Calculating Equivalent Power-on-Hours for Hercules™ Safety MCUs

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ABSTRACT

This application report describes using a spreadsheet to calculate the aging effect of temperature on Texas Instruments Hercules Safety MCUs.

The spreadsheet discussed in this application report can be downloaded from the following URL: http://www.ti.com/lit/zip/spna207.

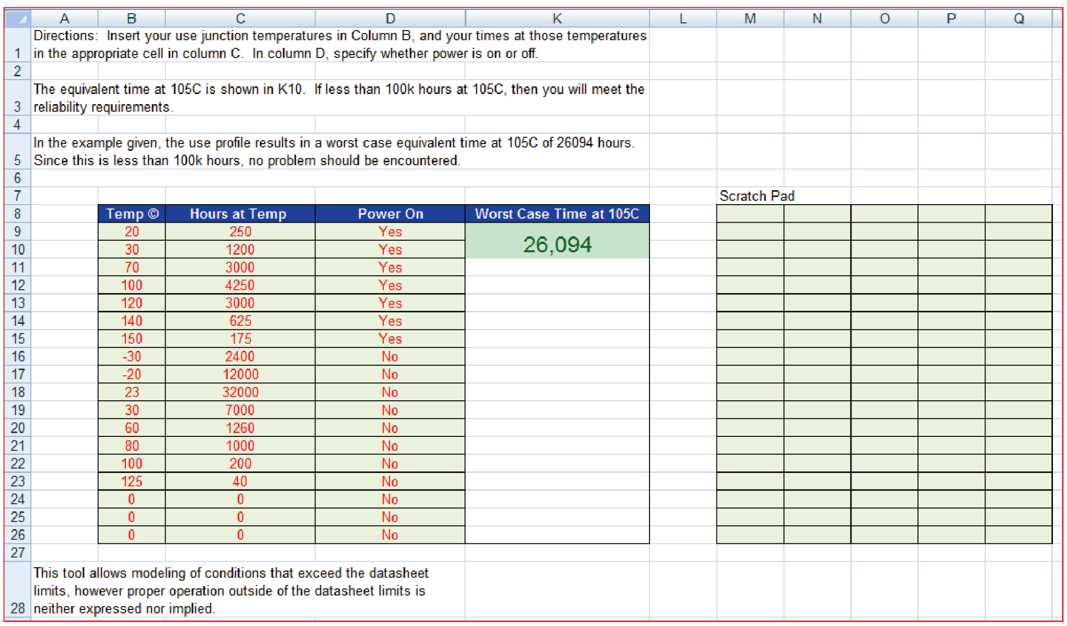
Contents

1 Introduction

Integrated circuits do "wear out". This is caused by shifts in the transistor threshold voltages, metal migration and loss of margin on non-volatile storage elements. All of these wear-out mechanisms are accelerated by temperature. Semiconductor manufacturers account for the wear out by designing with margin. But with continuous operation at high temperatures over long periods of time, how can a designer know if there is enough margin? Texas Instruments specifies a "Power-on-hours" value to give a conservative estimate of the useful life of our parts. This is normally specified as some number of hours at a particular voltage and junction temperature. Sometimes a voltage is given, but if not, it is assumed to be at the maximum voltage specified for the part. The Hercules Safety MCUs are typically specified for 100,000 hours at 105°C junction. To verify the Power-On-Hours for your specific part number, see the device-specific data sheet. Since the wear out effect varies greatly with temperature, this specification is not very useful without a way to translate it into a real world temperature profile. The spreadsheet attached to this application report is a way to do just that.

2 Using the Temperature Activation Factor Calculator

The Temperature Activation Factor Calculator is a protected Excel spreadsheet that is used to convert temperature profiles into the equivalent number of power-on hours for a Hercules MCU made using TI's 65 nanometer process (also known as F021). See Figure 1.



Directions: Insert your use junction temperatures in Column B, and your times at those temperatures in the appropriate cell in column C. In column D, specify whether power is on or off.

The equivalent time at 105C is shown in K10. If less than 100k hours at 105C, then you will meet the reliability requirements.

In the example given, the use profile results in a worst case equivalent time at 105C of 26094 hours. Since this is less than 100k hours, no problem should be encountered.

Scratch Pad

Temp ©	Hours at Temp	Power On	Worst Case Time at 105C
20	250	Yes	
30	1200	Yes	26,094
70	3000	Yes	
100	4250	Yes	
120	3000	Yes	
140	625	Yes	
150	175	Yes	
-30	2400	No	
-20	12000	No	
23	32000	No	
30	7000	No	
60	1260	No	
80	1000	No	
100	200	No	
125	40	No	
0	0	No	
0	0	No	
0	0	No	

This tool allows modeling of conditions that exceed the datasheet limits, however proper operation outside of the datasheet limits is neither expressed nor implied.

Figure 1. Temperature Activation Factor Calculator

The expected temperature profile is entered in cells B:9 through D:26. Column B is the high temperature of a range. Column C is the number of hours in that temperature range. For example, if row 9 represents 250 hours between -40°C and 20°C, then enter 20 in cell B:9 and 250 in cell C:9. Note that the temperature range is the junction temperature of the device, not the ambient temperature. For information about calculating junction temperatures, see SPRA953.

Column D is to indicate if the hours for this range are power-on. The cells are formatted with drop down boxes for "Yes" or "No". Some wear out mechanisms such as Electro-migration (EM), Time Dependent Di-electric Breakdown (TDDB), Negative Bias Temperature Instability (NBTI), and Channel Hot Carriers (CHC) only apply when the device is powered on. For more information on these wear out mechanisms, see SPRABX4.

Flash and One Time Programmable (OTP) memory Data Retention Loss (DRL) happens when the device is powered on or powered off. That is why both a power-on and a power-off profile should be entered into the spreadsheet. Typically, the device junction temperature is the same as the ambient temperature when the device is powered off.

The calculator calculates multiple power-on hour equivalents and displays the largest one in cell K:10. If the value from the Temperature Activation Factor Calculator is less than the number of power-on hours specified in the data sheet, then the device is operating within the reliability margins of the design.

All of these wear out mechanisms are very active at high junction temperatures but not very active at low junction temperatures. Therefore, you can group all of the hours below 30°C into a single range without unduly affecting the total power-on hours. However, you should use small temperature ranges above 100°C to get an accurate estimate of the power-on hours. The higher the temperature, the smaller the range you should use.

Cells M:8 through Q:26 are simply a scratch pad area. They can be used, for example, to convert a temperature profile given in percent of time into hours. The resulting hours can then be pasted into cells C:9 through C:26.

3 References

- *Calculating Useful Lifetimes of Embedded Processors* (SPRABX4)
- *Semiconductor and IC Package Thermal Metrics* (SPRA953)

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