

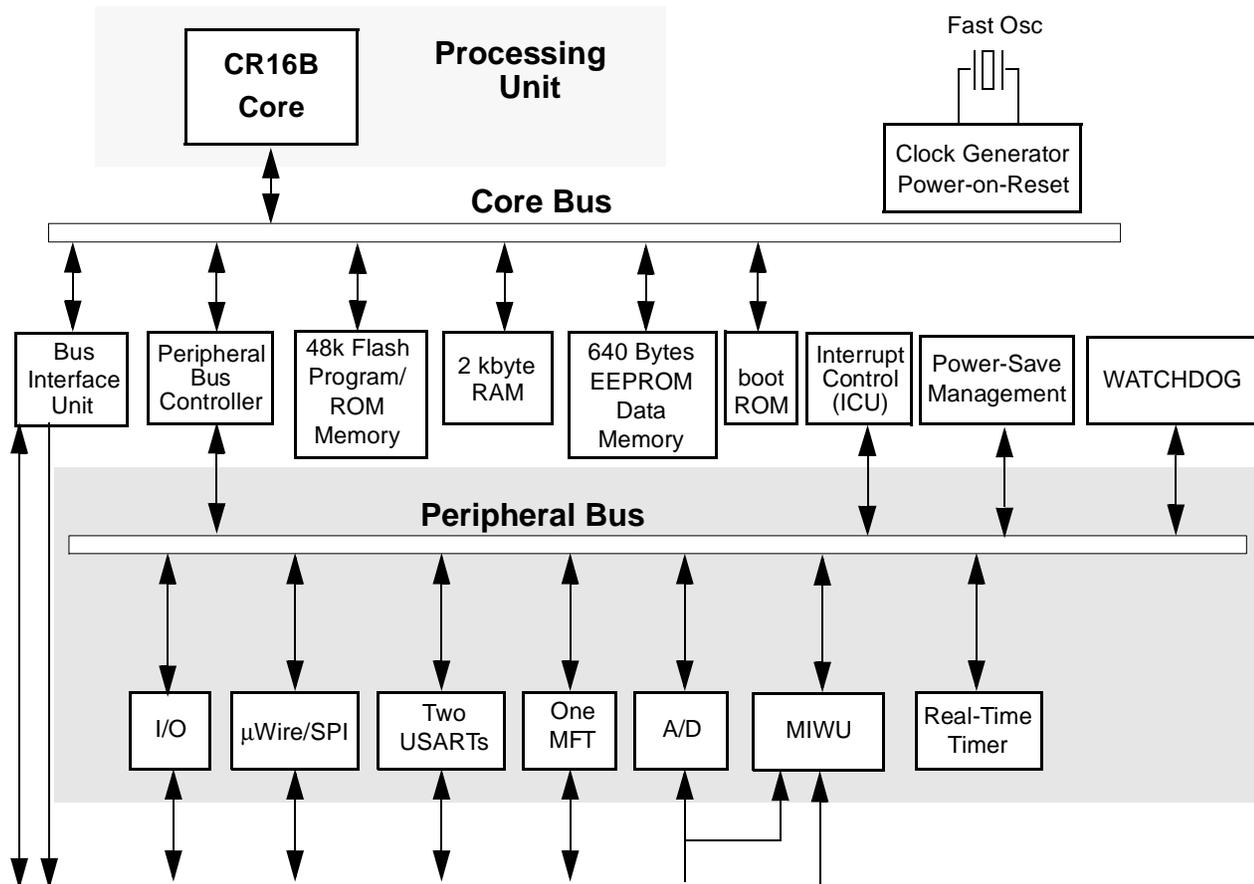
# CR16MFS9/CR16MFS5 CompactRISC 16-Bit Reprogrammable/ROM Microcontrollers

## 1.0 General Description

The CR16MFS9 and CR16MFS5 CompactRISC™ microcontrollers are general-purpose 16-bit microcontrollers based on a Reduced Instruction Set Computer (RISC) architecture. The device operates as a complete microcomputer with all system timing, interrupt logic, flash program memory or ROM memory, RAM, EEPROM data memory, and I/O ports included on-chip. It is ideally suited to a wide range of embedded controller applications because of its high performance, on-chip integrated features and low power consumption, resulting in decreased system cost.

The CR16MFS9 and CR16MFS5 offers the high performance of a RISC architecture while retaining the advantages of a traditional Complex Instruction Set Computer (CISC): compact code, on-chip memory and I/O, and reduced cost. The CPU uses a three-stage instruction pipeline that allows execution of up to one instruction per clock cycle, or up to 20 million instructions per second (MIPS) at a clock rate of 20 MHz.

## Block Diagram



Note: Not all peripherals shown above will be contained in every device.

CompactRISC™ is a trademark of National Semiconductor Corporation.

## 1.0 General Description (Continued)

All CR16MFS9 and CR16MFS5 devices have 48 kbytes of reprogrammable flash program memory or ROM Memory, 1.5 kbytes of ISP memory, 2 kbytes of static RAM, and 640 bytes of non-volatile EEPROM data memory. The 44-pin devices offer the same basic features as the 80-pin device, but with fewer I/O ports and peripheral modules due to the smaller number of available pins.

All CR16MFS9 and CR16MFS5 devices operate with a high-frequency crystal as the main clock source. The device supports several Power Save modes which are combined with multi-source interrupt and wake-up capabilities.

Powerful cross-development tools are available from National Semiconductor and third party suppliers to support the development and debugging of application software for the CR16MFS9 and CR16MFS5. These tools let you program the application software in C and are designed to take full advantage of the CompactRISC architecture.

— CompactRISC tools provide C programming and debugging support

## 2.0 Features

- CPU Features
  - Fully static core, capable of operating at any rate from 0 to 20 MHz (4 MHz minimum in active mode)
  - 50 ns instruction cycle time with a 20 MHz external clock frequency
  - Multi-source vectored interrupts (internal, external, and on-chip peripheral)
  - On-chip power-on reset
- On-Chip Memory
  - 48 kbytes of flash program memory or ROM memory
  - For flash program memory, 1.5 kbytes of ISP memory is used to store boot loader code
  - 2 kbytes of static RAM data memory
  - 640 bytes of non-volatile EEPROM data memory, word-programmable
- On-Chip Peripherals
  - Two Universal Synchronous/Asynchronous Receiver/Transmitter (USART) devices
  - Programmable Idle Timer and real-time timer
  - One dual 16-bit multi-function timer (MFT2)
  - SPI/MICROWIRE-PLUS serial interface
  - 8-channel, 8-bit Analog-to-Digital (A/D) converter with external voltage reference, programmable sample-and-hold delay, and programmable conversion frequency
  - Integrated WATCHDOG logic
- I/O Features
  - Up to 33 general-purpose I/O pins (shared with on-chip peripheral I/O pins)
  - Programmable I/O pin characteristics: TRI-STATE output, push-pull output, weak pull-up input, high-impedance input
  - Software-configurable Schmitt triggers on inputs
- Power Supply
  - 4.5V to 5.5V single-supply operation
- Temperature Range
  - -40°C to +85°C
  - -40°C to +125°C
- Development Support
  - Real-time emulation and full program debug capabilities available

## CR16 CompactRISC microcontroller Family Selection Guide

### Programmable devices

NSID	Speed (MHz)	Flash (kByte)	EEPROM Data Memory (Bytes)	SRAM (kBytes)	USART	Timer	I/Os	Temp. Range	Peripherals	Package Type
CR16MFS944Vx	20	48	640	2	2	1	33	E, I	ADC	44PLCC

### ROM devices

NSID	Speed (MHz)	ROM (kByte)	EEPROM Data Memory (Bytes)	SRAM (kBytes)	USART	Timer	I/Os	Temp. Range	Peripherals	Package Type
CR16MFS544Vxy	20	48	640	2	2	1	33	E, I	ADC	44PLCC

#### Note:

- Suffix x in the NSID is defined below:

Temperature Ranges:

E = Extended  
I = Industrial

-40°C to +125°C is represented when x is 7  
-40°C to +85°C is represented when x is 8

- Suffix y in the NSID defines the ROM code.

**Note:** All devices contains Clock and Reset, MICROWIRE/SPI, Multi-Input Wake-Up (MIWU), Power Management (PMM), and the Real-Time Timer and Watchdog (TWM) modules.

#### 44-Pin PLCC versus 80-Pin PQFP

For 44PLCC packages, MICROWIRE/SPI slave mode, the first 4 MIWU channels and the Vref pin are not available. 80-pin PQFP packages provide the MICROWIRE/SPI master and slave modes, 8 MIWU channels, Vref pin, and two US-ARTs and two MFTs.

#### CR16MFS9 Derivatives

National Semiconductor currently offers a variety of the CR16 CompactRISC Microcontrollers. The CR16MES offer limited functionality compared to the CR16MHS.

### 3.0 Device Overview

The CR16MFS9 and the CR16MFS5 CompactRISC micro-controllers are complete microcomputers with all system timing, interrupt logic, program memory, data memory, and I/O ports included on-chip, making it well-suited to a wide range of embedded controller applications. The block diagram on page 1 of the data sheet shows the major on-chip components of the CR16MFS9.

#### 3.1 CR16B CPU CORE

The CR16MFS9 and CR16MFS5 uses the CR16B CPU core module. This is the same core used in other CompactRISC family members.

The high performance of the CPU core results from the implementation of a pipelined architecture with a two-bytes-per-cycle pipelined system bus. As a result, the CPU can support a peak execution rate of one instruction per clock cycle.

Compared with conventional RISC processors, the CR16MFS9 and CR16MFS5 differ in the following ways:

- The CPU core uses on-chip rather than external memory. This eliminates the need for large and complex bus interface units.
- Most instructions are 16 bits, so all basic instructions are just two bytes long. (Additional bytes are sometimes required for immediate values, so instructions can be two or four bytes long.)
- Non-aligned word access is allowed. Each instruction can operate on 8-bit or 16-bit.
- Most embedded systems face EMI and noise constraints that limit clock speed to these lower ranges. A lower clock speed means a simpler, less costly silicon implementation.
- The instruction pipeline uses three stages. A smaller pipeline eliminates the need for costly branch prediction mechanisms and bypass registers, while maintaining adequate performance for typical embedded controller applications.

#### 3.2 MEMORY

The CompactRISC architecture supports a uniform linear address space of 2 megabytes. The CR16MFS9 and CR16MFS5 implementation of this architecture uses only the lowest 64 kbytes of address space. Four types of on-chip memory occupy specific intervals within this address space: 48 kbytes of flash program memory, 1.5 kbytes of ISP memory, 2 kbytes of static RAM, and 640 bytes of EEPROM data memory.

The 48 kbytes of flash program memory are used to store the application program. It has security features to prevent unintentional programming and to prevent unauthorized access to the program code. This memory can be programmed either with CR16MFS9 plugged into an EPROM programmer unit (external programming) or with the CR16MFS9 installed in the application system (in-system programming).

The 2 kbytes of static RAM are used for temporary storage of data and for the program stack and interrupt stack. Read and write operations can be byte-wide or word-wide, depending on the instruction executed by the CPU. Each memory access requires one clock cycle; no wait cycles or hold cycles are required.

The 640 bytes of EEPROM data memory are used for non-volatile storage of data, such as configuration settings entered by the end-user. The CPU reads or writes this memory by using ordinary byte-wide or word-wide memory access commands. After the CPU performs a write to this memory, the on-chip hardware completes the EEPROM programming in the background. A register status bit indicates the status of the EEPROM programming operation.

There is a factory programmed boot memory used to store In-System-Programming (ISP) code. (this code allows programming of the program memory via one of the USART interfaces in the final application.)

For the flash program memory, the CR16MFS9 device internally generates the necessary voltages for programming. No additional power supply is required.

#### 3.3 INPUT/OUTPUT PORTS

Each CR16MFS9 device has 33 software-configurable I/O pins, organized into five 8-pin ports called Port B, Port C, Port F, Port G, and Port I. Each pin can be configured to operate as a general-purpose input or general-purpose output. In addition, many I/O pins can be configured to operate as a designated input or output for an on-chip peripheral module such as the USART, timer, A/D converter, or MICROWIRE/SPI interface.

The I/O pin characteristics are fully programmable. Each pin can be configured to operate as a TRI-STATE output, push-pull output, weak pull-up input, or high-impedance input. Input pins can be software-configured to use Schmitt triggers for noise resistance.

Each 44-pin device has a subset of the pins available in the 80-pin device. This results in the loss of some features that are available in the larger-package device:

- USARTs and multi-function timers
- Synchronous mode in the remaining USART(s)
- Slave mode operation for the MICROWIRE/SPI interface
- Separate external  $V_{REF}$  for the A/D converter
- ComparatorsFour of the eight Multi-Input Wakeup pins
- NMI interrupt input pin

#### 3.4 BUS INTERFACE UNIT

The Bus Interface Unit (BIU) controls the interface between the on-chip modules to the internal core bus. It determines the configured parameters for bus access (such as the number of wait states for memory access) and issues the appropriate bus signals for each requested access.

The BIU uses a set of control registers to determine how many wait states and hold states are to be used when accessing EEPROM memory. Upon start-up of the device, these registers must be programmed with appropriate values so that the minimum allowable number states is used. This number varies with the clock frequency and the type of on-chip device being accessed.

#### 3.5 INTERRUPTS

The Interrupt Control Unit (ICU) receives interrupt requests from internal and external sources and generates interrupts to the CPU. An interrupt is an event that temporarily stops the normal flow of program execution and causes a separate in-

interrupt service routine to be executed. After the interrupt is serviced, CPU execution continues with the next instruction in the program following the point of interruption.

Interrupts from the timer, USARTs, MICROWIRE/SPI interface, multi-input wake-up, and A/D converter are all maskable interrupts; they can be enabled or disabled by the software. There are 16 of these maskable interrupts, organized into 16 predetermined levels of priority.

The highest-priority interrupt is the Non-Maskable Interrupt (NMI), which is generated by a signal received on the  $\overline{\text{NMI}}$  input pin. This interrupt is not available in the 44-pin packages.

### 3.6 MULTI-INPUT WAKE-UP

The Multi-Input Wake-up (MIWU) module can be used for either of two purposes: to provide inputs for waking up (exiting) from the HALT, IDLE, or Power Save mode; or to provide general-purpose edge-triggered maskable interrupts from external sources. This eight-channel module generates one combined interrupt to the CPU based on the signals received on its eight input channels. Channels can be individually enabled or disabled, and programmed to respond to positive or negative edges.

### 3.7 DUAL CLOCK AND RESET

The Dual Clock and Reset (CLK2RES) module generates a high-speed main system clock from an external crystal network. It also provides the main system reset signal and a power-on reset function.

For the 44-pin devices and for devices not using a secondary crystal network, the slow clock can be generated by dividing the high-speed main clock by a prescaler factor.

### 3.8 POWER MANAGEMENT

The Power Management Module (PMM) improves the efficiency of the CR16MFS9 and CR16MFS5 devices by changing the operating mode (and therefore the power consumption) according to the current level of activity.

The CR16MFS9 and CR16MFS5 devices can operate in any of four power modes:

- Active: The device operates at full speed using the high-frequency clock. All device functions are fully operational.
- Power Save: The device operates at reduced speed using the slow clock. The CPU and some modules can continue to operate at this low speed.
- IDLE: The device is inactive except for the Power Management Module and Timing and Watchdog Module, which continue to operate using the slow clock.
- HALT: The device is inactive but still retains its internal state (RAM and register contents).

### 3.9 MULTI-FUNCTION TIMER

The Multi-Function Timer (MFT16) module contains one independent timer/counter unit called MFT2, which contains a pair of 16-bit timer/counter registers. Each timer/counter unit can be configured to operate in any of the following modes:

- Processor-Independent Pulse Width Modulation (PWM) mode, which generates pulses of a specified width and duty cycle, and which also provides a general-purpose timer/counter

- Dual Input Capture mode, which measures the elapsed time between occurrences of external events, and which also provides a general-purpose timer/counter
- Dual Independent Timer mode, which generates system timing signals or counts occurrences of external events
- Single Input Capture and Single Timer mode, which provides one external event counter and one system timer

### 3.10 REAL-TIME TIMER AND WATCHDOG

The Timing and Watchdog Module (TWM) generates the clocks and interrupts used for timing periodic functions in the system. It also provides Watchdog protection against software errors. The module operates on the slow (32.768 KHz) clock.

The real-time timer generates a periodic interrupt to the CPU at a software-programmed interval. This can be used for real-time functions such as a time-of-day clock.

The Watchdog is designed to detect program execution errors such as an infinite loop or a “runaway” program. Once Watchdog operation is initiated, the application program must periodically write a specific value to a Watchdog register, within specific time intervals. If the software fails to do so, a Watchdog error is triggered, which resets the device.

### 3.11 USART

The USART is a Universal Synchronous/Asynchronous Receiver-Transmitter, a device used for serial communications. It supports a wide range of programmable baud rates and data formats, and handles parity generation and several error detection schemes. The baud rate is generated on-chip, under software control.

The synchronous mode of operation is not available in the 44-pin devices.

### 3.12 MICROWIRE/SPI

The MICROWIRE/SPI (MWSPI) interface module supports asynchronous serial communications with other devices that conform to MICROWIRE or Serial Peripheral Interface (SPI) specifications.

The MICROWIRE interface allows several devices to communicate over a single system consisting of three wires: serial in, serial out, and shift clock. At any given time, one device on the MICROWIRE interface operates as the master, while all other devices operate as slaves. An 80-pin CR16MHS supports the full set of slave select and Ready lines for multi-slave implementation, while a 44-pin CR16MFS has only the basic Data-in/Data-out/Clock lines, limiting its implementation to master mode.

### 3.13 A/D CONVERTER

The A/D Converter (ADC) module is an 8-channel multiplexed-input analog-to-digital converter. The A/D Converter receives an analog voltage signal on an input pin and converts the analog signal into an 8-bit digital value using successive approximation. The CPU can then read the result from a memory-mapped register. The module supports four automated operating modes, providing single-channel or scanned 4-channel operation in single or continuous mode.

The 80-pin device has a separate pin, Vref, for the A/D reference voltage. The 44-pin devices use the AVCC (analog VCC) power supply pin as the reference voltage.

### 3.14 DEVELOPMENT SUPPORT

A powerful cross-development tool set is available from National Semiconductor and third parties to support the development and debugging of application software for the CR16MFS9 and CR16MFS5. The tool set lets you program the application software in C and is designed to take full advantage of the CompactRISC architecture.

There are In-System Emulation (ISE) devices available for the CR16MFS9 and CR16MFS5 from iSYSTEM™, as well as lower-cost evaluation boards. See your National Semiconductor sales representative for current information on availability of various features of emulation equipment and evaluation boards.

## 4.0 Memory Map

The CompactRISC architecture supports a uniform linear address space of 2 megabytes. The device implementation of this architecture uses only the lowest 64 kbytes of address space, ranging from 0000 to FFFF hex.

**Table 1 Device Memory Map**

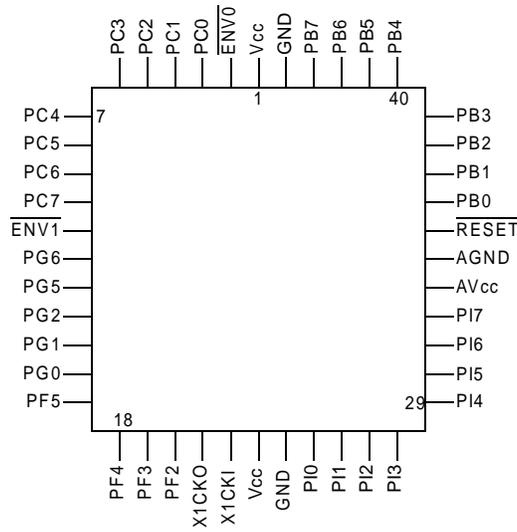
Address Range (hex)	Description
0000-BFFF	Flash Program/ROM Memory (48 kbytes)
DA00-DFF7	ISP Memory (1.5 kbytes)
DFF8-DFFF	Program ROM control/status
E000-E7FF	Static RAM (2 kbytes)
F000-F27F	EEPROM Data Memory (640 bytes)
F900-F930	Device configuration registers
FB00-FB06	Port B registers
FB10-FB16	Port C registers
FC40-FC88	Clock, Power Management, and Wake-up registers
FCA0-FCA8	Port G registers
FD20-FD28	Port F registers
FE00-FE0C	Interrupt registers
FE40-FE4E	USART 1 registers
FE60-FE68	MICROWIRE registers
FE80-FE8E	USART 2 registers
FEE0-FEE8	Port I registers
FF20-FF2A	Timer and WATCHDOG registers
FF60-FF70	MFT2 Timer registers
FFC0-FFD0	A/D Converter registers
FFE0-FFE0	Analog Comparator register

## 5.0 Device Pinouts

The CR16MFS9 and CR16MFS5 are available in the following package:

x represents 7, or 8

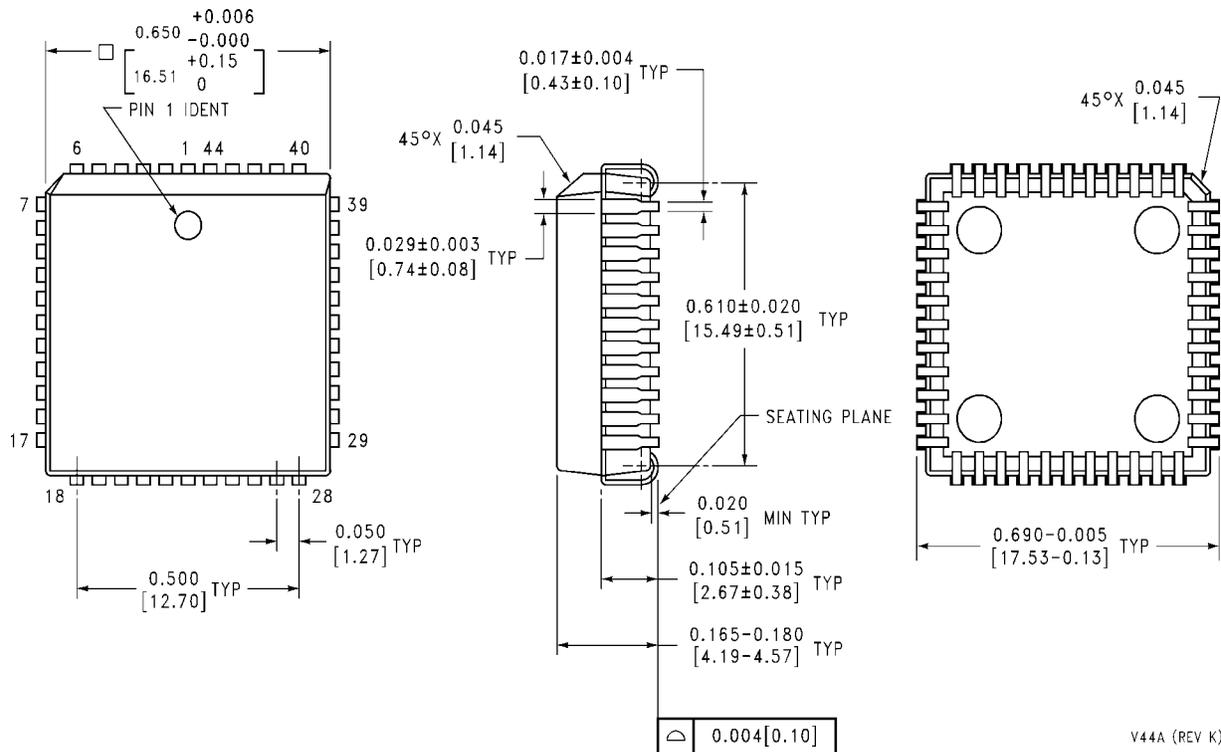
y represents ROM codes; for programmable devices, leave out y.



Top View

Order Number CR16MFS944Vx, CR16MFS544Vxy  
See NS Package Number V44A

## 6.0 Physical Dimension inches (millimeters) unless otherwise noted



44 Lead Molded Plastic Leaded Chip Carrier

Order Number CR16MFS944Vx, CR16MFS544Vxy  
See NS Package Number V44A

- Suffix x in the NSID is defined below:

Temperature Ranges:

x = 7 is -40°C to +125°C  
x = 8 is -40°C to +85°C

- Suffix y in the NSID defines the ROM code.

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



**National Semiconductor Corporation**  
Tel: 1-800-272-9959  
Fax: 1-800-737-7018  
Email: support@nsc.com

**National Semiconductor Europe**

Fax: +49 (0) 180-530 85 86  
Email: europe.support@nsc.com  
Deutsch Tel: +49 (0) 69 9508 6208  
English Tel: +44 (0) 870 24 0 2171  
Francais Tel: +33 (0) 1 41 91 8790

**National Semiconductor Asia Pacific Customer Response Group**  
Tel: 65-254-4466  
Fax: 65-250-4466  
Email: ap.support@nsc.com

**National Semiconductor Japan Ltd.**  
Tel: 81-3-5639-7560  
Fax: 81-3-5639-7507

www.national.com