AT27C512R

512-Kbit (64K x 8) One-Time Programmable, Read-Only Memory

Features

- Fast Read Access Time: 45 ns
- Low-Power CMOS Operation:
  - 100 µA maximum standby
  - 20 mA maximum active at 5 MHz
- 5V ± 10% Supply
- High Reliability CMOS Technology:
  - 2,000V ESD protection
  - 200 mA latch-up immunity
- Rapid Programming Algorithm – 100 µs/byte (typical)
- CMOS and TTL Compatible Inputs and Outputs
- Integrated Product Identification Code
- Industrial Temperature Range: -40°C to +85°C
- Green Package Options (Lead-free/Halide-free/RoHS compliant)

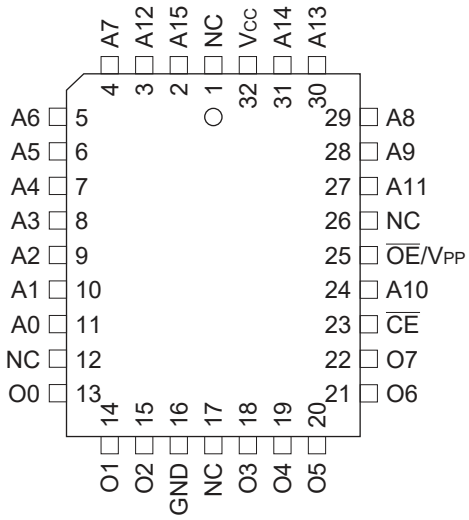
Packages

- 32-Lead PLCC and 28-Lead PDIP

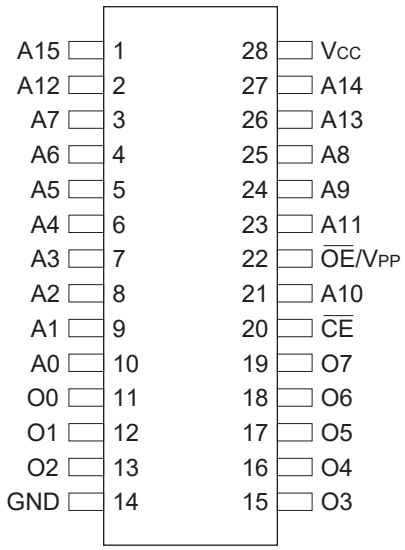
Table of Contents

1. Package Types (not to scale)

32-Lead PLCC [1]
Top View



28-Lead PDIP
Top View



Note:

1. PLCC package pins 1, 12, 17 and 26 are not connected.

2. Pin Description

The description of the pins are listed in Table 2.1.

Table 2-1. Pin Description

Name	32-Lead PLCC	28-Lead PDIP	Function
A0 - A15	2-11; 24; 27-31	1-10; 21; 23-27	Address Inputs
O0 - O7	13-15; 18-22	11-13; 15-19	Outputs
$\overline{CE}$	23	20	Chip Enable
$\overline{OE}/V_{PP}$	25	22	Output Enable/Program Supply
NC	1; 12; 17; 26	—	Not Connected
V_{CC}	32	28	Device Power Supply
GND	16	14	Ground

3. Description

The Microchip AT27C512R is a low-power, high-performance, 524,288-bit, One-Time Programmable, Read-Only memory (OTP EPROM) organized as 65,536 words of 8 bits each. It requires only one 5V power supply in normal Read mode operation. Any byte can be accessed in less than 45 ns, eliminating the need for speed-reducing WAIT states on high-performance microprocessor systems.

The Microchip-scaled CMOS technology provides low active power consumption and fast programming. Power consumption is typically only 8 mA in Active mode and less than 10 µA in Standby mode.

The AT27C512R is available in a choice of industry-standard, JEDEC-approved, PDIP and PLCC packages. All devices feature two-line control ($\overline{CE}$, $\overline{OE}$) to give designers the flexibility to prevent bus contention.

With 64 Kbyte storage capability, the AT27C512R allows firmware to be stored reliably and to be accessed by the system without the delays of mass storage media.

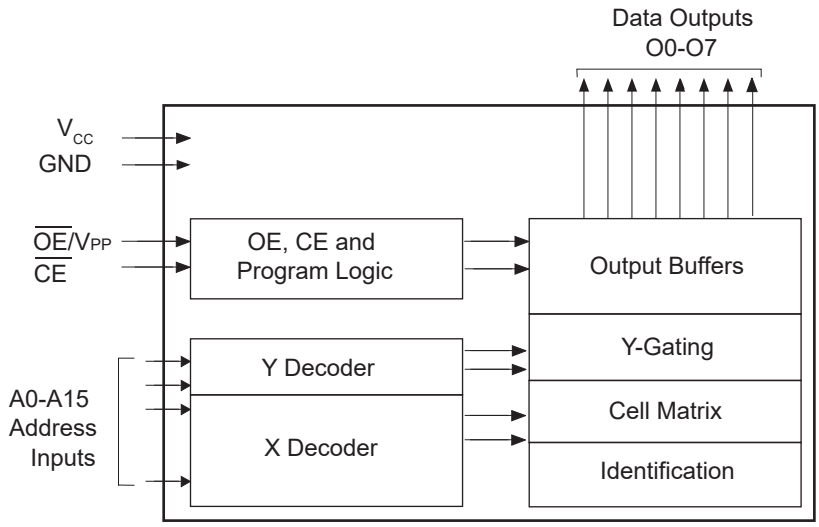
The AT27C512R has additional features to ensure high-quality and efficient production use. The rapid programming algorithm reduces the time required to program the part and guarantees reliable programming. Programming time is typically only 100 µs/byte. The integrated product identification code electronically identifies the device and manufacturer. This feature is used by industry-standard programming equipment to select the proper programming algorithms and voltages.

3.1 System Considerations

Switching between active and standby conditions via the chip enable pin may produce transient voltage excursions. Unless accommodated by the system design, these transients may exceed data sheet limits, resulting in device non-conformance. At a minimum, a 0.1 µF, high-frequency, low inherent inductance, ceramic capacitor should be utilized for each device. This capacitor should be connected between the V_{CC} and ground terminals of the device as close to the device as possible. Additionally, to stabilize the supply voltage level on printed circuit boards with large EPROM arrays, a 4.7 µF bulk electrolytic capacitor should be utilized and again connected between the V_{CC} and ground terminals. This capacitor should be positioned as close as possible to the point where the power supply is connected to the array.

3.2 Block Diagram

Figure 3-1. Block Diagram



4. Electrical Characteristics

4.1 Absolute Maximum Ratings

Temperature under bias	-55°C to +125°C
Storage temperature	-65°C to +150°C
Voltage on any pin with respect to ground	-2.0V to +7.0V(1)
Voltage on A9 with respect to ground	-2.0V to +14.0V(1)
V_{PP} supply voltage with respect to ground	-2.0V to +14.0V(1)

Note: Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note:

1. Minimum voltage is -0.6V DC, which may undershoot to -2.0V for pulses of less than 20 ns. Maximum output pin voltage is V_{CC} +0.75V DC, which may overshoot to +7.0V for pulses of less than 20 ns.

4.2 DC and AC Operating Range

Table 4-1. DC and AC Operating Range

Mode/Pin	$\overline{CE}$	$\overline{OE}/V_{PP}$	Ai	Outputs
Read	V_{IL}	V_{IL}	Ai	D_{OUT}
Output disable	V_{IL}	V_{IH}	X(1)	High-Z
Standby	V_{IH}	X(1)	X(1)	High-Z
Rapid program(2)	V_{IL}	V_{PP}	Ai	D_{IN}
PGM inhibit	V_{IH}	V_{PP}	X(1)	High-Z
Product identification(4)	V_{IL}	V_{IL}	A9 = V_H(3), A0 = V_{IH} or V_{IL} A1-A15 = V_{IL}	Identification code

Notes:

1. X can be V_{IL} or V_{IH}.
2. Refer to programming characteristics.
3. V_H = 12.0 ± 0.5V.
4. Two identifier bytes may be selected. All Ai inputs are held low (V_{IL}), except A9, which is set to V_H, and A0, which is toggled low (V_{IL}) to select the manufacturer’s identification byte and high (V_{IH}) to select the device code byte.

Table 4-2. DC and AC Operating Conditions for Read Operation

AT27C512R		-45	-70
Operating Temperature (Case)	Industrial Temperature Range	-40°C - 85°C	-40°C - 85°C
V_{CC} Supply		5V ± 10%	5V ± 10%

4.3 DC and Operating Characteristics for Read Operation

Table 4-3. DC and Operating Characteristics for Read Operation

Parameter	Symbol	Minimum	Maximum	Units	Condition	
Input Load Current	I_{LI}	—	±1	µA	Industrial	V_{IN} = 0V to V_{CC}
Output Leakage Current	I_{LO}	—	±5	µA	Industrial	V_{OUT} = 0V to V_{CC}
V_{CC}[1] Standby Current	I_{SB}	—	100	µA	I_{SB1} (CMOS), $\overline{CE}$ = V_{CC} ±0.3V	
			1	mA	I_{SB2} (TTL), $\overline{CE}$ = 2.0 to V_{CC} +0.5V	
V_{CC} Active Current	I_{CC}	—	20	mA	f = 5 MHz, I_{OUT} = 0 mA, $\overline{CE}$ = V_{IL}	
Input Low Voltage	V_{IL}	-0.6	0.8	V		
Input High Voltage	V_{IH}	2.0	V_{CC} + 0.5	V		
Output Low Voltage	V_{OL}	—	0.4	V	I_{OL} = 2.1 mA	
Output High Voltage	V_{OH}	2.4	—	—	I_{OH} = -400 µA	

Note:

1. V_{CC} must be applied simultaneously with or before $\overline{OE}/V_{PP}$, and removed simultaneously with or after $\overline{OE}/V_{PP}$.

4.4 AC Characteristics for Read Operation

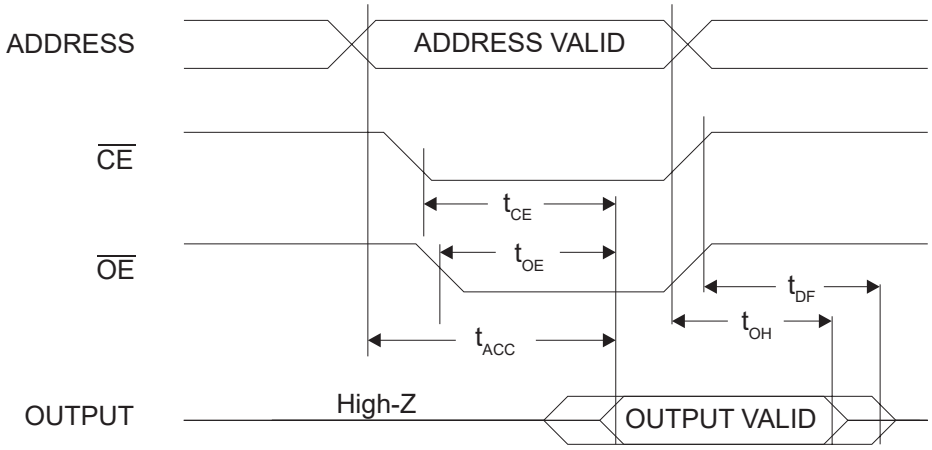
Table 4-4. AC Characteristics for Read Operation

Parameter	Symbol	-45		-70		Units	Condition
		Minimum	Maximum	Minimum	Maximum		
Address to Output Delay	t_{ACC}[1]	—	45	—	70	ns	$\overline{CE}$ = $\overline{OE}/V_{PP}$ = V_{IL}
$\overline{CE}$ to Output Delay	t_{CE}[1]	—	45	—	70	ns	$\overline{OE}/V_{PP}$ = V_{IL}
$\overline{OE}/V_{PP}$ to Output Delay	t_{OE}[1]	—	20	—	30	ns	$\overline{CE}$ = V_{IL}
$\overline{OE}/V_{PP}$ or $\overline{CE}$ High to Output Float, Whichever Occurred First	t_{DF}[1]	—	20	—	25	ns	$\overline{OE}/V_{PP}$ or $\overline{CE}$ High to Output Float, Whichever Occurred First
Output hold from address, $\overline{CE}$ or $\overline{OE}/V_{PP}$, whichever occurred first	t_{OH}	7	—	7	—	ns	Output hold from address, $\overline{CE}$ or $\overline{OE}/V_{PP}$, whichever occurred first

Note:

1. See Figure 4-1.

Figure 4-1. AC Waveform for Read Operation

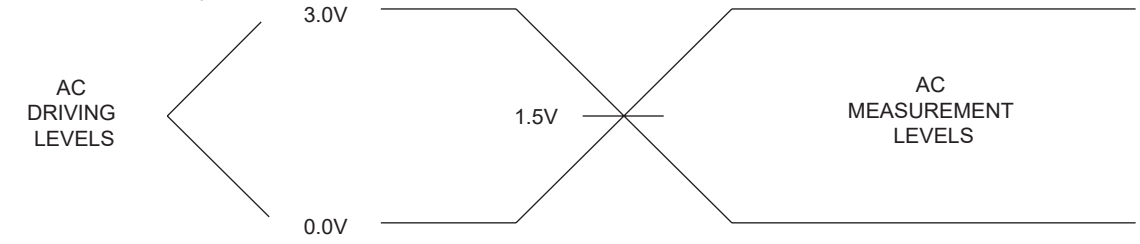


Notes:

1. Timing measurement reference level is 1.5V for -45 devices. Input AC drive levels are V_{IL} = 0.0V and V_{IH} = 3.0V. Timing measurement reference levels for all other speed grades are V_{OL} = 0.8V and V_{OH} = 2.0V. Input AC drive levels are V_{IL} = 0.45V and V_{IH} = 2.4V.
2. $\overline{OE}/V_{PP}$ may be delayed up to t_{CE} - t_{OE} after the falling edge of $\overline{CE}$ without impact on t_{CE}.
3. $\overline{OE}/V_{PP}$ may be delayed up to t_{ACC} - t_{OE} after the address is valid without impact on t_{ACC}.
4. This parameter is only sampled, and is not 100% tested.
5. Output float is defined as the point when data is no longer driven.

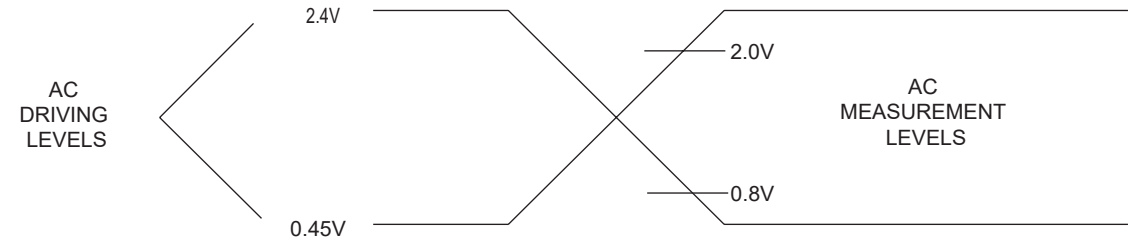
Figure 4-2. Input Test Waveforms and Measurement Levels

For -45 devices only:



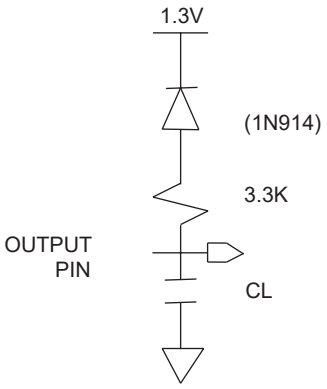
t_R, t_F < 5 ns (10% to 90%)

For -70 devices:



t_R, t_F < 20 ns (10% to 90%)

Figure 4-3. Output Test Load

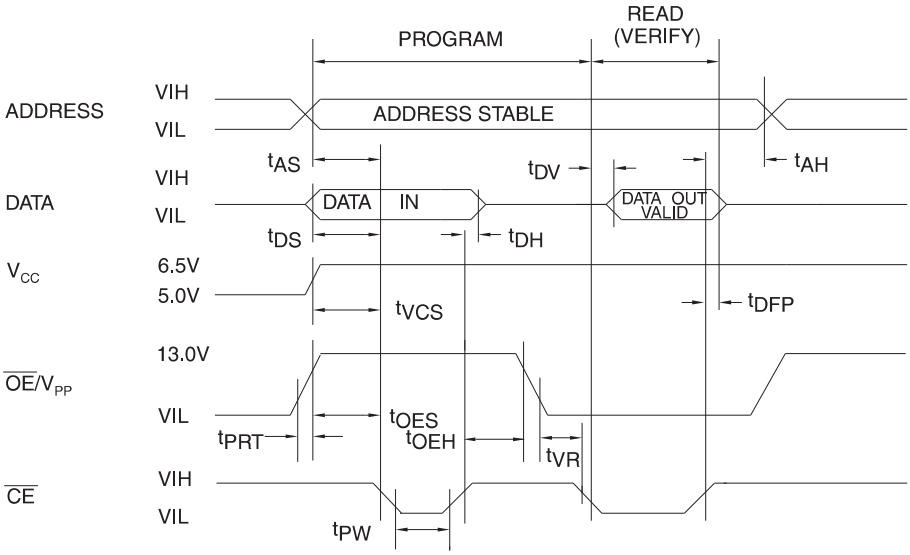


Note:

1. CL = 100 pF including jig capacitance, except for the -45 devices, where CL = 30 pF.

4.5 Programming waveforms

Figure 4-4. Programming Waveforms



Notes:

1. The input timing reference is 0.8V for V_{IL} and 2.0V for V_{IH}.
2. t_{OE} and t_{DFP} are characteristics of the device, but must be accommodated by the programmer.
3. When programming the AT27C512R, a 0.1 µF capacitor is required across V_{PP} and ground to suppress spurious voltage transients.

4.6 DC Programming Characteristics

Table 4-5. DC Programming Characteristics [1]

Parameter	Symbol	Limits		Units	Test Conditions
		Minimum	Maximum		
Input Load Current	I_{LI}	—	±10	µA	$V_{IN} = V_{IL}, V_{IH}$
Input Low Level	V_{IL}	-0.6	0.8	V	—
Input High Level	V_{IH}	2.0	V_{CC} + 1	V	—
Output Low Voltage	V_{OL}	—	0.4	V	I_{OL} = 2.1 mA
Output High Voltage	V_{OH}	2.4	—	V	I_{OH} = -400 µA
V_{CC} Supply Current (Program and Verify)	I_{CC2}	—	25	mA	—
$\overline{OE}/V_{PP}$ Current	I_{PP2}	—	25	mA	$\overline{CE} = V_{IL}$
A9 Product Identification Voltage	V_{ID}	11.5	12.5	V	—

Note:

1. T_A = +25 ± 5°C, V_{CC}= 6.5 ± 0.25V, $\overline{OE}/V_{PP}$ = 13.0 ± 0.25V.

4.7 AC Programming Characteristics

Table 4-6. AC Programming Characteristics[1]

Parameter	Symbol	Limits		Units	Test conditions
		Minimum	Maximum		
Address Setup Time	t_{AS}	2	—	µs	Input rise and fall times (10% to 90%) 20 ns Input pulse levels 0.45V to 2.4V Input timing reference level 0.8V to 2.0V Output timing reference level 0.8V to 2.0V
$\overline{OE}/V_{PP}$ Setup Time	t_{OES}	2	—	µs	
$\overline{OE}/V_{PP}$ Hold Time	t_{OEH}	2	—	µs	
Data Setup Time	t_{DS}	2	—	µs	
Address Hold Time	t_{AH}	0	—	µs	
Data Hold Time	t_{DH}	2	—	µs	
$\overline{CE}$ High to Output Float Delay[3]	t_{DFP}	0	130	ns	
V_{CC} Setup Time	t_{VCS}	2	—	µs	
$\overline{CE}$ Program Pulse Width[4]	t_{PW}	95	105	µs	
Data Valid From $\overline{CE}$[3]	t_{DV}	—	1	µs	
$\overline{OE}/V_{PP}$Recovery Time	t_{VR}	2	—	µs	
$\overline{OE}/V_{PP}$ Pulse Rise Time During Programming	t_{PRT}	50	—	ns	

Notes:

1. T_A = +25 ± 5°C, V_{CC}= 6.5 ± 0.25V, $\overline{OE}/V_{PP}$ = 13.0 ± 0.25V.
2. V_{CC} must be applied simultaneously with or before $\overline{OE}/V_{PP}$ and removed simultaneously with or after $\overline{OE}/V_{PP}$.
3. This parameter is only sampled, and is not 100% tested. Output float is defined as the point where data is no longer driven. See timing diagram.
4. Program pulse width tolerance is 100 µs ± 5%.

4.8 Electrical Specifications

4.8.1 Pin Capacitance

Table 4-7. Pin Capacitance(1,2)

Symbol	Typical	Maximum	Units	Conditions
C_{IN}	4	6	pF	V_{IN} = 0V
C_{OUT}	8	12	pF	V_{OUT} = 0V

Notes:

1. Typical values for nominal supply voltage. This parameter is only sampled, and is not 100% tested.
2. f = 1 MHz, T_A = 25°C

4.9 Integrated Product Identification Code

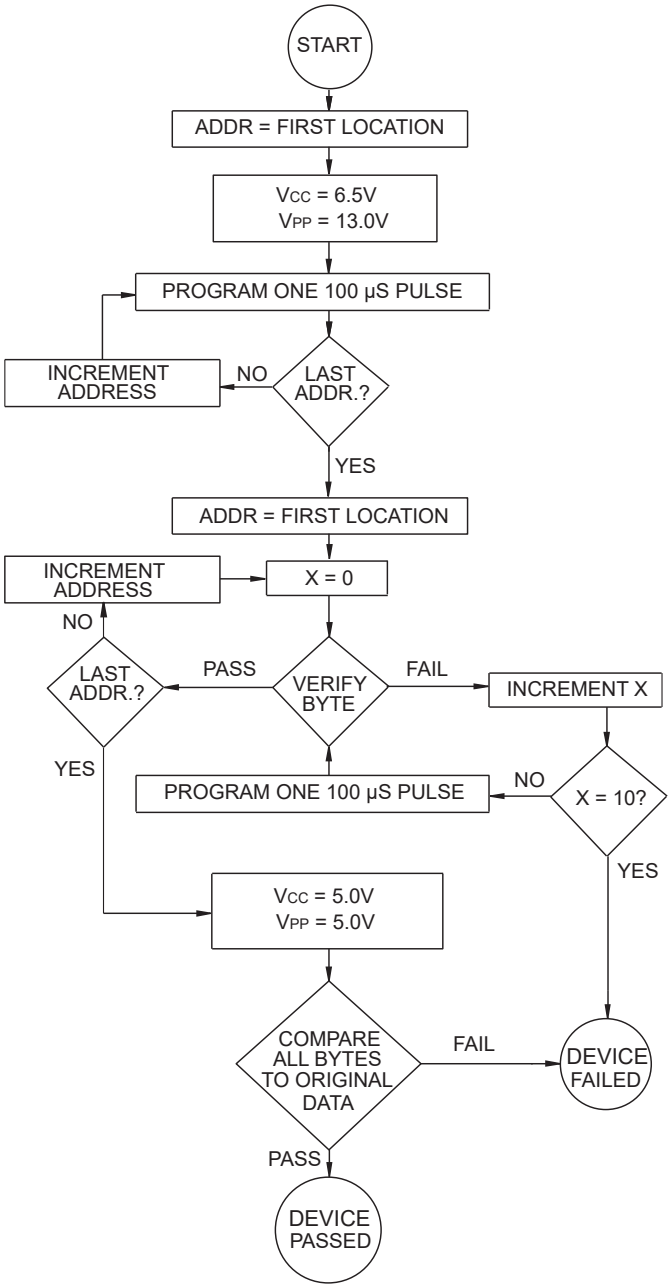
Table 4-8. Integrated Product Identification Code

Codes	Pins									Hex data
	A0	O7	O6	O5	O4	O3	O2	O1	O0	
Manufacturer	0	0	0	0	1	1	1	1	0	1E
Device type	1	0	0	0	0	1	1	0	1	0D

5. Rapid Programming Algorithm

A 100 µs $\overline{CE}$ pulse width is used to program. The address is set to the first location. V_{CC} is raised to 6.5V and $\overline{OE}/V_{PP}$ is raised to 13.0V. Each address is first programmed with one 100 µs $\overline{CE}$ pulse without verification. Then a verification/reprogramming loop is executed for each address. In the event a byte fails to pass verification, up to 10 successive 100 µs pulses are applied with a verification after each pulse. If the byte fails to verify after 10 pulses have been applied, the part is considered failed. After the byte verifies properly, the next address is selected until all have been checked. $\overline{OE}/V_{PP}$ is then lowered to V_{IL} and V_{CC} to 5.0V. All bytes are read again and compared with the original data to determine if the device passes or fails.

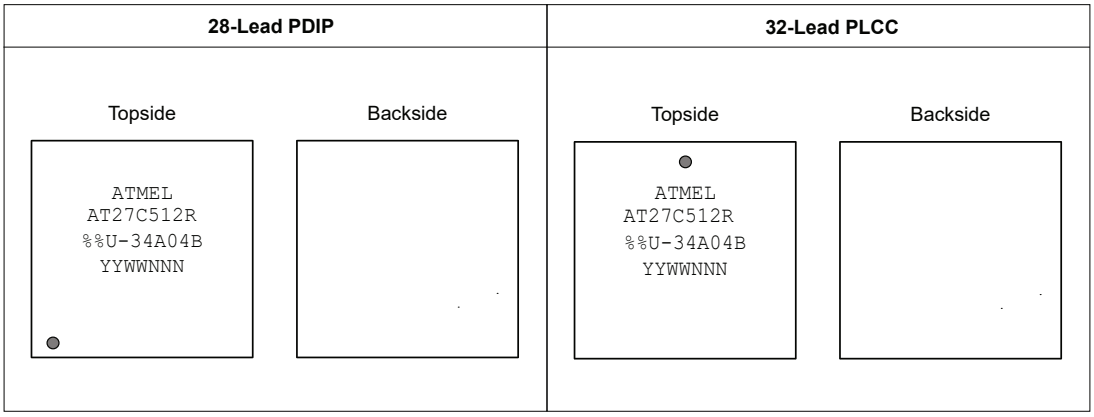
Figure 5-1. Rapid Programming Algorithm



6. Packaging Information

6.1 Package Marking Information

AT27C512R: Package Marking Information

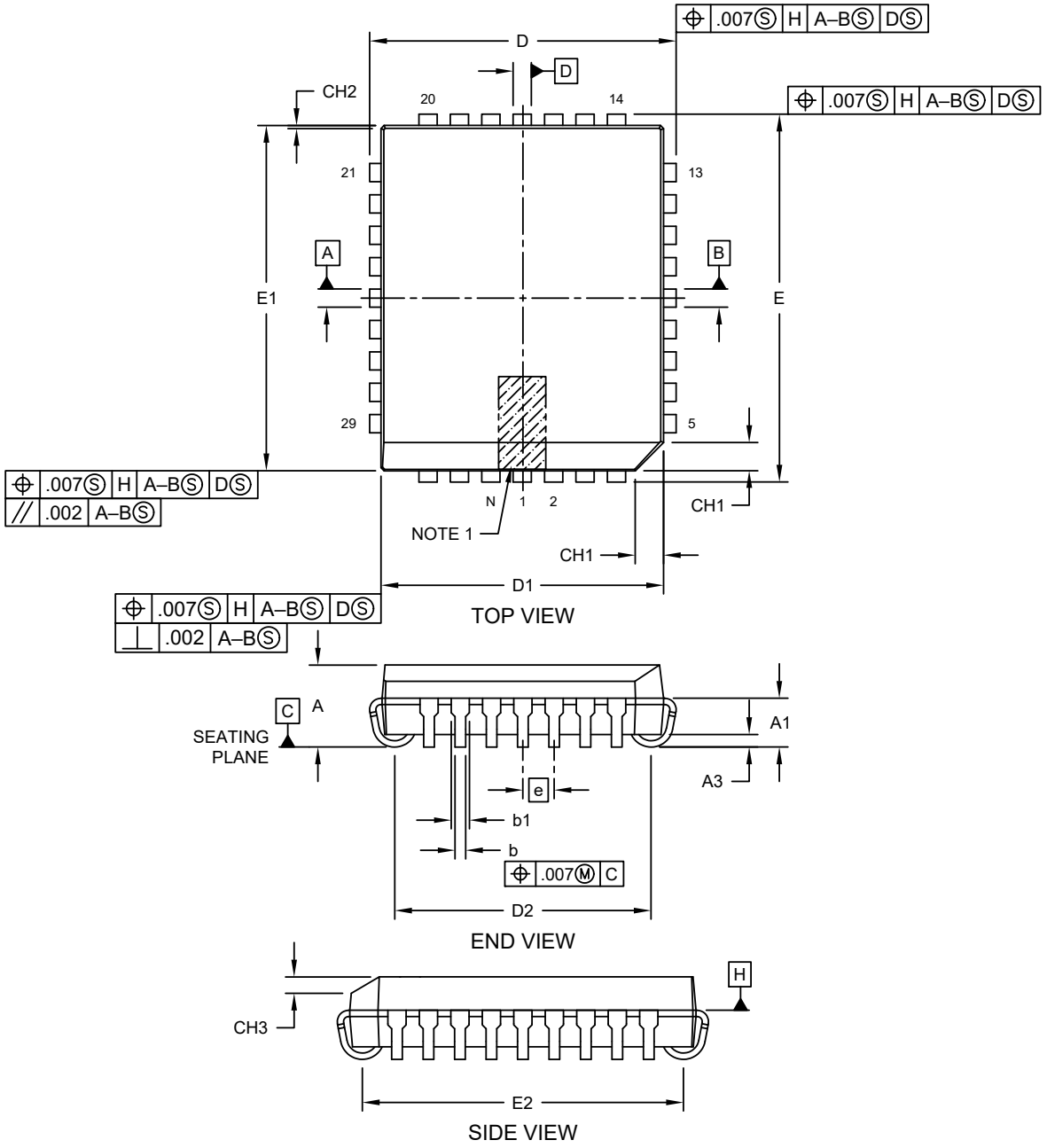


Note: no backside markings

		%% = Access Time	
		45: 45 ns 70: 70 ns	
		Lot Trace Code	
		YWWNNN: Lot Trace Code Y: Year, WW: Work Week NNN = Assembly Trace Code	

32-Lead Plastic Leaded Chip Carrier (L) - Rectangle [PLCC]

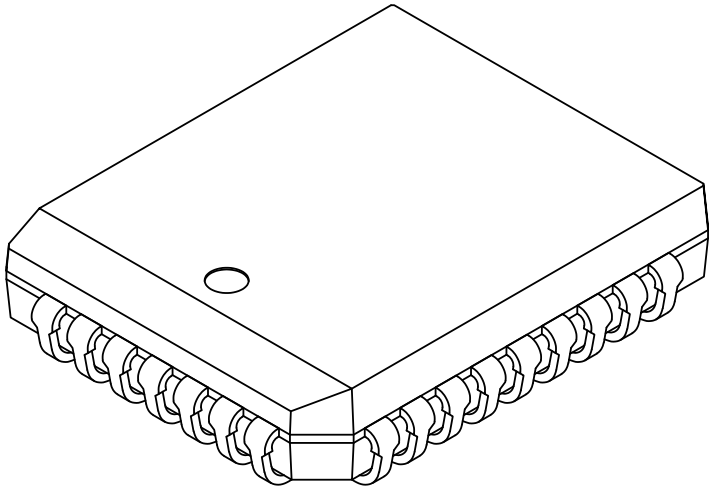
Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-023 Rev C Sheet 1 of 2

32-Lead Plastic Leaded Chip Carrier (L) - Rectangle [PLCC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		INCHES		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		32	
Pitch	e		.050 BSC	
Pins along Length	ND		7	
Pins along Width	NE		9	
Overall Height	A	.125	.132	.140
Contact Height	A1	.060	.0775	.095
Standoff §	A3	.015	-	-
Corner Chamfer	CH1	.042	.045	.048
Chamfers	CH2	-	-	.020
Side Chamfer Height	CH3	.023	.026	.029
Overall Length	D	.485	.490	.495
Overall Width	E	.585	.590	.595
Molded Package Length	D1	.447	.450	.453
Molded Package Width	E1	.547	.550	.553
Footprint Length	D2	.376	.411	.446
Footprint Width	E2	.476	.511	.546
Lead Thickness	c	.008	.010	.013
Upper Lead Width	b1	.026	.029	.032
Lower Lead Width	b	.013	.017	.021

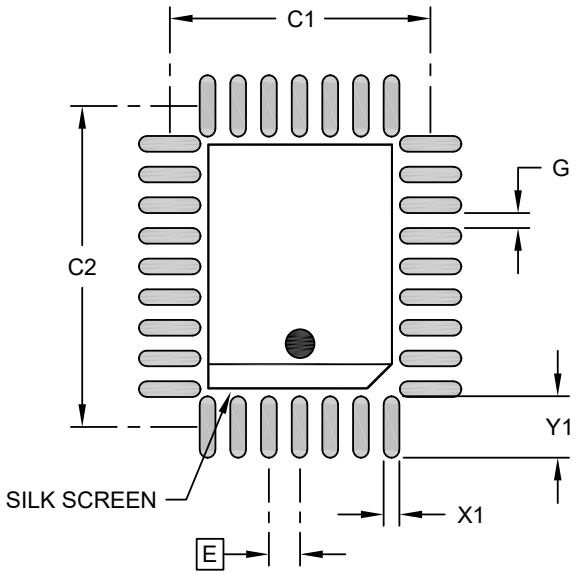
Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-023 Rev C Sheet 2 of 2

32-Lead Plastic Leaded Chip Carrier (L) - Rectangle [PLCC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		INCHES		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	.050 BSC		
Contact Pad Spacing	C1		.425	
Contact Pad Spacing	C2		.524	
Contact Pad Width (X32)	X1			.026
Contact Pad Length (X32)	Y1			.100
Contact Pad to Center Pad (X28)	G	.008		

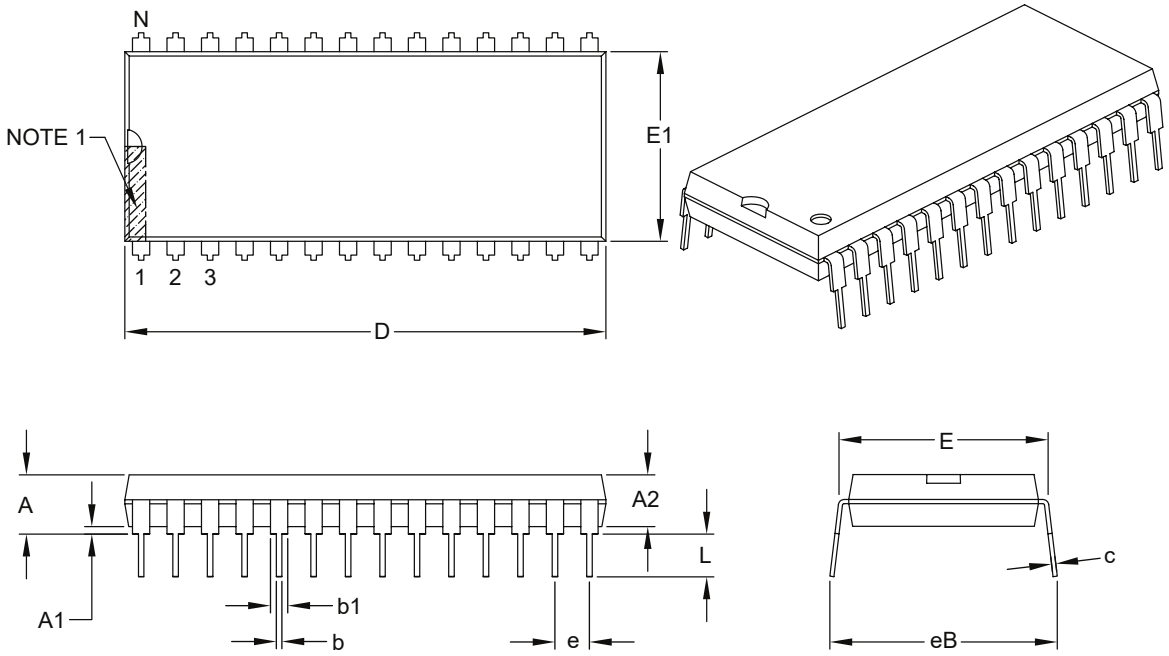
Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-2023 Rev C

28-Lead Plastic Dual In-Line (P) – 600 mil Body [PDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		INCHES		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		28	
Pitch	e		.100 BSC	
Top to Seating Plane	A	–	–	.250
Molded Package Thickness	A2	.125	–	.195
Base to Seating Plane	A1	.015	–	–
Shoulder to Shoulder Width	E	.590	–	.625
Molded Package Width	E1	.485	–	.580
Overall Length	D	1.380	–	1.565
Tip to Seating Plane	L	.115	–	.200
Lead Thickness	c	.008	–	.015
Upper Lead Width	b1	.030	–	.070
Lower Lead Width	b	.014	–	.022
Overall Row Spacing §	eB	–	–	.700

Notes:

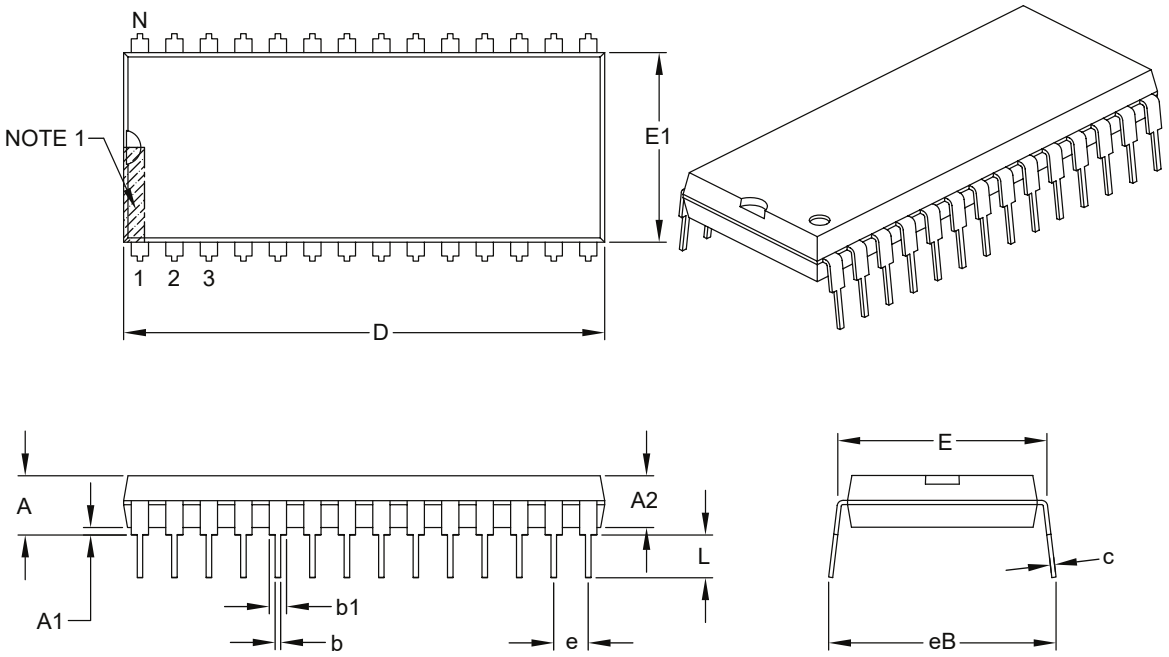
1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-079B

28-Lead Plastic Dual In-Line (PI) – 600 mil Body [PDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		INCHES		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		28	
Pitch	e		.100 BSC	
Top to Seating Plane	A	–	–	.250
Molded Package Thickness	A2	.125	–	.195
Base to Seating Plane	A1	.015	–	–
Shoulder to Shoulder Width	E	.590	–	.625
Molded Package Width	E1	.485	–	.580
Overall Length	D	1.380	–	1.565
Tip to Seating Plane	L	.115	–	.200
Lead Thickness	c	.008	–	.015
Upper Lead Width	b1	.030	–	.070
Lower Lead Width	b	.014	–	.022
Overall Row Spacing §	eB	–	–	.700

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic.
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
4. Dimensioning and tolerancing per ASME Y14.5M.

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-079B

7. Revision History

Revision A (December 2022)
Updated to the Microchip template. Microchip DS20006752A replaces Atmel document 0015. Updated Part Marking Information. Updated section content throughout for clarification.

Atmel Document 0015 Revision Q (October 2011)
Correct pinout note.

Atmel Document 0015 Revision P (April 2011)
Remove TSOP and SOIC packages; Add lead finish to ordering information.

Atmel Document 0015 Revision O (December 2007)

Microchip Information

The Microchip Website

Microchip provides online support via our website at www.microchip.com/. This website is used to make files and information easily available to customers. Some of the content available includes:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip design partner program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

Product Change Notification Service

Microchip's product change notification service helps keep customers current on Microchip products. Subscribers will receive email notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, go to www.microchip.com/pcn and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

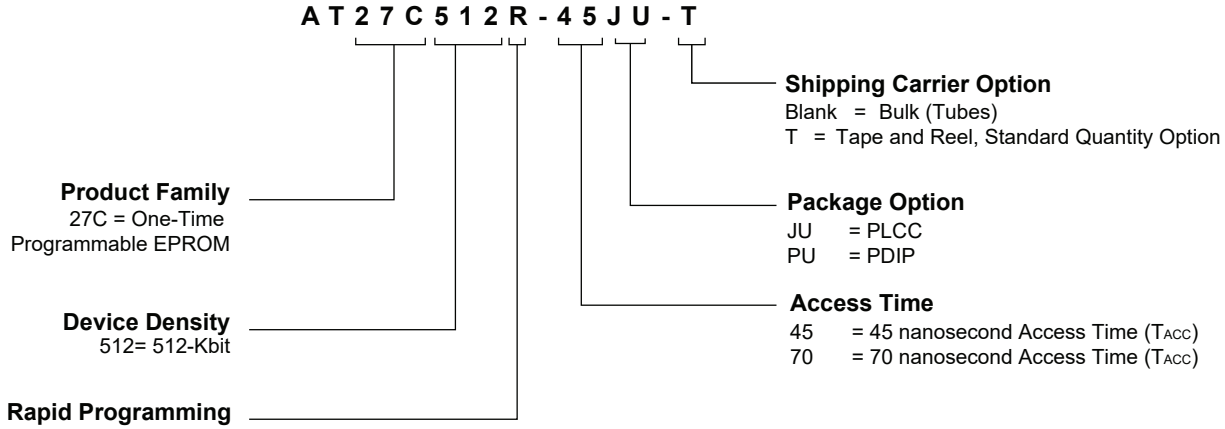
- Distributor or Representative
- Local Sales Office
- Embedded Solutions Engineer (ESE)
- Technical Support

Customers should contact their distributor, representative or ESE for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in this document.

Technical support is available through the website at: www.microchip.com/support

Product Identification System

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.



Examples

Device	Package	Package Drawing Code	Package Option	Shipping Carrier Option	Device Grade
AT27C512R-45JU	PLCC	L	JU	Bulk (Tubes)	Industrial Temperature (-40°C to +85°C)
AT27C512R-70JU	PLCC	L	JU	Bulk (Tubes)	
AT27C512R-45PU	PDIP	P	PU	Bulk (Tubes)	
AT27C512R-70PU	PDIP	P	PU	Bulk (Tubes)	
AT27C512R-45JU-T	PLCC	L	JU	Tape and Reel	
AT27C512R-70JU-T	PLCC	L	JU	Tape and Reel	

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip products:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner, within operating specifications, and under normal conditions.
- Microchip values and aggressively protects its intellectual property rights. Attempts to breach the code protection features of Microchip product is strictly prohibited and may violate the Digital Millennium Copyright Act.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is “unbreakable”. Code protection is constantly evolving. Microchip is committed to continuously improving the code protection features of our products.

Legal Notice

This publication and the information herein may be used only with Microchip products, including to design, test, and integrate Microchip products with your application. Use of this information in any other manner violates these terms. Information regarding device applications is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. Contact your

local Microchip sales office for additional support or, obtain additional support at www.microchip.com/en-us/support/design-help/client-support-services.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE, OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL, OR CONSEQUENTIAL LOSS, DAMAGE, COST, OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION.

Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, CryptoMemory, CryptoRF, dsPIC, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, Flashtec, Hyper Speed Control, HyperLight Load, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet- Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, TrueTime, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, Clockstudio, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, GridTime, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, IntelliMOS, Inter-Chip Connectivity, JitterBlocker, Knob-on-Display, KoD, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SmartHLS, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, Trusted Time, TSHARC, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

ISBN: 978-1-6683-1778-5

Quality Management System

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Worldwide Sales and Service

AMERICAS	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
Corporate Office 2355 West Chandler Blvd. Chandler, AZ 85224-6199 Tel: 480-792-7200 Fax: 480-792-7277 Technical Support: www.microchip.com/support Web Address: www.microchip.com **Atlanta** Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455 **Austin, TX** Tel: 512-257-3370 **Boston** Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088 **Chicago** Itasca, IL Tel: 630-285-0071 Fax: 630-285-0075 **Dallas** Addison, TX Tel: 972-818-7423 Fax: 972-818-2924 **Detroit** Novi, MI Tel: 248-848-4000 **Houston, TX** Tel: 281-894-5983 **Indianapolis** Noblesville, IN Tel: 317-773-8323 Fax: 317-773-5453 Tel: 317-536-2380 **Los Angeles** Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608 Tel: 951-273-7800 **Raleigh, NC** Tel: 919-844-7510 **New York, NY** Tel: 631-435-6000 **San Jose, CA** Tel: 408-735-9110 Tel: 408-436-4270 **Canada - Toronto** Tel: 905-695-1980 Fax: 905-695-2078	**Australia - Sydney** Tel: 61-2-9868-6733 **China - Beijing** Tel: 86-10-8569-7000 **China - Chengdu** Tel: 86-28-8665-5511 **China - Chongqing** Tel: 86-23-8980-9588 **China - Dongguan** Tel: 86-769-8702-9880 **China - Guangzhou** Tel: 86-20-8755-8029 **China - Hangzhou** Tel: 86-571-8792-8115 **China - Hong Kong SAR** Tel: 852-2943-5100 **China - Nanjing** Tel: 86-25-8473-2460 **China - Qingdao** Tel: 86-532-8502-7355 **China - Shanghai** Tel: 86-21-3326-8000 **China - Shenyang** Tel: 86-24-2334-2829 **China - Shenzhen** Tel: 86-755-8864-2200 **China - Suzhou** Tel: 86-186-6233-1526 **China - Wuhan** Tel: 86-27-5980-5300 **China - Xian** Tel: 86-29-8833-7252 **China - Xiamen** Tel: 86-592-2388138 **China - Zhuhai** Tel: 86-756-3210040	**India - Bangalore** Tel: 91-80-3090-4444 **India - New Delhi** Tel: 91-11-4160-8631 **India - Pune** Tel: 91-20-4121-0141 **Japan - Osaka** Tel: 81-6-6152-7160 **Japan - Tokyo** Tel: 81-3-6880- 3770 **Korea - Daegu** Tel: 82-53-744-4301 **Korea - Seoul** Tel: 82-2-554-7200 **Malaysia - Kuala Lumpur** Tel: 60-3-7651-7906 **Malaysia - Penang** Tel: 60-4-227-8870 **Philippines - Manila** Tel: 63-2-634-9065 **Singapore** Tel: 65-6334-8870 **Taiwan - Hsin Chu** Tel: 886-3-577-8366 **Taiwan - Kaohsiung** Tel: 886-7-213-7830 **Taiwan - Taipei** Tel: 886-2-2508-8600 **Thailand - Bangkok** Tel: 66-2-694-1351 **Vietnam - Ho Chi Minh** Tel: 84-28-5448-2100	**Austria - Wels** Tel: 43-7242-2244-39 Fax: 43-7242-2244-393 **Denmark - Copenhagen** Tel: 45-4485-5910 Fax: 45-4485-2829 **Finland - Espoo** Tel: 358-9-4520-820 **France - Paris** Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79 **Germany - Garching** Tel: 49-8931-9700 **Germany - Haan** Tel: 49-2129-3766400 **Germany - Heilbronn** Tel: 49-7131-72400 **Germany - Karlsruhe** Tel: 49-721-625370 **Germany - Munich** Tel: 49-89-627-144-0 Fax: 49-89-627-144-44 **Germany - Rosenheim** Tel: 49-8031-354-560 **Israel - Ra'anana** Tel: 972-9-744-7705 **Italy - Milan** Tel: 39-0331-742611 Fax: 39-0331-466781 **Italy - Padova** Tel: 39-049-7625286 **Netherlands - Drunen** Tel: 31-416-690399 Fax: 31-416-690340 **Norway - Trondheim** Tel: 47-72884388 **Poland - Warsaw** Tel: 48-22-3325737 **Romania - Bucharest** Tel: 40-21-407-87-50 **Spain - Madrid** Tel: 34-91-708-08-90 Fax: 34-91-708-08-91 **Sweden - Gothenberg** Tel: 46-31-704-60-40 **Sweden - Stockholm** Tel: 46-8-5090-4654 **UK - Wokingham** Tel: 44-118-921-5800 Fax: 44-118-921-5820