AN6076

Application note

How to save the application energy budget with page EEPROM family

Introduction

This document describes the key ultralow power features of the page EEPROM family listed in Table 1 and provides guidelines to reduce the energy budget of an application.

These typical embedded systems are usually powered by batteries:

- Hearing aids
- Fitness trackers
- IoT modules
- Asset tracking
- Environmental sensors

To achieve long battery life, low power consumption is a key factor for designers of such applications.

Table 1. Applicable products

Series	Root part number
Standard serial page EEPROM	M95P08-I, M95P08-E
	M95P16-I, M95P16-E
	M95P32-I, M95P32-E

1 Memory usage time

In an embedded electronic system, not all components are used 100% of the time. Memory is no exception, even if it is used intensively for writing or reading data.

Table 2 shows two typical application examples:

- Medical with intensive data logging
- Industrial with less data monitoring

The lifetime of the application is 10 years.

Table 2. Write cycle time in typical applications

	Medical	Industrial
Write cycle rate	1 page (512 bytes) per second	1 page (512 bytes) per minutes
Number of write cycles over 10 years	315 360 000	5 256 000
Total write cycle time (seconds)	630 720(1)	10 512 (1)
Total application lifetime (10 years) (seconds)	315 360 000	315 360 000
Total write cycle time vs. Total application lifetime (%)	0.2	0.003

1. *Calculated with a typical write cycle time of 2 ms, refer to the datasheet for more information*

This table does not take into account the read operations during the lifetime of the application. In fact, with the quad-output SPI protocol, the page EEPROM can read data at up to 320 Mbit/s. This means that at 80 MHz, a page is read in 12.8 µs and written in 2 ms (typical value). In terms of timing, writing a page is equivalent to reading almost 100 pages.

The total write cycle time therefore gives a good indication of how long the page EEPROM is used over the lifetime of the application, especially for intensive data logging applications.

According to Table 2, the memory is active (performing operation) less than 1% of the time. For this reason, this application note describes how the energy budget of the application can be drastically reduced when the page EEPROM is not active in Section 2 and Section 3.

Nevertheless, all applications do not record data intensively and do not run at 80MHz. Therefore, Section 4: Ultralow operating current consumption and Section 5: Peak current control show the great ultralow power performances of page EEPROM in typical SPI operations (read, write, erases).

2 Deep power down mode

When the page EEPROM is in standby mode, the memory is ready to receive new instructions and its current consumption is 16 µA (typical, 1.6 V ≤ V_{CC} ≤ 3.6 V, T = 25 °C). However, it is possible to put the memory into sleep mode when it is not being actively used.

This sleep mode is the deep power down feature where the power consumption is at its minimal. So, between two write operations, the current consumption drops excessively low with only 0.6 µA (typical value, V_{CC} = 1.8 V, T=25 °C).

The Table 2 shows that the medical and the industrial applications use the memory less than 1% one the time. So let's compare the energy required in deep power down mode and standby mode in this type of application.

Table 3. Energy in deep power down vs standby modes

Energy(1) spent (V_{CC} = 1.8 V)	
	Medical or industrial (2)
Deep power down	340
Standby	9 064

1. *Energy (unit Joule) is supplied by the combination of current, voltage, and time delivered by a circuit.*
2. *The difference of energy is very close between the two applications, this is why one single column is enough*

The deep power down mode of the page EEPROM reduces the energy consumption by 96% compared to the standby mode, thus ensuring a great energy-saving for the application batteries.

In deep power down mode, the faster you wake up the memory, the faster the application resumes. With a 30 µs wake-up time, the page EEPROM allows your application to restart instantly after a deep power down mode.

However, for some very sensitive ultra-low power applications, deep power down is not enough. The best option is to reduce this power consumption to zero when the memory is not in use. This is possible with the page EEPROM by driving the power supply (V_{CC}) with a microcontroller GPIO.

3 V_{CC} driven by a microcontroller GPIO

An intelligent solution to reduce power consumption is to manage the power supply (V_{CC}) of the page EEPROM by a microcontroller GPIO. Thus, when the memory is unused, the page EEPROM power supply can be cut.

When the page EEPROM is not actively used, V_{CC} is set to zero by a GPIO, eliminating the power consumption. As the page EEPROM power-up time is as fast as its wake-up time (30 µs - 10x faster than competition), the microcontroller can access very quickly to the memory even if it is turned off.

To ensure that the power-up operation was completed successfully and the page EEPROM is ready to operate, the user can monitor the PUF bits inside the security register and the WIP bit inside the status register:

- WIP = 1, power-up in progress
- WIP = 0, power-up completed
- PUF = 0, power-up successfully completed
- PUF = 1, power-up has failed

Table 4 shows the power reduction that GPIO-driven V_{CC} provides to the application.

Table 4. Energy reduction with V_{CC} driven by a GPIO

	Medical	Industrial
Energy write operation (10 years)(1)	1 703 J	28 J
Energy deep power down (10 years)	340 J	340 J
Total application energy	2043 J	368 J
Total application energy with Vcc driven by GPIO	1 703 J	28 J
% of energy reduction with GPIO	**-20 %**	**-92 %**

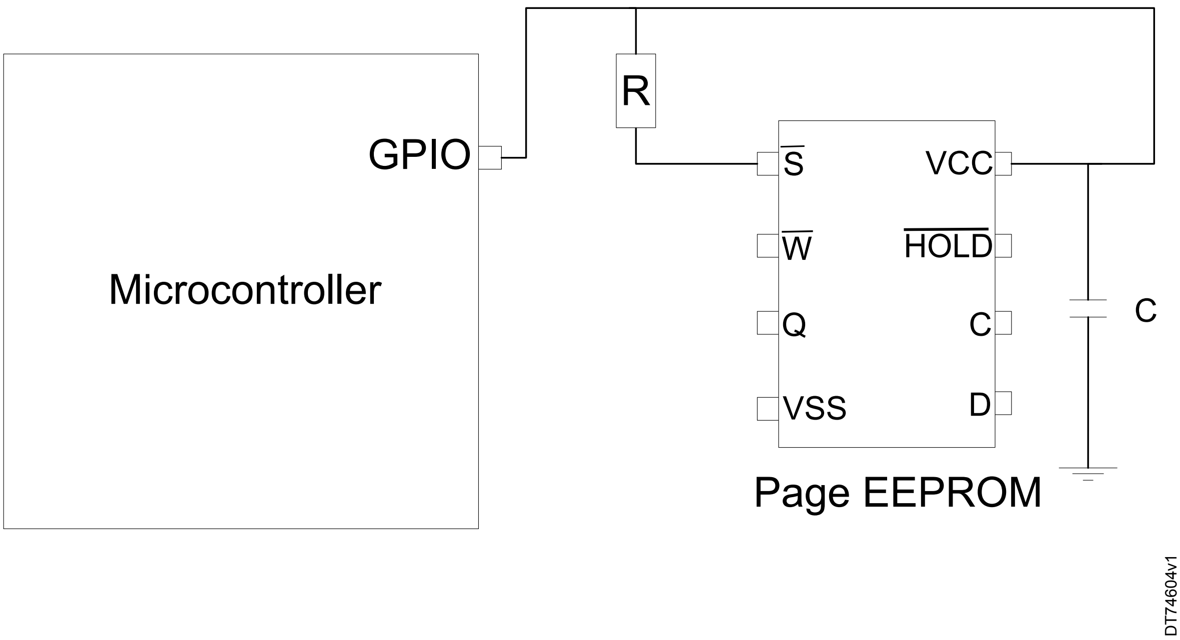
1. *Calculated with a write current consumption of 1.5 mA. Refer to the datasheet for more information*

By driving the V_{CC} with a microcontroller GPIO, an application saves up to 92% power. In addition, even very intensive data logging applications have a 20% reduction in power consumption.

3.1 Guidelines to drive the page EEPROM V_{CC} with a GPIO

The minimum output voltage level of the microcontroller must always be higher than the minimum voltage level of the page EEPROM (1.6 V).

Figure 1. GPIO driving V_{CC} page EEPROM pin



To ensure a stable DC supply voltage, it is recommended to decouple the V_{CC} line with a suitable capacitor (between 10 and 100 nF) close to the V_{CC}/V_{SS} pins of the device (see datasheet for more information).

The pull-up resistor R (whose typical value is 100 kΩ) ensures the deselection of the device if the bus controller leaves the $\overline{S}$ line in the high impedance state.

Depending on the maximum current supported by the microcontroller's GPIOs, the chip erase (typically 10 mA) is not recommended when connecting the page EEPROM V_{CC} pin to a microcontroller. It is suggested to use block erase instead, as it is very fast (typically 4 ms) to erase 64 KB of data. It is therefore important to check the current consumption of the page EEPROM is not higher than the maximum current supported by the microcontroller GPIOs.

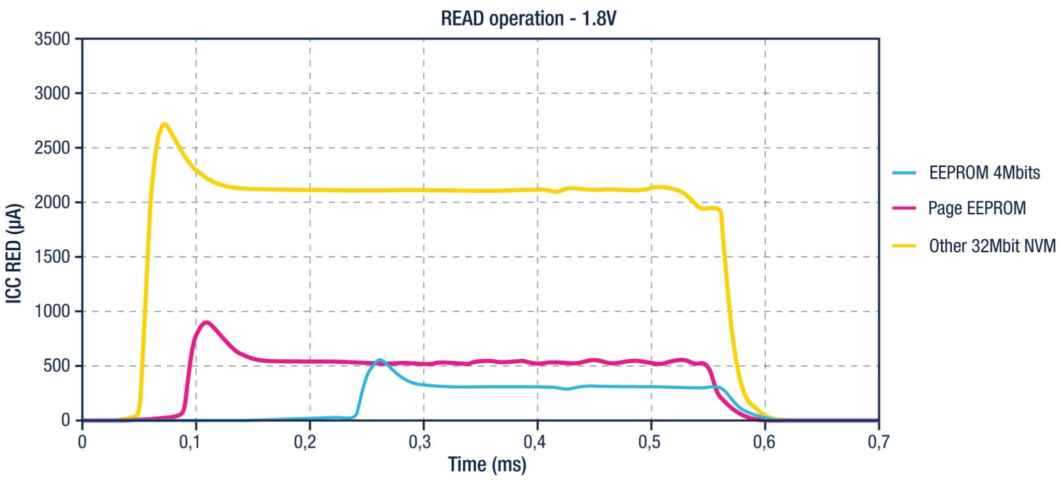
The use of a GPIO to drive the V_{CC} extends the battery life of any embedded system, even if the application requires intensive data logging. For the end user, batteries last longer and replacement costs are reduced.

4 Ultralow operating current consumption

The page EEPROM family has been designed to offer ultralow current consumption in any operation (read, write, erase…).

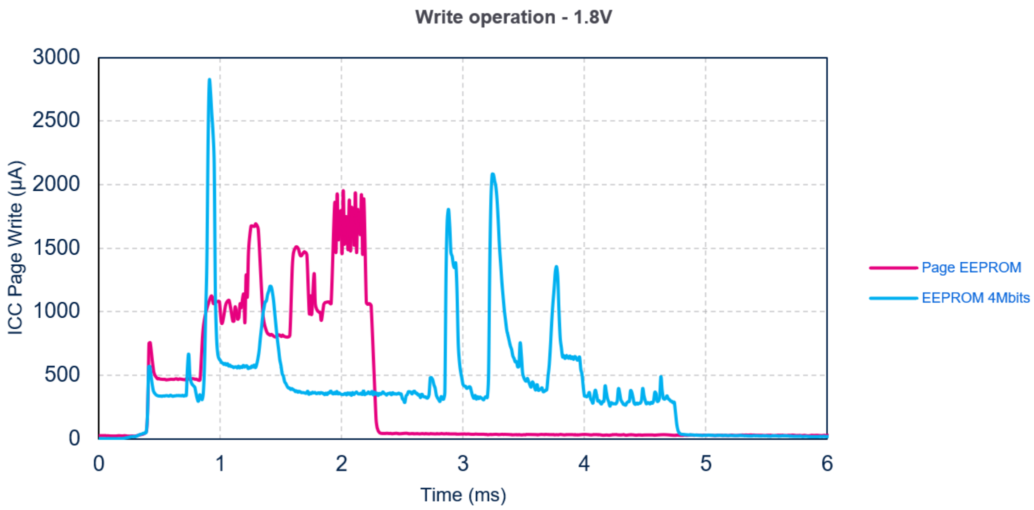
Note: In this section NVM is referred to as nonvolatile memory.

Figure 2. Current consumption in read operation



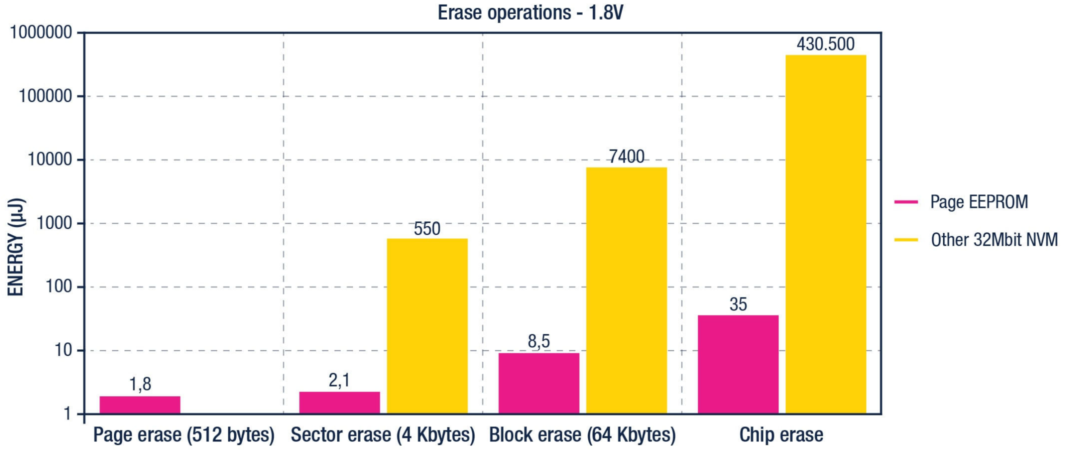
Even with a much higher memory density, the page EEPROM is able to come very close to the standard ST EEPROM current consumption. In this example, the page EEPROM read current consumption (500 µA) is much lower than other 32-Mbit NVMs, which can be 4x higher or more.

Figure 3. Current consumption in write operation



Regarding the write operation, the page EEPROM is a great improvement versus the standard EEPROM. Indeed, with less current consumption and a faster write sequence, the energy spent to write bytes is two times less than a standard EEPROM. It means that you can record more data while extending your battery lifetime.

Figure 4. Energy consumption in erase operations



Thanks to its very low power consumption and ultrafast erase time (4 ms for a block erase), page EEPROM power consumption outperforms other 32Mbit NVMs from the competition. The necessary energy in a block erase operation is 800 times lower for the Page EEPROM compared to the competition. Moreover, with page EEPROM fast erase operation, the downtime during a FOTA operation is greatly reduced, while the battery is drawn much less.

Note: FOTA is a Firmware Over The Air update. During the update, usually the firmware stored in the external memory is first erased then the new firmware is programmed.

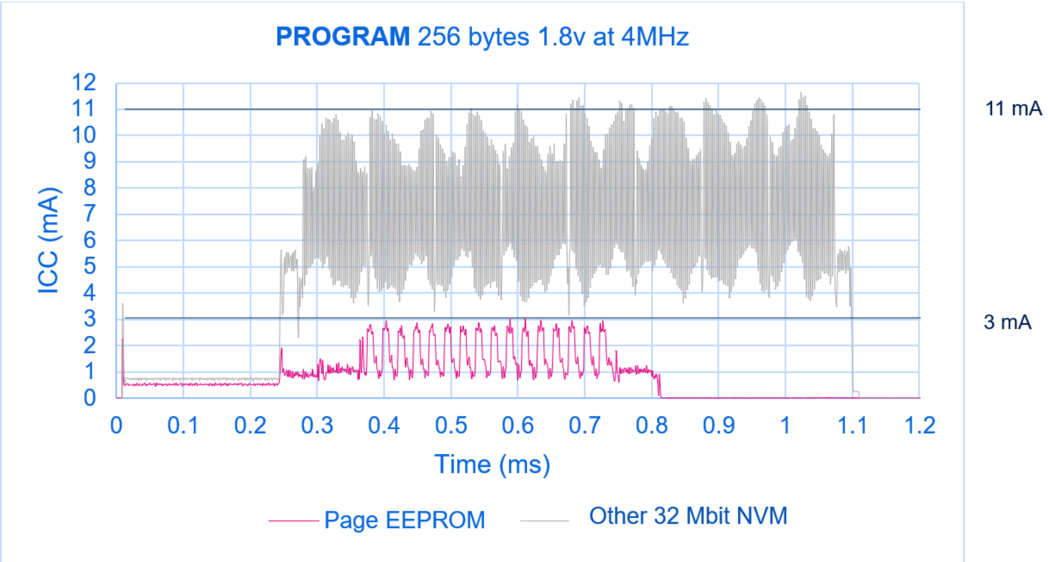
5 Peak current control

Current spikes are important in applications as they can place significant stress on the battery and affect its overall performance and lifetime. It can cause the battery to heat up, which can lead to thermal runaway.

In addition, high current peaks can cause voltage drops in the battery, which can affect the performance of the application it is powering. This can lead to problems such as reduced performance or even device shutdown.

Peak current control is therefore a key parameter in ensuring application performance. Below is a comparison of the peak current during program operation between a page EEPROM and a 32 Mbit NVM.

Figure 5. Current consumption in erase operations



Thanks to an ultra-low power architecture, the peak current of the page EEPROM is less than 3 mA for program operation. For erase operations, the peak current is between 3 mA and 4 mA.

When a system draws a large amount of current from the battery, the voltage can drop due to the internal resistance of the battery. To calculate the voltage drop caused by a peak current, simply multiply that current by the battery resistance value:

$V_D = R_B \times I_{CC}$

Where:

- V_D is the voltage drop
- R_B is the internal resistance of the battery
- I_{CC} is the current from the memory

For example, a zinc-air battery (1.4 V), which we find in medical applications, has an internal resistance of 16 Ω. Table 5 shows the voltage drop as a function of the peak current.

Table 5. Voltage drop as a function of the peak current

Current peak	Voltage drop
1 mA	16 mV
2 mA	32 mV
4 mA	64 mV
10 mA	160 mV
20 mA	320 mV
25 mA	400 mV

In this example, thanks to this peak current control, the voltage drop is only 64 mV, which means that page EEPROM products can easily fit into the tiny battery-powered applications.

With a competitor NVM, this voltage drop is as high as 160 mV or more. This makes the design extremely sensitive to current spikes and potentially causing the application to shut down.

6 Conclusion

An external memory is not used 100% of the time. To maximize battery life in an application, a memory must consume as little as possible when not in use and when in use.

When not in use, the page EEPROM is able to reduce the power consumption to 0.6 µA with the deep power-down mode. Thanks to the fast power-up time (30 µs), driving the page EEPROM V_{CC} with a microcontroller GPIO is quite simple and it allows to reduce the power consumption to almost 0 when the memory is not used.

Page EEPROM offers extremely low power consumption during typical operations (read, write program, erase). This power consumption, combined with very fast operation, allows the page EEPROM to consume very little power when the application needs the memory.

In addition, the page EEPROM has a peak current control of between 3 mA and 4 mA. This makes it suitable for all types of batteries, even the smallest, which are very sensitive to peak currents.

These ultra-low power characteristics make the page EEPROM an ideal candidate for battery-powered systems. Even if the battery is very small, the page EEPROM is almost transparent on the energy budget of the application. This is why this product family can be found in many embedded systems such as medical (hearing aids), asset tracking (fleet management), wearables (smart watches), and IoT (sensors).

Revision history

Table 6. Document revision history

Date	Version	Changes
11-Mar-2024	1	Initial release.

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