

TCSR-How to reduce Self Refresh Current according to temperature changes.

Application Notes(Oct.' 02)

Written by the member of Mobile Product Planning Group.

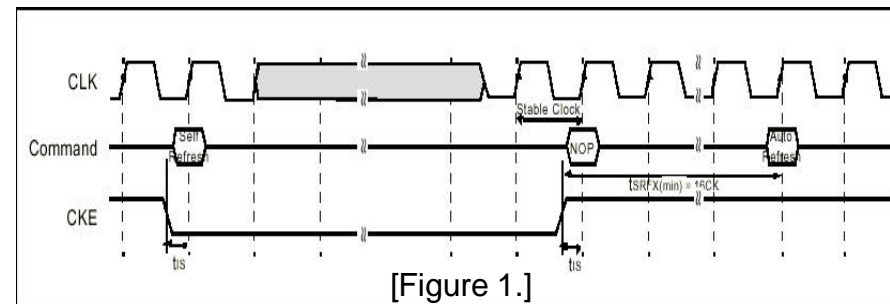
Introduction

SDRAM cell consists of one transistor and one capacitance to make maximum density in the smallest chip size. Its architecture is same from EDO to DDR SDRAM and even to Rambus DRAM. SDRAM stores its datum with electronic charge in its capacitance. Due to its capacitance, SDRAM needs refresh time because the capacitance discharge as time goes by, in other words, the datum which is stored in the capacitance disappears. The discharging time is dependent on temperature changes as well as time because high temperature makes worse refresh capability and finally makes the datum lost. Up to now, SDRAM used in Desktop and Server application has been used at the fixed location like inside building which has strong coolers. And also even in notebook PC environment, that has a cooler in the system. But, mobile application like PDA and cellular phone doesn't have any cooling capability and using temperature is different due to user's movement like one time in the automobile, another time in the outside. In this environment, refresh control according to temperature changes has been an important factor.

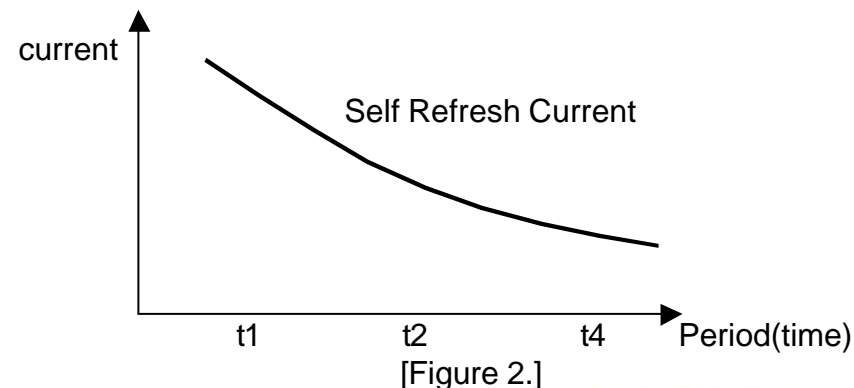
Refresh Characteristics

The most important factor for mobile application specially like PDA, Cellular Phone is power management; how to reduce power consumption. Mobile application doesn't have any strong external wall power, but only battery power which is limited and small capacity. The management of its limited and small power volume is critical for system vendors' competitiveness in that application. The status of cellular

phones is standby up to more than 50%, that is self refresh status to SDRAM side. The method to use self refresh is a little bit simple. [See Figure 1] But, some penalty for that mode is after exiting self refresh mode, minimum tRC is needed to start normal operation.



Power consumption in refresh mode is related with refresh period.[See Figure 2.] This graph shows the longer period, the lower current consumption. Power consumption at one refresh time is same regardless of its period, but in long time base, the power consumption difference between its short period and long period is big. Its period difference is rooted from leakage current due to various reasons.

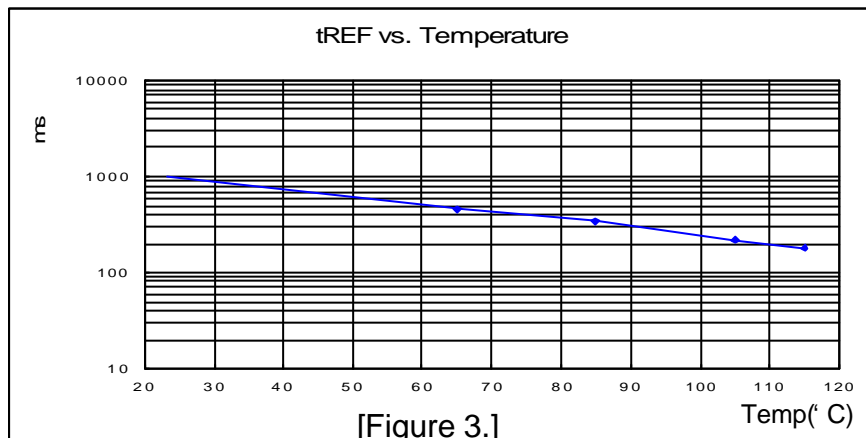


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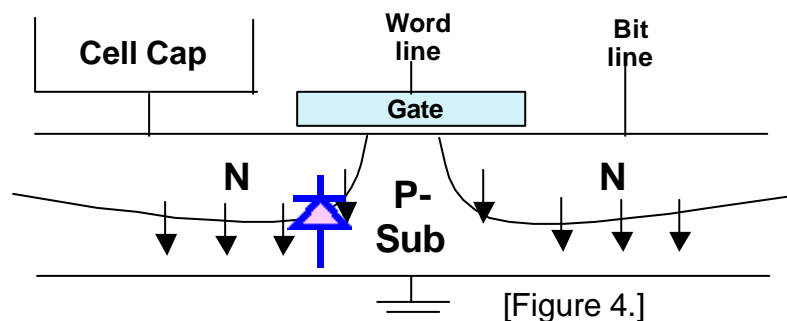
Among reasons, static refresh and dynamic refresh are major factors. Static refresh is a dominant factor in self refresh status, on the other hand, dynamic refresh happens mainly in normal operation. The effects to self refresh as temperature changes is higher temperature makes it worse.[See Figure 3].



[Figure 3.]

PN Junction Leakage for Static Refresh.

Static leakage is rooted from PN junction leakage. [See Figure 4].



[Figure 4.]

In balance status, there is no free electron due to tough barrier between balance band and conduction band. But, in high temperature, energy makes electron cross over Fermi's barrier to conduction band, that makes free electron moves and makes current flow which is called reverse PN diode. This phenomena is explained with a little bit complicated equations.

$$J_n = J_s(e^{qV_a/kT} - 1)e^{(x+xp)/L_n} \text{ ----- [Equation 1]}$$

$$Q = it = CV, \quad V = i \quad t/C \text{ ----- [Equation 2]}$$

Above two equations show why high temperature and time makes SDRAM's refresh characteristics worse. To make no reverse PN diode, absolute temperature(-273° C) is needed because there is no electron movement in that temperature.

What is TCSR ?

JEDEC defined mobile features for its special application with three functions; PASR(Partial Array Self Refresh), TCSR(Temperature Compensate Self Refresh), DPD(Deep Power Down). DPD is the strongest tool to reduce DRAM's power consumption, but it loses SDRAM's all data, which is not refresh function because refresh means saving its data. Also, it needs another power up sequence to operate SDRAM after exiting DPD, which is a little bit big penalty in performance point of view. Considering self refresh mode, TCSR is a good solution to reduce self refresh current of SDRAM without any losing data and any additional sequence in internal TCSR method.

How to use TCSR

JEDEC describes the method to use TCSR with ERMS option.[See Figure 5]. Before introducing TCSR, SDRAM covers wide temperature range from 0° C to 70° C (commercial temperature range) with a fixed self refresh period.

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EMRS	Address Bit							
	A4	A3	A4	A3	A4	A3	A4	A3
	1	0	0	1	0	0	1	1
JEDEC Temp. Range	-25 ~ 15`C		15 ~ 45`C		45 ~ 70`C		70 ~ 85`C	

[Figure 5.]

SDRAM should keep its data up to 64ms which is defined by JEDEC regardless of temperature changes, even though refresh characteristics is dependent on temperature changes. The real power of TCSR is to control self refresh current with considering temperature changes. If system temperature is under 45`C, the period of SDRAM will be longer, if temperature is 70`C, the period will be shorter to control power consumption of self refresh.

Another consideration factor to use TCSR.

Even though TCSR allows the system to control self refresh power of SDRAM as a function of temperature, it is difficulty to use in system level because the controller should have an external or internal temperature sensor, which increases system cost and pushes burden to control temperature. This mode is called ' External TCSR . Furthermore, if the controller wants to change its temperature range, the controller should issue MRS sequence one more, which is a little bit penalty. These explain why external TCSR is not widely used in mobile application up to now. Controller makers are pushing SDRAM vendors to include a temperature sensor in SDRAM due to TCSR's excellent performance for reducing self refresh current, which is called ' Internal TCSR' . Internal TCSR means SDRAM has a temperature sensor internally and controls the

refresh period as SDRAM temperature changes in self refresh mode. If SDRAM is entered into self refresh mode, SDRAM automatically check its temperature and controls self refresh period to reduce standby current. SDRAM can use multiple break points to control self refresh period like JEDEC definition. Even though JEDEC defines four temperature ranges which are too many ranges and the refresh characteristics curve doesn't show any big difference between -25~15`C and 15~45`C. On the other hand, over 45`C, the refresh characteristics is getting worse compared with under that temperature range. The range 45~70`C and 70~85`C doesn't show big difference also. Furthermore, system temperature doesn't go over 45`C in most time from system vendors' research results. SDRAM vendors for internal TCSR should decide to follow the break points of all JEDEC temperature ranges, or to reduce the number of its break points with its own solution.

Conclusion

Mobile market is now booming and booming. The most important factor in that market is how to reduce power consumption and more than 50% of usage, mobile application is in standby status which is self refresh mode to SDRAM side. Even though JEDEC already defined mobile features with three functions; PASR, TCSR and DPD. Among them, TCSR is a good solution to reduce self refresh current without losing its data and SDRAM vendors adapted an internal temperature sensor to control self refresh period which decides its current. TCSR can be divided into two methods; External TCSR and Internal TCSR. Internal TCSR provides a clear solution compared with external TCSR. External TCSR needs an

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external temp sensor and an additional MRS sequence to change its temperature range. But, internal TCSR provides no need of an external temp sensor and an additional MRS sequence. Only thing to be needed is to enter self refresh mode. The number of break points for internal TCSR may be different from vendor by vendor and finally decided by market needs.

For more information

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