



# DS80C310 High-Speed Microcontroller

[www.maxim-ic.com](http://www.maxim-ic.com)

## GENERAL DESCRIPTION

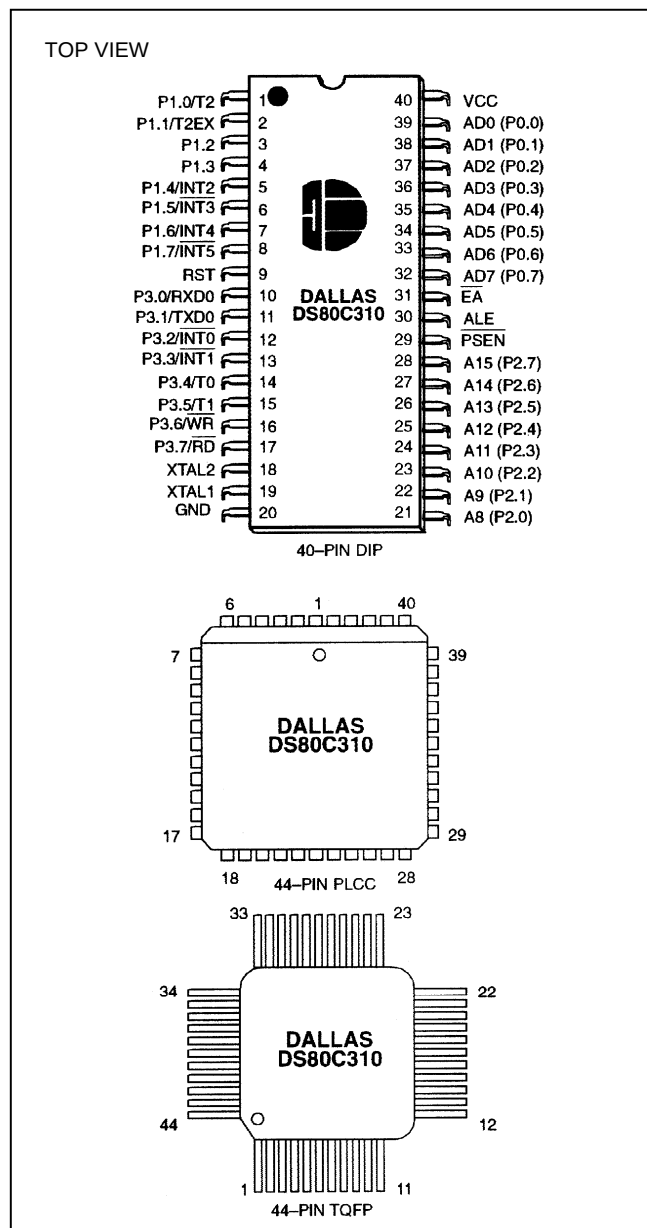
The DS80C310 is a fast 80C31/80C32-compatible microcontroller. It features a redesigned processor core without wasted clock and memory cycles. As a result, it executes every 8051 instruction between 1.5x and 3x faster than the original architecture for the same crystal speed. Typical applications have a speed improvement of 2.5x using the same code and the same crystal. The DS80C310 offers a 25MHz maximum crystal speed, resulting in apparent execution speeds of 62.5MHz (approximately 2.5x).

The DS80C310 is pin compatible with the standard 80C32 and includes standard resources such as three timer/counters, 256 bytes of RAM, and a serial port. It also provides dual data pointers (DPTRs) to speed block data memory moves. It also can adjust the speed of MOVX data memory access between two and nine machine cycles for flexibility in selecting external memory and peripherals. The DS80C310 offers upward compatibility with the DS80C320.

## FEATURES

- **80C32 Compatible**
  - 8051 Pin and Instruction Set Compatible
  - Full-Duplex Serial Port
  - Three 16-Bit Timer/Counters
  - 256 Bytes Scratchpad RAM
  - Multiplexed Address/Data Bus
  - Addresses 64kB ROM and 64kB RAM
- **High-Speed Architecture**
  - 4 Clocks/Machine Cycle (8051 = 12)
  - Runs DC to 25MHz Clock Rates
  - Single-Cycle Instruction in 160ns
  - Dual Data Pointer
  - Optional Variable Length MOVX to Access Fast/Slow RAM /Peripherals
- **10 Total Interrupt Sources with 6 External**
- **Internal Power-On Reset Circuit**
- **Upwardly Compatible with the DS80C320**
- **Available in 40-Pin Plastic DIP, 44-Pin PLCC, and 44-Pin TQFP**

## PIN CONFIGURATIONS



**Note:** Designers must have two documents to fully use all the features of this device: this data sheet and the High-Speed Microcontroller User's Guide, available on our website at [www.maxim-ic.com/microcontrollers](http://www.maxim-ic.com/microcontrollers). Data sheets contain pin descriptions, feature overviews, and electrical specifications, whereas the user's guide contains detailed information about device features and operation.

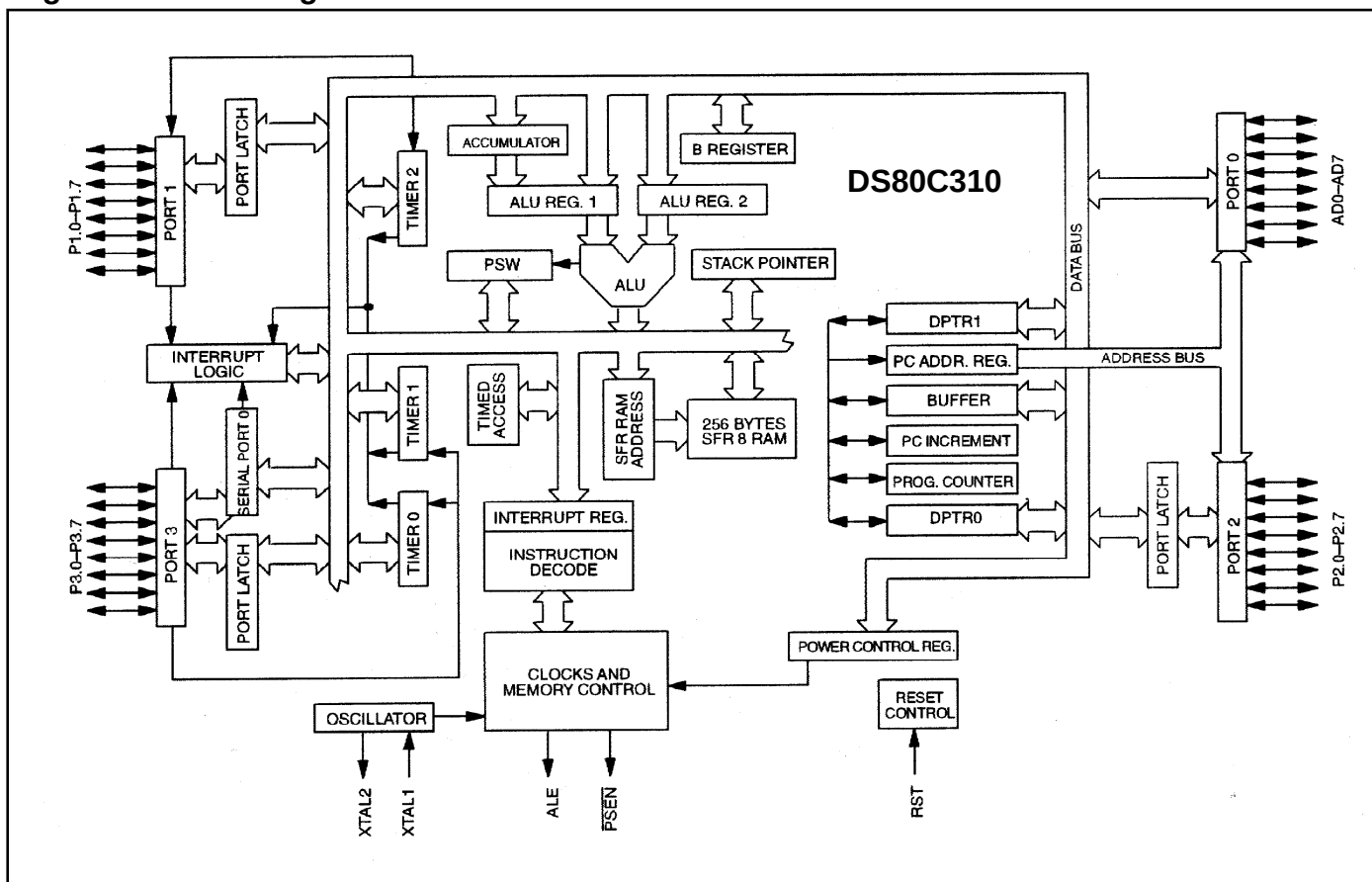
**Note:** Some revisions of this device may incorporate deviations from published specifications known as errata. Multiple revisions of any device may be simultaneously available through various sales channels. For information about device errata, click here: [www.maxim-ic.com/errata](http://www.maxim-ic.com/errata).

## ORDERING INFORMATION

| PART          | TEMP RANGE     | MAX CLOCK SPEED (MHz) | PIN-PACKAGE    |
|---------------|----------------|-----------------------|----------------|
| DS80C310-MCG  | 0°C to +70°C   | 25                    | 40 Plastic DIP |
| DS80C310-MCG+ | 0°C to +70°C   | 25                    | 40 Plastic DIP |
| DS80C310-QCG  | 0°C to +70°C   | 25                    | 44 PLCC        |
| DS80C310-QCG+ | 0°C to +70°C   | 25                    | 44 PLCC        |
| DS80C310-QNG  | -40°C to +85°C | 25                    | 44 PLCC        |
| DS80C310-QNG+ | -40°C to +85°C | 25                    | 44 PLCC        |
| DS80C310-ECG  | 0°C to +70°C   | 25                    | 44 TQFP        |
| DS80C310-ECG+ | 0°C to +70°C   | 25                    | 44 TQFP        |

+ Denotes a lead(Pb)-free/RoHS-compliant device.

**Figure 1. Block Diagram**



**PIN DESCRIPTION**

| PIN  |      |                   | NAME      | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |  |  |
|------|------|-------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
| PDIP | PLCC | TQFP              |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
| 1–8  | 2–9  | 40–44,<br>1, 2, 3 | P1.0–P1.7 | Port 1 (I/O). Port 1 functions as both an 8-bit bidirectional I/O port and an alternate functional interface for Timer 2 I/O and new external interrupts. The reset condition of Port 1 is with all bits at logic 1. In this state, a weak pullup holds the port high. This condition also serves as an input mode, since any external circuit that writes to the port overcomes the weak pullup. When software writes a 0 to any port pin, the DS80C310 activates a strong pulldown that remains on until either a 1 is written or a reset occurs. Writing a 1 after the port has been at 0 causes a strong transition driver to turn on, followed by a weaker sustaining pullup. Once the momentary strong driver turns off, the port once again becomes the output high (and input) state. The alternate modes of Port 1 are outlined as follows: |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |
|      |      |                   |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |  |  |

| PIN    |              |            | NAME         | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                   |      |      |                          |                        |      |           |          |      |      |      |
|--------|--------------|------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|------|------|--------------------------|------------------------|------|-----------|----------|------|------|------|
| PDIP   | PLCC         | TQFP       |              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 10–17  | 11,<br>13–19 | 5, 7–13    | P3.0–P3.7    | Port 3 (I/O). Port 3 functions as both an 8-bit bidirectional I/O port and an alternate functional interface for external Interrupts, Serial Port 0, Timer 0 and 1 Inputs, $\overline{\text{RD}}$ and $\overline{\text{WR}}$ strobes. The reset condition of Port 3 is with all bits at logic 1. In this state, a weak pullup holds the port high. This condition also serves as an input mode, since any external circuit that writes to the port will overcome the weak pullup. When software writes a 0 to any port pin, the DS80C310 will activate a strong pulldown that remains on until either a 1 is written or a reset occurs. Writing a 1 after the port has been at 0 will cause a strong transition driver to turn on, followed by a weaker sustaining pullup. Once the momentary strong driver turns off, the port once again becomes both the output high and input state. The alternate modes of Port 3 are as follows: |                                   |      |      |                          |                        |      |           |          |      |      |      |
|        |              |            |              | <table><tr><th colspan="3">PIN</th><th rowspan="2">PORT</th><th rowspan="2">ALTERNATE</th><th rowspan="2">FUNCTION</th></tr><tr><th>PDIP</th><th>PLCC</th><th>TQFP</th></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                   |      | PIN  |                          |                        | PORT | ALTERNATE | FUNCTION | PDIP | PLCC | TQFP |
|        |              |            |              | PIN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                   |      | PORT | ALTERNATE                | FUNCTION               |      |           |          |      |      |      |
|        |              |            |              | PDIP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | PLCC                              | TQFP |      |                          |                        |      |           |          |      |      |      |
|        |              |            |              | 10                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 11                                | 5    | P3.0 | RXD0                     | Serial Port 0 Input    |      |           |          |      |      |      |
|        |              |            |              | 11                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 13                                | 7    | P3.1 | TXD0                     | Serial Port 0 Output   |      |           |          |      |      |      |
|        |              |            |              | 12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 14                                | 8    | P3.2 | $\overline{\text{INT0}}$ | External Interrupt 0   |      |           |          |      |      |      |
|        |              |            |              | 13                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 15                                | 9    | P3.3 | $\overline{\text{INT1}}$ | External Interrupt 1   |      |           |          |      |      |      |
|        |              |            |              | 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 16                                | 10   | P3.4 | T0                       | Timer 0 External Input |      |           |          |      |      |      |
| 15     | 17           | 11         | P3.5         | T1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Timer 1 External Input            |      |      |                          |                        |      |           |          |      |      |      |
| 16     | 18           | 12         | P3.6         | $\overline{\text{WR}}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | External Data Memory Write Strobe |      |      |                          |                        |      |           |          |      |      |      |
| 17     | 19           | 13         | P3.7         | $\overline{\text{RD}}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | External Data Memory Read Strobe  |      |      |                          |                        |      |           |          |      |      |      |
| 18, 19 | 20, 21       | 14, 15     | XTAL2, XTAL1 | Crystal Oscillator Pins. XTAL1 and XTAL2 provide support for parallel resonant, AT-cut crystals. XTAL1 also acts as an input in the event that an external clock source is used in place of a crystal. XTAL2 serves as the output of the crystal amplifier.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 20     | 1, 22, 23    | 16, 17, 39 | GND          | Digital Circuit Ground                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 21     | 24           | 18         | A8(P2.0)     | Address Outputs (Port 2) (Output). Port 2 serves as the MSB for external addressing. P2.7 is A15 and P2.0 is A8. The DS80C310 automatically places the MSB of an address on P2 for external ROM and RAM access. Although Port 2 can be accessed like an ordinary I/O port, the value stored on the Port 2 latch is never seen on the pins (due to memory access). Therefore, writing to Port 2 in software is only useful for the instructions MOVX A, @ Ri or MOVX @ Ri, A. These instructions use the Port 2 internal latch to supply the external address MSB; the Port 2 latch value is supplied as the address information.                                                                                                                                                                                                                                                                                                       |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 22     | 25           | 19         | A9(P2.1)     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 23     | 26           | 20         | A10(P2.2)    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 24     | 27           | 21         | A11(P2.3)    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 25     | 28           | 22         | A12(P2.4)    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 26     | 29           | 23         | A13(P2.5)    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 27     | 30           | 24         | A14(P2.6)    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |
| 28     | 31           | 25         | A15(P2.7)    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                   |      |      |                          |                        |      |           |          |      |      |      |

| PIN  |        |       | NAME                     | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------|--------|-------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PDIP | PLCC   | TQFP  |                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 29   | 32     | 26    | $\overline{\text{PSEN}}$ | Active-Low Program Store Enable (Output). This signal is commonly connected to external ROM memory as a chip enable. $\overline{\text{PSEN}}$ is driven high when data memory (RAM) is being accessed through the bus and during a reset condition.                                                                                                                                                                                                 |
| 30   | 33     | 27    | ALE                      | Address Latch Enable (Output). The output functions as clock to latch the external address LSB from the multiplexed address/data bus on Port 0. This signal is commonly connected to the latch enable of an external 373 family transparent latch. ALE is forced high when the DS80C310 is in a reset condition.                                                                                                                                    |
| 31   | 35     | 29    | $\overline{\text{EA}}$   | Active-Low External Access (Input). This pin must be connected to ground for proper operation.                                                                                                                                                                                                                                                                                                                                                      |
| 32   | 36     | 30    | AD7(P0.7)                | Address/Data Bus 0–7 (Port 0) (I/O). Port 0 is the multiplexed address/data bus. During the time when ALE is high, the LSB of a memory address is presented. When ALE falls to logic 0, the port transitions to a bidirectional data bus. This bus is used to read external ROM and read/write external RAM memory or peripherals. Port 0 has no true port latch and cannot be written directly by software. The reset condition of Port 0 is high. |
| 33   | 37     | 31    | AD6(P0.6)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 34   | 38     | 32    | AD5(P0.5)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 35   | 39     | 33    | AD4(P0.4)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 36   | 40     | 34    | AD3(P0.3)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 37   | 41     | 35    | AD2(P0.2)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 38   | 42     | 36    | AD1(P0.1)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 39   | 43     | 37    | AD0(P0.0)                |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| 40   | 44     | 38    | V <sub>CC</sub>          | +5V Power Supply                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| –    | 12, 34 | 6, 28 | N.C.                     | No Connection (Reserved). These pins should not be connected. They are reserved for use with future devices in this family.                                                                                                                                                                                                                                                                                                                         |

## COMPATIBILITY

The DS80C310 is a fully static, CMOS, 8051-compatible microcontroller designed for high performance. In most cases the DS80C310 can drop into an existing socket for the 80C31 or 80C32 to significantly improve the operation. In general, software written for existing 8051-based systems works without modification on the DS80C310. The exception is critical timing because the high-speed microcontroller performs its instructions much faster than the original for any given crystal selection. The DS80C310 runs the standard 8051 family instruction set and is pin compatible with DIP, PLCC, or TQFP packages. The DS80C310 is a streamlined version of the DS80C320. It maintains upward compatibility but has fewer peripherals.

The DS80C310 provides three 16-bit timer/counters, a full-duplex serial port, and 256 bytes of direct RAM. I/O ports have the same operation as a standard 8051 product. Timers default to a 12 clock-per-cycle operation to keep their timing compatible with original 8051 family systems. However, timers are individually programmable to run at the new 4 clocks per cycle if desired.

The DS80C310 provides several new hardware functions that are controlled by Special Function Registers (SFRs). Table 1 summarizes the SFRs.

## PERFORMANCE OVERVIEW

The DS80C310 features a high-speed 8051-compatible core. Higher speed comes not just from increasing the clock frequency but from a newer, more efficient design.

This updated core does not have the dummy memory cycles that exist in a standard 8051. A conventional 8051 generates machine cycles using the clock frequency divided by 12. In the DS80C310, the same

machine cycle takes 4 clocks. Thus the fastest instruction, 1 machine cycle, executes three times faster for the same crystal frequency. Note that these are identical instructions. The majority of instructions on the DS80C310 will see the full 3-to-1 speed improvement. Some instructions will get between 1.5 and 2.4 to 1 improvement. All instructions are faster than the original 8051.

The numerical average of all op codes gives approximately a 2.5-to-1 speed improvement. Improvement of individual programs depends on the actual instructions used. Speed-sensitive applications would make the most use of instructions that are three times faster. However, the sheer number of 3-to-1 improved op codes makes dramatic speed improvements likely for any code. These architecture improvements and 0.8 $\mu$ m CMOS produce a peak instruction cycle in 160ns (6.25MIPS). The dual data pointer feature also allows the user to eliminate wasted instructions when moving blocks of memory.

## INSTRUCTION SET SUMMARY

All instructions in the DS80C310 perform the same functions as their 8051 counterparts. Their effect on bits, flags, and other status functions is identical. However, the timing of each instruction is different. This applies both in absolute and relative number of clocks.

For absolute timing of real-time events, the timing of software loops can be calculated using a table in the *High-Speed Microcontroller User's Guide*. However, counter/timers default to run at the older 12 clocks per increment. In this way, timer-based events occur at the standard intervals with software executing at higher speed. Timers optionally can run at 4 clocks per increment to take advantage of faster processor operation.

The relative time of two instructions might be different in the new architecture than it was previously. For example, in the original architecture the "MOVX A, @ DPTR" instruction and the "MOV direct, direct" instruction used 2 machine cycles or 24 oscillator cycles. Therefore, they required the same amount of time. In the DS80C310, the MOVX instruction takes as little as 2 machine cycles or 8 oscillator cycles but the "MOV direct, direct" uses 3 machine cycles or 12 oscillator cycles. While both are faster than their original counterparts, they now have different execution times. This is because the DS80C310 usually uses 1 instruction cycle for each instruction byte. The user concerned with precise program timing should examine the timing of each instruction for familiarity with the changes. Note that a machine cycle now requires just 4 clocks, and provides one ALE pulse per cycle. Many instructions require only 1 cycle, but some require 5. In the original architecture, all were 1 or 2 cycles except for MUL and DIV. Refer to the *High-Speed Microcontroller User's Guide* for details and individual instruction timing.

## SPECIAL FUNCTION REGISTERS (SFRs)

Special Function Registers control most special features of the DS80C310. The *High-Speed Microcontroller User's Guide* contains descriptions of all the SFRs. Functions that are not part of the standard 80C32 are in bold.

**Table 1. Special Function Registers**

| REGISTER     | BIT 7      | BIT 6             | BIT 5      | BIT 4      | BIT 3      | BIT 2             | BIT 1              | BIT 0                | ADDRESS |
|--------------|------------|-------------------|------------|------------|------------|-------------------|--------------------|----------------------|---------|
| SP           | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 81h     |
| DPL          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 82h     |
| DPH          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 83h     |
| <b>DPL1</b>  | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 84h     |
| <b>DPH1</b>  | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 85h     |
| <b>DPS</b>   | 0          | 0                 | 0          | 0          | 0          | 0                 | 0                  | SEL                  | 86h     |
| PCON         | SMOD       | SM0D0             | —          | —          | GF1        | GF0               | STOP               | IDLE                 | 87h     |
| TCON         | TF1        | TR1               | TF0        | TR0        | IE1        | IT1               | IE0                | IT0                  | 88h     |
| TMOD         | GATE       | C/ $\overline{T}$ | M1         | M0         | GATE       | C/ $\overline{T}$ | M1                 | M0                   | 89h     |
| TL0          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 8Ah     |
| TL1          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 8Bh     |
| TH0          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 8Ch     |
| TH1          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 8Dh     |
| <b>CKCON</b> | —          | —                 | <b>T2M</b> | <b>T1M</b> | <b>T0M</b> | <b>MD2</b>        | <b>MD1</b>         | <b>MD0</b>           | 8Eh     |
| P1           | P1.7       | P1.6              | P1.5       | P1.4       | P1.3       | P1.2              | P1.1               | P1.0                 | 90h     |
| <b>EXIF</b>  | <b>IE5</b> | <b>IE4</b>        | <b>IE3</b> | <b>IE2</b> | —          | —                 | —                  | —                    | 91h     |
| SCON         | SMO/FE     | SM1               | SM2        | REN        | TB8        | RB8               | TI                 | RI                   | 98h     |
| SBUF         | —          | —                 | —          | —          | —          | —                 | —                  | —                    | 99h     |
| P2           | P2.7       | P2.6              | P2.5       | P2.4       | P2.3       | P2.2              | P2.1               | P2.0                 | A0h     |
| IE           | EA         | —                 | ET2        | ES0        | ET1        | EX1               | ET0                | EX0                  | A8h     |
| SADDR0       | —          | —                 | —          | —          | —          | —                 | —                  | —                    | A9h     |
| P3           | P3.7       | P3.6              | P3.5       | P3.4       | P3.3       | P3.2              | P3.1               | P3.0                 | B0h     |
| IP           | —          | —                 | PT2        | PSO        | PT1        | PX1               | PT0                | PX0                  | B8h     |
| SADEN0       | —          | —                 | —          | —          | —          | —                 | —                  | —                    | B9h     |
| STATUS       | 0          | HIP               | LIP        | 1          | 1          | 1                 | 1                  | 1                    | C5h     |
| T2CON        | TF2        | EXF2              | RCLK       | TCLK       | EXEN2      | TR2               | C/ $\overline{T2}$ | CP/ $\overline{RL2}$ | C8h     |
| T2MOD        | —          | —                 | —          | —          | —          | —                 | T2OE               | DCEN                 | C9h     |
| RCAP2L       | —          | —                 | —          | —          | —          | —                 | —                  | —                    | CAh     |
| RCAP2H       | —          | —                 | —          | —          | —          | —                 | —                  | —                    | CBh     |
| TL2          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | CCh     |
| TH2          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | CDh     |
| PSW          | CY         | AC                | F0         | RS1        | RS0        | OV                | FL                 | P                    | D0h     |
| <b>WDCON</b> | —          | <b>POR</b>        | —          | —          | —          | —                 | —                  | —                    | D8h     |
| ACC          | —          | —                 | —          | —          | —          | —                 | —                  | —                    | E0h     |
| <b>EIE</b>   | —          | —                 | —          | —          | <b>EX5</b> | <b>EX4</b>        | <b>EX3</b>         | <b>EX2</b>           | E8h     |
| B            | —          | —                 | —          | —          | —          | —                 | —                  | —                    | F0h     |
| <b>EIP</b>   | —          | —                 | —          | —          | <b>PX5</b> | <b>PX4</b>        | <b>PX3</b>         | <b>PX2</b>           | F8h     |

## MEMORY ACCESS

The DS80C310 has 256 bytes of scratchpad RAM, but contains no on-chip ROM. Off-chip memory is accessed using the multiplexed address/data bus on P0 and the MSB address on P2. Timing diagrams are provided in the *Absolute Maximum Ratings* section. Program memory (ROM) is accessed at a fixed rate determined by the crystal frequency and the actual instructions. As mentioned above, an instruction cycle requires 4 clocks. Data memory (RAM) is accessed according to a variable speed MOVX instruction as described below.

## STRETCH MEMORY CYCLE

The DS80C310 allows the application software to adjust the speed of data memory access. The microcontroller can perform the MOVX in as few as 2 instruction cycles. However, this value can be stretched as needed so that both fast memory and slow memory or peripherals can be accessed with no glue logic. Even in high-speed systems, it may not be necessary or desirable to perform data memory access at full speed. In addition, there are a variety of memory-mapped peripherals such as LCD displays or UARTs that are not fast.

The stretch MOVX is controlled by the Clock Control Register at SFR location 8Eh as described below. This allows the user to select a stretch value between 0 and 7. A stretch of 0 results in a 2-machine-cycle MOVX. A stretch of 7 results in a MOVX of 9 machine cycles. Software can dynamically change this value depending on the particular memory or peripheral.

On reset, the stretch value defaults to 1, resulting in a 3-cycle MOVX. Therefore, RAM access is not performed at full speed. This is a convenience to existing designs that may not have fast RAM in place. When maximum speed is desired, the software should select a stretch value of 0. When using very slow RAM or peripherals, a larger stretch value can be selected. Note that this affects data memory only and the only way to slow program memory (ROM) access is to use a slower crystal.

Using a stretch value between 1 and 7 causes the microcontroller to stretch the read/write strobe and all related timing. This results in a wider read/write strobe allowing more time for memory/peripherals to respond. The timing of the variable speed MOVX is shown in the *Absolute Maximum Ratings* section. Note that full speed access is not the reset default case. Table 2 shows the resulting strobe widths for each stretch value. The memory stretch is implemented using the Clock Control Special Function Register at SFR location 8Eh. The stretch value is selected using bits CKCON.2–CKCON.0. In the table, these bits are referred to as M2 through M0. The first stretch (default) allows the use of common 120ns or 150ns RAMs without dramatically lengthening the memory access.

**Table 2. Data Memory Cycle Stretch Values**

| CKCON.2–CKCON.0 |    |    | MEMORY CYCLES | RD OR WR STROBE WIDTH IN CLOCKS | 25MHz STROBE WIDTH (ns) |
|-----------------|----|----|---------------|---------------------------------|-------------------------|
| M2              | M1 | M0 |               |                                 |                         |
| 0               | 0  | 0  | 2             | 2                               | 80                      |
| 0               | 0  | 1  | 3 (default)   | 4                               | 160                     |
| 0               | 1  | 0  | 4             | 8                               | 320                     |
| 0               | 1  | 1  | 5             | 12                              | 480                     |
| 1               | 0  | 0  | 6             | 16                              | 640                     |
| 1               | 0  | 1  | 7             | 20                              | 800                     |
| 1               | 1  | 0  | 8             | 24                              | 960                     |
| 1               | 1  | 1  | 9             | 28                              | 1120                    |

## DUAL DATA POINTER (DPTR)

Data memory block moves can be accelerated using the DS80C310 dual data pointer (DPTR). The standard 8032 DPTR is a 16-bit value that is used to address off-chip data RAM or peripherals. In the DS80C310, the standard data pointer is called DPTR and is located at SFR addresses 82h and 83h. These are the standard locations. No modification of standard code is needed to use DPTR. The new DPTR is located at SFR 84h and 85h and is called DPTR1. The DPTR select bit (DPS) chooses the active pointer and is located at the LSB of the SFR location 86h. No other bits in register 86h have any effect and are set to 0. The user switches between data pointers by toggling the LSB of register 86h. The increment (INC) instruction is the fastest way to accomplish this. All DPTR-related instructions use the currently selected DPTR for any activity. Therefore, only one instruction is required to switch from a source to a destination address. Using the DPTR saves code from needing to save source and destination addresses when doing a block move. Once loaded, the software simply switches between DPTR0 and 1. The relevant register locations are as follows.

|      |     |                         |
|------|-----|-------------------------|
| DPL  | 82h | Low byte original DPTR  |
| DPH  | 83h | High byte original DPTR |
| DPL1 | 84h | Low byte new DPTR       |
| DPH1 | 85h | High byte new DPTR      |
| DPS  | 86h | DPTR Select (lsb)       |

## STOP MODE ENHANCEMENTS

Setting bit 1 of the Power Control Register (PCON; 87h) invokes the stop mode. Stop mode is the lowest power state because it turns off all internal clocking. The  $I_{CC}$  of a standard stop mode is approximately 1 $\mu$ A (but is specified in the *Absolute Maximum Ratings* section). The CPU exits stop mode from an external interrupt or a reset condition. Internally generated interrupts are not useful since they require clocking activity.

The DS80C310 allows a resume from stop using INT2–INT5, which are edge-triggered interrupts. An internal crystal counter manages the startup timing. A delay of 65,536 clocks occurs to allow the crystal time to stabilize. Software must also insert a delay of 100 machine cycles following the exit from stop mode. This ensures stabilization of internal timing prior to time-critical software tasks such as serial port operations or bus access to memory-mapped I/O devices.

## PERIPHERAL OVERVIEW

The DS80C310 provides the same peripheral functions as the standard 80C32. The device is compatible with the DS80C320, but it does not offer all the peripherals.

## TIMER RATE CONTROL

There is one important difference between the DS80C310 and 8051 regarding timers. The original 8051 used 12 clocks per cycle for timers and machine cycles. The DS80C310 architecture normally uses 4 clocks per machine cycle. However, in the area of timers and serial ports, the DS80C310 defaults to 12 clocks per cycle on reset. This allows existing code with real-time dependencies such as baud rates to operate properly.

If an application needs higher speed timers or serial baud rates, the user can select individual timers to run at the 4-clock rate. The Clock Control Register (CKCON; 8Eh) determines these timer speeds. When the relevant CKCON bit is logic 1, the DS80C310 uses 4 clocks per cycle to generate timer speeds. When the bit is 0, the DS80C310 uses 12 clocks for timer speeds. The reset condition is 0. CKCON.5 selects the speed of Timer 2. CKCON.4 selects Timer 1 and CKCON.3 selects Timer 0. Note that unless a user desires very fast timing, it is unnecessary to alter these bits. Also note that the timer controls are independent.

## POWER-ON RESET

The DS80C310 holds itself in reset during a power-up until 65,536 clock cycles have elapsed. The power-on reset used by the DS80C310 differs somewhat from other members of the high-speed microcontroller family. The crystal oscillator can start anywhere between 1.0V and 4.5V, but is not specified. This eliminates the need for an RC reset circuit. For voltage-specific precision-brownout detection, an external component is needed. When the device goes through a power-on reset, the POR flag is set in the WDCON (D8h) register at bit 6.

## INTERRUPTS

The DS80C310 provides 10 interrupt sources with two priority levels. Software can assign high or low priority to all sources. All interrupts that are new to the 8051 have a lower natural priority than the originals.

**Table 3. Interrupt Sources and Priorities**

| NAME                     | DESCRIPTION                   | VECTOR | NATURAL PRIORITY |
|--------------------------|-------------------------------|--------|------------------|
| $\overline{\text{INT0}}$ | External Interrupt 0          | 03h    | 1                |
| TF0                      | Timer 0                       | 0Bh    | 2                |
| $\overline{\text{INT1}}$ | External Interrupt 1          | 13h    | 3                |
| TF1                      | Timer 1                       | 1Bh    | 4                |
| SCON                     | T1 or R1 from the serial port | 23h    | 5                |
| TF2                      | Timer 2                       | 2Bh    | 6                |
| $\overline{\text{INT2}}$ | External Interrupt 2          | 43h    | 7                |
| $\overline{\text{INT3}}$ | External Interrupt 3          | 4Bh    | 8                |
| INT4                     | External Interrupt 4          | 53h    | 9                |
| $\overline{\text{INT5}}$ | External Interrupt 5          | 5Bh    | 10               |

## ABSOLUTE MAXIMUM RATINGS

Voltage Range on Any Pin Relative to Ground.....-0.3V to ( $V_{CC} + 0.5V$ )  
 Voltage Range on  $V_{CC}$  Relative to Ground.....-0.3V to +6.0V  
 Operating Temperature Range.....-40°C to +85°C  
 Storage Temperature Range.....-55°C to +125°C  
 Soldering Temperature.....See IPC/JEDEC J-STD-020 Specification

*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 device reliability.*

## DC ELECTRICAL CHARACTERISTICS

( $V_{CC} = 4.5V$  to  $5.5V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ .) (Note 1)

| PARAMETER                                                                    | SYMBOL     | MIN  | TYP  | MAX            | UNITS     | NOTES |
|------------------------------------------------------------------------------|------------|------|------|----------------|-----------|-------|
| Supply Voltage                                                               | $V_{CC}$   | 4.0  | 5.0  | 5.5            | V         | 2     |
| Supply Current Active Mode at 25MHz                                          | $I_{CC}$   |      | 30   |                | mA        | 3     |
| Supply Current Idle Mode at 25MHz                                            | $I_{IDLE}$ |      | 15   |                | mA        | 4     |
| Supply Current Stop Mode                                                     | $I_{STOP}$ |      | 1    |                | $\mu A$   | 5     |
| Input Low Level                                                              | $V_{IL}$   | -0.3 |      | +0.8           | V         | 2     |
| Input High Level (Except XTAL1 and RST)                                      | $V_{IH}$   | 2.0  |      | $V_{CC} + 0.3$ | V         | 2     |
| Input High Level XTAL1 and RST                                               | $V_{IH2}$  | 3.5  |      | $V_{CC} + 0.3$ | V         | 2     |
| Output Low Voltage Ports 1, 3 at $I_{OL} = 1.6mA$                            | $V_{OL1}$  |      | 0.15 | 0.45           | V         | 2     |
| Output Low Voltage Port 0, 2, ALE, $\overline{PSEN}$ at $I_{OL} = 3.2mA$     | $V_{OL2}$  |      | 0.15 | 0.45           | V         | 2, 6  |
| Output High Voltage Port 1, 3, ALE, $\overline{PSEN}$ at $I_{OH} = -50\mu A$ | $V_{OH1}$  | 2.4  |      |                | V         | 2, 7  |
| Output High Voltage Ports 1, 3 at $I_{OH} = -1.5mA$                          | $V_{OH2}$  | 2.4  |      |                | V         | 2, 8  |
| Output High Voltage Port 0, 2, ALE, $\overline{PSEN}$ at $I_{OH} = -8mA$     | $V_{OH3}$  | 2.4  |      |                | V         | 2, 6  |
| Input Low Current Ports 1, 3 at 0.45V                                        | $I_{IL}$   |      |      | -55            | $\mu A$   | 9     |
| Transition Current from 1 to 0 Ports 1, 3 at 2V                              | $I_{TL}$   |      |      | -650           | $\mu A$   | 10    |
| Input Leakage Port 0, Bus Mode                                               | $I_L$      | -300 |      | +300           | $\mu A$   | 11    |
| RST Pulldown Resistance                                                      | $R_{RST}$  | 50   |      | 170            | $k\Omega$ |       |

**Note 1:** All parameters apply to both commercial and industrial temperature operation unless otherwise noted. Specifications to -40°C are guaranteed by design and not product tested.

**Note 2:** All voltages are referenced to ground.

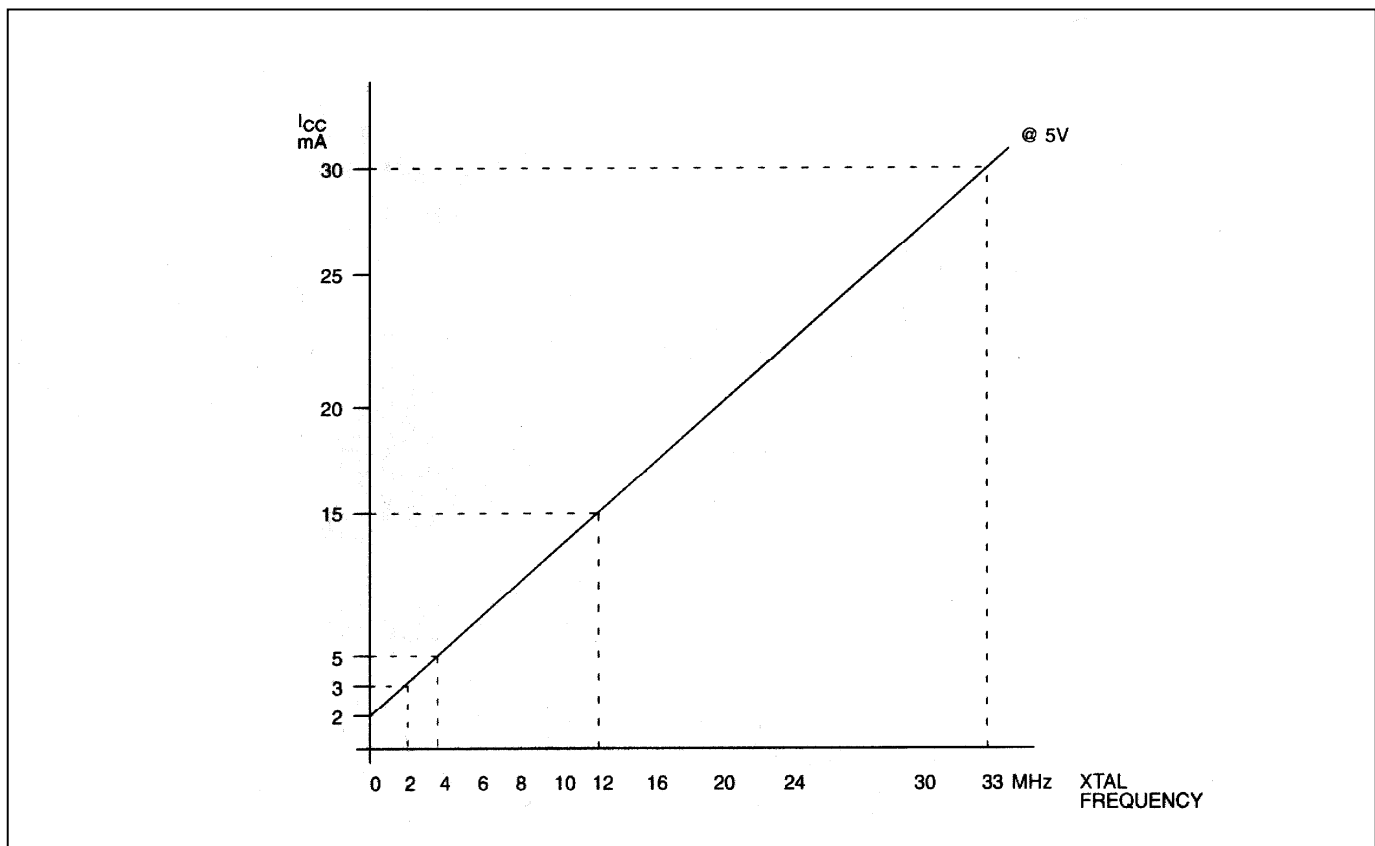
**Note 3:** Active current is measured with a 25MHz clock source driving XTAL1,  $V_{CC} = RST = 5.5V$ , all other pins disconnected.

**Note 4:** Idle mode current is measured with a 25MHz clock source driving XTAL1,  $V_{CC} = 5.5V$ , RST at ground, all other pins disconnected.

**Note 5:** Stop mode current measured with XTAL1 and RST grounded,  $V_{CC} = 5.5V$ , all other pins disconnected.

- Note 6:** When addressing external memory. This specification applies to the first clock cycle following the transition. On subsequent cycles following 1 to 0 transitions, the typical current sink capability of Port 0 and Port 2 is approximately 150 $\mu$ A, and the minimum current sink capability of ALE and PSEN is approximately 400 $\mu$ A. On subsequent cycles following 0 to 1 transitions, the typical current drive capability of Port 0 and Port 2 is approximately 110 $\mu$ A.
- Note 7:**  $RST = V_{CC}$ . This condition mimics operation of pins in I/O mode.
- Note 8:** During a 0 to 1 transition, a one-shot drives the ports hard for two clock cycles. This measurement reflects port in transition mode.
- Note 9:** Current required from external circuit to hold a logic-low level on an I/O pin while the corresponding port latch bit is set to 1. This is only the current required to hold the low level; transitions from 1 to 0 on an I/O pin must also overcome the transition current.
- Note 10:** Ports 1 and 3 source transition current when being pulled down externally. The current reaches its maximum at approximately 2V.
- Note 11:**  $0.45 < V_{IN} < V_{CC}$ . Not a high-impedance input. This port is a weak address holding latch because Port 0 is dedicated as an address bus on the DS80C310. Peak current occurs near the input transition point of the latch, approximately 2V.

**Figure 2. Typical  $I_{CC}$  vs. Frequency**



**AC ELECTRICAL CHARACTERISTICS (Note 1)**

| PARAMETER                                       |                     | SYMBOL       | 25MHz |          | VARIABLE<br>CLOCK |                  | UNITS |
|-------------------------------------------------|---------------------|--------------|-------|----------|-------------------|------------------|-------|
|                                                 |                     |              | MIN   | MAX      | MIN               | MAX              |       |
| Oscillator<br>Frequency                         | External Oscillator | $1/t_{CLCL}$ | 0     | 25       | 0                 | 25               | MHz   |
|                                                 | External Crystal    |              | 1     | 25       | 1                 | 25               |       |
| ALE Pulse Width                                 |                     | $t_{LHLL}$   | 40    |          | $1.5t_{CLCL}-5$   |                  | ns    |
| Port 0 Address Valid to ALE Low                 |                     | $t_{AVLL}$   | 10    |          | $0.5t_{CLCL}-5$   |                  | ns    |
| Address Hold after ALE Low                      |                     | $t_{LLAX1}$  | 2     | (Note 2) | $0.5t_{CLCL}-18$  | (Note 2)         | ns    |
| ALE Low to Valid Instruction In                 |                     | $t_{LLIV}$   |       | 56       |                   | $2.5t_{CLCL}-20$ | ns    |
| ALE Low to $\overline{PSEN}$ Low                |                     | $t_{LLPL}$   | 7     |          | $0.5t_{CLCL}-13$  |                  | ns    |
| $\overline{PSEN}$ Pulse Width                   |                     | $t_{PLPH}$   | 55    |          | $2t_{CLCL}-5$     |                  | ns    |
| $\overline{PSEN}$ Low to Valid Instruction In   |                     | $t_{PLIV}$   |       | 41       |                   | $2t_{CLCL}-20$   | ns    |
| Input Instruction Hold after $\overline{PSEN}$  |                     | $t_{PXIX}$   | 0     |          | 0                 |                  | ns    |
| Input Instruction Float after $\overline{PSEN}$ |                     | $t_{PXIZ}$   |       | 26       |                   | $t_{CLCL}-5$     | ns    |
| Port 0 Address to Valid Instruction In          |                     | $t_{AVIV1}$  |       | 71       |                   | $3t_{CLCL}-20$   | ns    |
| Port 2 Address to Valid Instruction In          |                     | $t_{AVIV2}$  |       | 81       |                   | $3.5t_{CLCL}-25$ | ns    |
| $\overline{PSEN}$ Low to Address Float          |                     | $t_{PLAZ}$   |       | (Note 2) |                   | (Note 2)         | ns    |

**Note 1:** All parameters apply to both commercial and industrial temperature operation unless otherwise noted. Specifications to -40°C are guaranteed by design and not product tested. AC electrical characteristics assume 50% duty cycle for the oscillator, and are not 100% tested but are guaranteed by design. All signals characterized with load capacitance of 80pF except Port 0, ALE,  $\overline{PSEN}$ , and WR with 100pF. Interfacing to memory devices with float times (turn-off times) over 25ns can cause contention. This does not damage the parts, but rather causes an increase in operating current. Port 2 and ALE timing changes in relation to duty cycle variation.

**Note 2:** Address is held in a weak latch until overdriven by external memory.

## MOVX CHARACTERISTICS

| PARAMETER                                                | SYMBOL      | VARIABLE CLOCK           |                 | UNITS | STRETCH<br>(Note 1) |
|----------------------------------------------------------|-------------|--------------------------|-----------------|-------|---------------------|
|                                                          |             | MIN                      | MAX             |       |                     |
| Data Access ALE Pulse Width                              | $t_{LHLL2}$ | $1.5t_{CLCL}-5$          |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2t_{CLCL}-5$            |                 |       | $t_{MCS}>0$         |
| Port 0 Address Valid to ALE Low                          | $t_{AVLL2}$ | $0.5t_{CLCL}-5$          |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{CLCL}-5$             |                 |       | $t_{MCS}>0$         |
| Address Hold after ALE Low for MOVX Write                | $t_{LLAX2}$ | $0.5t_{CLCL}-15$         |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{CLCL}-7$             |                 |       | $t_{MCS}>0$         |
| $\overline{RD}$ Pulse Width                              | $t_{RLRH}$  | $2t_{CLCL}-5$            |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{MCS}-10$             |                 |       | $t_{MCS}>0$         |
| $\overline{WR}$ Pulse Width                              | $t_{WLWH}$  | $2t_{CLCL}-5$            |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{MCS}-10$             |                 |       | $t_{MCS}>0$         |
| $\overline{RD}$ Low to Valid Data In                     | $t_{RLDV}$  | $2t_{CLCL}-20$           |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{MCS}-20$             |                 |       | $t_{MCS}>0$         |
| Data Hold after Read                                     | $t_{RHDX}$  | 0                        |                 | ns    |                     |
| Data Float after Read                                    | $t_{RHDZ}$  | $t_{CLCL}-5$             |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2t_{CLCL}-5$            |                 |       | $t_{MCS}>0$         |
| ALE Low to Valid Data In                                 | $t_{LLDV}$  | $2.5t_{CLCL}-28$         |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{CLCL}+t_{MCS}-40$    |                 |       | $t_{MCS}>0$         |
| Port 0 Address to Valid Data In                          | $t_{AVDV1}$ | $3t_{CLCL}-22$           |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2.0t_{CLCL}+t_{MCS}-25$ |                 |       | $t_{MCS}>0$         |
| Port 2 Address to Valid Data In                          | $t_{AVDV2}$ | $3.5t_{CLCL}-35$         |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2.5t_{CLCL}+t_{MCS}-35$ |                 |       | $t_{MCS}>0$         |
| ALE Low to $\overline{RD}$ or $\overline{WR}$ Low        | $t_{LLWL}$  | $0.5t_{CLCL}-14$         | $0.5t_{CLCL}+5$ | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{CLCL}-8$             | $t_{CLCL}+5$    |       | $t_{MCS}>0$         |
| Port 0 Address to $\overline{RD}$ or $\overline{WR}$ Low | $t_{AVWL1}$ | $t_{CLCL}-9$             |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2t_{CLCL}-8$            |                 |       | $t_{MCS}>0$         |
| Port 2 Address to $\overline{RD}$ or $\overline{WR}$ Low | $t_{AVWL2}$ | $1.5t_{CLCL}-10$         |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2.5t_{CLCL}-10$         |                 |       | $t_{MCS}>0$         |
| Data Valid to $\overline{WR}$ Transition                 | $t_{QVWX}$  | -14                      |                 | ns    |                     |
| Data Hold after Write                                    | $t_{WHQX}$  | $t_{CLCL}-11$            |                 | ns    | $t_{MCS}=0$         |
|                                                          |             | $2t_{CLCL}-10$           |                 |       | $t_{MCS}>0$         |
| $\overline{RD}$ Low to Address Float                     | $t_{RLAZ}$  | (Note 2)                 |                 | ns    |                     |
| $\overline{RD}$ or $\overline{WR}$ High to ALE High      | $t_{WHLH}$  | 0                        | 10              | ns    | $t_{MCS}=0$         |
|                                                          |             | $t_{CLCL}-5$             | $t_{CLCL}+9$    |       | $t_{MCS}>0$         |

**Note 1:**  $t_{MCS}$  is a time period related to the stretch memory cycle selection. The following table shows the value of  $t_{MCS}$  for each stretch selection.

| M2 | M1 | M0 | MOVX CYCLES                | $t_{MCS}$     |
|----|----|----|----------------------------|---------------|
| 0  | 0  | 0  | 2 machine cycles           | 0             |
| 0  | 0  | 1  | 3 machine cycles (default) | $4 t_{CLCL}$  |
| 0  | 1  | 0  | 4 machine cycles           | $8 t_{CLCL}$  |
| 0  | 1  | 1  | 5 machine cycles           | $12 t_{CLCL}$ |
| 1  | 0  | 0  | 6 machine cycles           | $16 t_{CLCL}$ |
| 1  | 0  | 1  | 7 machine cycles           | $20 t_{CLCL}$ |
| 1  | 1  | 0  | 8 machine cycles           | $24 t_{CLCL}$ |
| 1  | 1  | 1  | 9 machine cycles           | $28 t_{CLCL}$ |

**Note 2:** Address is held in a weak latch until overdriven by external memory.

## EXTERNAL CLOCK CHARACTERISTICS

| PARAMETER       | SYMBOL     | MIN | TYP | MAX | UNITS |
|-----------------|------------|-----|-----|-----|-------|
| Clock High Time | $t_{CHCX}$ | 10  |     |     | ns    |
| Clock Low Time  | $t_{CLCX}$ | 10  |     |     | ns    |
| Clock Rise Time | $t_{CLCL}$ |     |     | 5   | ns    |
| Clock Fall Time | $t_{CHCL}$ |     |     | 5   | ns    |

## SERIAL PORT MODE 0 TIMING CHARACTERISTICS

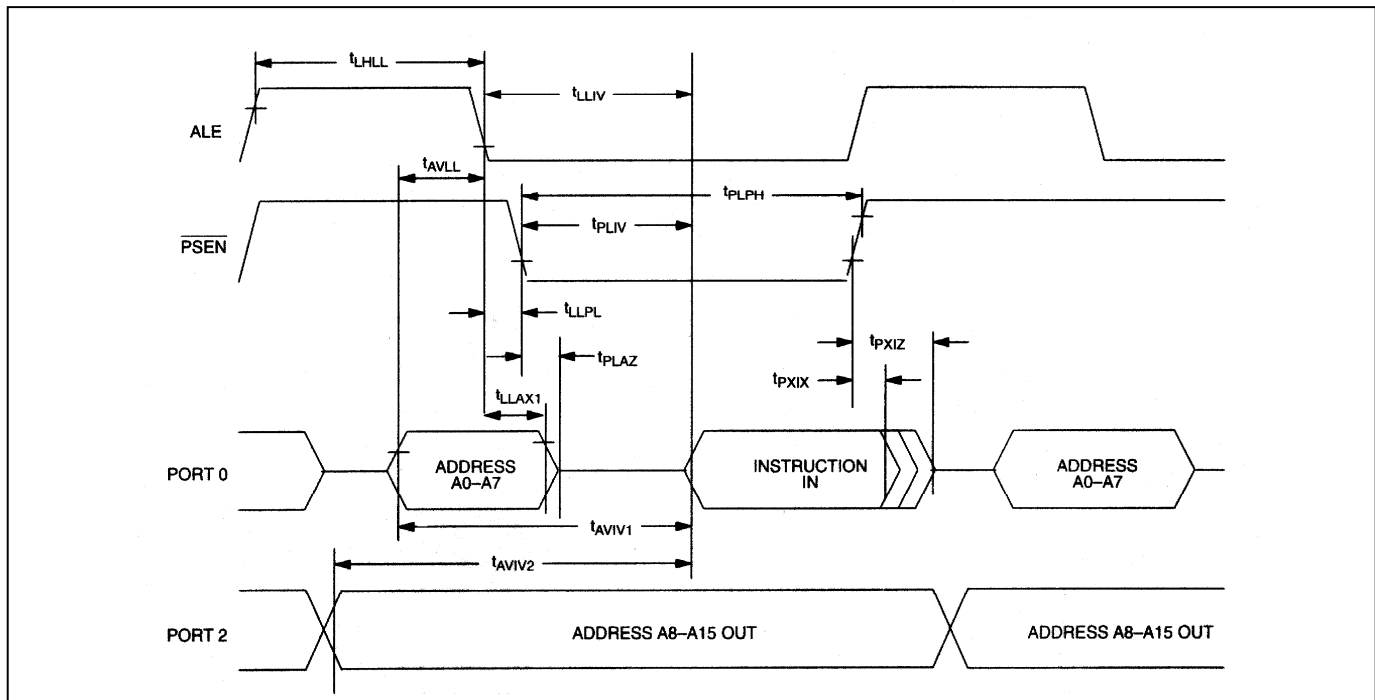
| PARAMETER                             | SYMBOL     | CONDITIONS                   | MIN | TYP          | MAX | UNITS |
|---------------------------------------|------------|------------------------------|-----|--------------|-----|-------|
| Serial Port Clock Cycle Time          | $t_{XLXL}$ | SM2 = 0, 12 clocks per cycle |     | $12t_{CLCL}$ |     | ns    |
|                                       |            | SM2 = 1, 4 clocks per cycle  |     | $4t_{CLCL}$  |     |       |
| Output Data Setup to Clock Rising     | $t_{QVXH}$ | SM2 = 0, 12 clocks per cycle |     | $10t_{CLCL}$ |     | ns    |
|                                       |            | SM2 = 1, 4 clocks per cycle  |     | $3t_{CLCL}$  |     |       |
| Output Data Hold from Clock Rising    | $t_{XHGX}$ | SM2 = 0, 12 clocks per cycle |     | $2t_{CLCL}$  |     | ns    |
|                                       |            | SM2 = 1, 4 clocks per cycle  |     | $t_{CLCL}$   |     |       |
| Input Data Hold after Clock Rising    | $t_{XHDX}$ | SM2 = 0, 12 clocks per cycle |     | $t_{CLCL}$   |     | ns    |
|                                       |            | SM2 = 1, 4 clocks per cycle  |     | $t_{CLCL}$   |     |       |
| Clock Rising Edge to Input Data Valid | $t_{XHDV}$ | SM2 = 0, 12 clocks per cycle |     | $11t_{CLCL}$ |     | ns    |
|                                       |            | SM2 = 1, 4 clocks per cycle  |     | $3t_{CLCL}$  |     |       |

## DEFINITION OF AC SYMBOLS

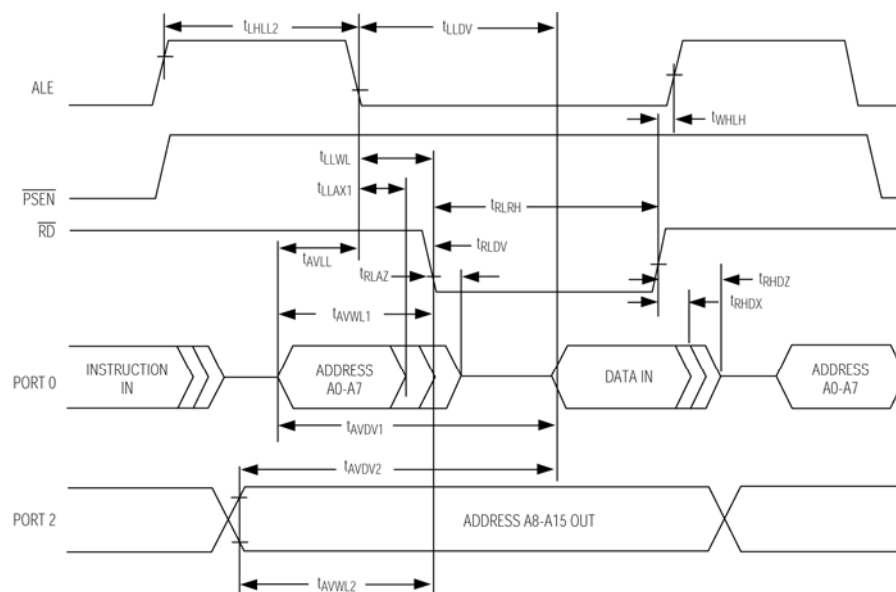
In an effort to remain compatible with the original 8051 family, this device specifies the same parameters as such devices, using the same symbols. For completeness, the following are description of the symbols.

|   |                               |
|---|-------------------------------|
| t | Time                          |
| A | Address                       |
| C | Clock                         |
| D | Input Data                    |
| H | Logic Level High              |
| L | Logic Level Low               |
| I | Instruction                   |
| P | $\overline{PSEN}$             |
| Q | Output Data                   |
| R | $\overline{RD}$ Signal        |
| V | Valid                         |
| W | $\overline{WR}$ Signal        |
| X | No longer a valid logic level |
| Z | Tri-State                     |

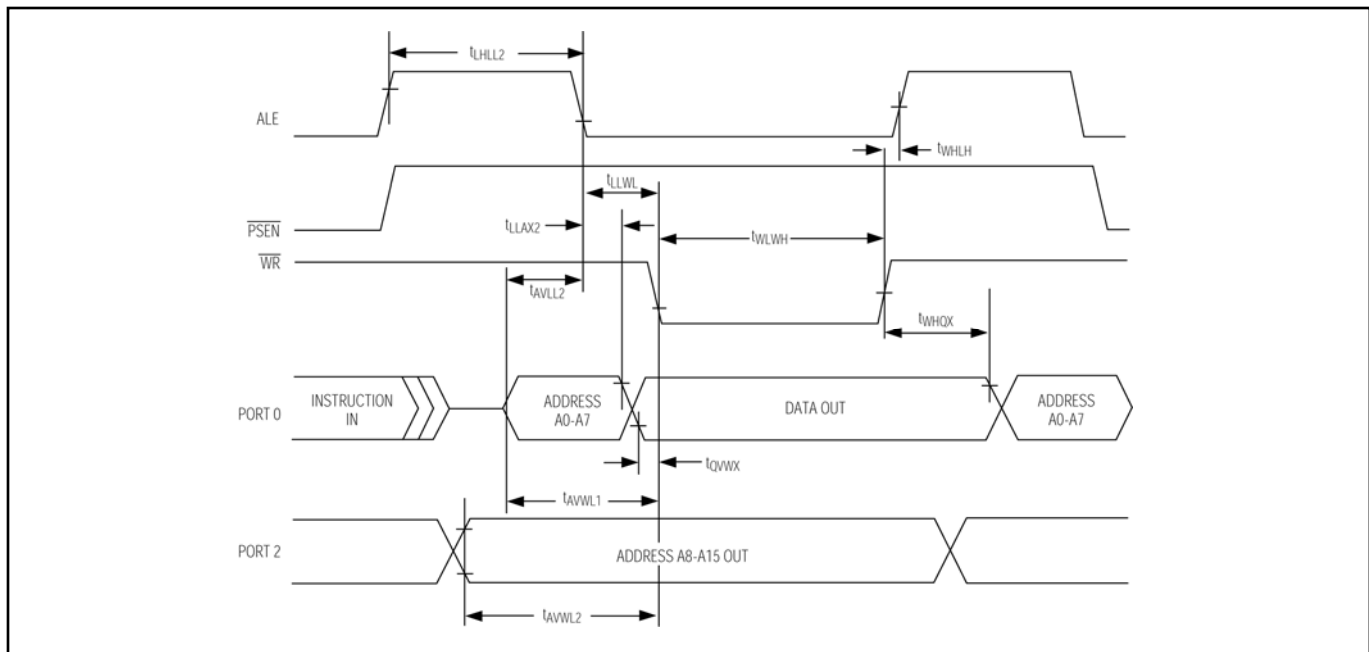
## EXTERNAL PROGRAM MEMORY READ CYCLE



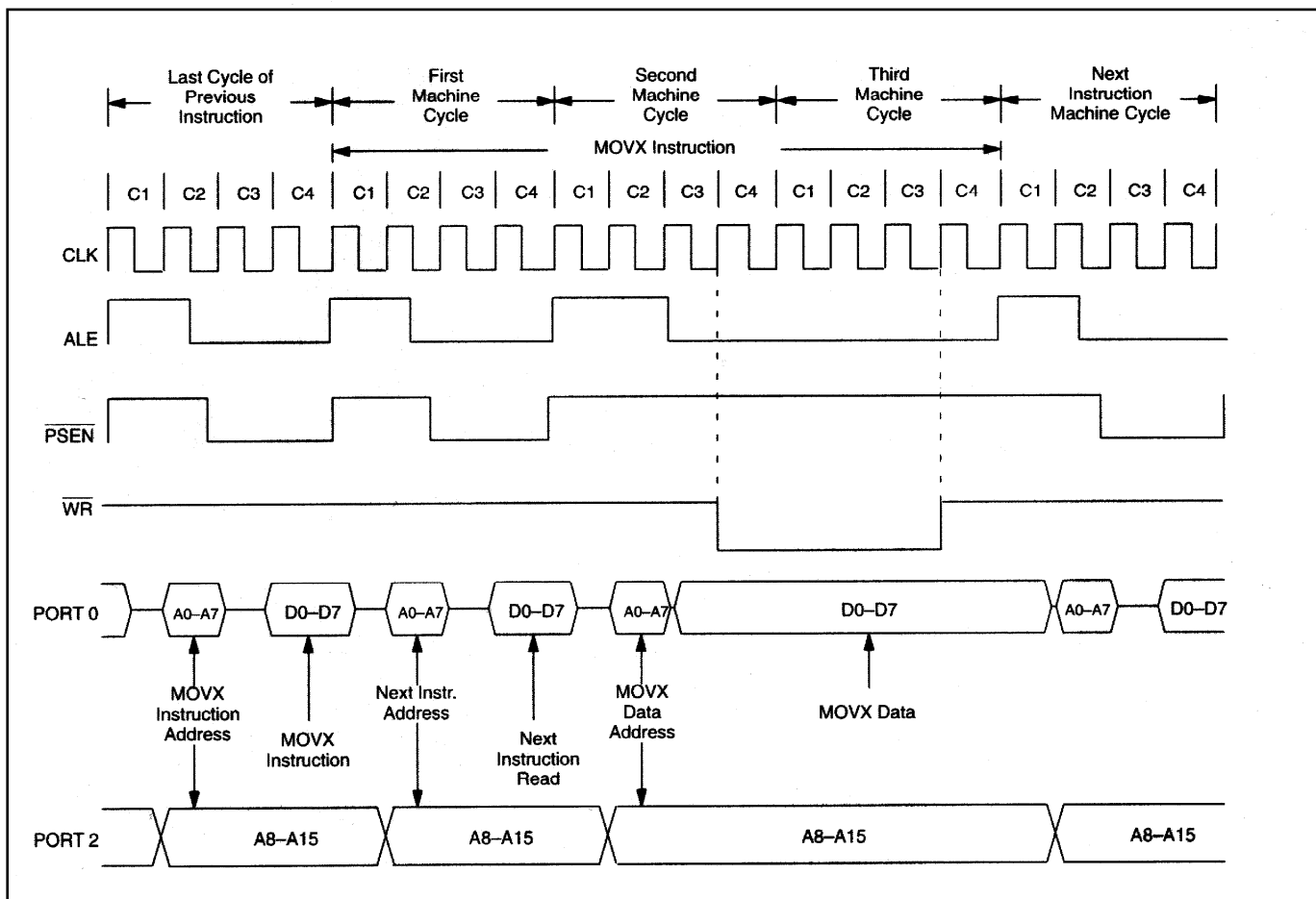
## EXTERNAL DATA MEMORY READ CYCLE



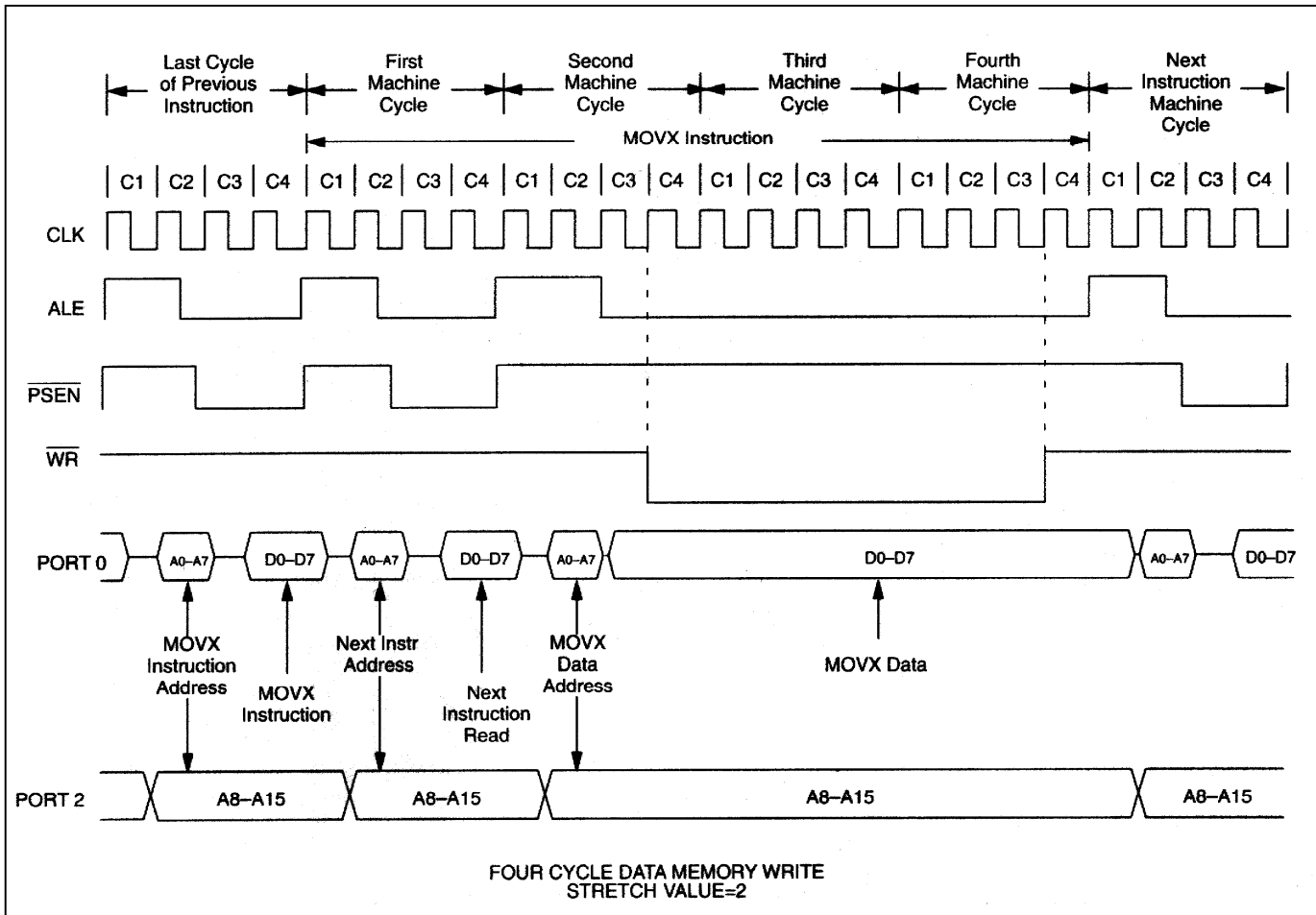
## DATA MEMORY WRITE CYCLE



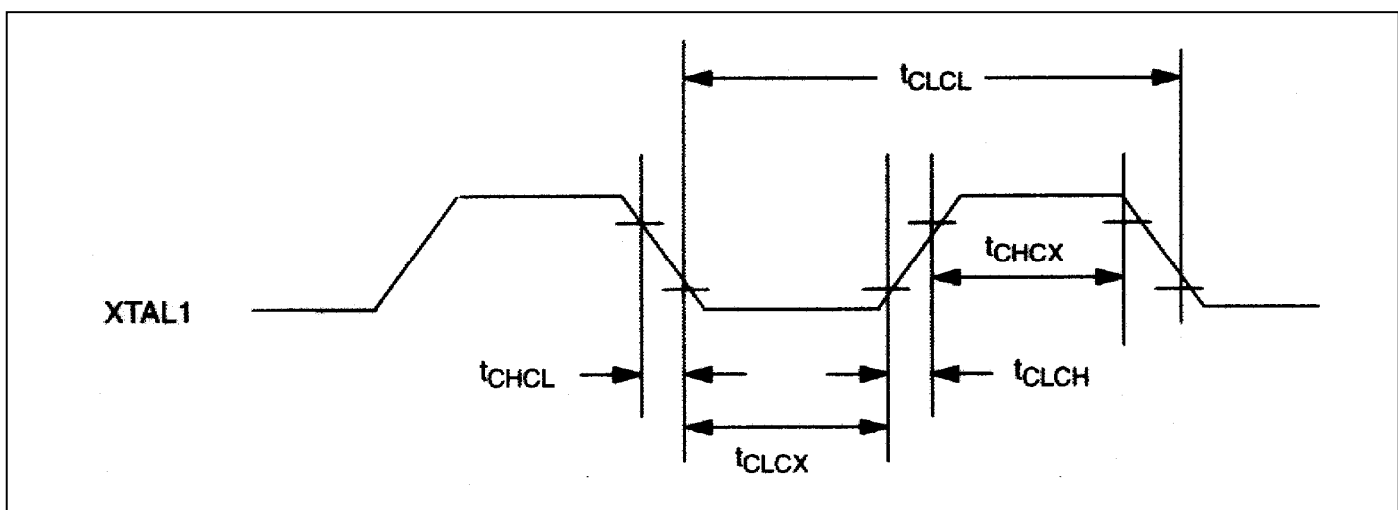
## DATA MEMORY WRITE WITH STRETCH = 1



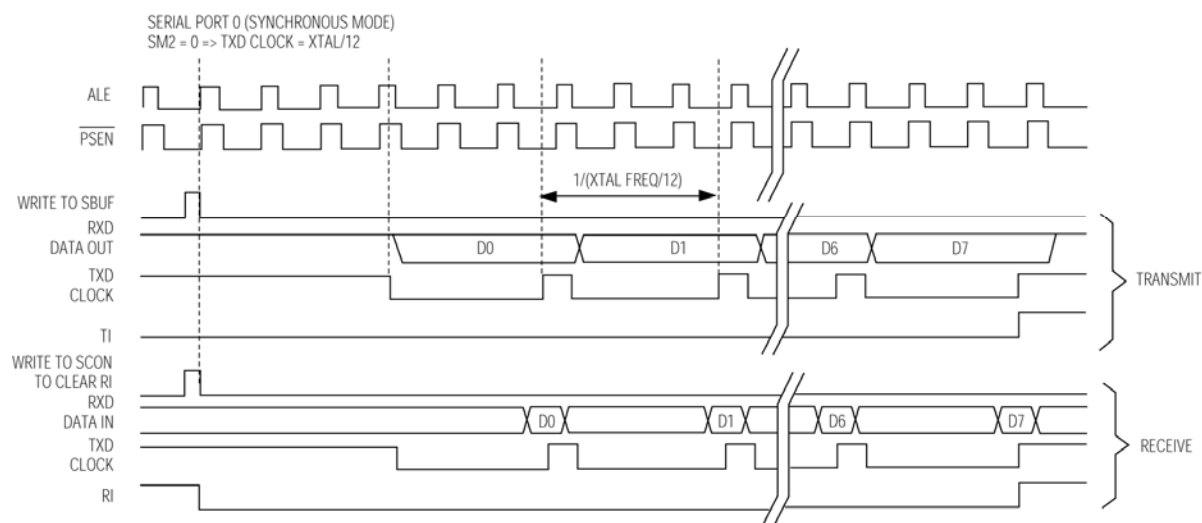
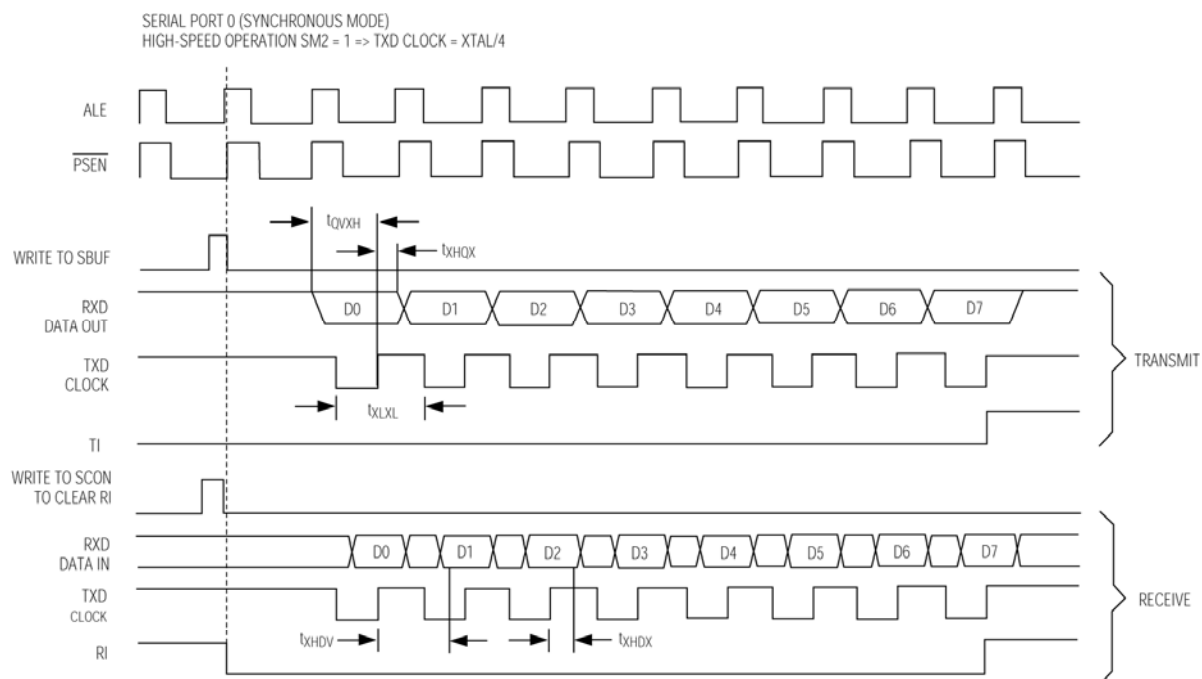
## DATA MEMORY WRITE WITH STRETCH = 2



## EXTERNAL CLOCK DRIVE



## SERIAL PORT MODE 0 TIMING



## PACKAGE INFORMATION

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO.                   |
|--------------|--------------|--------------------------------|
| 44 TQFP      | C44+2        | <a href="#"><u>21-0293</u></a> |
| 40 PDIP      | P40+1        | <a href="#"><u>21-0044</u></a> |
| 44 PLCC      | Q44+1        | <a href="#"><u>21-0049</u></a> |

## REVISION HISTORY

| REVISION<br>DATE | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | PAGES<br>CHANGED |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| 090198           | <ol style="list-style-type: none"> <li>1) Added note to clarify <math>I_{IL}</math> specification.</li> <li>2) Changed serial port mode 0 timing diagram label from <math>t_{QVXL}</math> to <math>t_{QVXH}</math>.</li> <li>3) Changed minimum oscillator frequency to 1MHz when using external crystal.</li> <li>4) Corrected “Data memory write with stretch” diagrams to show falling edge of ALE coincident with rising edge of C3 clock.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                  |
| 012401           | <ol style="list-style-type: none"> <li>1) Added errata disclaimer to page 1.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                  |
| 102405           | <ol style="list-style-type: none"> <li>1) Device moved to qualified status. Removed “Preliminary” status from data sheet.</li> <li>2) Removed references to 33MHz versions of the device.</li> <li>3) Added note requiring 100 machine cycles delay following stop mode exit. This edit transfers existing erratum from errata sheet into data sheet.</li> <li>4) Updated Absolute Maximum Ratings table to match current format.</li> <li>5) Displayed Electrical Characteristics test conditions.</li> <li>6) Added notation that -40°C specifications are guaranteed by design but not tested.</li> <li>7) Clarified DC Electrical Characteristics note that the specification only applies to the first clock cycle following the transition.</li> <li>8) Added lead-free part numbers to Ordering Information table.</li> <li>9) Added <math>t_{AVLL2}</math> specification.</li> <li>10) Updated AC timing characteristics with full characterization data.</li> </ol> |                  |
| 042106           | <ol style="list-style-type: none"> <li>1) Changed lead-free ordering information part numbers to correctly reflect that the “+” comes after part numbers (e.g., DS80C310-MCG+).</li> <li>2) Added Note 2 to the AC Electrical Characteristics and MOVX Characteristics tables.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 13, 14           |
| 8/09             | Removed additional references to 33MHz versions of the device.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1, 11            |