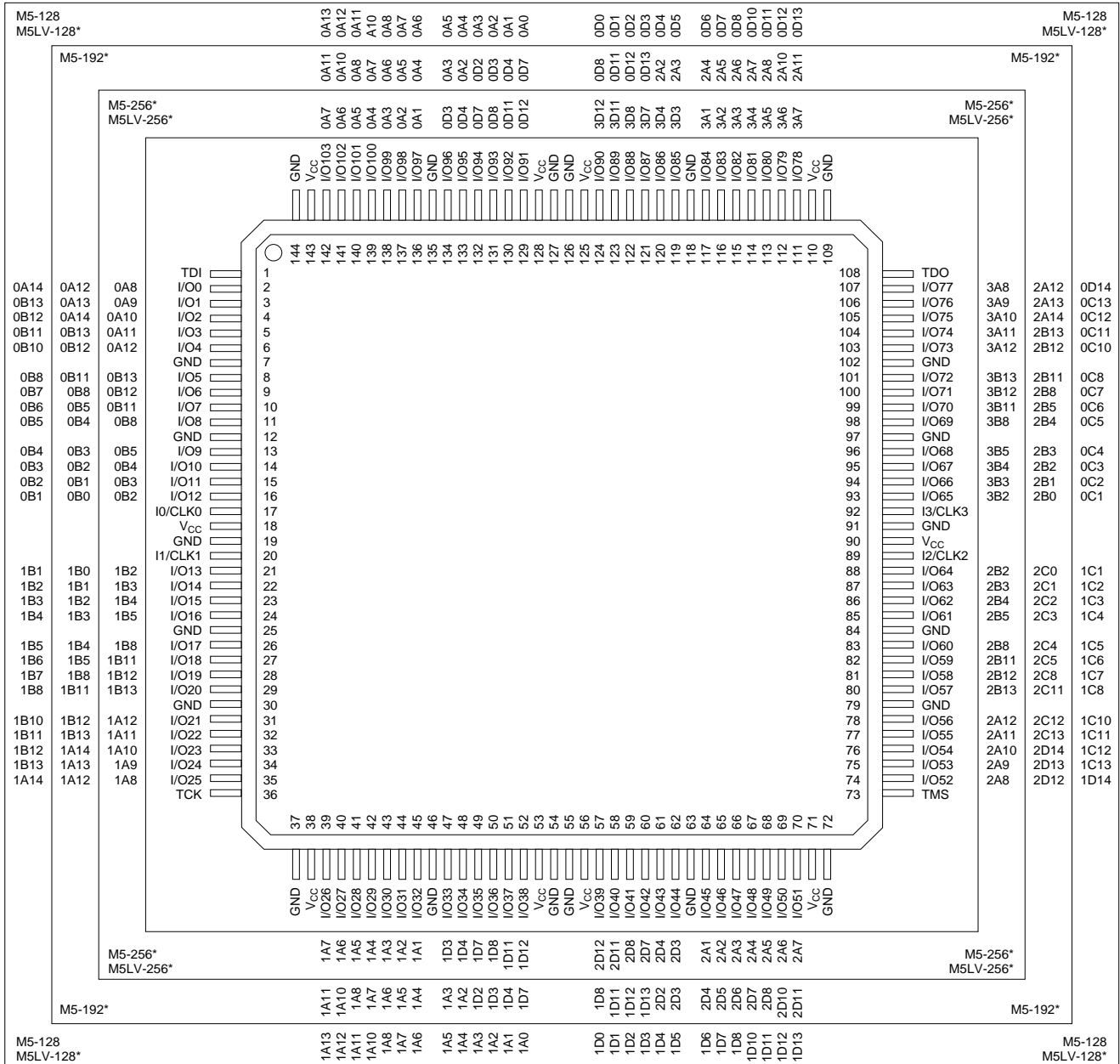
- | | |
|--------------------|----------------------------------|
| CLK = Clock | V _{CC} = Supply Voltage |
| GND = Ground | TDI = Test Data In |
| I = Input | TCK = Test Clock |
| I/O = Input/Output | TMS = Test Mode Select |
| NC = No Connect | TDO = Test Data Out |



144-PIN PQFP CONNECTION DIAGRAM

Top View

144-Pin PQFP

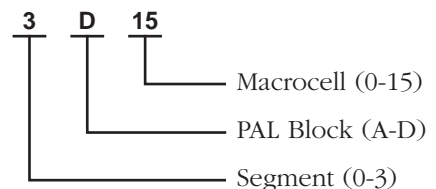


*Package obsolete, contact factory.

20446G-019

Pin Designations

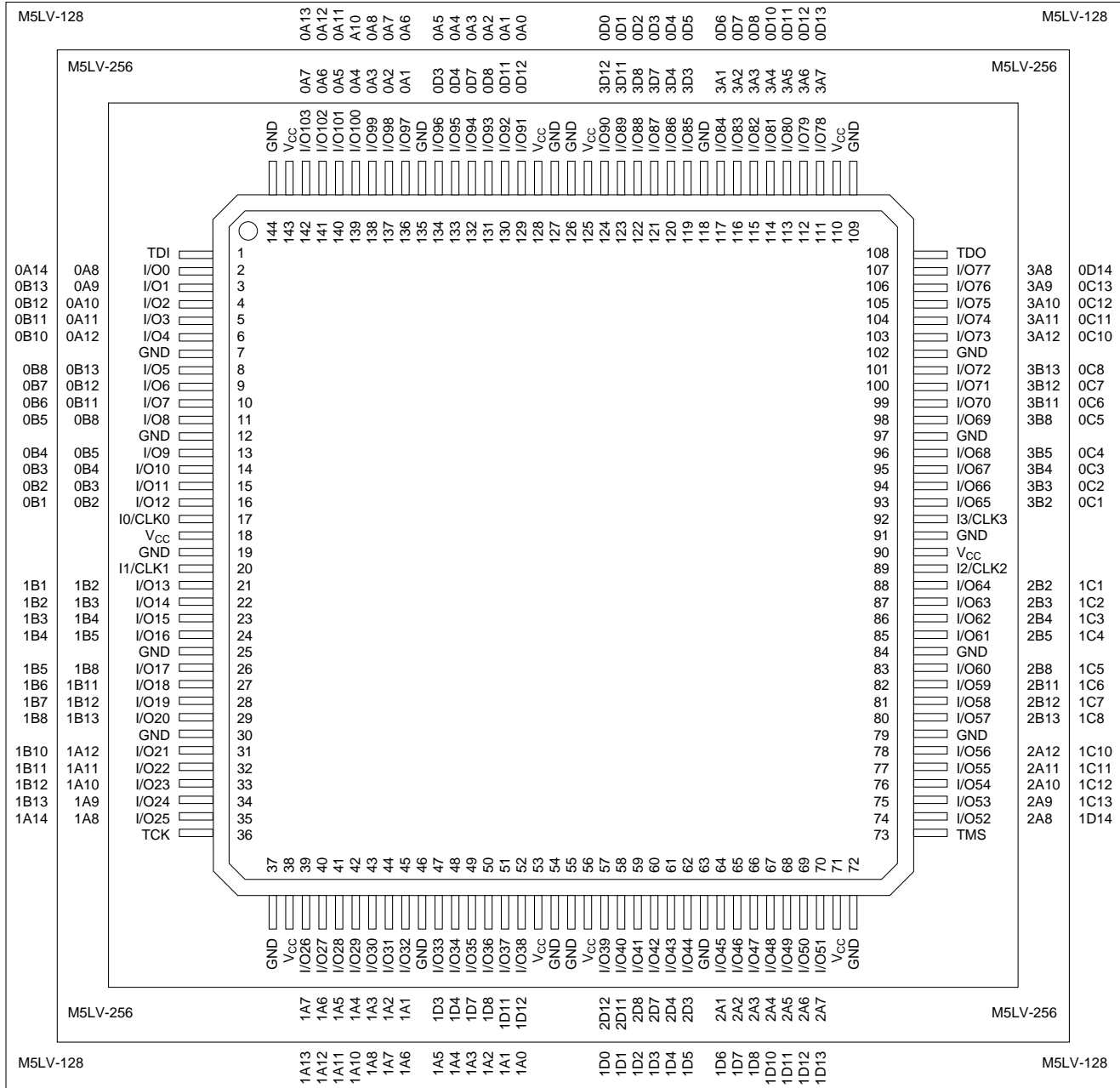
- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V_{CC} = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



144-PIN TQFP CONNECTION DIAGRAM

Top View

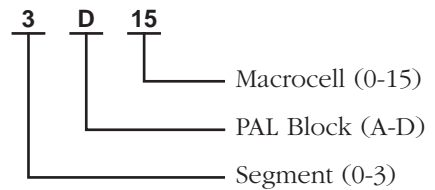
144-Pin TQFP



20446G-020

Pin Designations

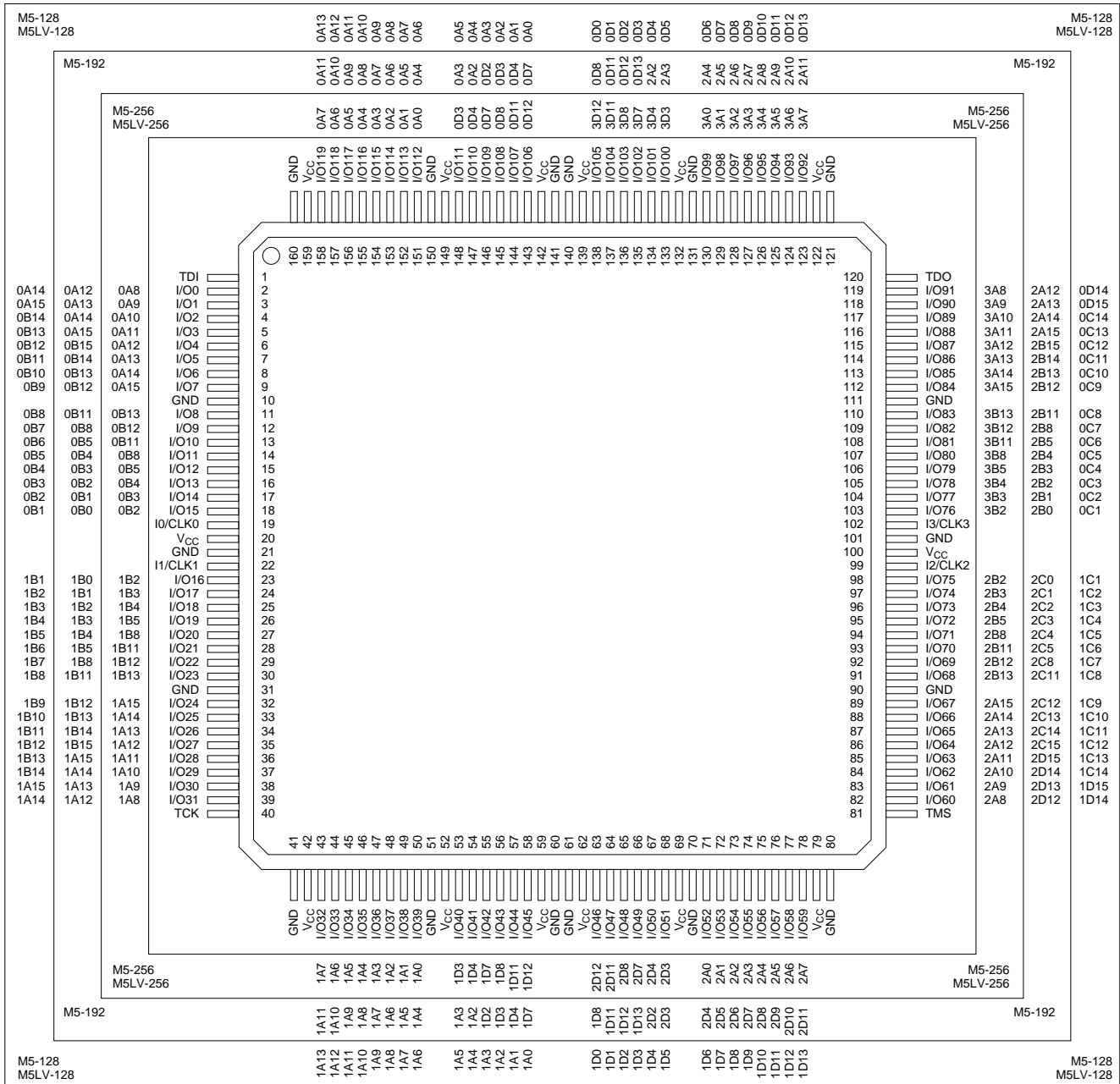
- | | |
|--------------------|----------------------------------|
| CLK = Clock | V _{CC} = Supply Voltage |
| GND = Ground | TDI = Test Data In |
| I = Input | TCK = Test Clock |
| I/O = Input/Output | TMS = Test Mode Select |
| NC = No Connect | TDO = Test Data Out |



160-PIN PQFP CONNECTION DIAGRAM

Top View

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

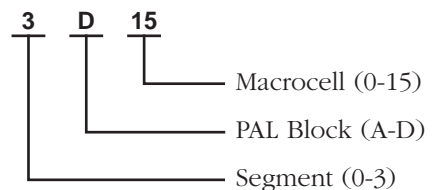


20446G-021

Pin Designations

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

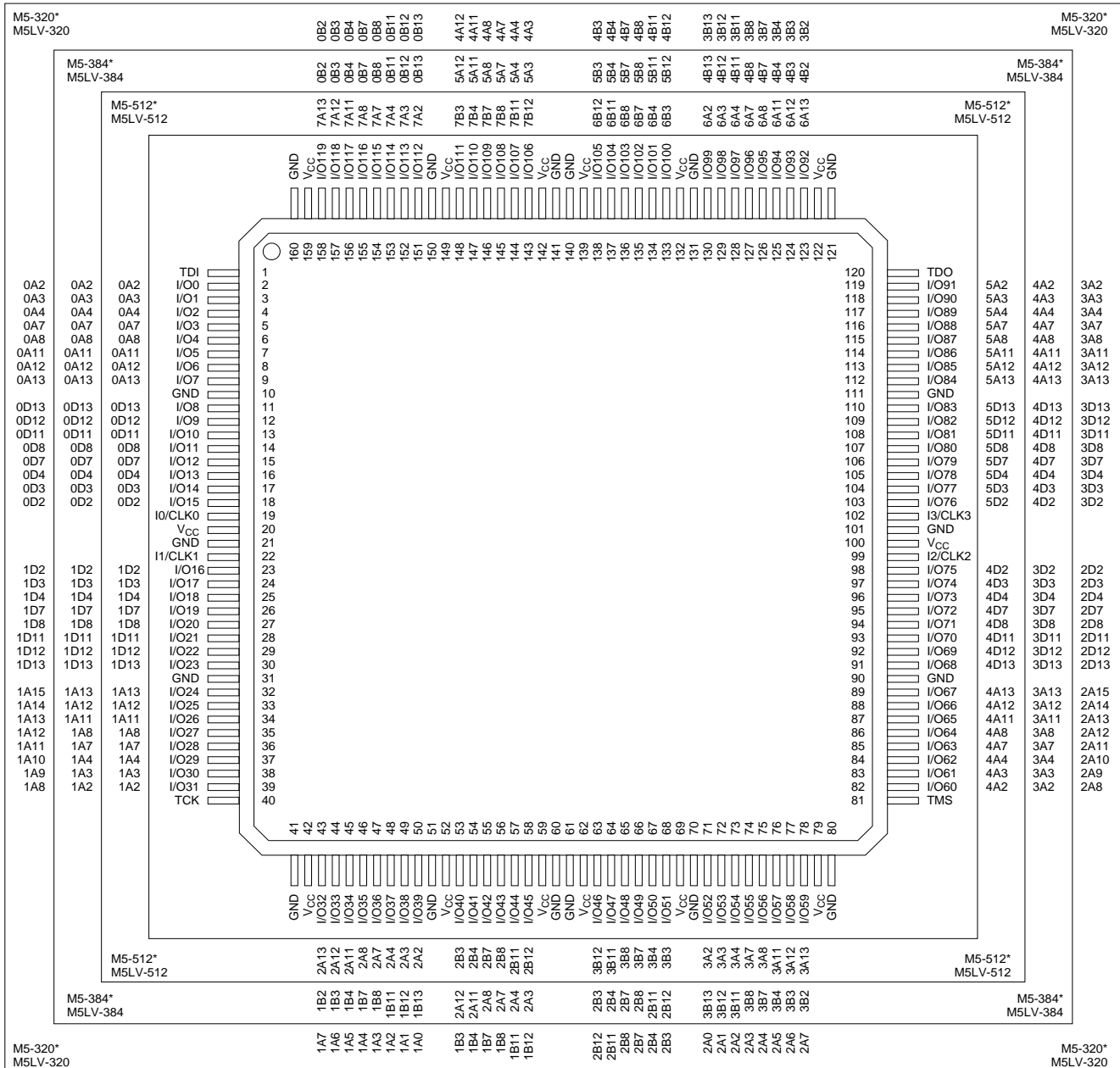
- V_{CC} = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



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

Top View

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

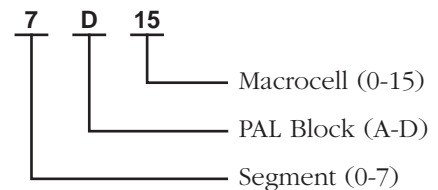


*Package obsolete, contact factory.

20446G-022

Pin Designations

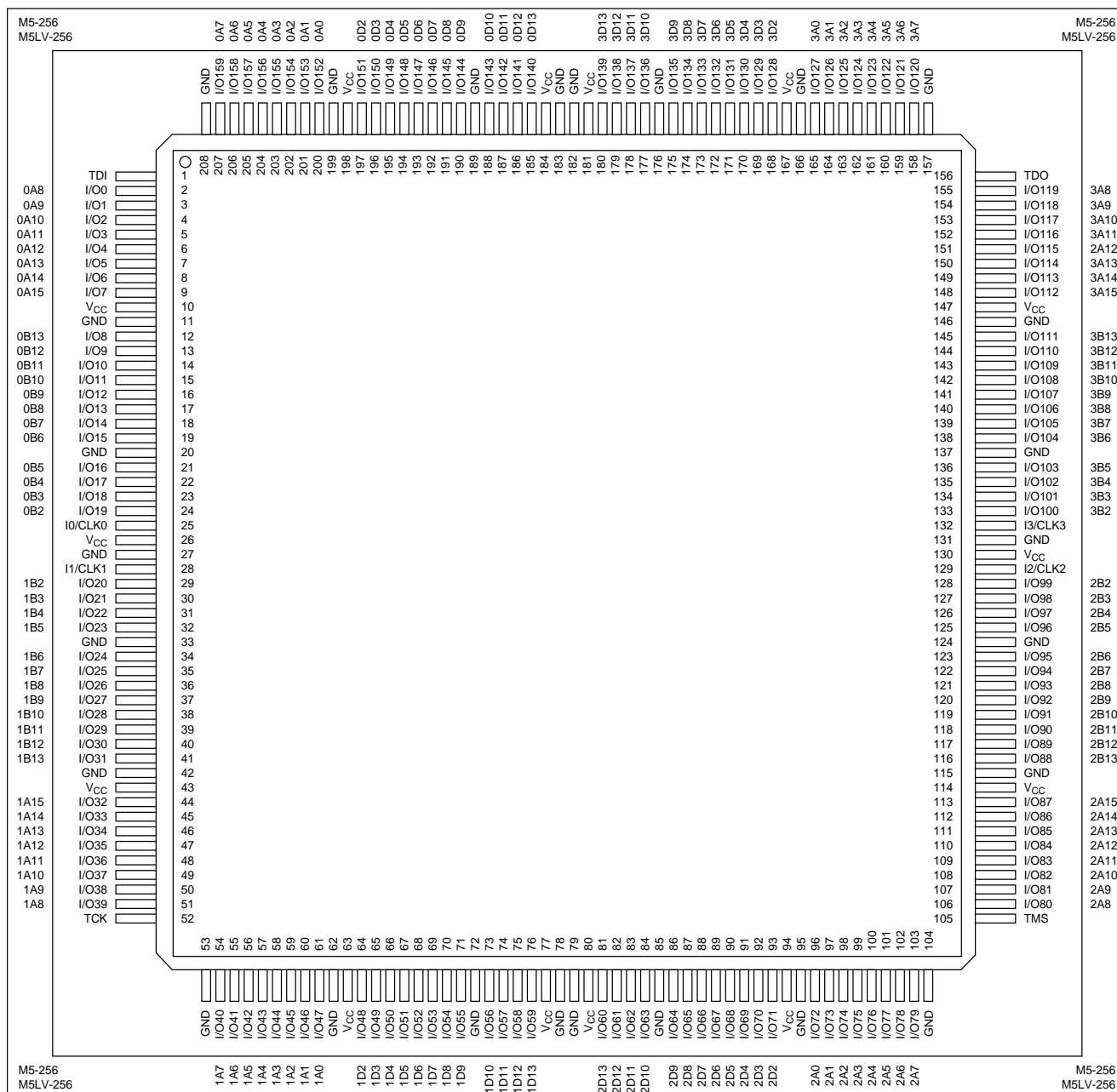
- | | |
|--------------------|----------------------------------|
| CLK = Clock | V _{CC} = Supply Voltage |
| GND = Ground | TDI = Test Data In |
| I = Input | TCK = Test Clock |
| I/O = Input/Output | TMS = Test Mode Select |
| NC = No Connect | TDO = Test Data Out |



208-PIN PQFP CONNECTION DIAGRAM

Top View

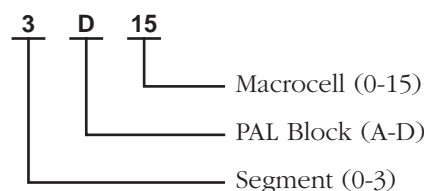
208-Pin PQFP (256 Macrocells)



20446G-023

Pin Designations

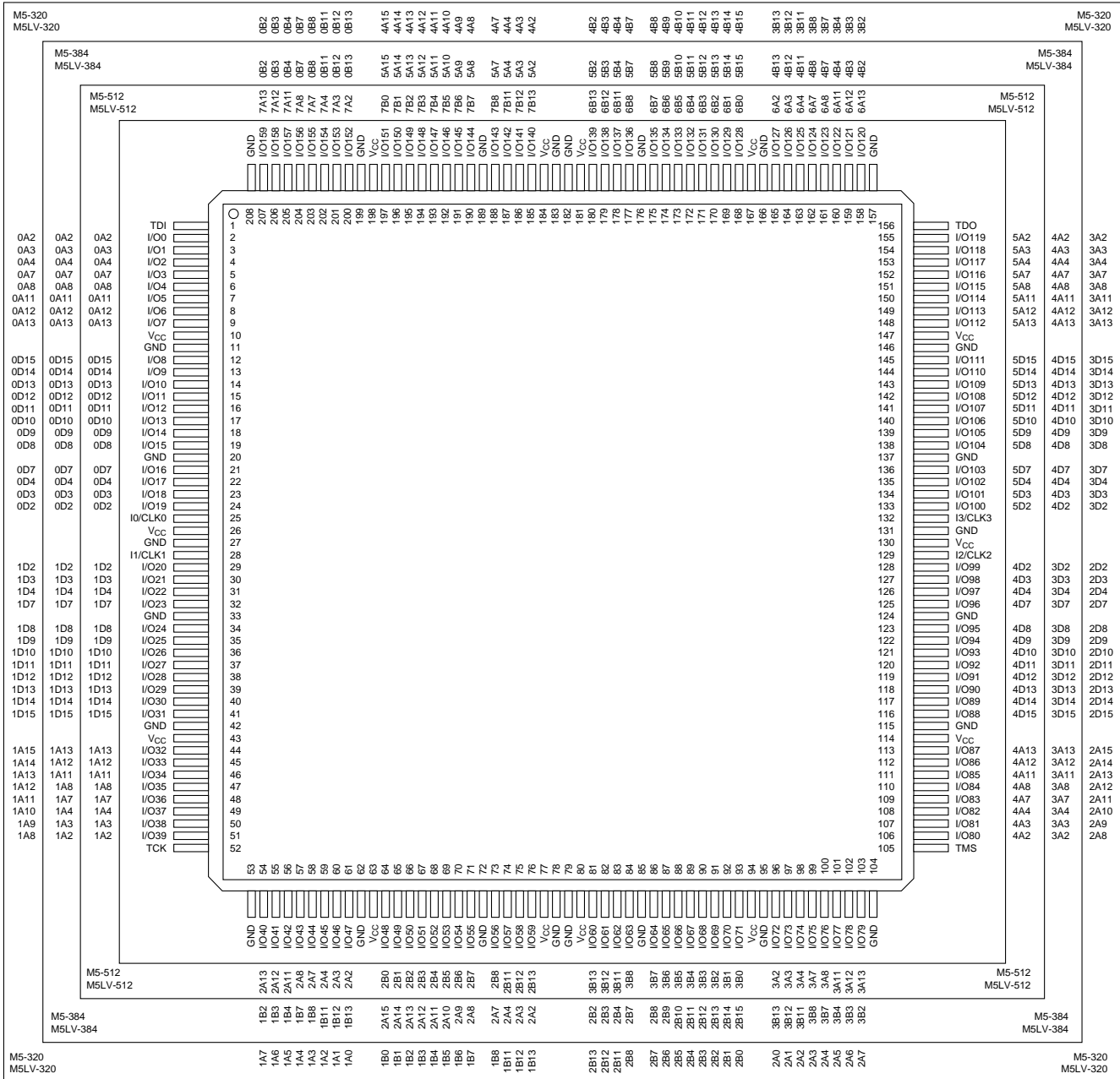
- | | |
|--------------------|----------------------------------|
| CLK = Clock | V _{CC} = Supply Voltage |
| GND = Ground | TDI = Test Data In |
| I = Input | TCK = Test Clock |
| I/O = Input/Output | TMS = Test Mode Select |
| NC = No Connect | TDO = Test Data Out |



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

Top View

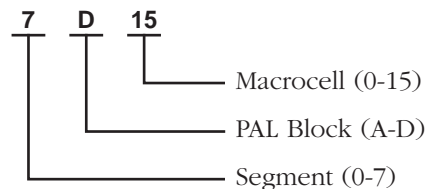
208-Pin PQFP (320, 384, 512 Macrocells)



20446G-024

Pin Designations

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



256-BALL BGA CONNECTION DIAGRAM — M5-320

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
20	GND	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/O30
19	I/O11	I/O12	V _{CC}	I/O14	I/O15	I/O16	I/O17	I/O18	I/O19	I/O34	I/O35	I/O37	I/O38	I/O39	I/O40	I/O41	I/O42	V _{CC}	I/O43	I/O44
18	GND	I/O28	V _{CC}	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	I/O42	V _{CC}	I/O43	I/O44
17	I/O44	I/O45	I/O46	V _{CC}	TDI	TDI	I/O47	V _{CC}	I/O48	I/O49	I/O50	I/O51	I/O52	I/O53	V _{CC}	I/O54	TCK	V _{CC}	I/O55	I/O56
16	I/O58	I/O59	I/O60	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	I/O61	I/O62	I/O63
15	GND	I/O64	I/O65	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O66	I/O67	I/O68	I/O69
14	I/O70	I/O71	I/O72	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	I/O73	I/O74	I/O75
13	I/O76	I/O77	I/O78	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O79	I/O80	I/O81	I/O82
12	GND	I/O84	I/O85	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O86	I/O87	I/O88	I/O89
11	GND	I/O90	I/O91	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O92	I/O93	I/O94	I/O95
10	GND	I/O96	I/O97	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O98	I/O99	I/O100	I/O101
9	GND	I/O102	I/O103	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O104	I/O105	I/O106	I/O107
8	I/O108	I/O109	I/O110	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O111	I/O112	I/O113	I/O114
7	I/O116	I/O117	I/O118	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	I/O119	I/O120	I/O121
6	GND	I/O122	I/O123	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O124	I/O125	I/O126	I/O127
5	I/O128	I/O129	I/O130	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}
4	I/O134	I/O135	I/O136	V _{CC}	TDO	I/O137	V _{CC}	I/O138	I/O139	I/O140	I/O141	I/O142	I/O143	V _{CC}	I/O144	TMS	V _{CC}	I/O145	I/O146	I/O147
3	GND	I/O148	V _{CC}	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 _{CC}	I/O163	I/O164
2	GND	I/O164	I/O165	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	¹³ /CLK3	¹² /CLK2	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177	I/O178	I/O179	I/O180
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	I/O192	I/O193

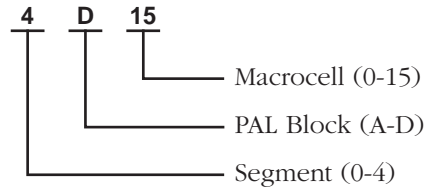
Pin Designations

CLK = Clock
 GND = Ground
 I = Input
 I/O = Input/Output
 NC = No Connect
 V_{CC} = Supply Voltage
 TDI = Test Data In
 TCK = Test Clock
 TMS = Test Mode Select
 TDO = Test Data Out

256-BALL BGA CONNECTION DIAGRAM — M5-320

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 _{CC}	3A2	3A4	3A12	3D14	3D10	3D5	3D0	2D0	2D5	2D9	2D14	2A14	2A10	2A8	V _{CC}	2A3	GND																			
4	3B13	3B11	3B3	V _{CC}	TDO	3A7	V _{CC}	3D11	3D6	3D1	2D1	2D6	2D11	V _{CC}	2A11	TMS	V _{CC}	2A6	2A2	2A0																			
5	4B14	4B15	3B4	V _{CC}	<p>Pin Designations</p> <p>CLK = Clock GND = Ground I = Input I/O = Input/Output NC = No Connect V_{CC} = Supply Voltage TDI = Test Data In TCK = Test Clock TMS = Test Mode Select TDO = Test Data Out</p>  <p>4 — Segment (0-4) D — PAL Block (A-D) 15 — Macrocell (0-15)</p>															4B14	4B15	3B4	V _{CC}																
6	GND	4B11	3B12	3B7																															V _{CC}	2A4	2A1	2B0	2B1
7	4B8	4B10	4B13	V _{CC}																															V _{CC}	2B3	2B2	2B5	2B7
8	4B4	4B6	4B9	4B12																															2B8	2B6	2B9	2B11	
9	GND	4B3	4B5	4B7																															2B13	2B10	2B12	GND	
10	GND	4B0	4B1	4B2																															1B13	1B14	1B15	GND	
11	GND	4A0	4A1	4A2																															1B8	1B10	1B12	GND	
12	GND	4A3	4A5	4A7																															1B3	1B6	1B9	1B11	
13	4A4	4A6	4A9	4A12																															V _{CC}	1A1	1B5	1B7	
14	4A8	4A10	4A13	V _{CC}																															1A4	1A5	1B0	1B1	
15	GND	4A11	0B12	0B7																1A8	V _{CC}	1A2	GND																
16	4A14	4A15	0B4	V _{CC}																1A13	1A9	1A7	GND																
17	0B13	0B11	0B3	V _{CC}																GND	1A6	1A3	GND																
18	GND	0B8	V _{CC}	0A2	0A4	TDI	0A7	V _{CC}	0D11	0D6	0D1	1D6	1D11	V _{CC}	1A11	TCK	1A8	V _{CC}	1A6	1A2																			
19	0B2	0A3	0A8	0A11	0A13	0A12	0D14	0D8	0D4	0D3	10/CLK0	1D4	1D8	1D9	1D13	1A15	1A12	V _{CC}	1A9	1A3																			
20	GND	GND	0D15	0D13	0D10	GND	0D7	GND	0D2	GND	11/CLK1	1D2	GND	1D7	GND	1D12	1D15	1A13	GND	GND																			
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	T	U	V	W	Y																			

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	AE	AF
1	NC	NC	NC	GND	NC	I/O245	GND	I/O246	I/O247	GND	I/O248	I/O249	I/O233	GND	I/O250	I/O251	I/O252	GND	I/O253	I/O254	GND	NC	I/O255	GND	NC	NC
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/O234	I/O235	I/O236	I/O237	I/O238	I/O239	I/O240	I/O241	I/O242	I/O243	I/O244	GND	NC
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/O215	I/O216	I/O217	I/O218	I/O219	I/O220	I/O221	I/O222	I/O223	TMS	NC	NC	NC
4	NC	I/O188	NC	TDO	I/O189	I/O190	I/O191	V _{CC}	I/O192	V _{CC}	I/O193	I/O194	I/O195	V _{CC}	I/O196	I/O197	I/O198	V _{CC}	I/O199	V _{CC}	I/O200	I/O201	V _{CC}	I/O202	I/O203	I/O204
5	GND	I/O183	I/O184	V _{CC}	I/O178	I/O176	I/O177	I/O178	I/O171	I/O165	I/O162	I/O156	I/O150	I/O143	I/O144	I/O145	I/O146	I/O152	I/O153	I/O160	I/O161	I/O166	I/O167	I/O168	I/O169	I/O170
6	NC	I/O176	I/O177	I/O178	I/O171	I/O165	I/O162	I/O156	I/O150	I/O143	I/O144	I/O145	I/O146	I/O152	I/O153	I/O160	I/O161	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	I/O172	I/O173	I/O174
7	GND	I/O169	I/O170	I/O171	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177	I/O178	I/O179	I/O180	I/O181	I/O182	I/O183	I/O184	I/O185	I/O186	I/O187	I/O188	I/O189	I/O190	I/O191	I/O192	I/O193
8	I/O162	I/O163	I/O164	I/O165	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177	I/O178	I/O179	I/O180	I/O181	I/O182	I/O183	I/O184	I/O185	I/O186	I/O187
9	I/O156	I/O157	I/O158	I/O159	V _{CC}	I/O150	I/O143	I/O144	I/O145	I/O146	I/O152	I/O153	I/O160	I/O161	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177
10	GND	I/O150	I/O151	V _{CC}	I/O145	I/O146	I/O147	I/O148	I/O149	I/O155	I/O152	I/O153	I/O160	I/O161	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177
11	I/O142	I/O143	I/O144	I/O145	I/O146	I/O147	I/O148	I/O149	I/O155	I/O152	I/O153	I/O160	I/O161	I/O166	I/O167	I/O168	I/O169	I/O170	I/O171	I/O172	I/O173	I/O174	I/O175	I/O176	I/O177	I/O178
12	I/O134	I/O135	I/O136	I/O137	I/O138	I/O139	I/O140	I/O141	I/O142	I/O143	I/O144	I/O145	I/O146	I/O147	I/O148	I/O149	I/O155	I/O152	I/O153	I/O160	I/O161	I/O166	I/O167	I/O168	I/O169	I/O170
13	I/O128	I/O129	I/O130	I/O131	I/O132	I/O133	I/O134	I/O135	I/O136	I/O137	I/O138	I/O139	I/O140	I/O141	I/O142	I/O143	I/O144	I/O145	I/O146	I/O147	I/O148	I/O149	I/O155	I/O152	I/O153	I/O160
14	GND	I/O122	I/O123	V _{CC}	I/O124	I/O125	I/O126	I/O127	I/O128	I/O129	I/O130	I/O131	I/O132	I/O133	I/O134	I/O135	I/O136	I/O137	I/O138	I/O139	I/O140	I/O141	I/O142	I/O143	I/O144	I/O145
15	I/O114	I/O115	I/O116	I/O117	I/O118	I/O119	I/O120	I/O121	I/O122	I/O123	I/O124	I/O125	I/O126	I/O127	I/O128	I/O129	I/O130	I/O131	I/O132	I/O133	I/O134	I/O135	I/O136	I/O137	I/O138	I/O139
16	NC	I/O107	I/O108	I/O109	I/O110	I/O111	I/O112	I/O113	I/O114	I/O115	I/O116	I/O117	I/O118	I/O119	I/O120	I/O121	I/O122	I/O123	I/O124	I/O125	I/O126	I/O127	I/O128	I/O129	I/O130	I/O131
17	I/O101	I/O102	I/O103	I/O104	V _{CC}	I/O105	I/O106	I/O107	I/O108	I/O109	I/O110	I/O111	I/O112	I/O113	I/O114	I/O115	I/O116	I/O117	I/O118	I/O119	I/O120	I/O121	I/O122	I/O123	I/O124	I/O125
18	GND	I/O87	I/O88	I/O89	V _{CC}	I/O87	I/O88	I/O89	I/O90	I/O91	I/O92	I/O93	I/O94	I/O95	I/O96	I/O97	I/O98	I/O99	I/O100	I/O101	I/O102	I/O103	I/O104	I/O105	I/O106	I/O107
19	I/O80	I/O81	I/O82	I/O83	I/O84	I/O85	I/O86	I/O87	I/O88	I/O89	I/O90	I/O91	I/O92	I/O93	I/O94	I/O95	I/O96	I/O97	I/O98	I/O99	I/O100	I/O101	I/O102	I/O103	I/O104	I/O105
20	I/O73	I/O74	I/O75	I/O76	I/O77	I/O78	I/O79	I/O80	I/O81	I/O82	I/O83	I/O84	I/O85	I/O86	I/O87	I/O88	I/O89	I/O90	I/O91	I/O92	I/O93	I/O94	I/O95	I/O96	I/O97	I/O98
21	I/O73	I/O74	I/O75	I/O76	I/O77	I/O78	I/O79	I/O80	I/O81	I/O82	I/O83	I/O84	I/O85	I/O86	I/O87	I/O88	I/O89	I/O90	I/O91	I/O92	I/O93	I/O94	I/O95	I/O96	I/O97	I/O98
22	GND	I/O68	I/O69	I/O70	V _{CC}	I/O71	I/O72	I/O73	I/O74	I/O75	I/O76	I/O77	I/O78	I/O79	I/O80	I/O81	I/O82	I/O83	I/O84	I/O85	I/O86	I/O87	I/O88	I/O89	I/O90	I/O91
23	I/O51	I/O52	I/O53	V _{CC}	I/O54	I/O55	V _{CC}	I/O56	V _{CC}	I/O57	I/O58	I/O59	V _{CC}	I/O60	I/O61	I/O62	V _{CC}	I/O63	V _{CC}	I/O64	I/O65	I/O66	TCK	NC	NC	NC
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	I/O50	NC	NC	NC	NC
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/O30	NC	NC	NC	NC
26	NC	NC	GND	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	NC	NC	NC	NC

Pin Designations

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

20446G-030

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

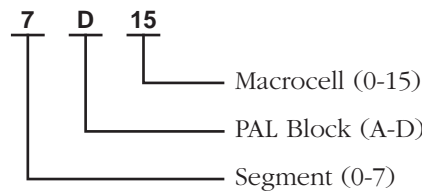
Bottom View (Macrocell Association)

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	AE	AF
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	NC	NC
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	GND	NC
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	NC	NC
4	NC	6A14	NC	TDO	5A0	5A3	5A6	V _{CC}	5A11	V _{CC}	5D12	5D7	5D2	V _{CC}	4D3	4D8	4D12	V _{CC}	4A11	V _{CC}	4A4	4A0	V _{CC}	3A15	3A13	NC
5	GND	6A12	6A13	V _{CC}																			3A14	3A11	3A9	GND
6	NC	6A9	6A10	6A15																			3A10	3A8	3A7	3A5
7	GND	6A6	6A8	6A11																			3A6	3A4	3A3	3A0
8	6A1	6A4	6A5	6A7																			3A2	3A1	3A0	NC
9	6B1	6A0	6A2	6A3																			V _{CC}	3B1	3B0	GND
10	GND	6B2	6B0	V _{CC}																			3B3	3B4	3B2	3B6
11	6B6	6B5	6B4	6B3																			3B7	3B8	3B9	3B10
12	6B10	6B9	6B8	6B7																			3B11	3B12	3B13	3B14
13	6B14	6B13	6B12	6B11																			V _{CC}	2B15	2B15	GND
14	GND	7B15	7B15	V _{CC}																			2B11	2B12	2B13	2B14
15	7B14	7B13	7B12	7B11																			2B7	2B8	2B9	2B10
16	NC	7B10	7B9	7B8																			2B3	2B4	2B5	2B6
17	7B7	7B6	7B5	7B4																			V _{CC}	2B0	2B2	GND
18	GND	7B3	7B2	V _{CC}																			2A3	2A2	2A0	2B1
19	7B1	7B0	7A1	7A4																			2A7	2A5	2A4	2A1
20	7A0	7A2	7A3	7A8																			2A11	2A8	2A6	GND
21	7A5	7A6	7A7	7A12																			2A15	2A10	2A9	NC
22	GND	7A9	7A11	7A15																			V _{CC}	2A13	2A12	GND
23	7A10	7A13	7A14	V _{CC}																			TCK	NC	2A14	NC
24	NC	NC	TDI	0A2	0A5	0A4	V _{CC}	0A11	0D14	0D12	0D8	0D3	I0/CLK0	1D2	1D5	1D12	V _{CC}	1A15	1A10	1A6	1A4	1A1	NC	NC	GND	
25	GND	GND	0A1	0A3	0A8	0A7	0A10	0A15	0D13	0D10	0D6	0D2	0D0	I1/CLK1	1D4	1D8	1D10	1A15	1A14	1A9	1A5	1A2	NC	NC	NC	
26	NC	NC	0A2	0A6	NC	GND	0A13	0D15	GND	0D9	0D5	0D1	GND	I1/CLK1	1D3	1D6	GND	1D15	GND	1A12	NC	GND	NC	NC	NC	

Pin Designations

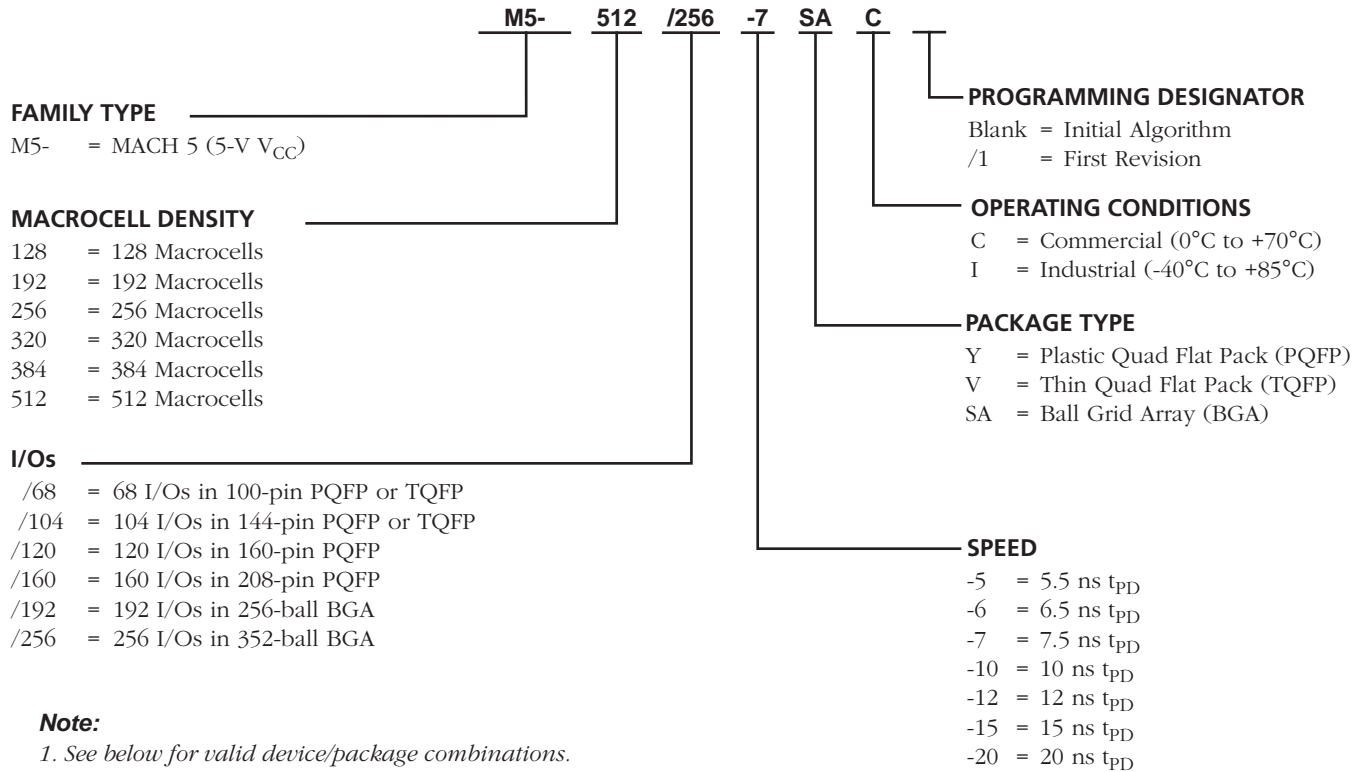
- CLK = Clock
- GND = Ground
- I = Input
- I/O = Input/Output
- NC = No Connect
- V_{CC} = Supply Voltage
- TDI = Test Data In
- TCK = Test Clock
- TMS = Test Mode Select
- TDO = Test Data Out



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5V M5 ORDERING INFORMATION^{1,2}

Lattice standard products are available in several packages and operating ranges. The order number (Valid Combination) is formed 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		VC, VI
M5-192/120		YC, YI
M5-256/68		VC, VI
M5-256/120		YC, YI
M5-256/160		YC, YI

Device Marking

Actual device marking differs from the ordering part number (OPN). All MACH 5 devices are dual-marked with both Commercial and Industrial grades. The Industrial grade is slower, i.e., M5-512/256-7AC-10AI.

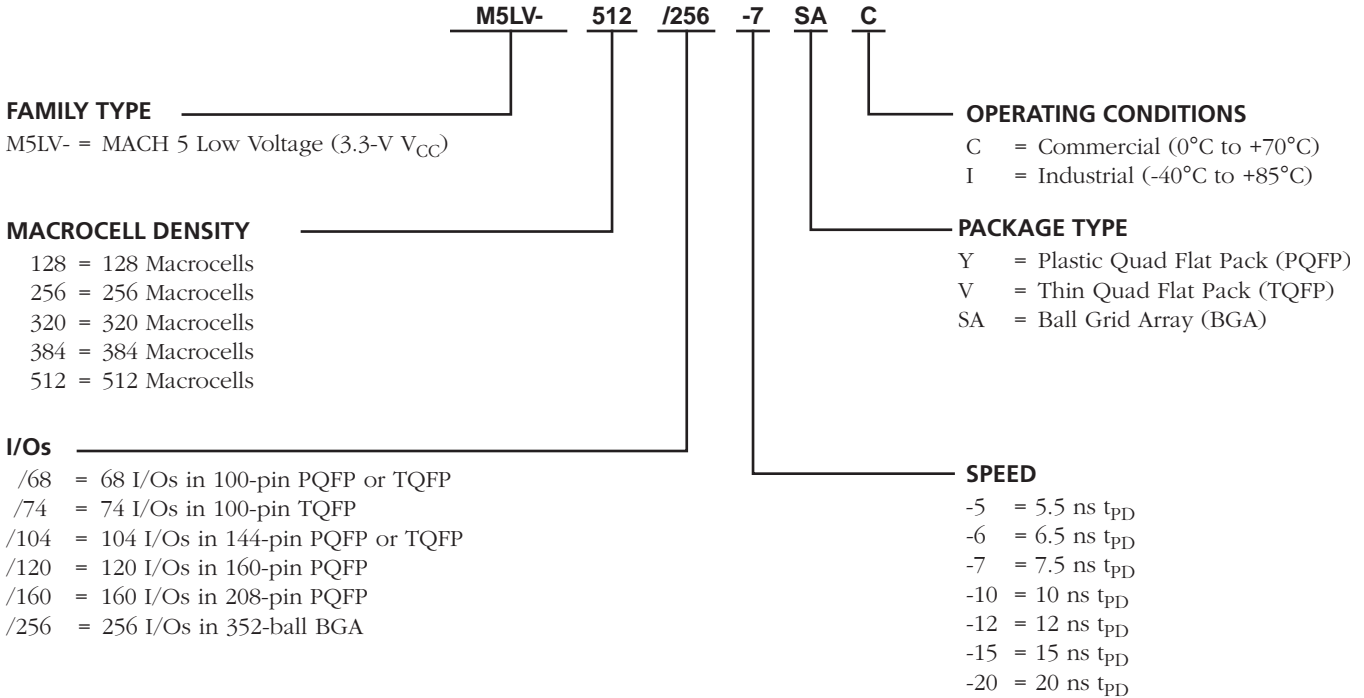
Valid Combinations		
M5-320/160	Commercial: -6, -7, -10, -12, -15 Industrial: -7, -10, -12, -15, -20	YC, YI
M5-320/192		SAC, SAI,
M5-384/160		YC, YI
M5-512/160		YC, YI
M5-512/256		SAC, SAI

Valid Combinations

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

3.3V M5LV ORDERING INFORMATION¹

Lattice standard products are available in several packages and operating ranges. The order number (Valid Combination) is formed 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	VC, VI
M5LV-128/74		VC, VI
M5LV-128/104		VC, VI
M5LV-128/120		YC, YI
M5LV-256/68		YC, YI
M5LV-256/74		VC, VI
M5LV-256/104		VC, VI
M5LV-256/120		YC, YI
M5LV-256/160		YC, YI

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	YC, YI
M5LV-320/160		YC, YI
M5LV-384/120		YC, YI
M5LV-384/160		YC, YI
M5LV-512/120		YC, YI
M5LV-512/160		YC, YI
M5LV-512/256		SAC, SAI

Valid Combinations

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