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## 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**

Select devices have been discontinued.  
See Ordering Information section for product status.

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

| Feature                             | M5-128/1<br>M5LV-128 |     | M5-192/1 | M5-256/1<br>M5LV-256 |     | M5-320<br>M5LV-320 |     | M5-384<br>M5LV-384 |     | M5-512<br>M5LV-512 |     |
|-------------------------------------|----------------------|-----|----------|----------------------|-----|--------------------|-----|--------------------|-----|--------------------|-----|
| Supply Voltage (V)                  | 5                    | 3.3 | 5        | 5                    | 3.3 | 5                  | 3.3 | 5                  | 3.3 | 5                  | 3.3 |
| 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 <sub>PD</sub> (ns)                | 5.5                  | 5.5 | 5.5      | 5.5                  | 5.5 | 6.5                | 6.5 | 6.5                | 6.5 | 6.5                | 6.5 |
| t <sub>SS</sub> (ns)                | 3.0                  | 3.0 | 3.0      | 3.0                  | 3.0 | 3.0                | 3.0 | 3.0                | 3.0 | 3.0                | 3.0 |
| t <sub>COS</sub> (ns)               | 4.5                  | 4.5 | 4.5      | 4.5                  | 4.5 | 5.0                | 5.0 | 5.0                | 5.0 | 5.0                | 5.0 |
| f <sub>CNT</sub> (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<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 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 E<sup>2</sup>CMOS 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*.

Select devices have been discontinued.  
See Ordering Information section for product status.

Table 2. MACH 5 Speed Grades

| Device              | Speed Grade <sup>1</sup> |    |      |      |      |      |     |
|---------------------|--------------------------|----|------|------|------|------|-----|
|                     | -5                       | -6 | -7   | -10  | -12  | -15  | -20 |
| M5-128 <sup>2</sup> |                          |    | 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 <sup>2</sup> |                          |    | 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<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>

|              | M5-128/1<br>M5LV-128 |        | M5-192/1 | M5-256/1<br>M5LV-256 |         | M5-320<br>M5LV-320 |      | M5-384<br>M5LV-384 |      | M5-512<br>M5LV-512 |      |
|--------------|----------------------|--------|----------|----------------------|---------|--------------------|------|--------------------|------|--------------------|------|
|              | 5                    | 3.3    |          | 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,

Select devices have been discontinued.  
See Ordering Information section for product status.

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.

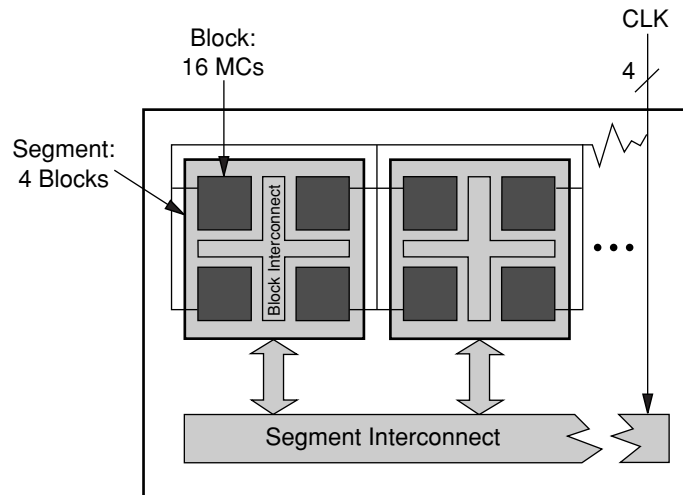


Figure 1. MACH 5 Block Diagram

20446G-001

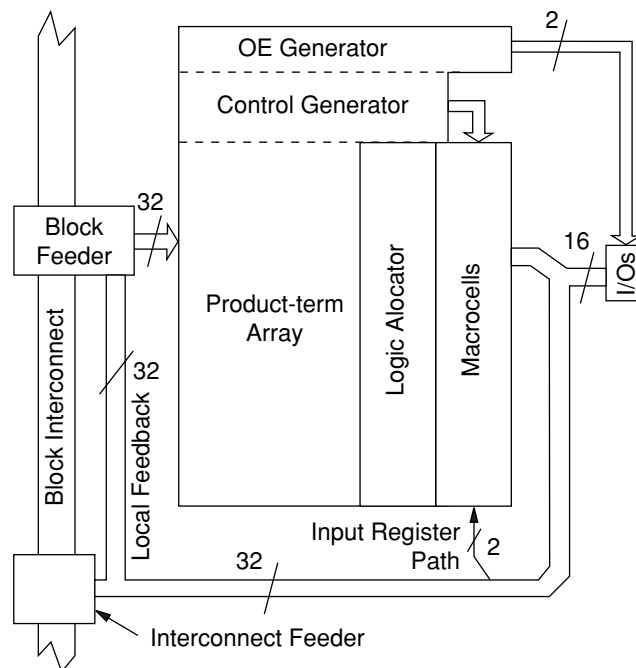
The MACH 5 PAL blocks consist of the elements listed below (Figure 2). While each PAL block resembles an independent PAL device, it has superior control and logic generation capabilities.

- ◆ 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.

Select devices have been discontinued.  
See Ordering Information section for product status.



20446G-002

**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 <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>                                                     |

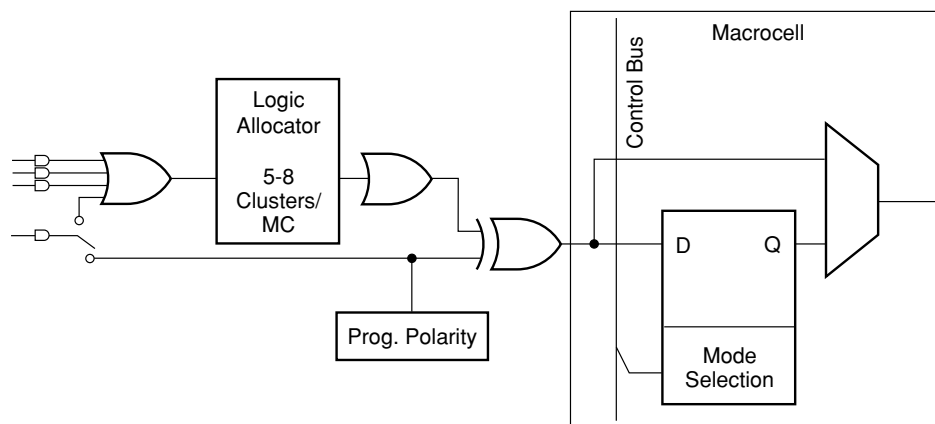
Select devices have been discontinued.  
See Ordering Information section for product status.

## 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

Select devices have been discontinued. See Ordering Information section for product status.

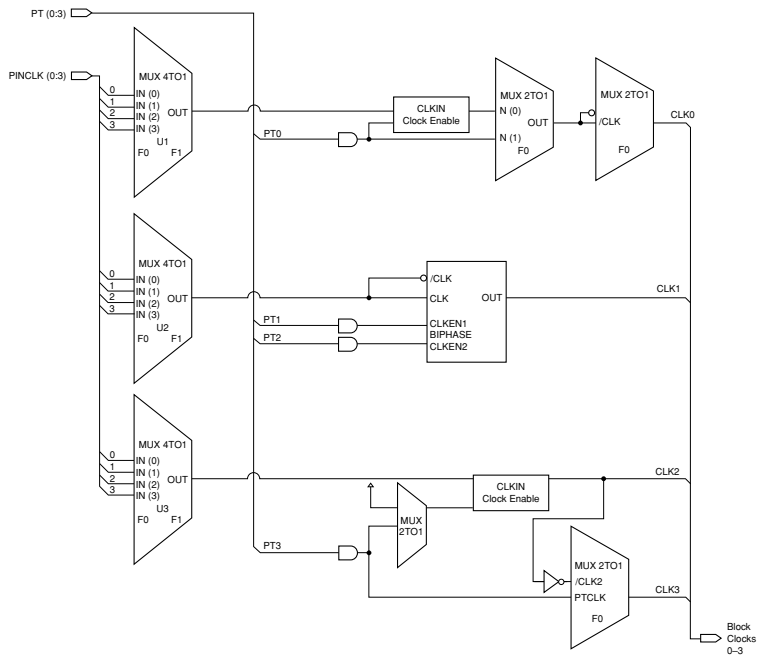
- ◆ Global clock (0, 1, 2, or 3) with positive and negative edge clock enable (biphase)

#### Clock Line 2 Options

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

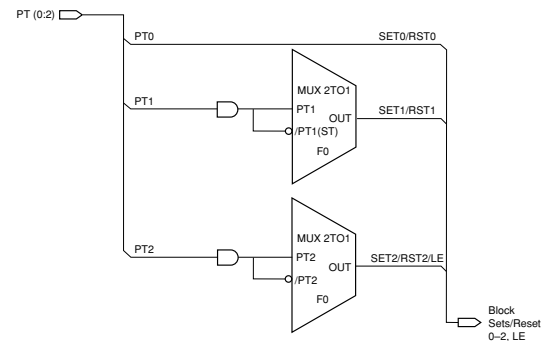
#### Clock Line 3 Options

- ◆ 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**



20446G-005

**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.

**Select devices have been discontinued.  
See Ordering Information section for product status.**

## 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).

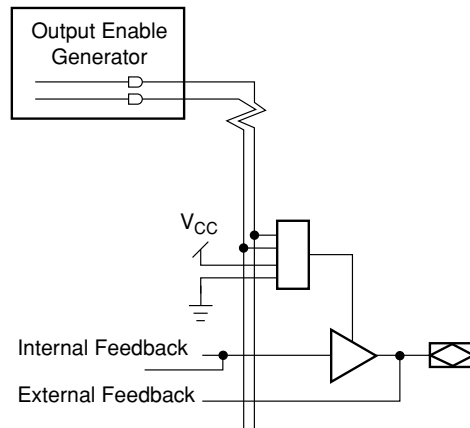


**Figure 6. Output Enable Generator and I/O Cell**

20446G-006

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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.

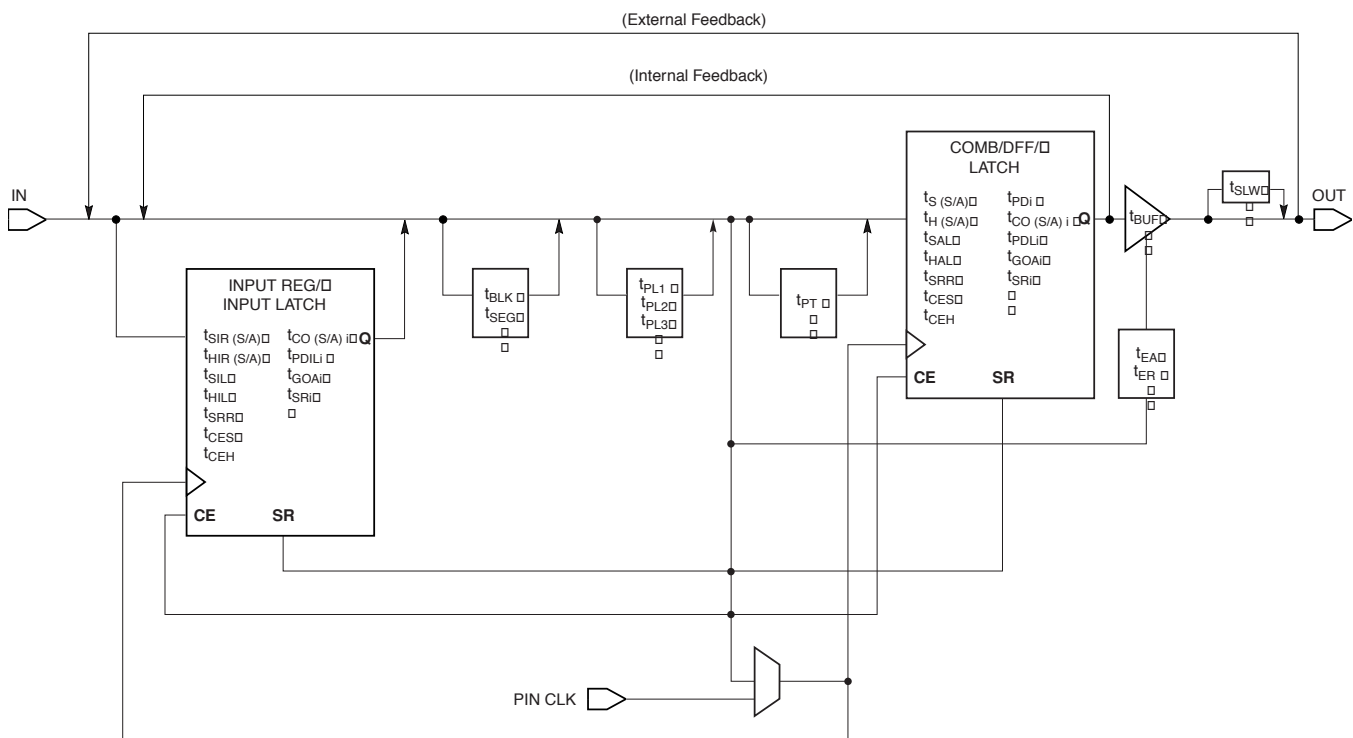


Figure 7. MACH 5 Timing Model

20446G-014

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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.

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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 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.

Select devices have been discontinued.  
See Ordering Information section for product status.

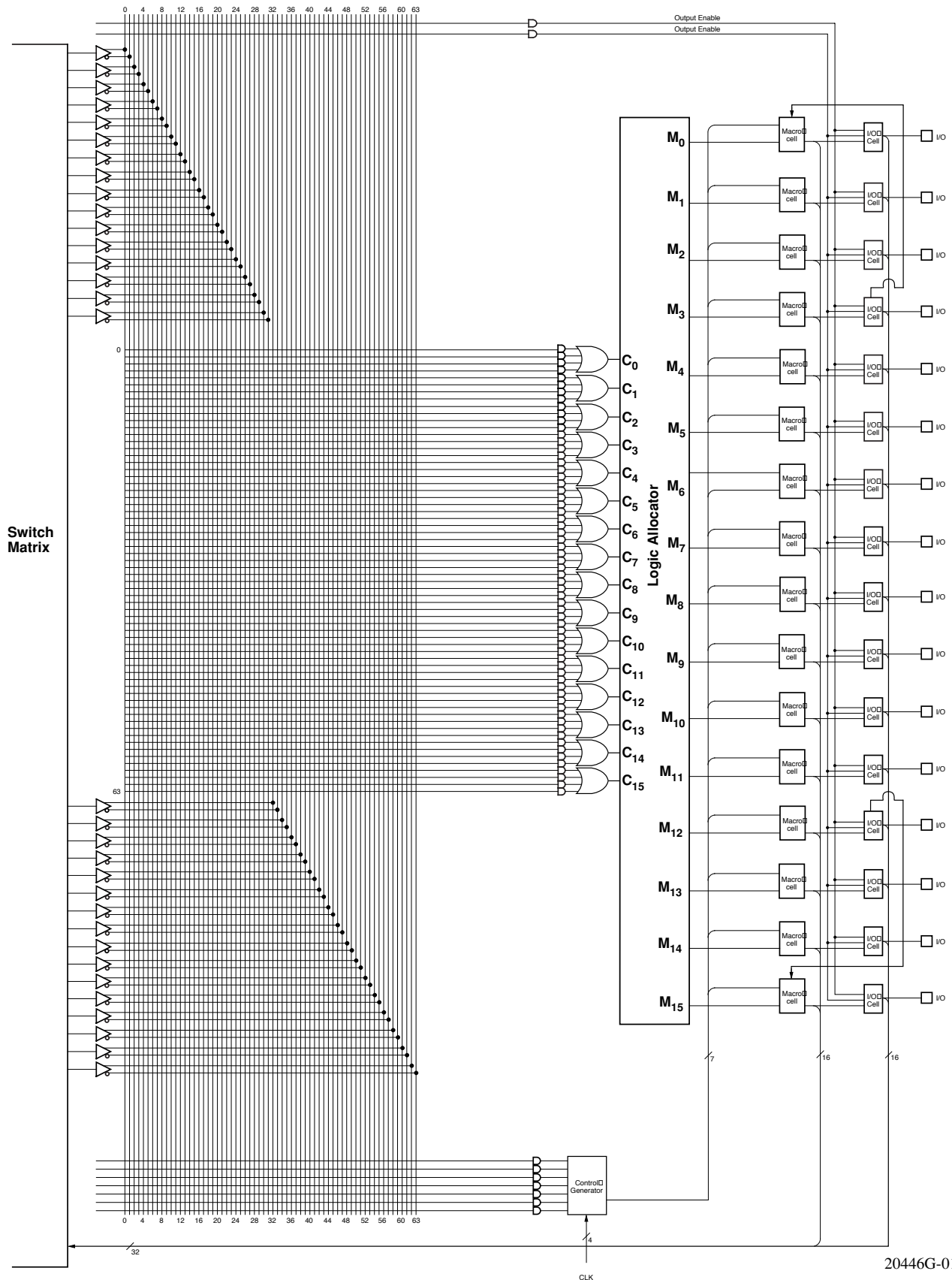
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## SECURITY BIT

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.

**Select devices have been discontinued.  
See Ordering Information section for product status.**

## MACH 5 PAL BLOCK

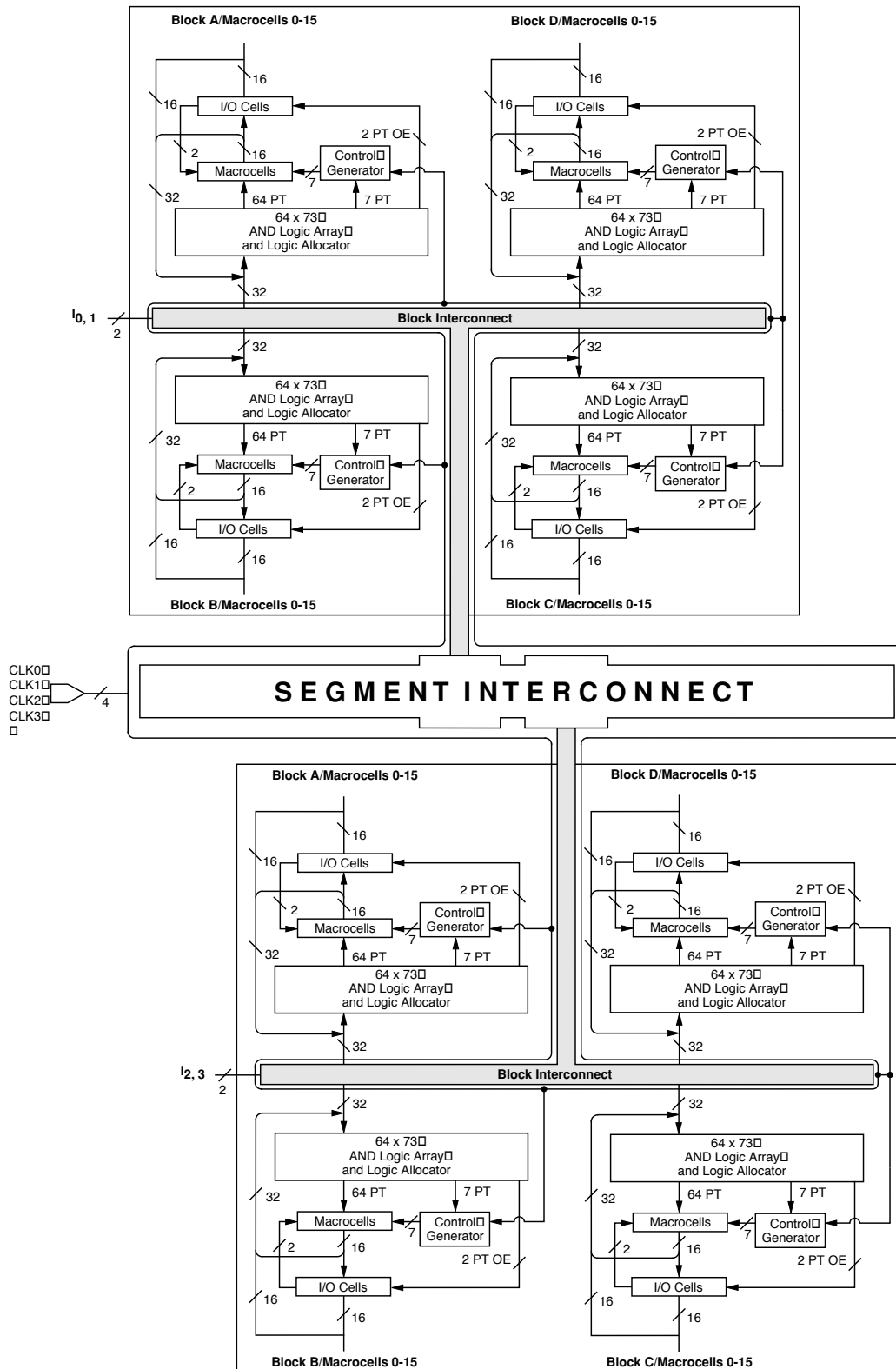


Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-015

## BLOCK DIAGRAM — M5(LV)-128/XXX

### SEGMENT 0

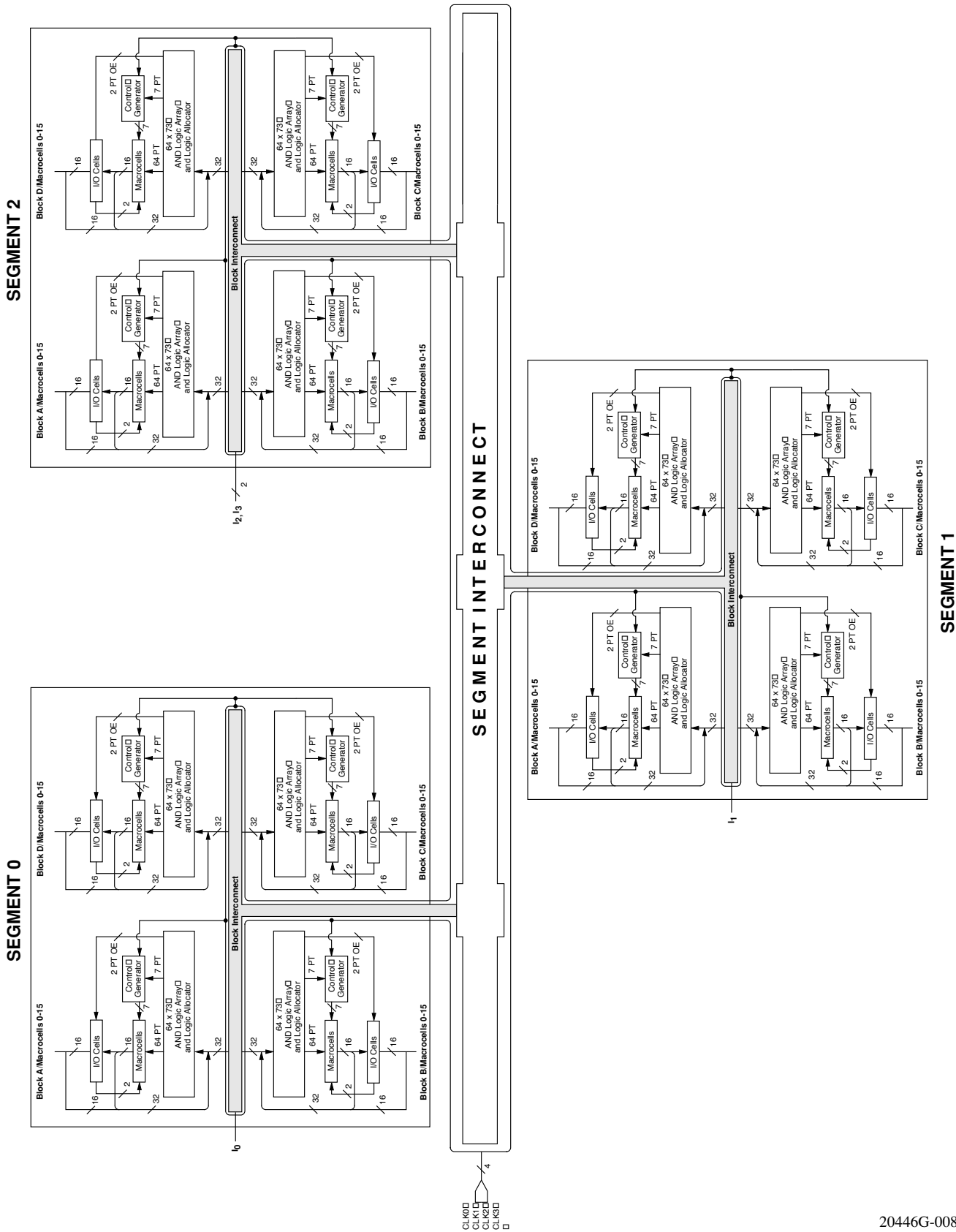


Select devices have been discontinued.  
See Ordering Information section for product status.

### SEGMENT 1

20446G-007

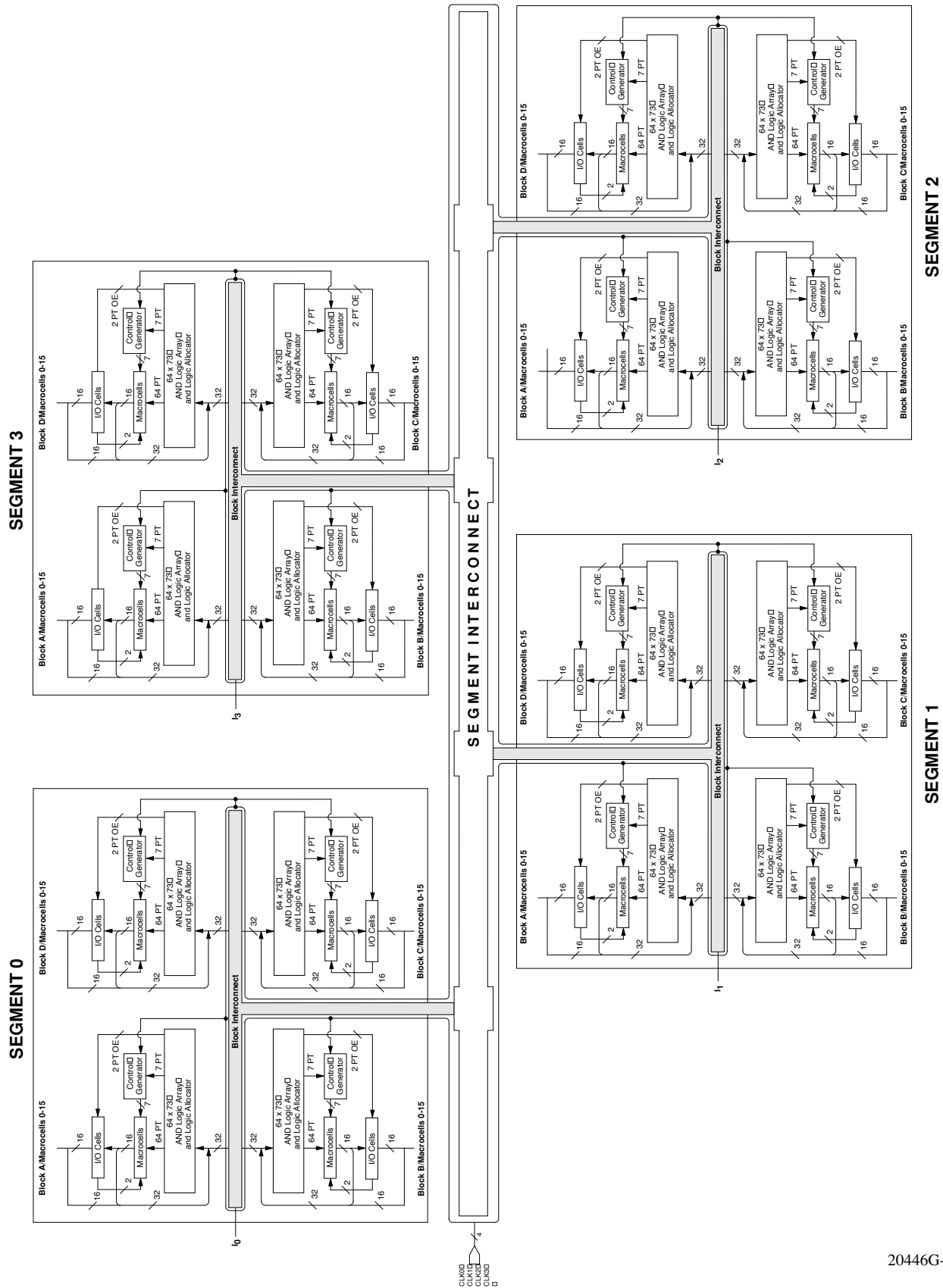
## BLOCK DIAGRAM — M5-192/XXX



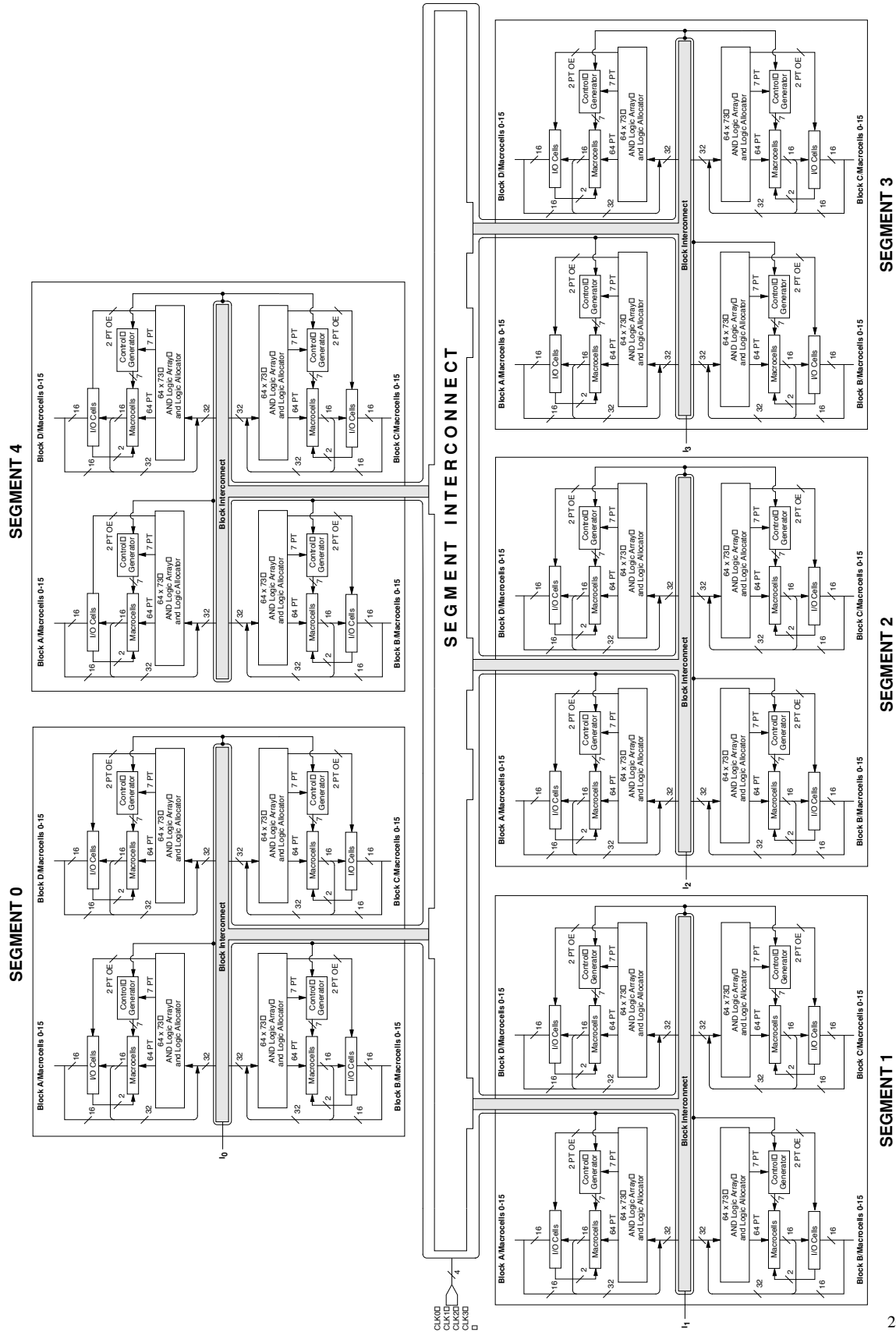
Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-008

## BLOCK DIAGRAM — M5(LV)-256/XXX



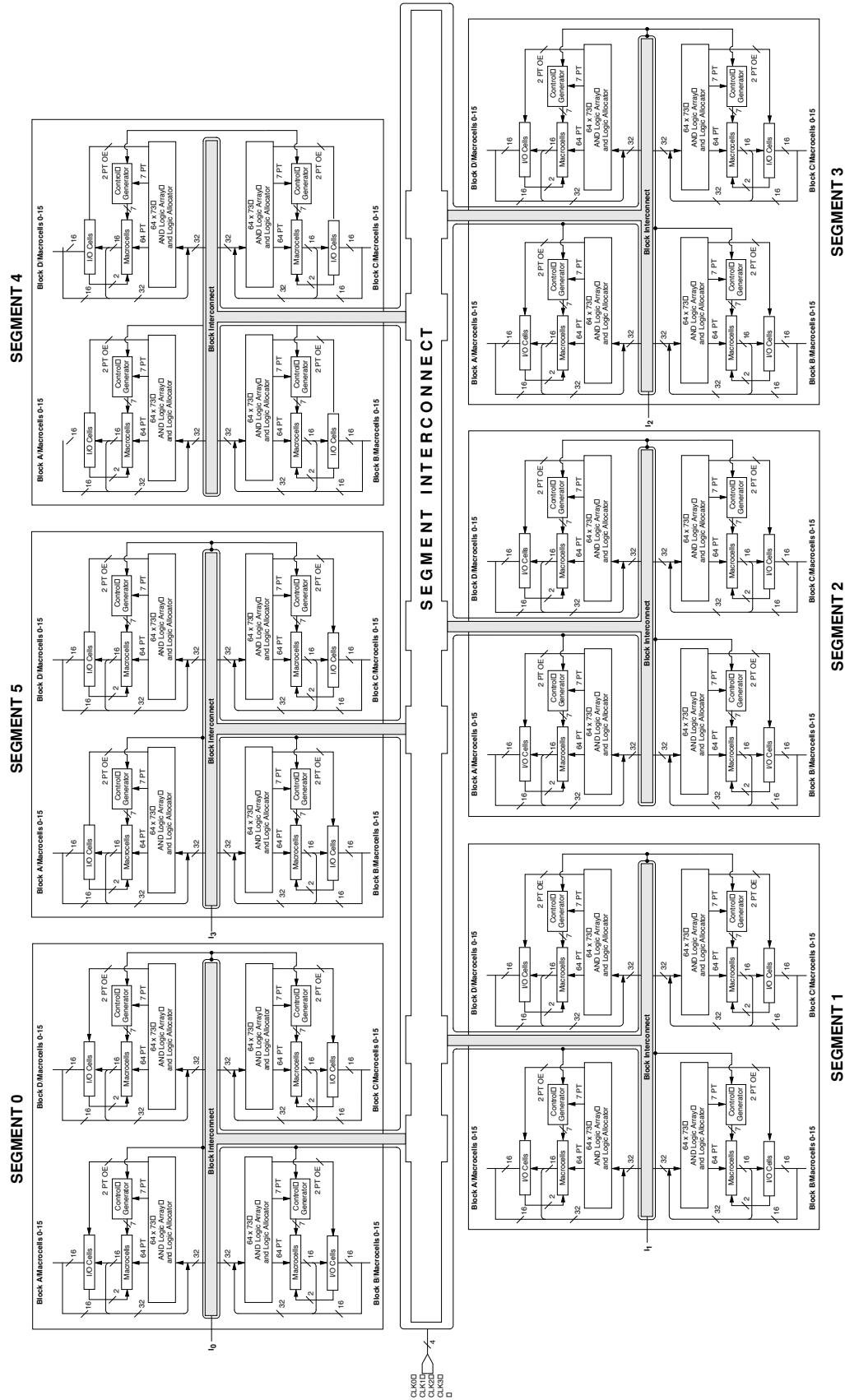
# BLOCK DIAGRAM — M5(LV)-320/XXX



Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-010

## BLOCK DIAGRAM — M5(LV)-384/XXX

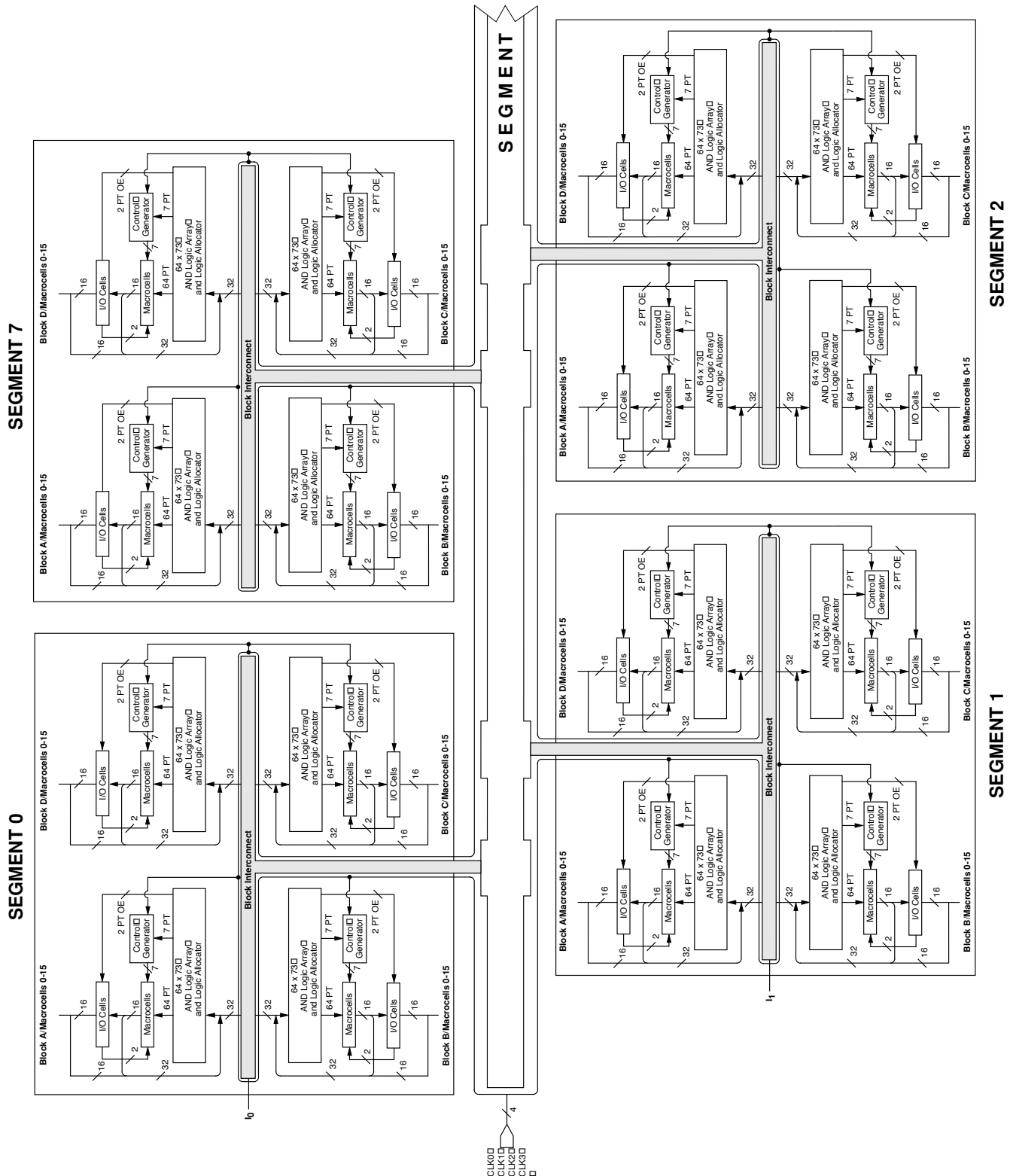


Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-011

# BLOCK DIAGRAM — M5(LV)-512/XXX

Continued

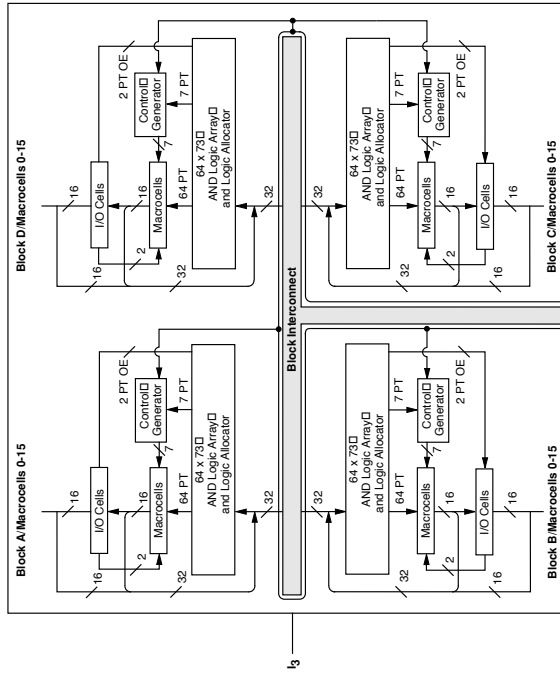


Select devices have been discontinued.  
See Ordering Information section for product status.

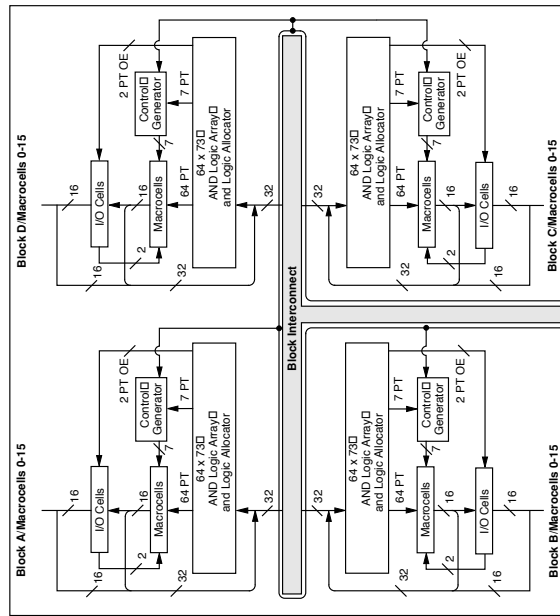
20446G-012

## BLOCK DIAGRAM — M5(LV)-512/XXX

**SEGMENT 5**

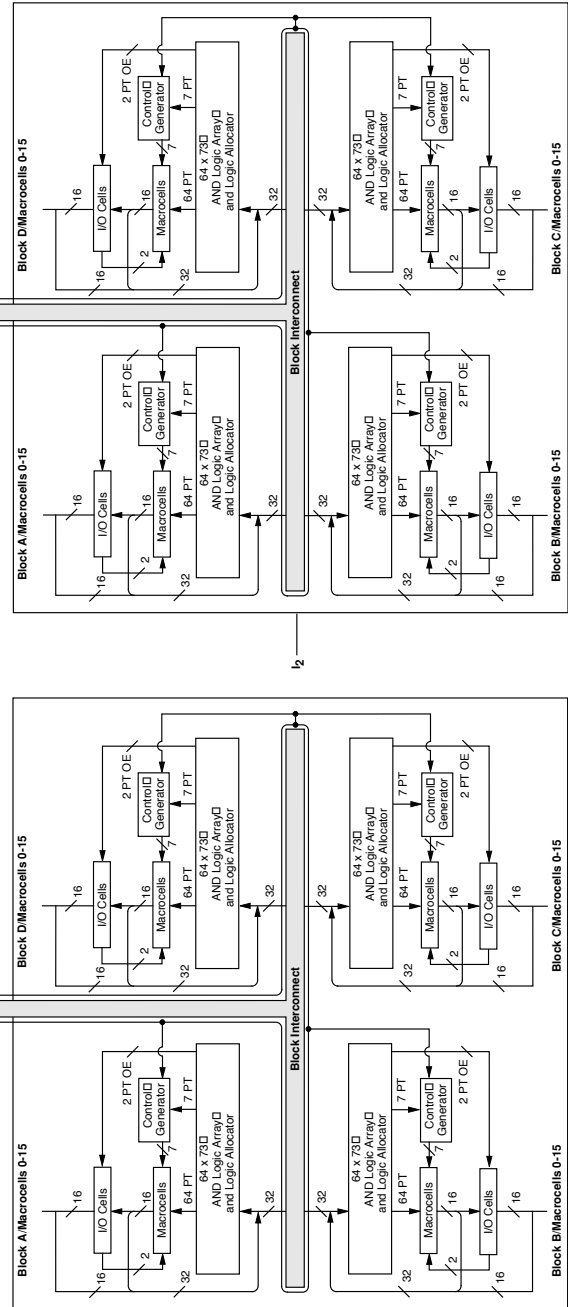


**SEGMENT 6**



Continued

### INTERCONNECT



**SEGMENT 4**

**SEGMENT 3**

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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.*

Select devices have been discontinued.  
See Ordering Information section for product status.

## 5-V DC CHARACTERISTICS OVER OPERATING RANGES

| Parameter Symbol | Parameter Description                                                                     | Test Description                                                                              | Min | Typ | Max  | Unit          |
|------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----|-----|------|---------------|
| $V_{OH}$         | Output HIGH Voltage<br>(For M5-128/1, M5-192/1, M5-256/1, M5-320, M5-384, M5-512 Devices) | $I_{OH} = -3.2 \text{ mA}$ , $V_{CC} = \text{Min}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$     | 2.4 |     |      | V             |
|                  |                                                                                           | $I_{OH} = -100 \mu\text{A}$ , $V_{CC} = \text{Max}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$    |     | 3.3 | 3.6  | V             |
|                  | Output HIGH Voltage<br>(For M5-128, M5-192, M5-256 Devices)                               | $I_{OH} = -3.2 \text{ mA}$ , $V_{CC} = \text{Min}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$     | 2.4 |     |      | V             |
|                  |                                                                                           | $I_{OH} = -2.5 \text{ mA}$ , $V_{CC} = 5.25 \text{ V}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$ |     |     | 3.6  | V             |
| $V_{OL}$         | Output LOW Voltage (Note 2)                                                               | $I_{OL} = +16 \text{ mA}$ , $V_{CC} = \text{Min}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$      |     |     | 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   | $\mu\text{A}$ |
| $I_{IL}$         | Input LOW Leakage Current                                                                 | $V_{IN} = 0$ , $V_{CC} = \text{Max}$ (Note 4)                                                 |     |     | -10  | $\mu\text{A}$ |
| $I_{OZH}$        | Off-State Output Leakage Current HIGH                                                     | $V_{OUT} = 5.25$ , $V_{CC} = \text{Max}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$ (Note 4)      |     |     | 10   | $\mu\text{A}$ |
| $I_{OZL}$        | Off-State Output Leakage Current LOW                                                      | $V_{OUT} = 0$ , $V_{CC} = \text{Max}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$ (Note 4)         |     |     | -10  | $\mu\text{A}$ |
| $I_{SC}$         | Output Short-Circuit Current                                                              | $V_{OUT} = 0.5 V_{CC} = \text{Max}$ , $V_{IN} = V_{IH} \text{ or } V_{IL}$ (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.*

Select devices have been discontinued.  
See Ordering Information section for product status.

## 3.3-V DC CHARACTERISTICS OVER OPERATING RANGES

| Parameter Symbol | Parameter Description                 | Test Description                                                                          |                                   | Min            | Max  | Unit    |
|------------------|---------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------|----------------|------|---------|
| $V_{OH}$         | Output HIGH Voltage                   | $V_{CC} = \text{Min}$                                                                     | $I_{OH} = -100 \mu A$             | $V_{CC} - 0.2$ |      | V       |
|                  |                                       | $V_{IN} = V_{IH} \text{ or } V_{IL}$                                                      | $I_{OH} = 3.2 \text{ mA}$         | 2.4            |      | V       |
| $V_{OL}$         | Output LOW Voltage                    | $V_{CC} = \text{Min}$                                                                     | $I_{OL} = 100 \mu A$              |                | 0.2  | V       |
|                  |                                       | $V_{IN} = V_{IH} \text{ or } V_{IL}$                                                      | $I_{OL} = 16 \text{ mA (Note 1)}$ |                | 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   | $\mu A$ |
| $I_{IL}$         | Input LOW Leakage Current             | $V_{IN} = 0, V_{CC} = \text{Max (Note 3)}$                                                |                                   |                | -10  | $\mu A$ |
| $I_{OZH}$        | 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   | $\mu A$ |
| $I_{OZL}$        | 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  | $\mu A$ |
| $I_{SC}$         | 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 RANGES<sup>1</sup>

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

Select devices have been discontinued.  
See Ordering Information section for product status.

## M5(LV) TIMING PARAMETERS OVER OPERATING RANGES<sup>1</sup> (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 <sub>PL1</sub>          | Power level 1 delay (Note 2)                                        |     | 4.0<br>(5.0)  |     | 4.0  |     | 4.0<br>(5.0)  |     | 4.0<br>(5.0)  |     | 4.0<br>(5.0)  |      | 4.0<br>(5.0)  |      | 4.0<br>(5.0)  | ns   |
| t <sub>PL2</sub>          | Power level 2 delay (Note 2)                                        |     | 6.0<br>(9.0)  |     | 6.0  |     | 6.0<br>(9.0)  |     | 6.0<br>(9.0)  |     | 6.0<br>(9.0)  |      | 6.0<br>(9.0)  |      | 6.0<br>(9.0)  | ns   |
| t <sub>PL3</sub>          | Power level 3 delay (Note 2)                                        |     | 9.0<br>(17.5) |     | 9.0  |     | 9.0<br>(17.5) |     | 9.0<br>(17.5) |     | 9.0<br>(17.5) |      | 9.0<br>(17.5) |      | 9.0<br>(17.5) | ns   |
| Additional Cluster Delay: |                                                                     |     |               |     |      |     |               |     |               |     |               |      |               |      |               |      |
| t <sub>PT</sub>           | Product term cluster delay                                          |     | 0.3           |     | 0.3  |     | 0.3           |     | 0.3           |     | 0.3           |      | 0.3           |      | 0.3           | ns   |
| Interconnect Delays:      |                                                                     |     |               |     |      |     |               |     |               |     |               |      |               |      |               |      |
| t <sub>BLK</sub>          | Block interconnect delay                                            |     | 1.5           |     | 1.5  |     | 1.5           |     | 2.0           |     | 2.0           |      | 2.0           |      | 2.0           | ns   |
| t <sub>SEG</sub>          | Segment interconnect delay                                          |     | 4.5           |     | 4.5  |     | 5.0           |     | 6.0           |     | 6.0           |      | 6.0           |      | 6.0           | ns   |
| Reset and Preset Delays:  |                                                                     |     |               |     |      |     |               |     |               |     |               |      |               |      |               |      |
| t <sub>SRI</sub>          | Asynchronous reset or preset to internal register output            |     | 6.0           |     | 8.0  |     | 8.0           |     | 10.0          |     | 12.0          |      | 14.0          |      | 16.0          | ns   |
| t <sub>SR</sub>           | Asynchronous reset or preset to register output                     |     | 8.0           |     | 10.0 |     | 10.0          |     | 12.0          |     | 14.0          |      | 16.0          |      | 18.0          | ns   |
| t <sub>SRR</sub>          | Reset and set register recovery time                                | 5.5 |               | 7.5 |      | 7.5 |               | 8.0 |               | 9.0 |               | 10.0 |               | 11.0 |               | ns   |
| t <sub>SRW</sub>          | Asynchronous reset or preset width                                  | 3.0 |               | 4.0 |      | 4.0 |               | 5.0 |               | 6.0 |               | 7.0  |               | 8.0  |               | ns   |
| Clock Enable Delays:      |                                                                     |     |               |     |      |     |               |     |               |     |               |      |               |      |               |      |
| t <sub>CES</sub>          | Clock enable setup time                                             | 4.0 |               | 5.0 |      | 5.0 |               | 6.0 |               | 7.0 |               | 7.0  |               | 8.0  |               | ns   |
| t <sub>CEH</sub>          | Clock enable hold time                                              | 3.0 |               | 4.0 |      | 4.0 |               | 5.0 |               | 6.0 |               | 6.0  |               | 7.0  |               | ns   |
| Width:                    |                                                                     |     |               |     |      |     |               |     |               |     |               |      |               |      |               |      |
| t <sub>WLS</sub>          | Global clock width low (Note 3)                                     | 2.5 |               | 3.0 |      | 3.0 |               | 4.0 |               | 5.0 |               | 6.0  |               | 6.0  |               | ns   |
| t <sub>WHS</sub>          | Global clock width high (Note 3)                                    | 2.5 |               | 3.0 |      | 3.0 |               | 4.0 |               | 5.0 |               | 6.0  |               | 6.0  |               | ns   |
| t <sub>WLA</sub>          | Product term clock width low                                        | 3.0 |               | 4.0 |      | 4.0 |               | 5.0 |               | 6.0 |               | 7.0  |               | 8.0  |               | ns   |
| t <sub>WHA</sub>          | Product term clock width high                                       | 3.0 |               | 4.0 |      | 4.0 |               | 5.0 |               | 6.0 |               | 7.0  |               | 8.0  |               | ns   |
| 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  |               | ns   |
| 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  |               | ns   |

Select devices have been discontinued.  
See Ordering Information section for product status.

## M5(LV) TIMING PARAMETERS OVER OPERATING RANGES<sup>1</sup> (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 <sub>MAX</sub>  | External feedback, PAL block level. Min of 1/(t <sub>WLS</sub> + t <sub>WHS</sub> ) or 1/(t <sub>SS</sub> + t <sub>COS</sub> )  | 133 |     | 125 |     | 100  |     | 83.3 |     | 71.4 |     | 55.6 |     | 45.5 |     | MHz  |
|                   | Internal feedback, PAL block level. Min of 1/(t <sub>WLS</sub> + t <sub>WHS</sub> ) or 1/(t <sub>SS</sub> + t <sub>COSi</sub> ) | 182 |     | 167 |     | 125  |     | 100  |     | 83.3 |     | 62.5 |     | 50.0 |     | MHz  |
|                   | No feedback PAL block level. Min of 1/(t <sub>WLS</sub> + t <sub>WHS</sub> ) or 1/(t <sub>SS</sub> + t <sub>HS</sub> )          | 200 |     | 167 |     | 167  |     | 125  |     | 100  |     | 83.3 |     | 83.3 |     | MHz  |
| f <sub>MAXA</sub> | External feedback, PAL block level. Min of 1/(t <sub>WLA</sub> + t <sub>WHA</sub> ) or 1/(t <sub>SA</sub> + t <sub>COA</sub> )  | 91  |     | 91  |     | 71.4 |     | 58.8 |     | 47.6 |     | 41.7 |     | 35.7 |     | MHz  |
|                   | Internal feedback, PAL block level. Min of 1/(t <sub>WLA</sub> + t <sub>WHA</sub> ) or 1/(t <sub>SA</sub> + t <sub>COAi</sub> ) | 111 |     | 111 |     | 83.3 |     | 66.7 |     | 52.6 |     | 45.5 |     | 38.5 |     | MHz  |
|                   | No feedback, PAL block level. Min of 1/(t <sub>WLA</sub> + t <sub>WHA</sub> ) or 1/(t <sub>SA</sub> + t <sub>HA</sub> )         | 167 |     | 125 |     | 125  |     | 100  |     | 83.3 |     | 71.4 |     | 62.5 |     | MHz  |
| f <sub>MAXI</sub> | Maximum input register frequency 1/(t <sub>SIRS</sub> + t <sub>HIRS</sub> ) or 1/(2 x t <sub>WICW</sub> )                       | 167 |     | 125 |     | 125  |     | 100  |     | 83.3 |     | 71.4 |     | 62.5 |     | MHz  |

### Notes:

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

Select devices have been discontinued.  
See Ordering Information section for product status.

## CAPACITANCE<sup>1</sup>

| 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   |
| $C_{I/O}$        | 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

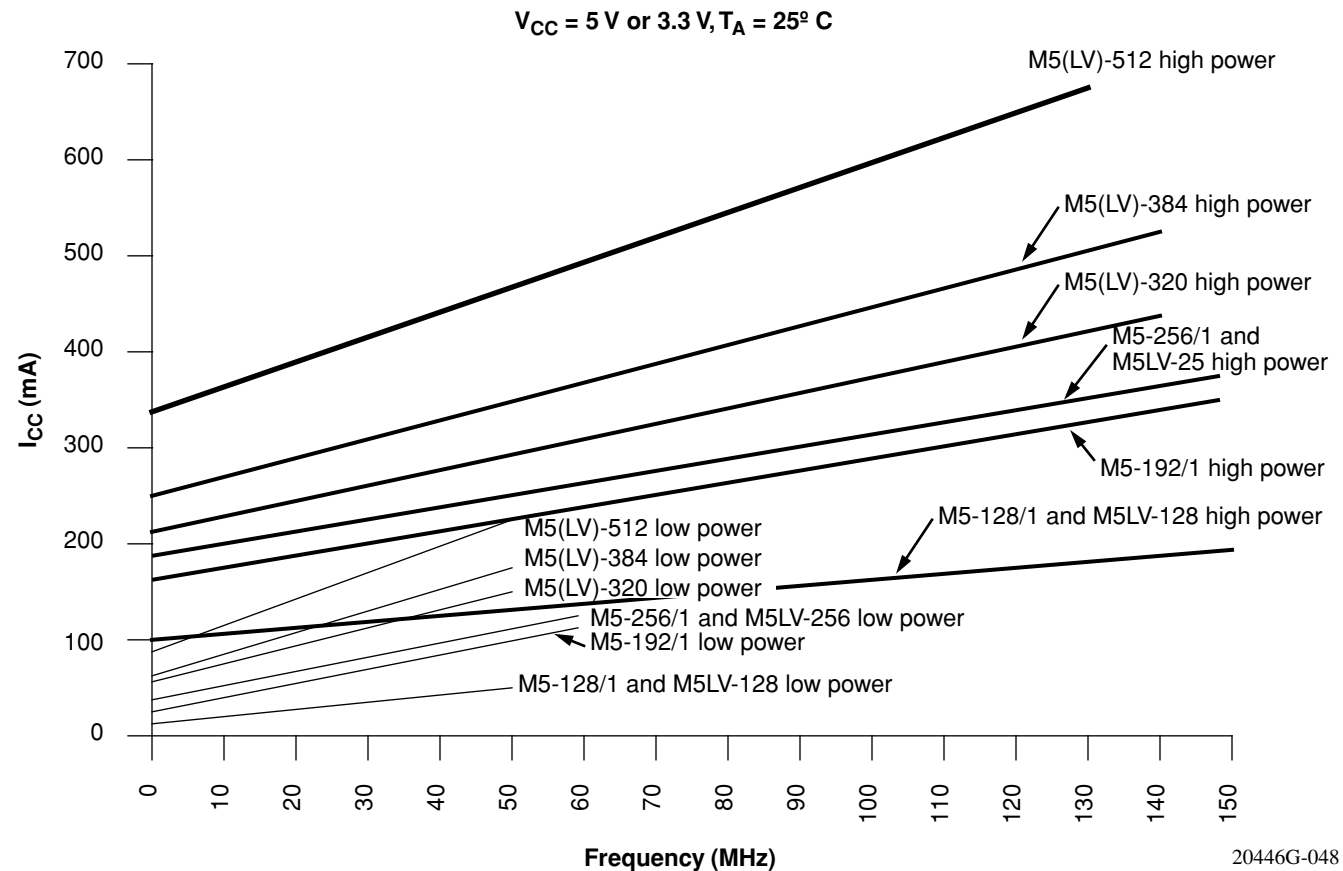


Figure 8.  $I_{CC}$  Curves at High/Low Power Modes

Select devices have been discontinued. See Ordering Information section for product status.

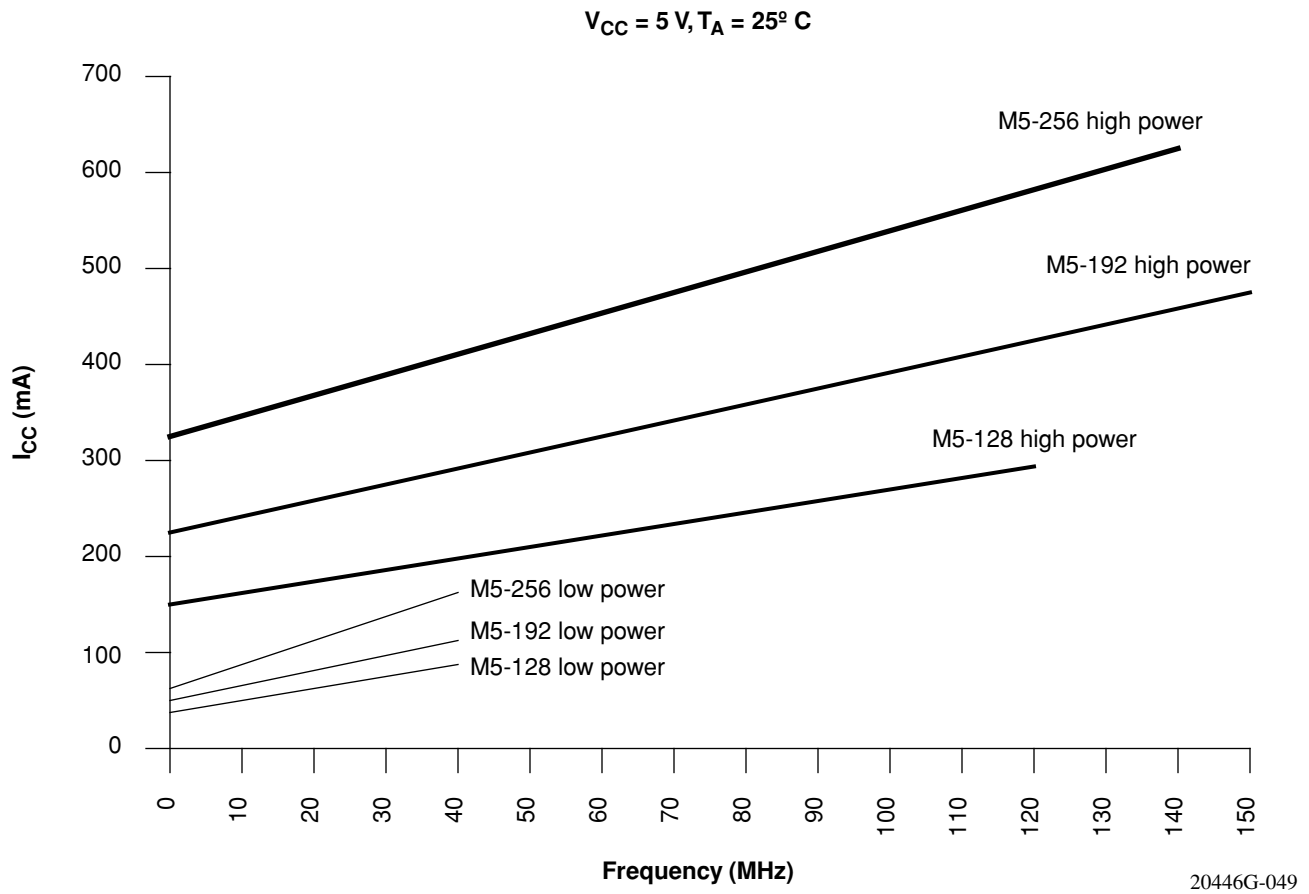


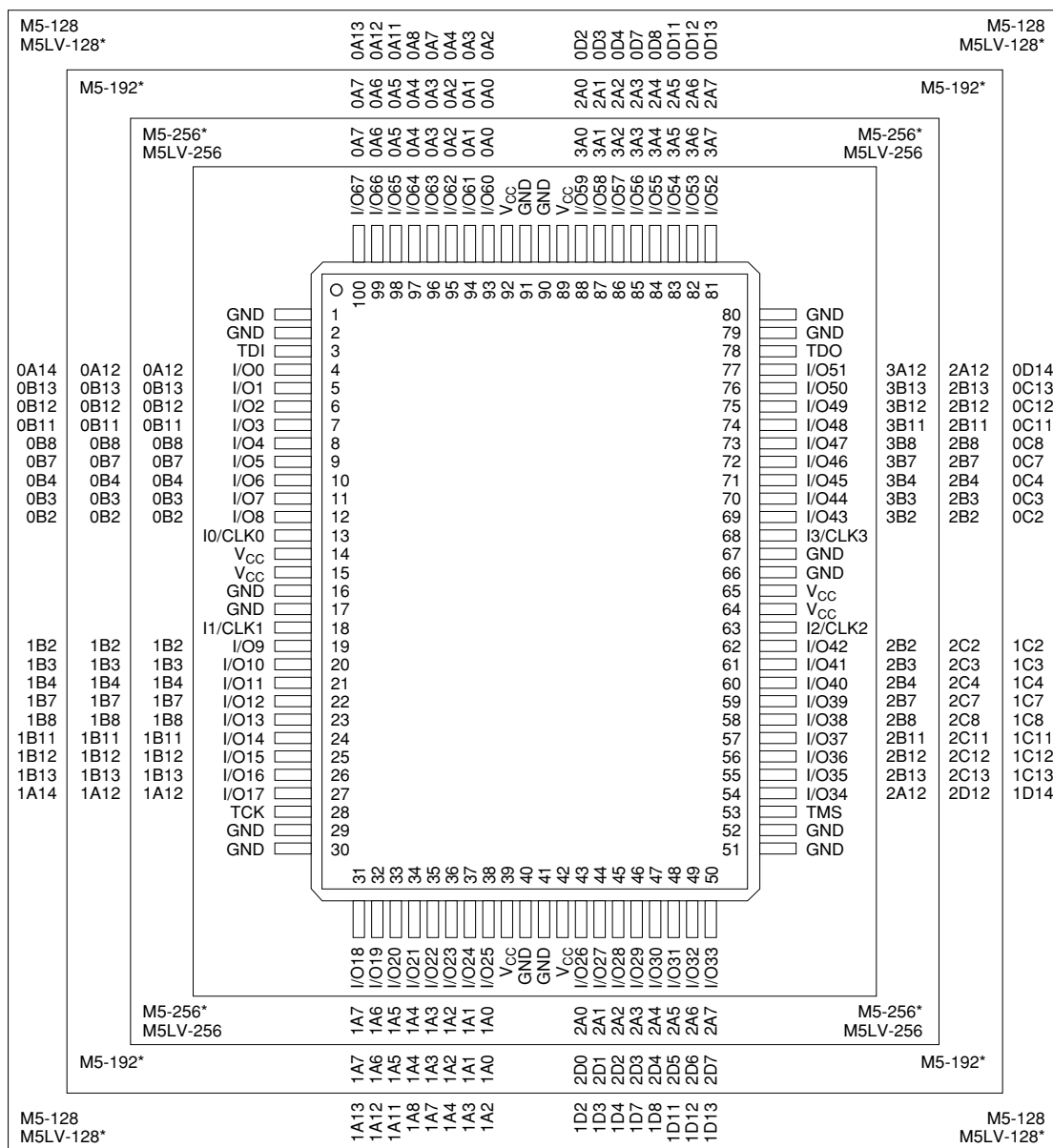
Figure 9.  $I_{CC}$  Curves at High/Low Power Modes

Select devices have been discontinued.  
See Ordering Information section for product status.

## 100-PIN PQFP CONNECTION DIAGRAM

### Top View

100-Pin PQFP (68 I/O)



\*Package obsolete, contact factory.

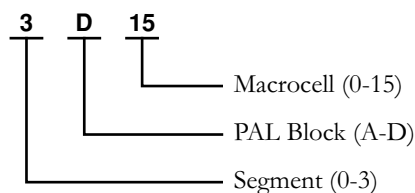
20446G-016

Select devices have been discontinued.  
See Ordering Information section for product status.

### 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

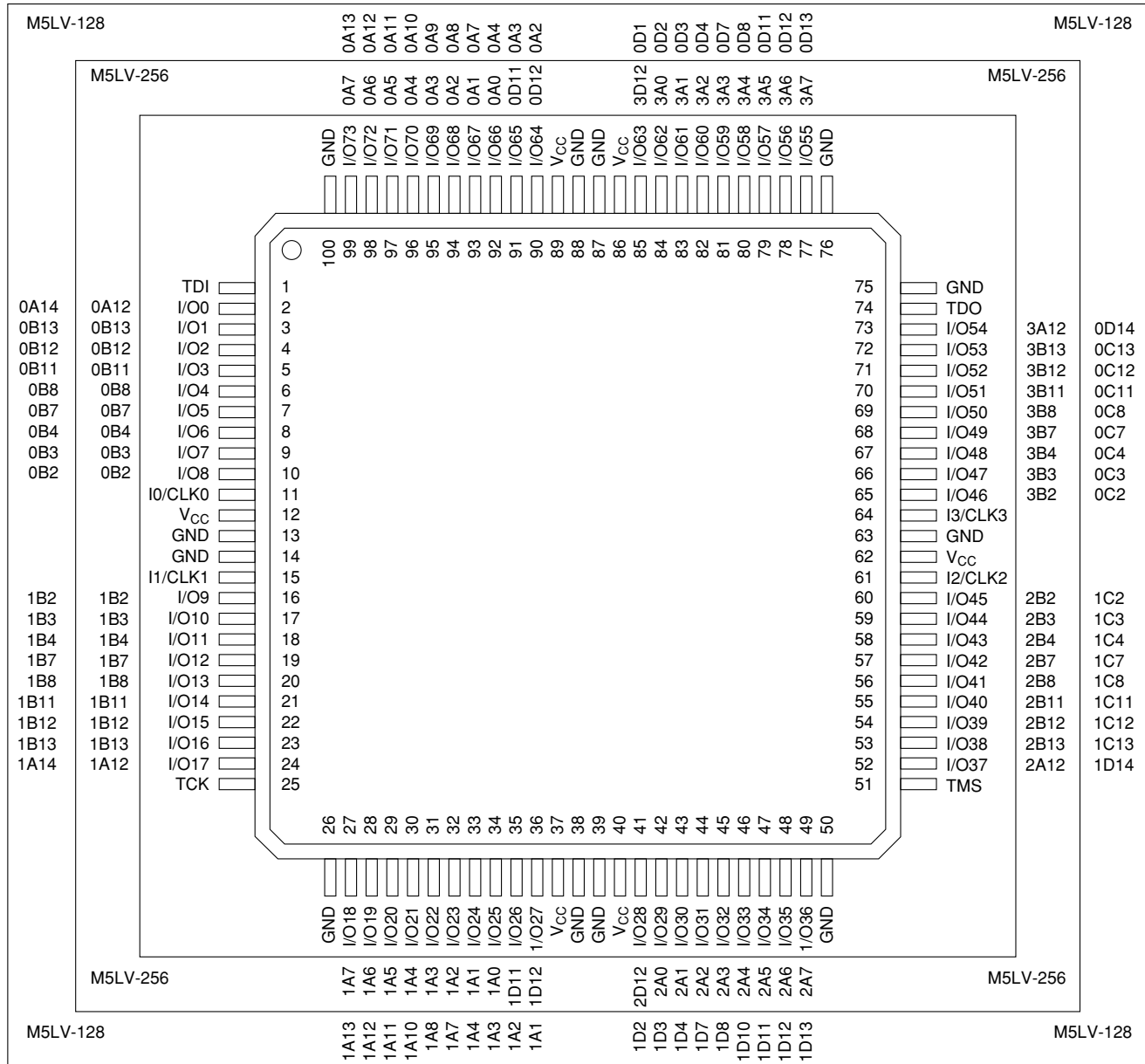




# 100-PIN TQFP CONNECTION DIAGRAM – 74 I/O

## Top View

100-Pin TQFP (74 I/O)

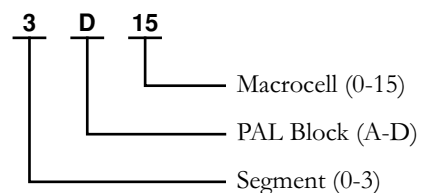


Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-018

### Pin Designations

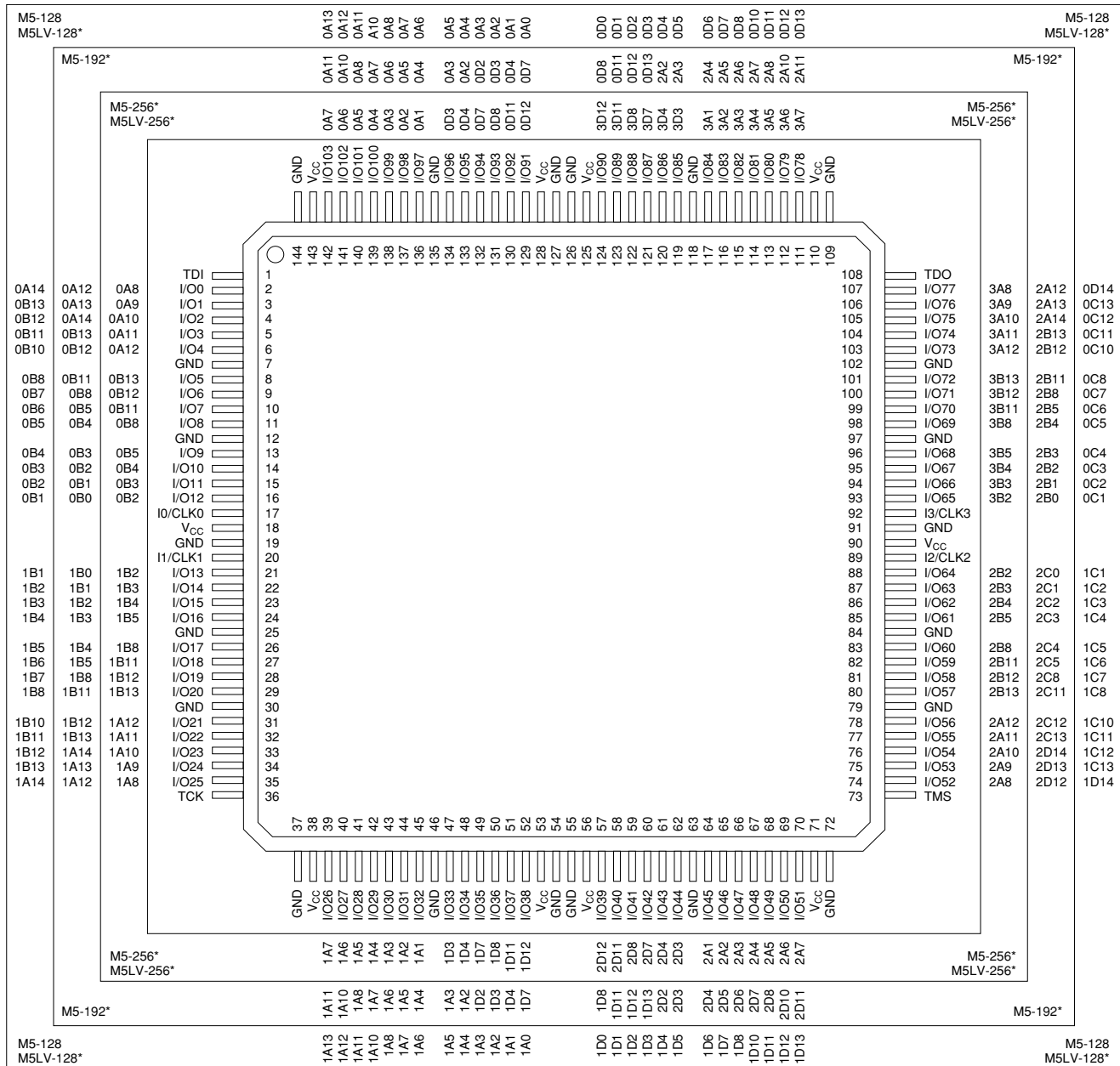
|                    |                                  |
|--------------------|----------------------------------|
| CLK = Clock        | V <sub>CC</sub> = Supply Voltage |
| GND = Ground       | TDI = Test Data In               |
| I = Input          | TCK = Test Clock                 |
| I/O = Input/Output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



# 144-PIN PQFP CONNECTION DIAGRAM

## Top View

144-Pin PQFP



Select devices have been discontinued.  
See Ordering Information section for product status.

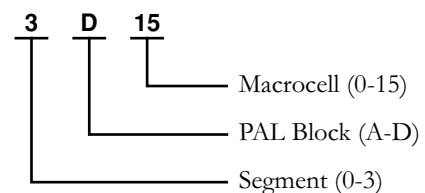
\*Package obsolete, contact factory.

20446G-019

### Pin Designations

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

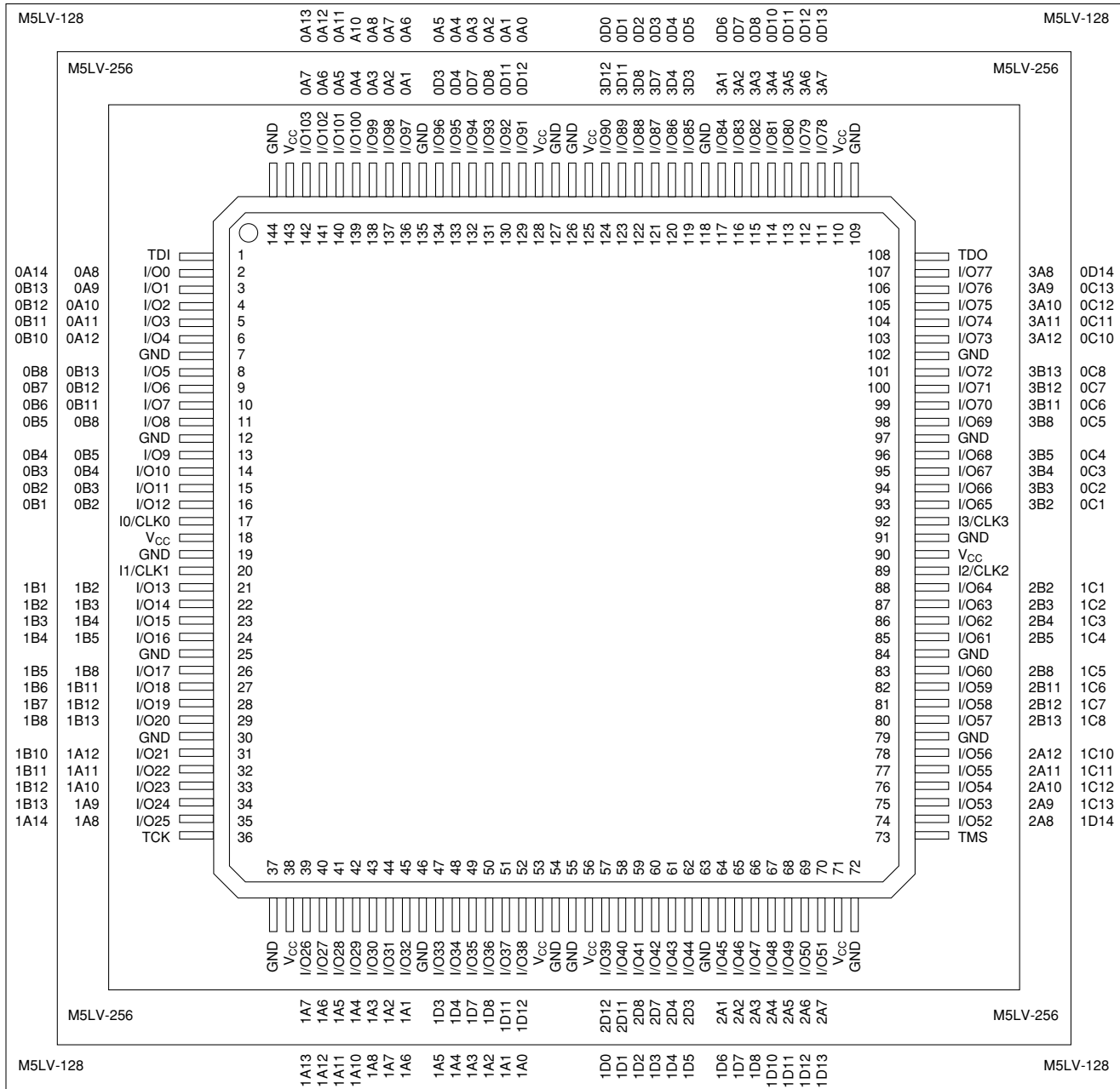
V<sub>CC</sub> = Supply Voltage  
TDI = Test Data In  
TCK = Test Clock  
TMS = Test Mode Select  
TDO = Test Data Out



# 144-PIN TQFP CONNECTION DIAGRAM

## Top View

144-Pin TQFP



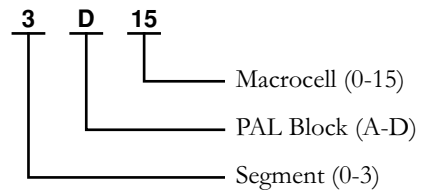
Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-020

### Pin Designations

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

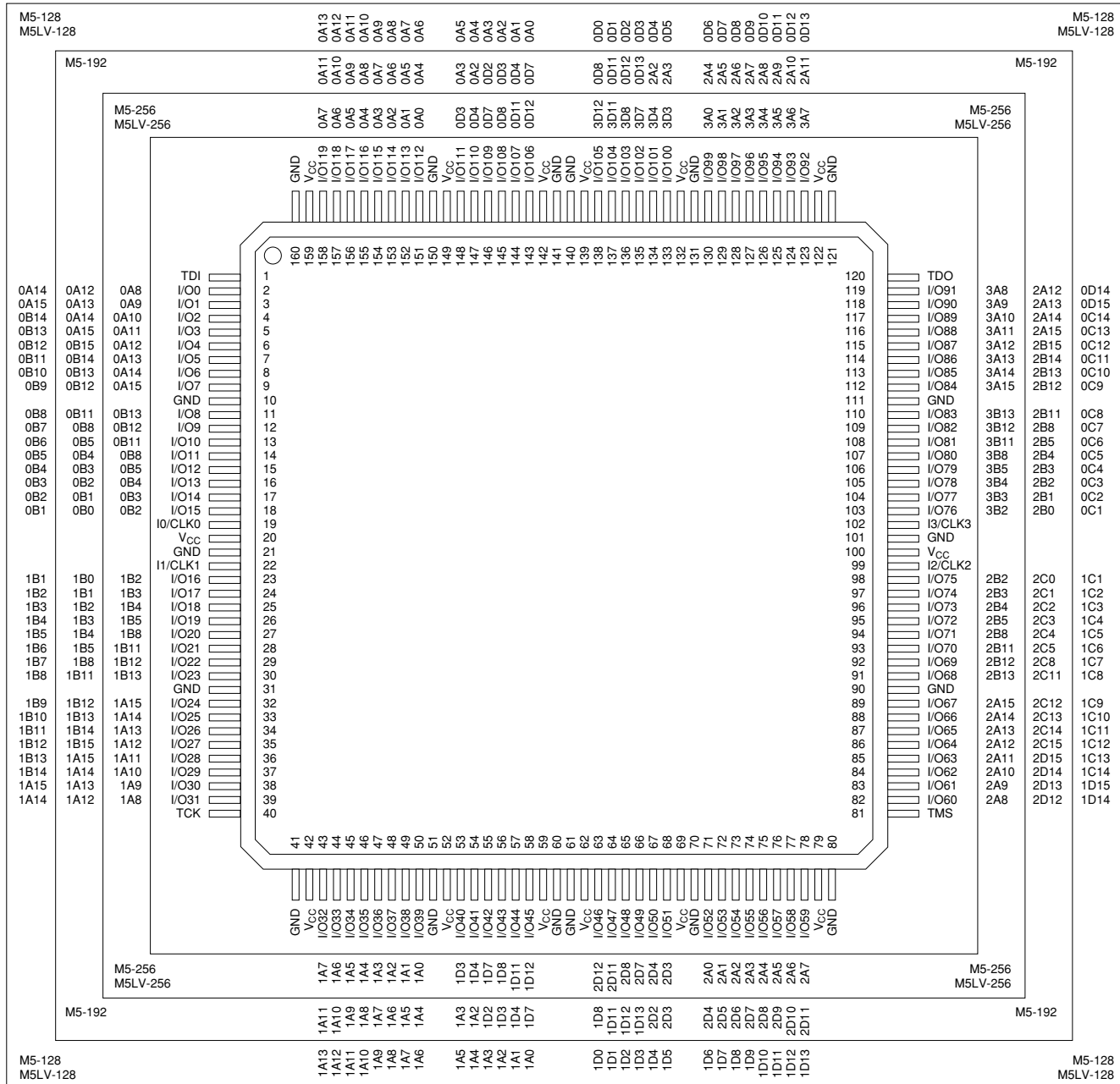
V<sub>CC</sub> = Supply Voltage  
TDI = Test Data In  
TCK = Test Clock  
TMS = Test Mode Select  
TDO = Test Data Out



# 160-PIN PQFP CONNECTION DIAGRAM

## Top View

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



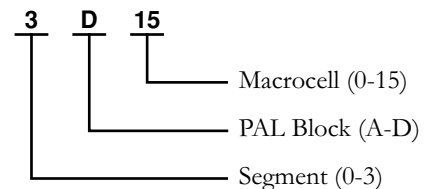
Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-021

### Pin Designations

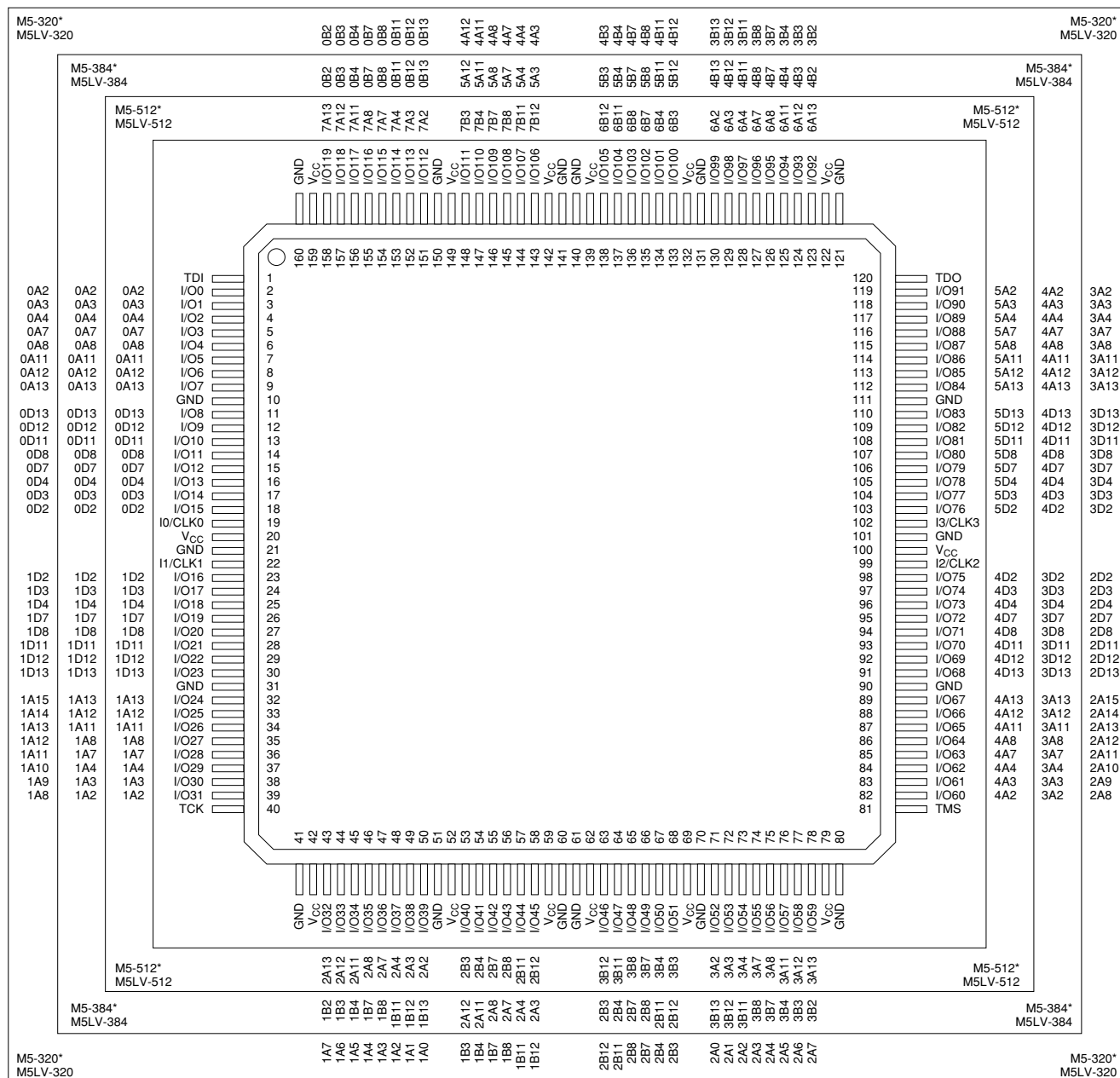
CLK = Clock  
GND = Ground  
I = Input  
I/O = Input/Output  
NC = No Connect

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.

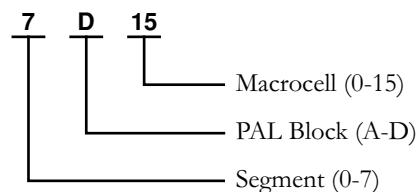
Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-022

## Pin Designations

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

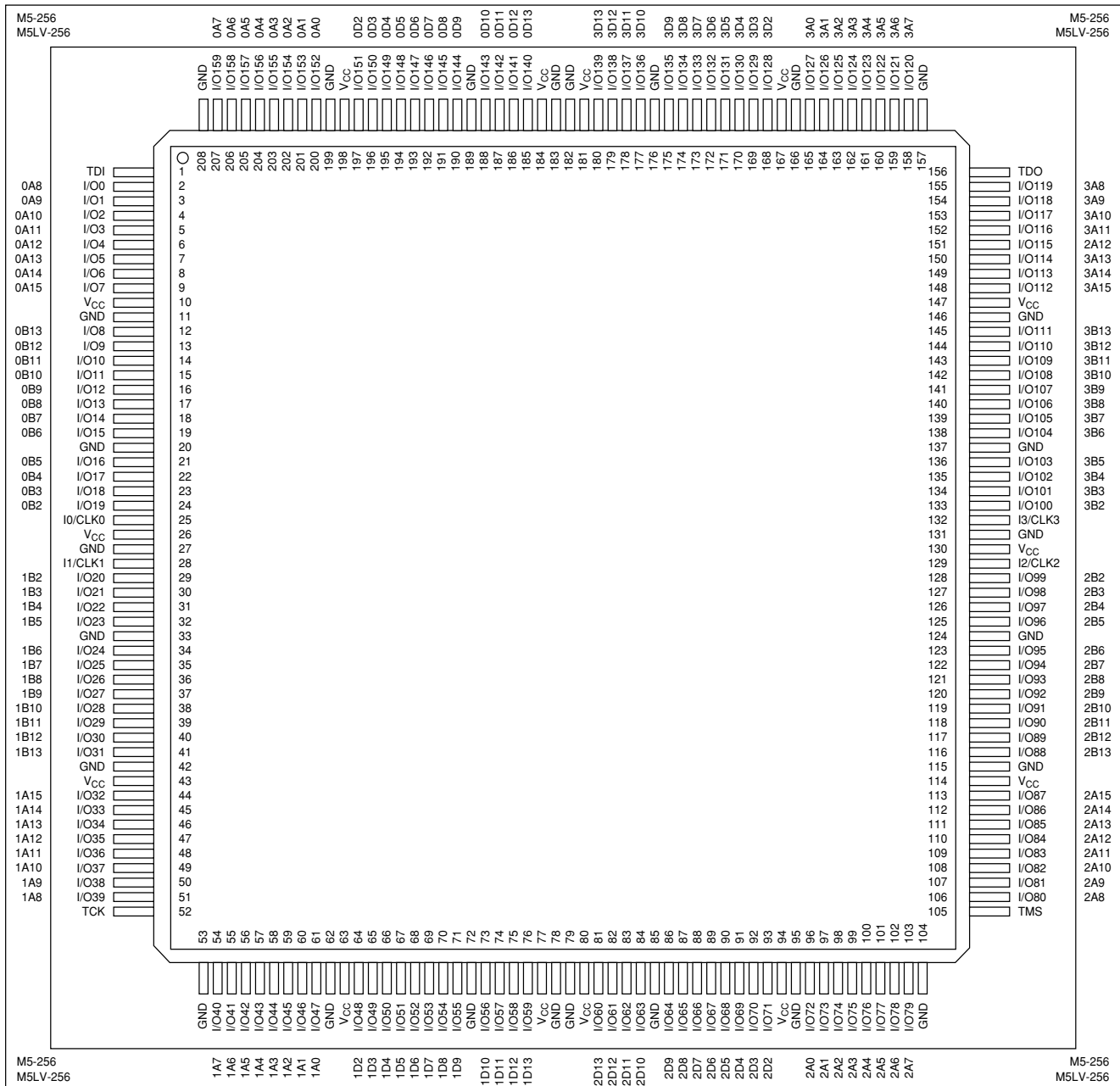
V<sub>CC</sub> = Supply Voltage  
TDI = Test Data In  
TCK = Test Clock  
TMS = Test Mode Select  
TDO = Test Data Out



## 208-PIN PQFP CONNECTION DIAGRAM

### Top View

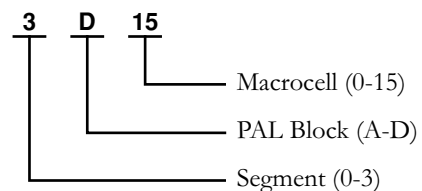
208-Pin PQFP (256 Macrocells)



Select devices have been discontinued.  
See Ordering Information section for product status.

### Pin Designations

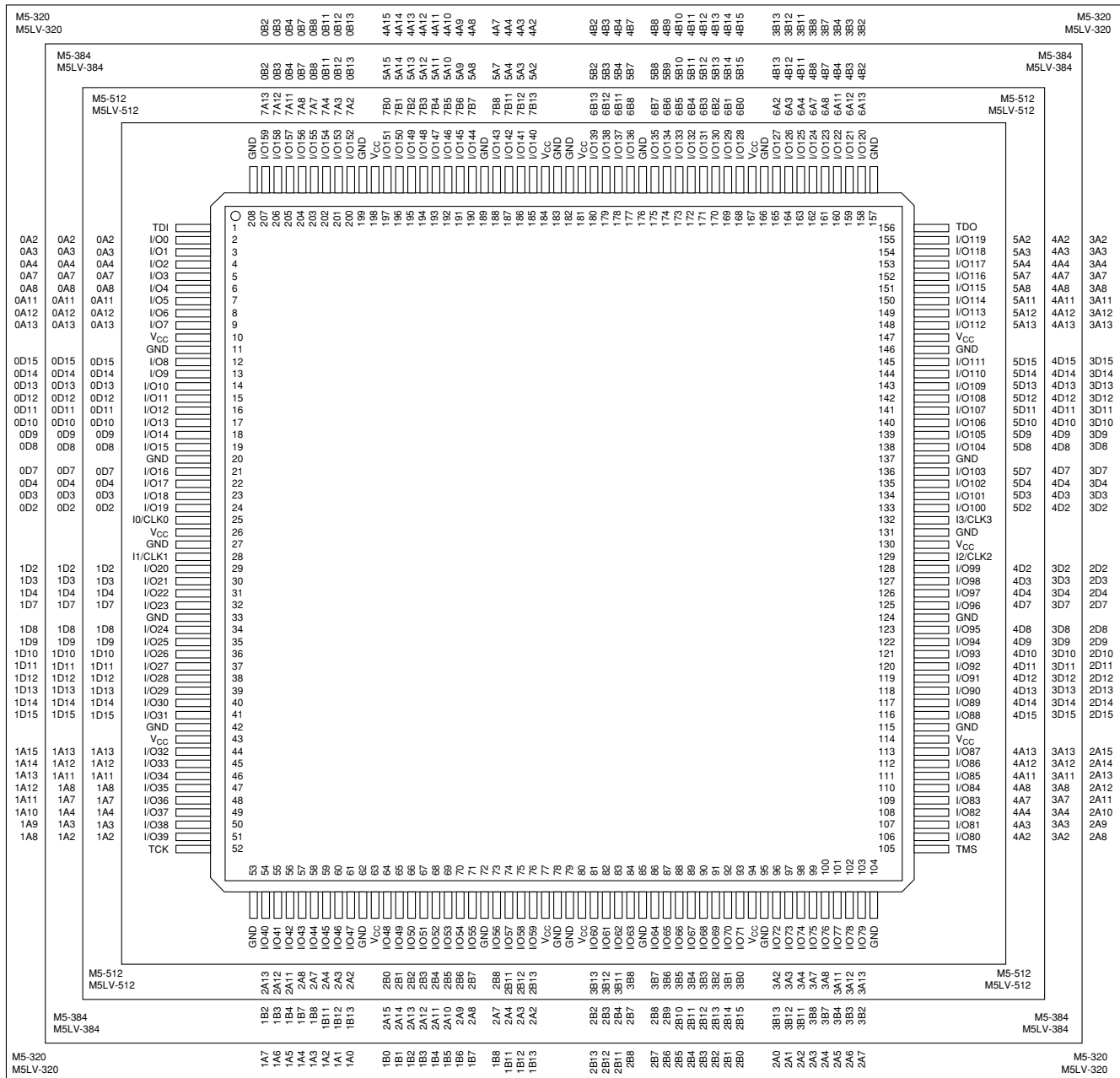
|     |   |              |     |   |                  |
|-----|---|--------------|-----|---|------------------|
| CLK | = | Clock        | VCC | = | Supply Voltage   |
| GND | = | Ground       | TDI | = | Test Data In     |
| I   | = | Input        | TCK | = | Test Clock       |
| I/O | = | Input/Output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



20446G-023

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

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



Select devices have been discontinued.  
See Ordering Information section for product status.

20446G-024

## 256-BALL BGA CONNECTION DIAGRAM — M5-320

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

256-Ball BGA

|   | 20    | 19    | 18              | 17              | 16              | 15    | 14              | 13    | 12    | 11    | 10    | 9      | 8      | 7               | 6      | 5               | 4               | 3               | 2      | 1      |   |
|---|-------|-------|-----------------|-----------------|-----------------|-------|-----------------|-------|-------|-------|-------|--------|--------|-----------------|--------|-----------------|-----------------|-----------------|--------|--------|---|
| A | GND   | I/O11 | GND             | I/O44           | I/O58           | GND   | I/O70           | I/O76 | GND   | GND   | GND   | GND    | I/O108 | I/O116          | GND    | I/O128          | I/O134          | GND             | GND    | GND    | A |
| B | GND   | I/O12 | I/O28           | I/O45           | I/O59           | I/O64 | I/O71           | I/O77 | I/O84 | I/O90 | I/O96 | I/O102 | I/O109 | I/O117          | I/O122 | I/O129          | I/O135          | I/O148          | I/O164 | GND    | B |
| C | I/O0  | I/O13 | V <sub>CC</sub> | I/O46           | I/O60           | I/O65 | I/O72           | I/O78 | I/O85 | I/O91 | I/O97 | I/O103 | I/O110 | I/O118          | I/O123 | I/O130          | I/O136          | V <sub>CC</sub> | I/O165 | I/O181 | C |
| D | I/O1  | I/O14 | I/O29           | V <sub>CC</sub> | V <sub>CC</sub> | I/O66 | V <sub>CC</sub> | I/O79 | I/O86 | I/O92 | I/O98 | I/O104 | I/O111 | V <sub>CC</sub> | I/O124 | V <sub>CC</sub> | V <sub>CC</sub> | I/O149          | I/O166 | I/O182 | D |
| E | I/O2  | I/O15 | I/O30           | TDI             |                 |       |                 |       |       |       |       |        |        |                 |        |                 | TDI             | I/O150          | I/O167 | I/O183 | E |
| F | GND   | I/O16 | I/O31           | I/O47           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O137          | I/O151          | I/O168 | GND    | F |
| G | I/O3  | I/O17 | I/O32           | V <sub>CC</sub> |                 |       |                 |       |       |       |       |        |        |                 |        |                 | V <sub>CC</sub> | I/O152          | I/O169 | I/O184 | G |
| H | GND   | I/O18 | I/O33           | I/O48           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O138          | I/O153          | I/O170 | GND    | H |
| J | I/O4  | I/O19 | I/O34           | I/O49           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O139          | I/O154          | I/O171 | I/O185 | J |
| K | GND   | I/O20 | I/O35           | I/O50           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O140          | I/O155          | I/O172 | I/O186 | K |
| L | I/O5  | I/O21 | I/O36           | I/O51           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O141          | I/O156          | I/O173 | GND    | L |
| M | I/O6  | I/O22 | I/O37           | I/O52           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O142          | I/O157          | I/O174 | I/O187 | M |
| N | GND   | I/O23 | I/O38           | I/O53           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O143          | I/O158          | I/O175 | GND    | N |
| P | I/O7  | I/O24 | I/O39           | V <sub>CC</sub> |                 |       |                 |       |       |       |       |        |        |                 |        |                 | V <sub>CC</sub> | I/O159          | I/O176 | I/O188 | P |
| R | GND   | I/O25 | I/O40           | I/O54           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O144          | I/O160          | I/O177 | GND    | R |
| T | I/O8  | I/O26 | I/O41           | TCK             |                 |       |                 |       |       |       |       |        |        |                 |        |                 | TMS             | I/O161          | I/O178 | I/O189 | T |
| U | I/O9  | I/O27 | I/O42           | V <sub>CC</sub> |                 |       |                 |       |       |       |       |        |        |                 |        |                 | V <sub>CC</sub> | I/O162          | I/O179 | I/O190 | U |
| V | I/O10 | I/O28 | V <sub>CC</sub> | I/O55           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O145          | V <sub>CC</sub> | I/O180 | I/O191 | V |
| W | GND   | I/O29 | I/O43           | I/O56           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O146          | I/O163          | I/O181 | GND    | W |
| Y | GND   | I/O30 | GND             | I/O57           |                 |       |                 |       |       |       |       |        |        |                 |        |                 | I/O147          | GND             | I/O182 | I/O192 | Y |

#### 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    |

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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  | 1   |   |
| 2  | GND  | 3B2  | 3A3             | 3A8             | 3A13                                                                                                                                                                                                                                                                                                                           | 3D13 | 3D9             | 3D8             | 3D4  | 3D3 | I3/CLK3 | 2D3 | 2D4  | 2D8             | 2D12            | 2A15 | 2A13            | 2A12            | 2A9  | 2A7  | 2   |   |
| 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  | 3   |   |
| 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  | 4   |   |
| 5  | 4B14 | 4B15 | 3B4             | V <sub>CC</sub> | <div>Pin Designations</div> <div>CLK = Clock</div> <div>GND = Ground</div> <div>I = Input</div> <div>I/O = Input/Output</div> <div>NC = No Connect</div> <div>V<sub>CC</sub> = Supply Voltage</div> <div>TDI = Test Data In</div> <div>TCK = Test Clock</div> <div>TMS = Test Mode Select</div> <div>TDO = Test Data Out</div> |      |                 |                 |      |     |         |     |      |                 |                 |      | V <sub>CC</sub> | 2A4             | 2A5  | 2B0  | 2B1 | 5 |
| 6  | GND  | 4B11 | 3B12            | 3B7             |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | V <sub>CC</sub> | 2A1             | 2B4  | GND  | 6   |   |
| 7  | 4B8  | 4B10 | 4B13            | V <sub>CC</sub> |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 2B3             | 2B6             | 2B5  | 2B7  | 7   |   |
| 8  | 4B4  | 4B6  | 4B9             | 4B12            |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 2B8             | 2B10            | 2B12 | 2B11 | 8   |   |
| 9  | GND  | 4B3  | 4B5             | 4B7             |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 2B13            | 2B14            | 2B15 | GND  | 9   |   |
| 10 | GND  | 4B0  | 4B1             | 4B2             |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 1B13            | 1B14            | 1B15 | GND  | 10  |   |
| 11 | GND  | 4A0  | 4A1             | 4A2             |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 1B8             | 1B10            | 1B12 | GND  | 11  |   |
| 12 | GND  | 4A3  | 4A5             | 4A7             |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 1B3             | 1B6             | 1B9  | 1B11 | 12  |   |
| 13 | 4A4  | 4A6  | 4A9             | 4A12            |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | V <sub>CC</sub> | 1B2             | 1B5  | 1B7  | 13  |   |
| 14 | 4A8  | 4A10 | 4A13            | V <sub>CC</sub> |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | 1A4             | 1A1             | 1B4  | GND  | 14  |   |
| 15 | GND  | 4A11 | 0B12            | 0B7             |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | V <sub>CC</sub> | 1A5             | 1B0  | 1B1  | 15  |   |
| 16 | 4A14 | 4A15 | 0B4             | V <sub>CC</sub> |                                                                                                                                                                                                                                                                                                                                |      |                 |                 |      |     |         |     |      |                 |                 |      | V <sub>CC</sub> | 1A6             | 1A2  | 1A0  | 16  |   |
| 17 | 0B13 | 0B11 | 0B3             | V <sub>CC</sub> | TDI                                                                                                                                                                                                                                                                                                                            | 0A4  | 0A7             | V <sub>CC</sub> | 0D11 | 0D6 | 0D1     | 1D1 | 1D6  | 1D11            | V <sub>CC</sub> | TCK  | 1A8             | V <sub>CC</sub> | GND  | 17   |     |   |
| 18 | GND  | 0B8  | V <sub>CC</sub> | 0A2             | 0A13                                                                                                                                                                                                                                                                                                                           | 0A12 | 0D14            | 0D8             | 0D4  | 0D3 | I0/CLK0 | 1D0 | 1D5  | 1D10            | 1A14            | 1A10 | 1A12            | 1A9             | 1A3  | GND  | 18  |   |
| 19 | 0B2  | 0A3  | 0A8             | 0A11            | 0A13                                                                                                                                                                                                                                                                                                                           | 0D12 | 0D8             | 0D4             | 0D3  | GND | I0/CLK0 | 1D4 | 1D8  | 1D9             | 1D13            | 1A15 | 1A12            | 1A9             | 1A7  | GND  | 19  |   |
| 20 | GND  | GND  | 0D15            | 0D13            | 0D10                                                                                                                                                                                                                                                                                                                           | GND  | 0D7             | GND             | 0D2  | GND | 1D2     | 1D3 | GND  | 1D7             | GND             | 1D12 | 1D15            | 1A13            | GND  | GND  | 20  |   |

4

D

15

Macrocell (0-15)

PAL Block (A-D)

Segment (0-4)

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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 I <sub>3</sub> /CLK <sub>3</sub> | 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 <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 | I/O203 | I/O204 |
| 5  | GND    | I/O183 | I/O184 | V <sub>CC</sub> |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O185          | I/O186 | I/O187 | GND    |
| 6  | NC     | I/O176 | I/O177 | I/O178          | I/O171          |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O179          | I/O180 | I/O181 | I/O182 |
| 7  | GND    | I/O169 | I/O170 | I/O171          | I/O165          |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O172          | I/O173 | I/O174 | I/O175 |
| 8  | I/O162 | I/O163 | I/O164 | I/O165          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O166          | I/O167 | I/O168 | NC     |
| 9  | I/O156 | I/O157 | I/O158 | I/O159          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | V <sub>CC</sub> | I/O160 | I/O161 | GND    |
| 10 | GND    | I/O150 | I/O151 | V <sub>CC</sub> | I/O145          |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O152          | I/O153 | I/O154 | I/O155 |
| 11 | I/O142 | I/O143 | I/O144 | I/O145          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O146          | I/O147 | I/O148 | I/O149 |
| 12 | I/O134 | I/O135 | I/O136 | I/O137          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O138          | I/O139 | I/O140 | I/O141 |
| 13 | I/O128 | I/O129 | I/O130 | I/O131          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | V <sub>CC</sub> | I/O132 | I/O133 | GND    |
| 14 | GND    | I/O122 | I/O123 | V <sub>CC</sub> |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O124          | I/O125 | I/O126 | I/O127 |
| 15 | I/O114 | I/O115 | I/O116 | I/O117          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O118          | I/O119 | I/O120 | I/O121 |
| 16 | NC     | I/O107 | I/O108 | I/O109          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O110          | I/O111 | I/O112 | I/O113 |
| 17 | I/O101 | I/O102 | I/O103 | I/O104          |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | V <sub>CC</sub> | I/O105 | I/O106 | GND    |
| 18 | GND    | I/O87  | I/O88  | I/O89           | V <sub>CC</sub> |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O97           | I/O98  | I/O99  | I/O100 |
| 19 | I/O80  | I/O81  | I/O82  | I/O83           |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O91           | I/O92  | I/O93  | I/O94  |
| 20 | I/O73  | I/O74  | I/O75  | I/O76           |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O84           | I/O85  | I/O86  | GND    |
| 21 | GND    | I/O68  | I/O69  | I/O70           |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | I/O77           | I/O78  | I/O79  | NC     |
| 22 |        |        |        |                 |                 |        |                 |                 |                 |                 |        |        |                                         |                 |        |        |                 |                 |                 |                 |        |        | V <sub>CC</sub> | I/O71  | I/O72  | GND    |
| 23 | I/O51  | I/O52  | I/O53  | V <sub>CC</sub> | I/O54           | I/O55  | V <sub>CC</sub> | I/O56           | V <sub>CC</sub> | I/O57           | I/O58  | I/O59  | V <sub>CC</sub>                         | I/O60           | I/O61  | I/O62  | V <sub>CC</sub> | I/O63           | V <sub>CC</sub> | I/O64           | I/O65  | I/O66  | TCK             | NC     | I/O67  | 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     | GND    | GND    |
| 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 <sub>0</sub> /CLK <sub>0</sub>  | I/O22           | I/O23  | I/O24  | I/O25           | I/O26           | I/O27           | I/O28           | I/O29  | I/O30  | I/O31           | NC     | NC     | NC     |
| 26 | NC     | NC     | GND    | I/O0            | NC              | GND    | I/O1            | I/O2            | GND             | I/O3            | I/O4   | I/O5   | GND I <sub>1</sub> /CLK <sub>1</sub>    | I/O6            | I/O7   | GND    | I/O8            | I/O9            | GND             | I/O10           | NC     | GND    | 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    |

20446G-030

Select devices have been discontinued.  
See Ordering Information section for product status.

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

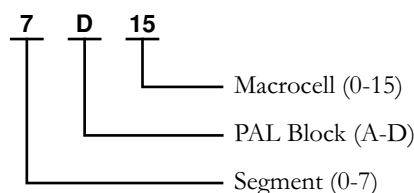
### Bottom View (Macrocell Association)

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  | GND  |
| 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 <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 | 3A13 | 3A12 |
| 5  | GND  | 6A12 | 6A13 | V <sub>CC</sub> |     |      |                 |                 |                 |                 |      |     |         |                 |     |     |      |                 |      |                 |      |     | 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  | 3B0  | NC   |
| 9  | 6B1  | 6A0  | 6A2  | 6A3             |     |      |                 |                 |                 |                 |      |     |         |                 |     |     |      |                 |      |                 |      |     | V <sub>CC</sub> | 3B1  | 3B2  | GND  |
| 10 | GND  | 6B2  | 6B0  | V <sub>CC</sub> |     |      |                 |                 |                 |                 |      |     |         |                 |     |     |      |                 |      |                 |      |     | 3B3             | 3B4  | 3B5  | 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 <sub>CC</sub> | 2B15 | 3B15 | GND  |
| 14 | GND  | 7B15 | 6B15 | V <sub>CC</sub> |     |      |                 |                 |                 |                 |      |     |         |                 |     |     |      |                 |      |                 |      |     | 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 <sub>CC</sub> | 2B0  | 2B2  | GND  |
| 18 | GND  | 7B3  | 7B2  | V <sub>CC</sub> |     |      |                 |                 |                 |                 |      |     |         |                 |     |     |      |                 |      |                 |      |     | 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 <sub>CC</sub> | 2A13 | 2A12 | GND  |
| 23 | 7A10 | 7A13 | 7A14 | V <sub>CC</sub> |     |      |                 |                 |                 |                 |      |     |         |                 |     |     |      |                 |      |                 |      |     | TCK             | NC   | 2A14 | NC   |
| 24 | NC   | NC   | TDI  | 0A2             | 0A0 | 0A4  | V <sub>CC</sub> | 0A11            | V <sub>CC</sub> | 0D14            | 0D12 | 0D8 | 0D3     | V <sub>CC</sub> | 1D2 | 1D7 | 1D12 | V <sub>CC</sub> | 1A10 | 1A6             | 1A3  | 1A4 | 1A1             | NC   | GND  | GND  |
| 25 | GND  | GND  | 0A1  | 0A3             | 0A8 | 0A7  | 0A10            | 0A15            | 0D13            | 0D10            | 0D7  | 0D2 | 0D0     | I0/CLK0         | 1D1 | 1D5 | 1D9  | 1D14            | 1A15 | 1A14            | 1A9  | 1A5 | 1A2             | NC   | NC   | NC   |
| 26 | NC   | NC   | GND  | 0A6             | NC  | GND  | 0A13            | 0D15            | GND             | 0D9             | 0D5  | 0D1 | GND     | I1/CLK1         | 1D3 | 1D6 | GND  | 1D11            | 1D15 | GND             | 1A12 | NC  | GND             | 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

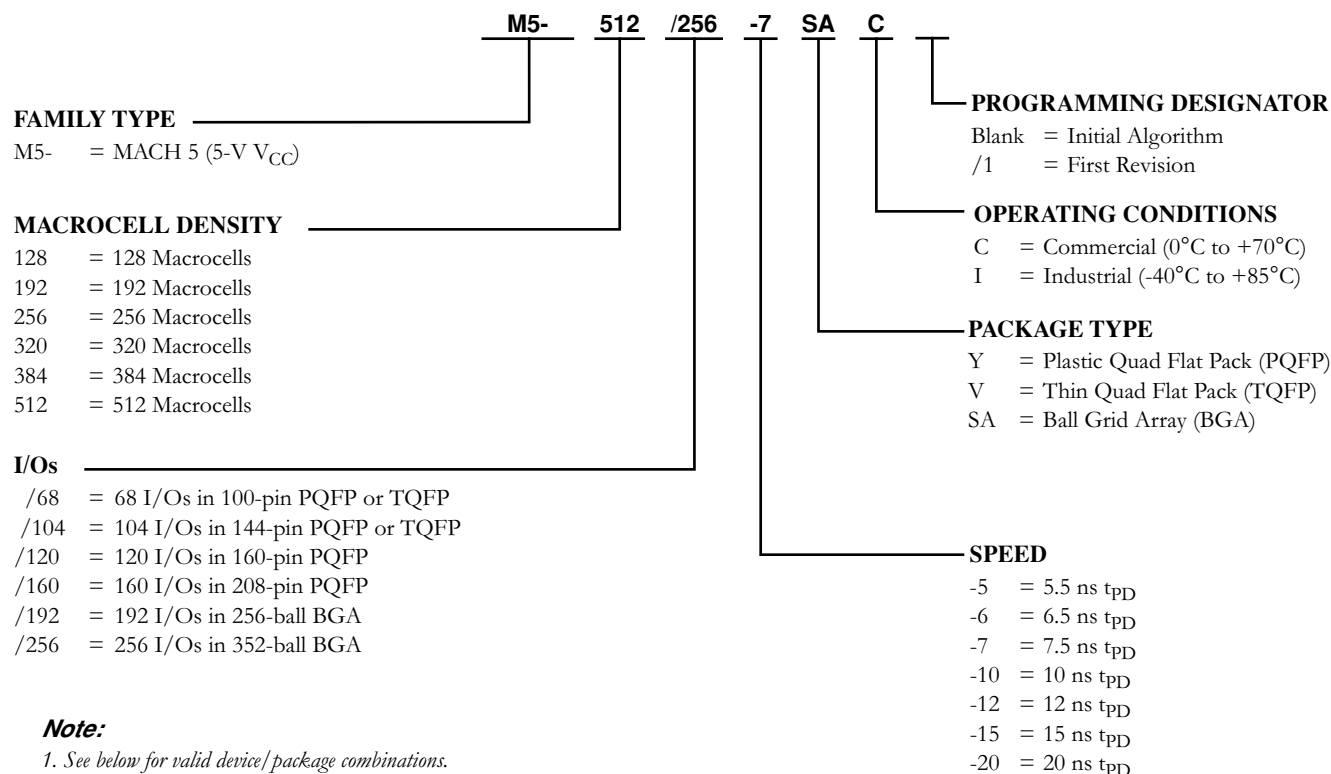


20446G-031

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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 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:<br>-5, -7, -10, -12, -15<br>Industrial:<br>-7, -10, -12, -15, -20 | YC, VC, YI, VI                    |
| M5-128/104         |                                                                               | YC <sup>1</sup> , YI <sup>1</sup> |
| 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 devices are dual-marked with both Commercial and Industrial grades. The Industrial grade is slower, i.e., M5-512/256-7AC-10AI.

1. M5-128/104-xxYC/1 and M5-128/104-xxYI/1 have been discontinued per PCN #06-07. Contact Rochester Electronics for available inventory.

| Valid Combinations |                                                                               |          |
|--------------------|-------------------------------------------------------------------------------|----------|
| M5-320/160         | Commercial:<br>-6, -7, -10, -12, -15<br>Industrial:<br>-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 |

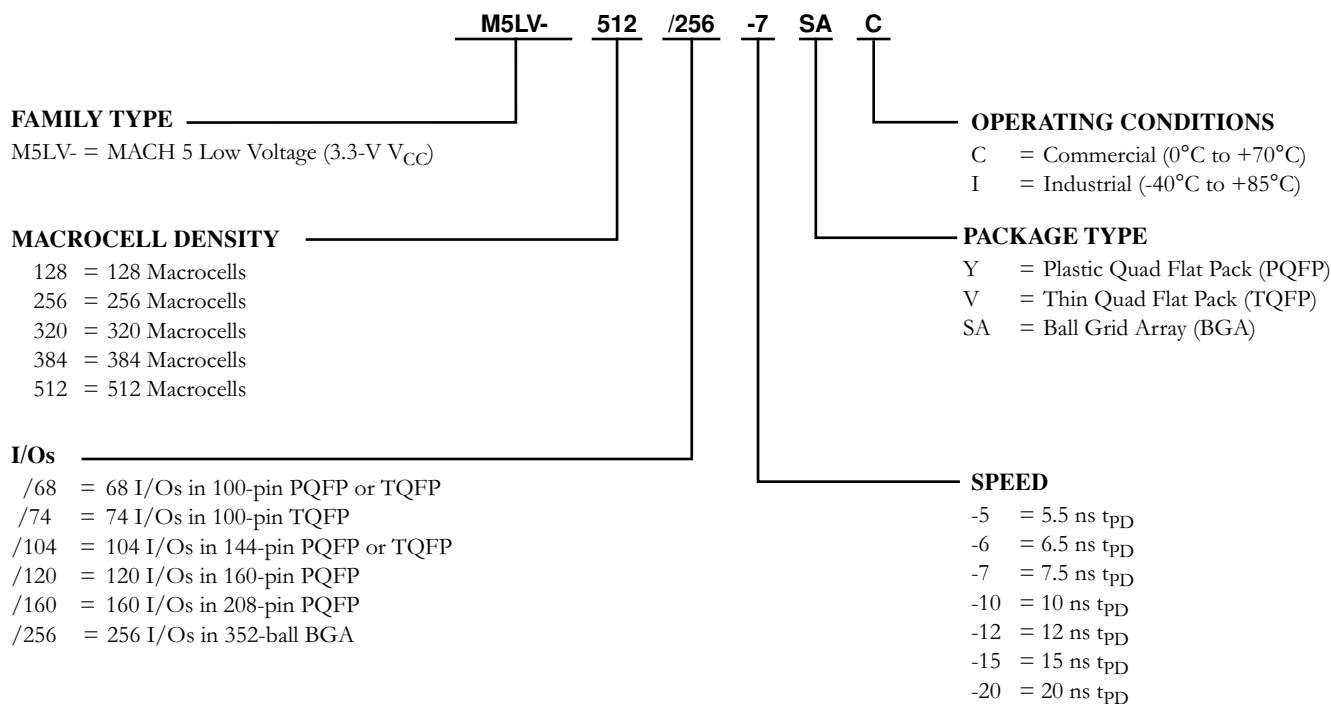
### Valid Combinations

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.

Select devices have been discontinued.  
See Ordering Information section for product status.

## 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 formed by a combination of the elements below.



**Note:**

1. See below for valid device/package combinations.

| Valid Combinations |                                  |        |
|--------------------|----------------------------------|--------|
| M5LV-128/68        | Commercial:<br>-5, -7, -10, -12  | VC, VI |
| M5LV-128/74        |                                  | VC, VI |
| M5LV-128/104       |                                  | VC, VI |
| M5LV-128/120       |                                  | YC, YI |
| M5LV-256/68        | Industrial:<br>-7, -10, -12, -15 | 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:<br>-6, -7, -10, -12, -15 | YC, YI   |
| M5LV-320/160       |                                      | YC, YI   |
| M5LV-384/120       |                                      | YC, YI   |
| M5LV-384/160       |                                      | YC, YI   |
| M5LV-512/120       | Industrial:<br>-10, -12, -15, -20    | 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.

Select devices have been discontinued.  
See Ordering Information section for product status.