MICROCHIP

AN562

Using the Microchip Endurance Predictive Software

INTRODUCTION

Endurance, as it applies to non-volatile memory, refers to the number of times an individual memory cell can be erased and/or written (some architectures do not erase before every write). Advances in process technology have made it possible to increase these limits and for Microchip to offer new concepts - Total Endurance™ and a split architectural design for variable endurance. These concepts lead to more reliable products with more bits per dice, such as the 24C32 and 24C65.

TOTAL ENDURANCE ™

When defining endurance, we need to look at a few common definitions and possible misconceptions. Endurance with respect to EEPROMs is defined in number of Erase/Write (E/W) Cycles and is the most common rating referred to when discussing or specifying endurance. E/W ratings are based on the environmental and operating conditions of voltage, temperature, cycling mode and rate (for each byte in the application not on the number of opcodes or control byte commands) and is never based on any read functions whether they be a data read or configuration read. If a part is rated at 100K E/W cycles, then each individual byte can be erased and written 100,000 times. This is probably the most common misinterpretation made by system designers. Endurance is thus an interactive application-specific reliability parameter. It is not a typical data sheet specification, such as a parametric AC/DC specification with benchmark standards for measurement. Microchip has done extensive predictive laboratory studies on Microchip 2- and 3-wire Serial EEPROMs. These studies led to the concept of using the computer to predict the theoretical wear out of the floating gate and ultimately to project the point in time of a product's life cycle when the first non-volatile memory bit or periphery failure should occur. After many man-years of data collecting, predicting and verifying the results, Microchip feels confident in publishing and offering for the general technical community this predictive model in the form of IBM® PC-compatible software. Microchip has a patent pending on this predictive mathematical model.

TOTAL ENDURANCE PREDICTIVE SOFTWARE

The predictive software described here originally was being developed as a tool for determining endurance levels of Microchip non-volatile devices. Upon seeing the potential of the software as a design aid, it was decided to make a version that could be purchased by the engineering community. The benefit gained from this software is the ability to predict endurance capability of Microchip's EEPROM devices under various operating conditions. Prior to this tool becoming available, the only way to assemble this type of data would be to do extensive life testing in the target system. It should be noted that this predictive model applies only to Microchip Technology Inc. non-volatile devices.

The program uses an iterative statistical model developed by Microchip Technology Inc. physicists. The model was first used in a DOS-based text program as a proof of concept and for developing the exhaustive database needed for such a tool (included on the program disk as enddos.exe). This model was then imported to a Windows™-based software package with full GUI capabilities and all the normal cut, paste, print, viewing properties. The model actually operates as a mathematical function which is called from within the Windows Visual Basic shell and is passed all of the pertinent operational, process, and device information. The model then, after calculating the essential data points, returns this information to the main program to be formatted and displayed both textually and graphically.

Applying the predictive data to the high endurance block of the 24C65, using the 24LC04 which has similar characteristics, and assuming the following:

- a five-year life
- an expected E/W cycles of 10 times per day
- a function of 11 bytes

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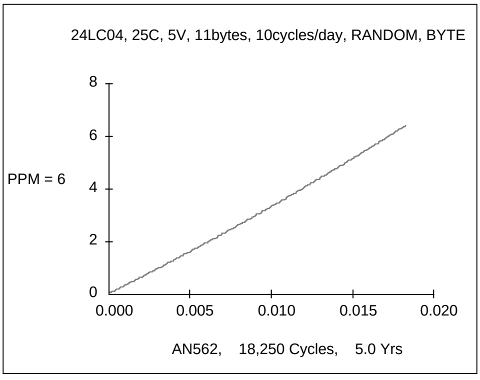
Operational specifications:

Device	24C65 (24LC04B)
Voltage	5
Temperature	25 C
Bytes/Cycle	11
E/W/Day	10
App. Life (Yr.)	5
Cycling Mode	BYTE
Data Pattern	RANDOM

The 4K HE block with 1 M E/W cycles typical, in this application, should yield the following results:

FIT	1.0	PPM	6
Time	5.0	Write cycles	18,250

FIGURE 1



The results shown are predictive in nature and should reflect an accurate representation of the expected results. For a more detailed description of endurance, see the related application notes AN536 and AN537 contained elsewhere in this volume. All operation parameters, along with the process technology, effect the effective endurance of a non-volatile device. The voltage, temperature, cycles per, bytes per cycle, and even the number of times written per day (time between write cycles) all have an effect on the oxide breakdown or periphery failure rate of a particular non-volatile process.

Endurance is not a well-defined concept within the semiconductor industry. The number of erase/write cycles which a particular EEPROM can endure is dependent not only upon the design of the device but also upon the application environment in which it is used. Therefore, blanket claims such as “1 million erase/write cycles typical” can only be validated based upon the specific parameters of each application. Yet until now, there has been no tool available for predicting the endurance of a particular EEPROM device within a set of application parameters. Trade-off analysis can be painfully time-consuming and only marginally accurate without specific knowledge of the behavior of the device under different conditions of use.

The Microchip Total Endurance Software allows the designer to trade off voltage, temperature, write cycles, number of bytes written, number of writes per day, PPM and FIT rates, and years of use in order to optimize the system and accurately predict product lifetime and reliability.

The following is an example using the Endurance Software to aid in the design of an electronic phone book/ auto-dialer:

> The auto-dialer may have new numbers added or changed several times per day; but how can the manufacturer specify the life of the unit, and at what rate of update of the phone numbers? First, the designer must make some assumptions. If we assume that the average user will change or add 50 phone numbers per day, and the manufacturer is willing to live with a 0.1% failure rate (1,000 PPM) after 10 years of use, then we have almost enough information to verify whether we are in the ball park given the physics of the EEPROM device which will store the numbers. We also need to know the operating voltage and temperature of the application; we will say that a 3.3V lithium button battery is powering the unit and the temperature range is limited to that for which the LCD display will function: 0°C to 70°C. End-of-life voltage for the battery is approximately 2.0V; assuming that the ASIC or microcontroller in the application will operate down to 2.5V, the EEPROM also has a 2.5V requirement. The designer would like to be able to store 100 phone numbers of 16 bytes each, which results in a 1.6K byte requirement for the Serial EEPROM. Because 1.6K bytes is equal to 12.8K bits, a 16K bit 2-wire Serial EEPROM will more than suffice. Specifically, Microchip’s 24LC16B will operate down to 2.5V and even includes a write-protect feature which can be used to block inadvertent writes in a noisy environment.

Here is a summary of the application:

Device	24LC16B
Voltage	2.5V - 3.3V
Temperature	0°C to 70°C (55°C typical)
Cycles per day	50
Bytes per cycle	16
Application life	10 years

Once these values are entered into the Total Endurance program, it outputs the following:

Device Data:	Input Parameters
Device	24LC16B
Voltage	3.3
Temperature	55
Bytes/Cycle	16
E/W	50
App. Life (Yrs)	10
Cycling Mode	BYTE
Pulse Width (Ms)	N/A
Data Pattern	RANDOM

Device Data:	Output Parameters
FIT	21.0
PPM	1,842
Time	10.0
Write cycles	182,500

Both of the lists above were copied directly from the Total Endurance program output to the Microsoft® Windows clipboard and pasted into this document (the Total Endurance program has a handy menu click to make this easy).

Unfortunately for our designer, the desired 0.1% failure rate has almost doubled to 0.18% (1842 PPM). But fortunately for the designer, the Total Endurance program makes trade-off analysis very simple and fast. At this point there are at least three options: (1) live with almost 2000 PPM, or (2) look at the endurance plot and check whether there is a reasonable number of E/W cycles which will provide a 1000 PPM failure rate, or (3) specify a PPM rate to the Total Endurance program and let it crank out the number of cycles it will take.

Below is the endurance plot, again pasted directly from the Total Endurance program:

You can see that by reducing the number of cycles from the 182,500 which resulted from our first trial to about 100,000, we can achieve a PPM rate of about 1000 (0.1%). But how does 100,000 cycles translate into application life or cycles per day?

By switching the Total Endurance program mode to a PPM request mode instead of application life mode, we can query the program for this information. Let's ask it for the application life of the product given a 1000 PPM failure rate. Here are the results:

Device Data:	Input Parameters
Device	24LC16B
Voltage	3.3
Temperature	55
Bytes/Cycle	16
E/W	50
PPM Level (Yrs)	1000
Cycling Mode	BYTE
Pulse Width (Ms)	N/A
Data Pattern	RANDOM

Device Data:	Output Parameters
PPM	1,000
Time	5.97
Write cycles	109,000

Now we have some more options: (1) specify the product life at 5 years or (2) trade-off other parameters of the application such as voltage or temperature, or (3) decide which is more important – a 10-year product lifetime, or the ability to change 50 numbers every single day. Maybe this analysis has caused our designer to re-evaluate the 50 cycle-per-day requirement. Will the user really change or add that many numbers per day – half of the unit's total capacity? Maybe 20 or even 10 is a more practical figure. Realistically, a user may enter or change quite a few numbers the first week or two of the application, and after that the unit will be used mostly for reading and dialing numbers.

Changing the number of erase/write cycles to 20 per day gives us the following results:

Device Data:	Input Parameters
Device	24LC16B
Voltage	3.3
Temperature	55
Bytes/Cycle	16
E/W	20
PPM Level (Yrs)	1000
Cycling Mode	BYTE
Pulse Width (Ms)	N/A
Data Pattern	RANDOM

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Device Data:	Output Parameters
PPM	1,000
Time	14.93
Write cycles	109,000

Wow! Reducing the number of cycles per day not only brought us back to a 10-year life, it gave us some margin on that, too. Keeping all the other parameters the same and forcing a 10-year lifetime gives us the following final results:

Device Data:	Output Parameters
FIT	7.1
PPM	625
Time	10.0
Write cycles	73,000

The new PPM rate of 625 gives our triumphant designer more than 30% margin on his PPM target of 1000.

This example shows the significant reduction in time for design trade-off analysis and time-to-market which can be achieved with a useful tool like the Microchip Total Endurance Disk. In addition, it demonstrates the increase in robustness of the system design by providing known quantities and readily accessible handles to modify those quantities in the trade-off analysis. This tool can literally reduce weeks of effort into a few minutes of point and click.

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Note the following details of the code protection feature on PICmicro® MCUs.

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the PICmicro microcontroller in a manner outside the operating specifications contained in the data sheet. The person doing so may be engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as “unbreakable”.
- Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our product.

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Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs and microperipheral products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 certified.

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