SPECIAL FEATURES

- 4096 bits of read/write nonvolatile memory (DS1993 and DS1994)
- 1024 bits of read/write nonvolatile memory (DS1992)
- 256–bit scratchpad ensures integrity of data transfer
- Memory partitioned into 256–bit pages for packetizing data
- Data integrity assured with strict read/write protocols
- Contains real time clock/calendar in binary format (DS1994)
- Interval timer can automatically accumulate time when power is applied (DS1994)
- Programmable cycle counter can accumulate the number of system power–on/off cycles (DS1994)
- Programmable alarms can be set to generate interrupts for interval timer, real time clock, and/or cycle counter (DS1994)
- Write protect feature provides tamper–proof time data (DS1994)
- Programmable expiration date that will limit access to SRAM and timekeeping (DS1994)
- Clock accuracy is better than ±2 minute/month at 25°C (DS1994)
- Operating temperature range from –40°C to +70°C
- Over 10 years of data retention

COMMON iButton FEATURES

- Unique, factory–lasered and tested 64–bit registration number (8–bit family code + 48–bit serial number + 8–bit CRC tester) assures absolute traceability because no two parts are alike
- Multidrop controller for MicroLAN™
- Digital identification and information by momentary contact
- Chip–based data carrier compactly stores information
- Data can be accessed while affixed to object
- Economically communicates to bus master with a single digital signal at 16.3k bits per second
- Standard 16 mm diameter and 1–Wire protocol ensure compatibility with iButton family
- Button shape is self–aligning with cup–shaped probes
- Durable stainless steel case engraved with registration number withstands harsh environments
- Easily affixed with self–stick adhesive backing, latched by its flange, or locked with a ring pressed onto its rim
- Presence detector acknowledges when reader first applies voltage
- Meets UL#913 (4th Edit.): Intrinsically Safe Apparatus, Approved under Entity Concept for use in Class I, Division 1, Group A, B, C and D Locations

F5 MICROCAN™

All dimensions shown in millimeters.

ORDERING INFORMATION

- DS1992L–F5  F5 MicroCan
- DS1993L–F5  F5 MicroCan
- DS1994L–F5  F5 MicroCan

EXAMPLES OF ACCESSORIES

- DS9096P  Self–Stick Adhesive Pad
- DS9101  Multi–Purpose Clip
- DS9093RA  Mounting Lock Ring
- DS9093F  Snap–In Fob
- DS9092  iButton Probe
iButton DESCRIPTION

The DS1992/DS1993/DS1994 Memory iButton (hereafter referred to as DS199X) is a rugged read/write data carrier that acts as a localized database that can be easily accessed with minimal hardware. The nonvolatile memory and optional timekeeping capability offer a simple solution to storing and retrieving vital information pertaining to the object to which the iButton is attached. Data is transferred serially via the 1-Wire protocol which requires only a single data lead and a ground return.

The scratchpad is an additional page that acts as a buffer when writing to memory. Data is first written to the scratchpad where it can be read back. After the data has been verified, a copy scratchpad command will transfer the data to memory. This process insures data integrity when modifying the memory. The durable MicroCan package is highly resistant to environmental hazards such as dirt, moisture, and shock. Its compact coin-shaped profile is self-aligning with mating receptacles, allowing the DS199X to be easily used by human operators. Accessories permit the DS199X to be mounted on almost any surface including plastic key fobs, photo-ID badges and printed circuit boards.

Applications include access control, work-in-progress tracking, electronic travelers, storage of calibration constants, and debit tokens. With the optional timekeeping functions (DS1994), a real-time clock/calendar, interval timer, cycle counter, and programmable interrupts are available in addition to the nonvolatile memory. The internal clock can be programmed to deny memory access based on absolute time/date, total elapsed time, or the number of accesses. These features allow the DS1994 to be used to create a stopwatch, alarm clock, time and date stamp, logbook, hour meter, calendar, system power cycle timer, interval timer, and event scheduler.

OVERVIEW

The DS199X has four main data components: 1) 64-bit lasered ROM, 2) 256-bit scratchpad, 3) 1024-bit (DS1992) or 4096-bit (DS1993 and DS1994) SRAM, and 4) timekeeping registers (DS1994). The timekeeping section utilizes an on-chip oscillator that is connected to a 32.768 kHz crystal. The SRAM and timekeeping registers reside in one contiguous address space referred to hereafter as memory. All data is read and written least significant bit first.

The memory functions will not be available until the ROM function protocol has been established. This protocol is described in the ROM functions flow chart (Figure 9). The master must first provide one of four ROM function commands: 1) read ROM, 2) match ROM, 3) search ROM, or 4) skip ROM. After a ROM function sequence has been successfully executed, the memory functions are accessible and the master may then provide any one of the four memory function commands (Figure 6).
DS199X BLOCK DIAGRAM Figure 1

- **64-BIT LASERED ROM**
- **INTERNAL REGISTERS & COUNTERS**
- **ROM FUNCTION CONTROL**
- **MEMORY FUNCTION CONTROL**
- **MEMORY**
- **32,768 Hz OSCILLATOR**
- **256-BIT SCRATCHPAD**
- **3V LITHIUM**
- **TIMEKEEPING FUNCTIONS**
- **HOLDING REGISTERS**

**PARASITE-POWERED CIRCUITRY**

**NOTE:** SHADED AREAS ONLY PRESENT IN DS1994
**PARASITE POWER**

The block diagram (Figure 1) shows the parasite-powered circuitry. This circuitry “steals” power whenever the data input is high. The data line will provide sufficient power as long as the specified timing and voltage requirements are met. The advantages of parasite power are two-fold: 1) by parasitizing this input, lithium is conserved and 2) if the lithium is exhausted for any reason, the ROM may still be read normally.

**64-BIT LASERED ROM**

Each DS199X contains a unique ROM code that is 64 bits long. The first eight bits are a 1-wire family code. The next 48 bits are a unique serial number. The last eight bits are a CRC of the first 56 bits. (See Figure 2.)

The 1-wire CRC is generated using a polynomial generator consisting of a shift register and XOR gates as shown in Figure 3. The polynomial is $X^8 + X^5 + X^4 + 1$. Additional information about the Dallas 1-Wire Cyclic Redundancy Check is available in the Book of DS19xx Button Standards.

The shift register bits are initialized to zero. Then starting with the least significant bit of the family code, one bit at a time is shifted in. After the 8th bit of the family code has been entered, then the serial number is entered. After the 48th bit of the serial number has been entered, the shift register contains the CRC value. Shifting in the eight bits of CRC should return the shift register to all zeros.
DS1994 MEMORY MAP Figure 4a

NOTE: Each page is 32 bytes (256 bits). The hex values represent the starting address for each page or register.
NOTE: Each page is 32 bytes (256 bits). The hex values represent the starting address for each page or register.
MEMORY
The memory map in Figure 4 shows a 32-byte page called the scratchpad and additional 32-byte pages called memory. The DS1992 contains pages 0 through 3 which make up the 1024-bit SRAM. The DS1993 and DS1994 contain pages 0 through 15 which make up the 4096-bit SRAM. The DS1994 also contains page 16 which has only 30 bytes that contain the timekeeping registers.

The scratchpad is an additional page that acts as a buffer when writing to memory. Data is first written to the scratchpad where it can be read back. After the data has been verified, a copy scratchpad command will transfer the data to memory. This process insures data integrity when modifying the memory.

TIMEKEEPING (DS1994)
A 32,768 Hz crystal oscillator is used as the time base for the timekeeping functions. The oscillator can be turned on or off by an enable bit in the control register. The oscillator must be on for the real time clock, interval timer and cycle counter to function.

The timekeeping functions are double buffered. This feature allows the master to read time or count without the data changing while it is being read. To accomplish this, a snapshot of the counter data is transferred to holding registers which the user accesses. This occurs after the eighth bit of the Read Memory Function command.

Real-Time Clock
The real-time clock is a 5-byte binary counter. It is incremented 256 times per second. The least significant byte is a count of fractional seconds. The upper four bytes are a count of seconds. The real-time clock can accumulate 136 years of seconds before rolling over. Time/date is represented by the number of seconds since a reference point which is determined by the user. For example, 12:00 A.M., January 1, 1970 could be a reference point.

Interval Timer
The interval timer is a 5-byte binary counter. When enabled, it is incremented 256 times per second. The least significant byte is a count of fractional seconds. The interval timer can accumulate 136 years of seconds before rolling over. The interval timer has two modes of operation which are selected by the AUTO/MAN bit in the control register. In the auto mode, the interval timer will begin counting after the data line has been high for a period of time determined by the DSEL bit in the control register. Similarly, the interval timer will stop counting after the data line has been low for a period of time determined by the DSEL bit. In the manual mode, time accumulation is controlled by the STOP/START bit in the control register.

NOTE: For auto mode operation, the high level on the data line must be greater than or equal to 2.1 volts.

Cycle Counter
The cycle counter is a 4-byte binary counter. It increments after the falling edge of the data line if the appropriate data line timing has been met. This timing is selected by the DSEL bit in the control register. (See “Status/Control” section).

NOTE: For cycle counter operation, the high level on the data line must be greater than or equal to 2.1 volts.

Alarm Registers
The alarm registers for the real-time clock, interval timer, and cycle counter all operate in the same manner. When the value of a given counter equals the value in its associated alarm register, the appropriate flag bit is set in the status register. If the corresponding interrupt enable bit(s) in the status register is set, an interrupt is generated. If a counter and its associated alarm register are write protected when an alarm occurs, access to the device becomes limited. (See “Status/Control”, “Interrupts”, and the “Programmable Expiration” sections.)

STATUS/CONTROL REGISTERS (DS1994)
The status and control registers are the first two bytes of page 16 (see “Memory Map”, Figure 4).

Status Register

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td><strong>X</strong></td>
</tr>
<tr>
<td>6</td>
<td><strong>X</strong></td>
</tr>
<tr>
<td>5</td>
<td>CCE</td>
</tr>
<tr>
<td>4</td>
<td>ITE</td>
</tr>
<tr>
<td>3</td>
<td>RTE</td>
</tr>
<tr>
<td>2</td>
<td>CCF</td>
</tr>
<tr>
<td>1</td>
<td>ITF</td>
</tr>
<tr>
<td>0</td>
<td>RTF</td>
</tr>
</tbody>
</table>

* Don't care bits
* Read Only

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td><strong>RTF</strong> Real-time clock alarm flag</td>
</tr>
<tr>
<td>1</td>
<td><strong>ITF</strong> Interval timer alarm flag</td>
</tr>
<tr>
<td>2</td>
<td><strong>CCF</strong> Cycle counter alarm flag</td>
</tr>
</tbody>
</table>

020698 7/20
When a given alarm occurs, the corresponding alarm flag is set to a logic 1. The alarm flag(s) is cleared by reading the status register.

| 3  | RTE  | Real-time interrupt enable |
| 4  | ITE  | Interval timer interrupt enable |
| 5  | CCE  | Cycle counter interrupt enable |

Writing any of the interrupt enable bits to a logic 0 will allow an interrupt condition to be generated when its corresponding alarm flag is set (see “Interrupts” section).

**Control Register**

```
<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSEL</td>
<td>STOP</td>
<td>START</td>
<td>AUTO</td>
<td>MAN</td>
<td>OSC</td>
<td>RO</td>
<td>WPC</td>
</tr>
</tbody>
</table>
```

- **0 WPR**: Write protect real-time clock/alarm registers
- **1 WPI**: Write protect interval timer/alarm registers
- **2 WPC**: Write protect cycle counter/alarm registers

Setting a write protect bit to a logic 1 will permanently write protect the corresponding counter and alarm registers, all write protect bits, and additional bits in the control register. The write protect bits can not be written in a normal manner (see “Write Protect/Programmable Expiration” section).

| 3  | RO  | Read Only |
| 4  | OSC | Oscillator Enable |

This bit controls the crystal oscillator. When set to a logic 1, the oscillator will start operation. When the oscillator bit is a logic 0, the oscillator will stop.

| 5  | AUTO/MAN | Automatic/Manual Mode |
| 6  | STOP/START | Stop/Start (in Manual Mode) |

If the interval timer is in manual mode, the interval timer will start counting when this bit is set to a logic 0 and will stop counting when set to a logic 1. If the interval timer is in automatic mode, this bit has no effect.

| 7  | DSEL | Delay Select Bit |

This bit selects the delay that it takes for the cycle counter and the interval timer (in auto mode) to see a transition on the data line. When this bit is set to a logic 1, the delay time is $123 \pm 2 \text{ ms}$. This delay allows communication on the data line without starting or stopping the interval timer and without incrementing the cycle counter. When this bit is set to a logic 0, the delay time is $3.5 \pm 0.5 \text{ ms}$.

**MEMORY FUNCTION COMMANDS**

The “Memory Function Flow Chart” (Figure 6) describes the protocols necessary for accessing the memory. An example follows the flowchart. Three address registers are provided as shown in Figure 5. The first two registers represent a 16-bit target address (TA1, TA2). The third register is the ending offset/data status byte (E/S).

The target address points to a unique byte location in memory. The first five bits of the target address (T4:T0) represent the byte offset within a page. This byte offset points to one of 32 possible byte locations within a given page. For instance, 00000b points to the first byte of a page where as 11111b would point to the last byte of a page.

The third register (E/S) is a read only register. The first five bits (E4:E0) of this register are called the ending offset. The ending offset is a byte offset within a page (1 of 32 bytes). Bit 5 (PF) is the partial byte flag. Bit 6 (OF) is the overflow flag. Bit 7 (AA) is the authorization accepted flag.
ADDRESS REGISTERS

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA1</td>
<td>T7</td>
<td>T6</td>
<td>T5</td>
<td>T4</td>
<td>T3</td>
<td>T2</td>
<td>T1</td>
</tr>
<tr>
<td>TA2</td>
<td>T15</td>
<td>T14</td>
<td>T13</td>
<td>T12</td>
<td>T11</td>
<td>T10</td>
<td>T9</td>
</tr>
<tr>
<td>E/S</td>
<td>AA</td>
<td>OF</td>
<td>PF</td>
<td>E4</td>
<td>E3</td>
<td>E2</td>
<td>E1</td>
</tr>
</tbody>
</table>

Write Scratchpad Command [0Fh]
After issuing the write scratchpad command, the user must first provide the 2-byte target address, followed by the data to be written to the scratchpad. The data will be written to the scratchpad starting at the byte offset (T4:T0). The ending offset (E4: E0) will be the byte offset at which the host stops writing data. The maximum ending offset is 11111b (31d). If the host attempts to write data past this maximum offset, the overflow flag (OF) will be set and the remaining data will be ignored. If the user writes an incomplete byte and an overflow has not occurred, the partial byte flag (PF) will be set.

Read Scratchpad Command [AAh]
This command may be used to verify scratchpad data and target address. After issuing the read scratchpad command, the user may begin reading. The first two bytes will be the target address. The next byte will be the ending offset/data status byte (E/S) followed by the scratchpad data beginning at the byte offset (T4: T0). The user may read data until the end of the scratchpad after which the data read will be all logic 1’s.

Copy Scratchpad [55h]
This command is used to copy data from the scratchpad to memory. After issuing the copy scratchpad command, the user must provide a 3-byte authorization pattern. This pattern must exactly match the data contained in the three address registers (TA1, TA2, E/S, in that order). If the pattern matches, the AA (Authorization Accepted) flag will be set and the copy will begin. A logic 0 will be transmitted after the data has been copied until a reset pulse is issued by the user. Any attempt to reset the part will be ignored while the copy is in progress. Copy typically takes 30 µs.

The data to be copied is determined by the three address registers. The scratchpad data from the beginning offset through the ending offset, will be copied to memory, starting at the target address. Anywhere from 1 to 32 bytes may be copied to memory with this command. Whole bytes are copied even if only partially written. The AA flag will be cleared only by executing a write scratchpad command.

Read Memory [F0h]
The read memory command may be used to read the entire memory. After issuing the command, the user must provide the 2-byte target address. After the two bytes, the user reads data beginning from the target address and may continue until the end of memory, at which point logic 1’s will be read. It is important to realize that the target address registers will contain the address provided. The ending offset/data status byte is unaffected.

The hardware of the DS1992/DS1993/DS1994 provides a means to accomplish error–free writing to the memory section. To safeguard reading data in the 1-Wire environment and to simultaneously speed up data transfers, it is recommended to packetize data into packets of the size of one memory page each. Such a packet would typically store a 16–bit CRC with each page of data to insure rapid, error–free data transfers that eliminate having to read a page multiple times to determine if the received data is correct or not. (See the Book of DS19xx Button Standards, Chapter 7 for the recommended file structure to be used with the 1–Wire environment.)
MEMORY FUNCTION FLOW CHART  Figure 6

1. **MASTER TX MEMORY FUNCTION COMMAND**
   - **0Fh WRITE SCRATCHPAD**
     - **Y**: **MASTER TX TA1 (T7:T0)**
     - **N**: **MASTER TX TA2 (T15:T8)**
   - **DS199X SETS SCRATCHPAD OFFSET = (T4:T0) AND CLEARS (PF OF AA)**
   - **Y**: **INCREMENT SCRATCHPAD OFFSET**
     - **N**: **SCRATCHPAD OFFSET = 11111b**
   - **Y**: **PARTIAL BYTE WRITTEN**
     - **N**: **MASTER TX DATA**
   - **OF = 1**
     - **N**: **MASTER TX DATA**
   - **N**: **MASTER TX RESET**

2. **AAh READ SCRATCHPAD**
   - **Y**: **MASTER RX TA1 (T7:T0)**
   - **N**: **MASTER RX TA2 (T15:T8)**
   - **DS199X SETS SCRATCHPAD OFFSET = (T4:T0)**
   - **Y**: **INCREMENT SCRATCHPAD OFFSET**
     - **N**: **SCRATCHPAD OFFSET = 11111b**
   - **Y**: **MASTER RX "1"s**
     - **N**: **MASTER RX "0"s**
   - **Y**: **MASTER RX RESET**
   - **N**: **MASTER RX "0"s**

3. **55h COPY SCRATCHPAD**
   - **Y**: **MASTER TX TA1 (T7:T0)**
   - **N**: **MASTER TX TA2 (T15:T8)**
   - **DS199X COPIES SCRATCHPAD DATA TO MEMORY**
   - **Y**: **MASTER TX "1"s**
     - **N**: **MASTER TX "0"s**
   - **Y**: **MASTER TX RESET**
   - **N**: **MASTER TX "0"s**

4. **F0h READ MEMORY**
   - **Y**: **MASTER RX ENDING OFFSET/DATA STATUS BYTE (E/S)**
     - **N**: **AUTHORIZATION CODE MATCH ?**
       - **Y**: **AA = 1**
         - **N**: **DS199X TX "1"s**
           - **Y**: **DS199X TX "1"s**
             - **N**: **DS199X TX "0"s**
               - **Y**: **MASTER RX "1"s**
                 - **N**: **MASTER RX "0"s**
                   - **Y**: **INCREMENT MEMORY ADDRESS**
                     - **N**: **MEMORY ADDRESS = 21Dh**
                       - **Y**: **MASTER RX "1"s**
                         - **N**: **MASTER RX "0"s**
                           - **Y**: **MASTER TX PRESENCE PULSE (SEE FIGURE 9)**

5. **DS199X SETS SCRATCHPAD OFFSET = (T4:T0) AND CLEARS (PF OF AA)**
   - **Y**: **INCREMENT SCRATCHPAD OFFSET**
     - **N**: **SCRATCHPAD OFFSET = 11111b**
   - **Y**: **PARTIAL BYTE WRITTEN**
     - **N**: **MASTER TX DATA**
   - **OF = 1**
     - **N**: **MASTER TX DATA**
   - **N**: **MASTER TX RESET**

6. **MASTER RX TA1 (T7:T0)**
   - **Y**: **DS199X SETS SCRATCHPAD OFFSET = (T4:T0)**
     - **N**: **INCREMENT SCRATCHPAD OFFSET**
       - **N**: **SCRATCHPAD OFFSET = 11111b**
   - **Y**: **MASTER RX "1"s**
     - **N**: **MASTER RX "0"s**
   - **Y**: **MASTER RX RESET**
   - **N**: **MASTER RX "0"s**

7. **MASTER RX TA2 (T15:T8)**
   - **Y**: **DS199X SETS MEMORY ADDRESS = (T15:T0)**
     - **N**: **INCREMENT MEMORY ADDRESS**
       - **N**: **MEMORY ADDRESS = 21Dh**
         - **Y**: **MASTER RX "1"s**
           - **N**: **MASTER RX "0"s**
             - **Y**: **MASTER TX PRESENCE PULSE (SEE FIGURE 9)**

8. **MASTER TX TA1 (T7:T0)**
   - **Y**: **DS199X SETS MEMORY ADDRESS = (T15:T0)**
     - **N**: **INCREMENT MEMORY ADDRESS**
       - **N**: **MEMORY ADDRESS = 21Dh**
         - **Y**: **MASTER RX "1"s**
           - **N**: **MASTER RX "0"s**
             - **Y**: **MASTER TX PRESENCE PULSE (SEE FIGURE 9)**
MEMORY FUNCTION EXAMPLES

Example: Write two data bytes to memory locations 0026h and 0027h (the seventh and eighth bytes of page 1). Read entire memory.

<table>
<thead>
<tr>
<th>MASTER MODE</th>
<th>DATA (LSB FIRST)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX</td>
<td>Reset</td>
<td>Reset pulse (480–960 µs)</td>
</tr>
<tr>
<td>RX</td>
<td>Presence</td>
<td>Presence pulse</td>
</tr>
<tr>
<td>TX</td>
<td>CCh</td>
<td>Issue “skip ROM” command</td>
</tr>
<tr>
<td>TX</td>
<td>0Fh</td>
<td>Issue “write scratchpad” command</td>
</tr>
<tr>
<td>TX</td>
<td>26h</td>
<td>TA1, beginning offset=6</td>
</tr>
<tr>
<td>TX</td>
<td>00h</td>
<td>TA2, address=0026h</td>
</tr>
<tr>
<td>TX</td>
<td>&lt;2 data bytes&gt;</td>
<td>Write 2 bytes of data to scratchpad</td>
</tr>
<tr>
<td>TX</td>
<td>Reset</td>
<td>Reset pulse</td>
</tr>
<tr>
<td>RX</td>
<td>Presence</td>
<td>Presence pulse</td>
</tr>
<tr>
<td>TX</td>
<td>CCh</td>
<td>Issue “skip ROM” command</td>
</tr>
<tr>
<td>TX</td>
<td>AAh</td>
<td>Issue “read scratchpad” command</td>
</tr>
<tr>
<td>RX</td>
<td>26h</td>
<td>Read TA1, beginning offset=6</td>
</tr>
<tr>
<td>RX</td>
<td>00h</td>
<td>Read TA2, address=0026h</td>
</tr>
<tr>
<td>RX</td>
<td>07h</td>
<td>Read E/S, ending offset=7, flags=0</td>
</tr>
<tr>
<td>RX</td>
<td>&lt;2 data bytes&gt;</td>
<td>Read scratchpad data and verify</td>
</tr>
<tr>
<td>TX</td>
<td>Reset</td>
<td>Reset pulse</td>
</tr>
<tr>
<td>RX</td>
<td>Presence</td>
<td>Presence pulse</td>
</tr>
<tr>
<td>TX</td>
<td>CCh</td>
<td>Issue “skip ROM” command</td>
</tr>
<tr>
<td>TX</td>
<td>55h</td>
<td>Issue “copy scratchpad” command</td>
</tr>
<tr>
<td>TX</td>
<td>26h</td>
<td>TA1</td>
</tr>
<tr>
<td>TX</td>
<td>00h</td>
<td>TA2</td>
</tr>
<tr>
<td>TX</td>
<td>07h</td>
<td>E/S</td>
</tr>
<tr>
<td>TX</td>
<td>Reset</td>
<td>Reset pulse</td>
</tr>
<tr>
<td>RX</td>
<td>Presence</td>
<td>Presence pulse</td>
</tr>
<tr>
<td>TX</td>
<td>CCh</td>
<td>Issue “skip ROM” command</td>
</tr>
<tr>
<td>TX</td>
<td>F0h</td>
<td>Issue “read memory” command</td>
</tr>
<tr>
<td>TX</td>
<td>00h</td>
<td>TA1, beginning offset=0</td>
</tr>
<tr>
<td>TX</td>
<td>00h</td>
<td>TA2, address=0000h</td>
</tr>
<tr>
<td>RX</td>
<td>&lt;128 bytes (DS1992)&gt;</td>
<td>Read entire memory</td>
</tr>
<tr>
<td>RX</td>
<td>&lt;512 bytes (DS1993)&gt;</td>
<td></td>
</tr>
<tr>
<td>RX</td>
<td>&lt;542 bytes (DS1994)&gt;</td>
<td></td>
</tr>
<tr>
<td>TX</td>
<td>Reset</td>
<td>Reset pulse</td>
</tr>
<tr>
<td>RX</td>
<td>Presence</td>
<td>Presence pulse, done</td>
</tr>
</tbody>
</table>
WRITE PROTECT/PROGRAMMABLE EXPIRATION (DS1994)

The write protect bits (WPR, WPI, WPC) provide a means of write protecting the timekeeping data and limiting access to the DS1994 when an alarm occurs (programmable expiration).

The write protect bits may not be written by performing a single copy scratchpad command. Instead, to write these bits, the copy scratchpad command must be performed three times. Please note that the AA bit will set, as expected, after the first copy command is successfully executed. Therefore, the authorization pattern for the second and third copy command should have this bit set. The read scratchpad command may be used to verify the authorization pattern.

WRITE PROTECT CHART

<table>
<thead>
<tr>
<th>WRITE PROTECT BIT SET:</th>
<th>WPR</th>
<th>WPI</th>
<th>WPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Protected from User Modification:</td>
<td>Real Time Clock</td>
<td>Interval Timer</td>
<td>Cycle Counter</td>
</tr>
<tr>
<td>WPR</td>
<td>WPI</td>
<td>WPC</td>
<td>RO</td>
</tr>
<tr>
<td>STOP/START</td>
<td>AUTO/MAN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Becomes write “1” only, i.e., once written to a logic “1”, may not be written back to a logic “0”.

1-WIRE BUS SYSTEM

The 1-wire bus is a system which has a single bus master and one or more slaves. In most instances the DS199X behaves as a slave. The exception is when the DS1994 generates an interrupt due to a timekeeping alarm. The discussion of this bus system is broken down into three topics: hardware configuration, transaction sequence, and 1-wire signalling (signal types and timing).

HARDWARE CONFIGURATION

The 1-wire bus has only a single line by definition; it is important that each device on the bus be able to drive it at the appropriate time. To facilitate this, each device attached to the 1-wire bus must have open drain or 3-state outputs. The 1-wire port of the DS199X is open drain with an internal circuit equivalent to that shown in Figure 8. A multidrop bus consists of a 1-Wire bus with multiple slaves attached. The 1-wire bus has a maximum data rate of 16.3k bits per second and requires a pull-up resistor of approximately 5 kΩ.

The idle state for the 1-wire bus is high. If for any reason a transaction needs to be suspended, the bus MUST be left in the idle state if the transaction is to resume. If this does not occur and the bus is left low for more than 120 µs, one or more of the devices on the bus may be reset.
TRANSACTION SEQUENCE
The protocol for accessing the DS199X via the 1-wire port is as follows:

- Initialization
- ROM Function Command
- Memory Function Command
- Transaction/Data

INITIALIZATION
All transactions on the 1-wire bus begin with an initialization sequence. The initialization sequence consists of a reset pulse transmitted by the bus master followed by presence pulse(s) transmitted by the slave(s).

The presence pulse lets the bus master know that the DS199X is on the bus and is ready to operate. For more details, see the “1-Wire Signalling” section.

ROM FUNCTION COMMANDS
Once the bus master has detected a presence, it can issue one of the four ROM function commands. All ROM function commands are eight bits long. A list of these commands follows (refer to flowchart in Figure 9):

- **Read ROM [33h]**
  This command allows the bus master to read the DS199X’s 8-bit family code, unique 48-bit serial number, and 8-bit CRC. This command can only be used if there is a single DS199X on the bus. If more than one slave is present on the bus, a data collision will occur when all slaves try to transmit at the same time (open drain will produce a wired-AND result). The resultant family code and 48-bit serial number will usually result in a mismatch of the CRC.

- **Match ROM [55h]**
  The match ROM command, followed by a 64-bit ROM sequence, allows the bus master to address a specific DS199X on a multidrop bus. Only the DS199X that exactly matches the 64-bit ROM sequence will respond to the subsequent memory function command. All slaves that do not match the 64-bit ROM sequence will wait for a reset pulse. This command can be used with a single or multiple devices on the bus.

- **Skip ROM [CCh]**
  This command can save time in a single drop bus system by allowing the bus master to access the memory functions without providing the 64-bit ROM code. If more than one slave is present on the bus and a read command is issued following the Skip ROM command, data collision will occur on the bus as multiple slaves transmit simultaneously (open drain pull-downs will produce a wired-AND result).

- **Search ROM [F0h]**
  When a system is initially brought up, the bus master might not know the number of devices on the 1-Wire bus or their 64-bit ROM codes. The search ROM command allows the bus master to use a process of elimination to identify the 64-bit ROM codes of all slave devices on the bus. The search ROM process is the repetition of a simple 3-step routine: read a bit, read the complement of the bit, then write the desired value of that bit. The bus master performs this simple, 3-step routine on each bit of the ROM. After one complete pass, the bus master knows the contents of the ROM in one device. The remaining number of devices and their ROM codes may be identified by additional passes. See Chapter 5 of the Book of DS19xx iButton Standards for a comprehensive discussion of a search ROM, including an actual example.

- **Search Interrupt [ECh]** (DS1994)
  This ROM command works exactly as the normal ROM Search, but it will identify only devices with interrupts that have not yet been acknowledged.
ROM FUNCTIONS FLOW CHART  Figure 9

- MASTER T_x RESET PULSE
- DS199X T_x PRESENCE PULSE
- MASTER T_x ROM FUNCTION COMMAND
  - DS199X T_x FAMILY CODE 1 BYTE
    - DS199X T_x MATCH ROM COMMAND
    - DS199X T_x SERIAL NUMBER 6 BYTES
    - DS199X T_x CRC BYTE
    - DS199X T_x MATCH ROM COMMAND
  - DS199X T_x MATCH ROM COMMAND
  - FOR SEARCH ROM COMMAND
  - EDR INTERRUPT SEARCH
  - CRC SKIP ROM COMMAND
  - INTERRUPT ACTIVE
  - N
  - Y
  - Y
  - N
  - N
- DS1994 ONLY
- (SEE FIGURE 6)
1–WIRE SIGNALLING

The DS199x requires strict protocols to ensure data integrity. The protocol consists of five types of signalling on one line: Reset Sequence with Reset Pulse and Presence Pulse, Write 0, Write 1, Read Data and interrupt pulse (DS1994). All these signals except presence pulse and interrupt pulse are initiated by the bus master. The initialization sequence required to begin any communication with the DS199x is shown in Figure 10. A reset pulse followed by a presence pulse indicates the DS199x is ready to send or receive data given the correct ROM command and memory function command. The bus master transmits (TX) a reset pulse ($t_{RSTL}$, minimum 480 µs). The bus master then releases the line and goes into receive mode (RX). The 1–Wire bus is pulled to a high state via the pull–up resistor. After detecting the rising edge on the data line, the DS199x waits ($t_{PDH}$, 15–60 µs) and then transmits the presence pulse ($t_{PDL}$, 60–240 µs). There are special conditions if interrupts are enabled where the bus master must check the state of the 1–Wire bus after being in the RX mode for 480 µs. These conditions will be discussed in the "Interrupt" section.

READ/WRITE TIME SLOTS

The definitions of write and read time slots are illustrated in Figure 11. All time slots are initiated by the master driving the data line low. The falling edge of the data line synchronizes the DS199x to the master by triggering a delay circuit in the DS199x. During write time slots, the delay circuit determines how long the DS199x will hold the data line low overriding the 1 generated by the master. If the data bit is a "1", the iButton will leave the read data time slot unchanged.

INITIALIZATION PROCEDURE "RESET AND PRESENCE PULSES" Figure 10

In order not to mask interrupt signalling by other devices on the 1–Wire bus, $t_{RSTL} + t_{R}$ should always be less than 960 µs.
READ/WRITE TIMING DIAGRAM  Figure 11

Write–One Time Slot

Write–Zero Time Slot

Read–Data Time Slot
Interrupts (DS1994)
If the DS1994 detects an alarm condition, it will automatically set the corresponding alarm flag in the Status Register. An interrupt condition begins whenever any alarm flag is set and the flag’s corresponding interrupt bit is enabled. The interrupt condition ceases when the alarm flags are cleared (i.e., the interrupt is acknowledged by reading the Status Register, address 200H) or if the corresponding interrupt enable bit is disabled.

The DS1994 can produce two types of interrupts: spontaneous interrupts, called type 1, and delayed interrupts, type 2. Spontaneous interrupts need to be armed by a Reset Pulse after all communication on the 1-Wire bus has finished. A single falling slope on the 1-Wire bus will disarm this type of interrupt. If an alarm condition occurs while the device is disarmed, at first a type 2 interrupt will be produced.

Spontaneous interrupts are signalled by the DS1994 by pulling the data line low for 960 to 3840 µs as the interrupt condition begins (Figure 12). After this long low pulse a Presence Pulse will follow. If the alarm condition occurs just after the master has sent a Reset Pulse, i.e., during the high or low time of the Presence Pulse, the DS1994 will not assert its Interrupt Pulse until the Presence Pulse is finished (Figure 13).

If the DS1994 cannot assert a spontaneous interrupt, either because the data line was not pulled high, communication was in progress, or the interrupt was not armed, it will extend the next Reset Pulse to a total length of 960 to 3840 µs (delayed interrupt). If the alarm condition occurs during the reset low time of the Reset Pulse, the DS1994 will immediately assert its interrupt pulse; thus the total low time of the pulse can be extended up to 4800 µs (Figure 14). If a DS1994 with a not previously signaled alarm detects a power–on cycle on the 1–Wire bus, it will send a Presence Pulse and wait for the Reset Pulse sent by the master to extend it and to subsequently issue a Presence Pulse (Figure 15). As long as an interrupt has not been acknowledged by the master, the DS1994 will continue sending interrupt pulses.

The interrupt signaling discussed so far is valid for the first opportunity the device has to signal an interrupt. It is not required for the master to acknowledge an interrupt immediately. If an interrupt is not acknowledged, the DS1994 will continue signaling the interrupt with every Reset Pulse. To do so, DS1994 devices of Revision B (earlier production parts) will always use the waveform of the Type 2 Interrupt (Figure 14). Devices of Revision C (latest production) will either use the waveform of the Type 2 Interrupt (Figure 14) or the waveform of the Type 1A Interrupt (Figure 13). The waveform of the Type 2 Interrupt will be observed after a communication to a device other than the interrupting one; after successful communication to the interrupting device (without acknowledging the interrupt) the waveform of the Type 1A Interrupt will be found.

The revision code of the DS1994 is branded on the lid of the MicroCan. The field RR (see figure on Page 1), just above the family code, will read Bx for Revision B and Cx for Revision C. (The character “x” represents a 1-digit number that is not related to the chip inside.) The revision code can also be determined indirectly by observing the waveforms used for interrupt signaling.

**TYPE 1 INTERRUPT** Figure 12

![Diagram of Type 1 Interrupt](image)

Note: No communication following Presence Pulse, i.e. no falling edge.

Interrupt condition occurs here.
TYPE 1A INTERRUPT (SPECIAL CASE) Figure 13

Interrupt condition occurs during the Presence Pulse, but the interrupt is not generated until the Presence Pulse is completed.

TYPE 2 INTERRUPT Figure 14

Interrupt condition exists prior to master releasing reset.

TYPE 2 INTERRUPT (SPECIAL CASE) Figure 15

Interrupt condition occurs while the bus is powered down. Bus powers up.

LINE TYPE LEGEND:
- Bus master active low
- DS1994 active low
- Both bus master and DS1994 active low
- Resistor pull-up
PHYSICAL SPECIFICATIONS
Size
Weight
Humidity
Altitude
Expected Service Life
Safety
Meet UL#913 (4th Edit.); Intrinsically Safe Apparatus, Approved under Entity Concept for use in Class I, Division 1, Group A, B, C and D Locations

ABSOLUTE MAXIMUM RATINGS*
Voltage on any Pin Relative to Ground
Operating Temperature
Storage Temperature

* This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

DC ELECTRICAL CHARACTERISTICS

PARAMETER | SYMBOL | MIN  | TYP  | MAX  | UNITS
---|---|---|---|---|---
Logic 1 | $V_{IH}$ | 2.2 | $V_{CC}+0.3$ | 1, 8 | V
Logic 0 | $V_{IL}$ | $–0.3$ | $+0.8$ | 1 | V
Output Logic Low @ 4mA | $V_{OL}$ | $0.4$ | | 1 | V
Output Logic High | $V_{OH}$ | $V_{PUP}$ | 6.0 | 1, 2 | V
Input Load Current | $I_{L}$ | 5 | | | $\mu$A

CAPACITANCE

PARAMETER | SYMBOL | MIN  | TYP  | MAX  | UNITS
---|---|---|---|---|---
I/O (1-Wire) | $C_{IN/OUT}$ | 100 | 800 | | pF

AC ELECTRICAL CHARACTERISTICS

PARAMETER | SYMBOL | MIN  | TYP  | MAX  | UNITS
---|---|---|---|---|---
Time Slot | $t_{SLOT}$ | 60 | | 120 | $\mu$s
Write 1 Low Time | $t_{LOW1}$ | 1 | | 15 | $\mu$s
Write 0 Low Time | $t_{LOW0}$ | 60 | | 120 | $\mu$s
Read Data Valid | $t_{RDV}$ | | exactly 15 | | $\mu$s
Release Time | $t_{RELEASE}$ | 0 | 15 | 45 | $\mu$s
Read Data Setup | $t_{SU}$ | | 1 | | $\mu$s
Interrupt | $t_{INT}$ | 960 | | 4800 | $\mu$s
Recovery Time | $t_{REC}$ | | 1 | | $\mu$s
Reset Time High | $t_{RSTH}$ | 480 | | | $\mu$s
Reset Time Low | $t_{RSTL}$ | 480 | | 960 | $\mu$s
Presence Detect High | $t_{PDHIGH}$ | 15 | | 60 | $\mu$s
Presence Detect Low | $t_{PDLOW}$ | 60 | | 240 | $\mu$s
NOTES:
1. All voltages are referenced to ground.
2. $V_{PUP}$ = external pull-up voltage.
3. Input load is to ground.
4. An additional reset or communication sequence cannot begin until the reset high time has expired.
5. Read data setup time refers to the time the host must pull the 1-Wire bus low to read a bit. Data is guaranteed to be valid within 1 $\mu$s of this falling edge and will remain valid for 14 $\mu$s minimum. (15 $\mu$s total from falling edge on 1-Wire bus.)
6. Capacitance on the data line could be 800 pF when power is first applied. If a 5 k$\Omega$ resistor is used to pull-up the data line to $V_{CC}$, 5 $\mu$s after power has been applied, the parasite capacitance will not affect normal communications.
7. The reset low time ($t_{RSTL}$) should be restricted to a maximum of 960 $\mu$s, to allow interrupt signalling, otherwise, it could mask or conceal interrupt pulses.
8. $V_{IH}$ is a function of the external pull-up resistor and the $V_{CC}$ power supply (DS1992, DS1993 only).
9. DS1994 only.