INTRODUCTION

When developing a system that will ultimately utilize a ROM-based microcontroller (MCU), it is still typical to make use of an EPROM-based MCU during the final stages of the design. Initial development may also include the use of some type of emulator system, but prototype units normally make use of a windowed EPROM or OTP EPROM MCU, and the design is optimized/validated based upon the performance of the EPROM-based device without, in many cases, taking into consideration potential differences in the performance of the ROM-based device that will ultimately be used.

CAUSE OF OTP VS. ROM DIFFERENCES

While MCU manufacturers go to great lengths to ensure that the performance differences of EPROM vs. ROM devices are minimized, there are external factors that historically have prevented fully achieving this goal. There are a number of key factors that can contribute to differing performance between the two types of devices, which include:

- **Operating Voltage Range:**
  ROM devices operate to a lower \( V_{DD_{MIN}} \) due to the difference in physics between EPROM and ROM memory cells.

- **Parametrics:**
  ROM and EPROM devices are not manufactured using the same fabrication process, leading to subtle differences in parametric performance.

- **Functional Operation:**
  One device may have design changes implemented to improve performance or correct errata that exists on the other device.

Each of these issues is discussed in more detail in the appropriate sections that follow.

Designers who are developing systems using EPROM products that are targeted to move to ROM devices as production volumes increase, or who find themselves needing to convert an existing EPROM-based design to ROM, should thoroughly review this application note to determine if the potential for problems exist. This document is not intended to be an all encompassing list of all possible issues, it is simply a reference resource for key items that have previously been identified as potentially causing problems.

OPERATING VOLTAGE RANGE

EPROM devices operate at \( V_{DD} \) levels above ~2.3V limited by the device physics of an EPROM cell. The ROM devices do not have this limitation and, therefore, typically operate down below 2.0V. When designing a low voltage system and developing/validating the design using an EPROM device, it is necessary to use a higher \( V_{DD} \) level than that which will actually be used in the final design. The gain of the internal transistors are sensitive to the \( V_{DD} \) value and this can lead to functional performance differences in the oscillator start-up/stabilization time, the watchdog timer speed, \( V_{IH}/V_{IL} \), and \( V_{OH}/V_{OL} \) levels. Each of these issues is discussed in greater detail under the ‘Parametrics’ section.

The system designer(s) should ensure adequate margin to the published specifications when using EPROM-based devices for development, and the use of ROM prototypes is highly recommended for low voltage application validation.

PARAMETRICS

The parametric performance of the ROM equivalent of an EPROM-based device may vary due to the processes used to fabricate the two different devices. There are a number of different scenarios that lead to the two devices being fabricated using different process technologies. First, ROM devices do not require several of the process steps required to make an EPROM device, so the processes are different by definition. Second, ROM devices are often manufactured using different starting wafer sizes and/or different process geometries. These options help maximize the cost savings that can be realized with ROM devices.

All of these may lead to some amount of variation in the parametric performance between the EPROM and ROM devices. The manufacturer ensures that both the ROM and EPROM devices meet the datasheet specifications so that drop in compatibility is maintained. However, it is sometimes the case that a design...
becomes dependent upon the actual parametric performance of a device instead of being designed to operate under the worst case specifications. This can lead to problems when developing a ROM application using an EPROM, or if trying to port a EPROM product to ROM to realize a cost reduction.

**OSCILLATOR PERFORMANCE**

Oscillator performance is a key parameter that may vary relatively significantly between the EPROM and ROM devices. The operation of the oscillator is highly dependent upon the internal transistor gains, which are determined by the process technology used during fabrication.

The transistor gains of the oscillator circuit effect oscillator start-up time and the oscillator stability with a given set of external components (crystal/resonator, capacitors, resistors). It is absolutely critical that the system designer(s) make every effort to verify the performance of the ROM device with the intended crystal/resonator design. This is highly recommended for oscillator verification whenever possible.

Another potential issue is, if the VDD ramp rate is relatively slow, the oscillator start-up timer may start sooner, relative to the start of the VDD ramp.

**WATCHDOG TIMER (WDT)**

The watchdog timer (WDT) is another function which can be highly sensitive to the parametrics of the process used to fabricate the device. The WDT utilizes an internal free running RC oscillator. The values of the internal resistor and capacitor may vary relatively significantly between the EPROM and ROM devices. It is, therefore, necessary to either allow for this in the selection of the WDT time-out value, or verify the design using actual ROM devices, if possible.

**CURRENT CONSUMPTION**

The current consumption between EPROM and ROM devices may also vary as a result of parametric differences in the processes. This includes both IDD and IPD values. Again, the manufacturer ensures that both devices meet the datasheet specifications, but designs that are very power sensitive should be evaluated using actual ROM devices, if possible.

**VOLTAGE THRESHOLDS**

Another area where process parametrics may cause subtle differences in device operation is related to the VIL/VIH and VOL/VOH values of the device. Because these levels are a dependent upon the internal transistor thresholds, which is a function of the process used to manufacture the device, careful consideration should be given to the input and output level specifications, and the system should be designed to work with the specified worst case values.

**ELECTROSTATIC DISCHARGE (ESD) PERFORMANCE**

In some cases, there may be a difference in the actual ESD performance of the ROM versus EPROM devices. This may lead to problems in some designs, where ESD events are likely or common. The system designer should check the ROM device datasheet to determine if there is a difference in the ESD specification and, for applications that are expected to be particularly susceptible to ESD, should perform system validation with ROM devices, if possible.

**FUNCTIONAL OPERATION**

Functional operation differences between EPROM and ROM devices that are meant to be equivalent occasionally do occur. These differences are typically due to the fact that one of the devices (usually the EPROM) is developed and released first and contains some errata concerning actual functional performance. The second device typically implements fixes for some or all the known errata and, therefore, does not function identically to the other.

In other cases, changes or improvements may have been implemented to enhance a device but the enhancements may not have been released to production on both devices, so there is some period where the devices do not function identically.

It should also be noted that it should not be assumed that any or all errata for the EPROM device has, or will be, corrected in the ROM device, and it is also possible that new errata is introduced on the ROM device that did not exist on the EPROM device.

Functional differences are often related to the operation of one of the peripheral blocks including:

- USART
- SSP
- PWM
- Timers
- MCLR operation
- A/D Converter

In all cases, the system designer(s) should specifically request any errata that exists for each of the two devices, as well as any known device specific issues between the EPROM and ROM versions of the device being used. And finally, ROM prototypes should be used whenever possible for final system validation.

**ROM PROTOTYPES**

Microchip offers customers a ROM prototype service, which allows systems in the latest stages of design valuations to be checked out using a ROM PIC rather than an EPROM-based micro. This should be used if there are any concerns about the functional or parameter differences between the EPROM micro and the intended ROM device.
SUMMARY

When developing a new ROM application using an EPROM-based MCU, or when attempting to move an established EPROM-based design to ROM to reduce costs, there are a number of key factors to be considered to minimize problems and ensure a reliable ROM design. The ideas presented in this application note are not intended to be all inclusive, but do represent key issues that have been identified in the past as presenting potential problems. It can not be stressed enough that actual ROM devices should be used for system/design validation whenever possible. This alone significantly reduces the risk of unanticipated application performance issues occurring in the future. It is also key that all hardware be designed so that acceptable operation at worst case device specifications is ensured.
AMERICAS
Corporate Office
Microchip Technology Inc.
2335 West Chandler Blvd.
Chandler, AZ 85224-6189
Tel: 480-786-7200 Fax: 480-786-7277
Technical Support: 480-786-7627
Web Address: http://www.microchip.com

Atlanta
Microchip Technology Inc.
500 Sugar Mill Road, Suite 200B
Atlanta, GA 30350
Tel: 770-640-0034 Fax: 770-640-0307

Boston
Microchip Technology Inc.
5 Mount Royal Avenue
Marlborough, MA 01752
Tel: 508-480-9990 Fax: 508-480-8575

Chicago
Microchip Technology Inc.
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0075 Fax: 630-285-0075

Dallas
Microchip Technology Inc.
4570 Westgrove Drive, Suite 160
Addison, TX 75241
Tel: 972-818-0000 Fax: 972-818-2924

Dayton
Microchip Technology Inc.
Two Prestige Place, Suite 150
Miamisburg, OH 45342
Tel: 937-291-1654 Fax: 937-291-9175

Detroit
Microchip Technology Inc.
Tri-Aria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

Los Angeles
Microchip Technology Inc.
18201 Von Karman, Suite 1090
Irvine, CA 92862
Tel: 949-263-1888 Fax: 949-263-1338

New York
Microchip Technology Inc.
150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 631-273-5305 Fax: 631-273-5335

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

AMERICAS (continued)

Toronto
Microchip Technology Inc.
5925 Airport Road, Suite 200
Mississauga, Ontario L4V 1W1, Canada
Tel: 905-405-6279 Fax: 905-405-6253

ASIA/PACIFIC

Hong Kong
Microchip Asia Pacific
Unit 2101, Tower 2
Metroplaza
223 Hong Fong Road
Kowloon, N.T., Hong Kong
Tel: 852-2-401-1200 Fax: 852-2-401-3431

Beijing
Microchip Technology, Beijing
Unit 915, 6 Chaoyangmen Bei Dajie
Dong Erhu Road, Dongcheng District
New China Hong Kong Manhattan Building
Beijing 100027 PRC
Tel: 86-10-85828120 Fax: 86-10-85828104

India
Microchip Technology Inc.
India Liaison Office
No. 6, Legacy, Convent Road
Bangalore 560 025, India
Tel: 91-80-229-0061 Fax: 91-80-229-0062

Japan
Microchip Technology Int'l Inc.
Benex S-1 6F
3-18-20, Shinjyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa 222-0033 Japan
Tel: 81-45-471-6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg, 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Shanghai
Microchip Technology
RM 406 Shanghai Golden Bridge Bldg.
2077 Yan’an Road West, Hong Qiao District
Shanghai, PRC 200033
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

ASIA/PACIFIC (continued)

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore 188980
Tel: 65-334-8870 Fax: 65-334-8850

Taiwan, R.O.C
Microchip Technology Taiwan
10F-1C 207
Tung Hua North Road
Taipei, Taiwan, ROC
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

United Kingdom
Arizona Microchip Technology Ltd.
505 Eskdale Road
Withersham Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5858 Fax: 44-118 921-5835

Denmark
Microchip Technology Denmark ApS
Regus Business Centre
Lautrup holj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Arizona Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - 1er Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Arizona Microchip Technology GmbH
Gustav-Heinemann-Ring 125
D-81739 Munchen, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy
Arizona Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

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