AN5733

Application note

Using ST25DV-I2C series for ultra-low power applications

Introduction

For the purposes of this document, the ST25DV-I2C series Dynamic NFC Tags is replaced by ST25DV-I2C.

This application note describes how to use ST25DV-I2C series Dynamic NFC Tags in ultra-low power applications by minimizing the power consumption on the wired power.

1 Overview

In ultra-low power applications where all devices need to consume the minimum energy during active phases, as well as during standby phases, it is possible to reduce the ST25DV-I2C Dynamic Tag’s power consumption to less than 1 nA during standby periods.

During ultra-low power standby periods, the ST25DV-I2C is able to communicate through RF (radio frequency) interface, and is still able to wake up the microcontroller by sending interrupts on various RF events.

In case any I^2C access is required, it is possible to wake up the ST25DV-I2C easily, and to enter back in ultra-low power mode right after, to limit power consumption. When entering and exiting this ultra-low power mode, there is no influence on the active RF session.

2 ST25DV-I2C power supply

ST25DV-I2C is powered in three different ways:

- RF power:
  – RF field is present and V_{CC} pin is not connected or grounded. ST25DV-I2C is powered exclusively from energy provided by the RF field. All functions are available, except the access from the I_2C interface and the fast transfer mode.
- Wired power:
  – RF field is not present and V_{CC} pin voltage is above 1.8 V. ST25DV-I2C is powered exclusively from the V_{CC} pin. All functions are available, except the access from the RF interface, energy harvesting and GPO functions.
- Both RF and wired power:
  – RF field is present and V_{CC} pin voltage is above 1.8 V. ST25DV-I2C is powered almost exclusively from the V_{CC}. All functions are available.

When in wired power-mode, a specific low-power mode is available (12-pins package only) to reduce the power consumption on V_{CC}. This mode is entered by pulling the LPD pin high. In this mode, the power consumption of the tag on the V_{CC} pin is reduced to less than 1 uA. If the RF field is present, all functions are still available while in low-power mode, except access from I^2C interface and fast transfer mode.

It is possible to further reduce power consumption so that ST25DV-I2C consumes no current on the V_{CC} pin, while keeping its RF communication capabilities.

3 ST25DV-I2C ultra-low power setup

The objective is to reduce the ST25DV-I2C power consumption on the wired interface to its minimum, meaning that no current is drawn when I^2C is not accessed.

When I^2C is accessed from the RF side, the ST25DV-I2C doesn't need to be powered through the V_{CC} pin. ST25DV-I2C must be powered through V_{CC} only when accessing its I^2C interface or when using the fast transfer mode.

To reduce the wired-power consumption to its minimum while keeping the device functionalities, the V_{CC} power supply must be controlled and must provide power on this line only when required, during I^2C accesses.

For this purpose, the V_{CC} pin can be connected directly to the GPIO of a microcontroller. The limit of the operating current drawn by the ST25DV-I2C which is less than 200 µA at V_{CC} = 1.8 V, allows most microcontrollers' GPIOs to act as V_{CC} power supply. The microcontroller can then power the ST25DV-I2C only during I^2C accesses by controlling V_{CC} through the GPIO.

The microcontroller can set the GPIO connected to ST25DV-I2C's V_{CC} pin to a high level to power up the ST25DV-I2C. When the microcontroller sets the GPIO connected to ST25DV-I2C's V_{CC} pin to a low level or high impedance, the state of the SDT25DV-I2C is dependent on RF field. If no RF field is present, the tag is powered off. If an RF field is present and strong enough to power the tag, the ST25DV-I2C remains powered through its antenna. In both cases, no more current is drawn on the V_{CC} pin.

Nevertheless, switching V_{CC} off when the RF field is present can create a device reboot if V_{CC} fall time is too fast. This is potentially a problem if this reboot occurs during the EEPROM programing cycle following a RF write request.

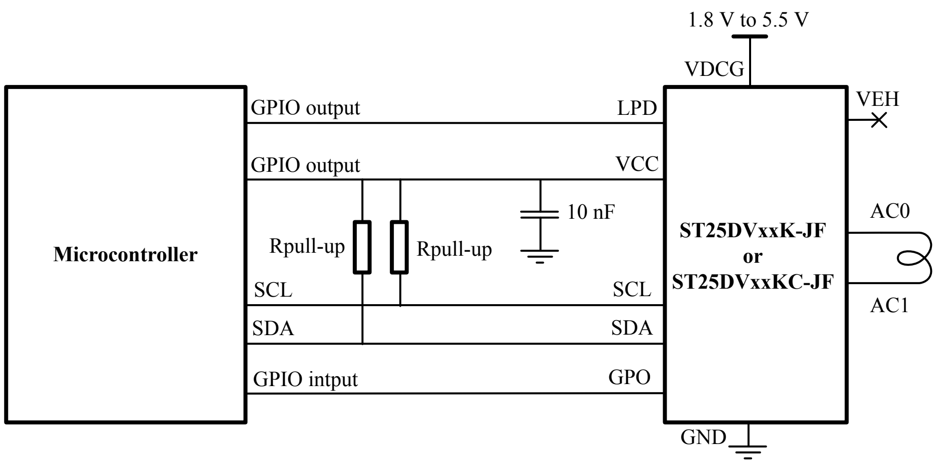
The microcontrollers can to be informed when a RF write request is processed, using GPO interrupts, but synchronization between RF and I^2C side can be difficult. To avoid this issue, the recommended method to switch off the ST25DV-I2C is to first enter in low-power mode and only then remove the V_{CC} power in sequence. When entering in low-power mode by setting LDP pin high, the ST25DV-I2C first switches its internal power source input from V_{CC} pin to the antenna's rectified power (RF field source) and then only switches off the internal regulator.

Entering in low-power mode before switching off the V_{CC} ensures that the ST25DV-I2C does not reboot if the RF field is strong enough to power the tag. This allows the microcontroller to switch off the ST25DV-I2C safely, with no risk of interrupting a write cycle into the EEPROM.

For ST25DV-I2C version where the LPD pin is available (12-pins UFDFPN12 and 10-pins WLCSP10 packages), the figure below shows the schematic that can be used to control the ST25DV-I2C in ultra-low power applications:

- LPD pin is connected to GPIO output pin of the microcontroller.
- V_{CC} pin is connected to GPIO output pin of the microcontroller. The ST25DV-I2C is powered by this GPIO pin which must be able to deliver up to 200 uA under 1.8 V.
- VDGC pin (GPO output stage power supply) is connected to a permanent power supply to allow interrupts on RF events at any time (even when ST25DV-I2C is not powered through V_{CC} pin).
- GPO pin is connected to a GPIO input pin of the microcontroller. It delivers RF events interrupt signal.

Figure 1. ST25DV-I2C ultra-low power application schematic



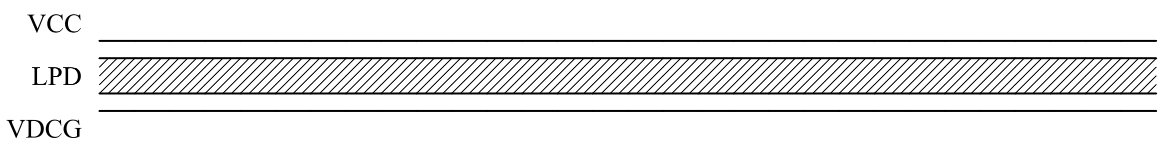
3.1 Ultra-low power state

To save power, the ST25DV-I2C is completely shut down most of the time. In that state, the GPIO connected to ST25DV-I2C's V_{CC} pin can be either forced to low-level output, in high impedance mode. The GPIO connected to the ST25DV-I2C's LPD pin can be in any state, high or low output, or high impedance without any influence on power consumption.

If the ST25DV-I2C is powered by the RF field, it can receive and answer from any RF command and can send an interrupt signal on its GPO pin to the microcontroller. The V_{DCG} pin needs to be permanently powered. I^2C communication is not working. In that state, the ST25DV-I2C power consumption is null.

The figure below shows the ultra-low power state.

Figure 2. Ultra-low power state



3.2 Waking up from ultra-low power state

When I_2C access or fast transfer mode is needed, the microcontroller must first wake-up the ST25DV-I2C. This is done by setting the ST25DV-I2C's V_{CC} pin voltage to more than 1.8 V.

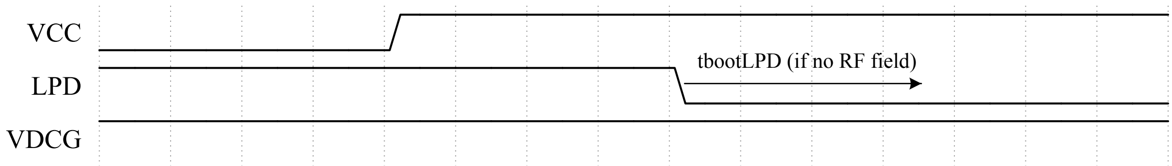
To avoid any reboot during V_{CC} transition from low to high, the microcontroller must first set the GPIO connected to the ST25DV-I2C's LDP pin to high-level output. Then it can safely set the GPIO connected to the ST25DV - I2C's V_{CC} pin to high-level output as well. LPD level must be stabilized high before changing V_{CC} level.

When V_{CC} is stabilized, the microcontroller can then set the GPIO connected to the ST25DV-I2C's LDP pin to low-level output. If the RF field is present, the ST25DV-I2C is already booted and is immediately ready to receive I^2C commands. If no RF field is present, the ST25DV-I2C boots, and after $t_{bootLPD}$ time, the ST25DV-I2C is ready to receive I^2C commands.

Note: *Refer to the datasheets Dynamic NFC/RFID tag IC with 4-Kbit, 16-Kbit or 64-Kbit EEPROM, fast transfer mode capability and optimized I^2C (DS13519) and Dynamic NFC/RFID tag IC with 4-Kbit, 16-Kbit or 64-Kbit EEPROM, and fast transfer mode capability (DS10925) for $t_{bootLPD}$ time value and I2C DC power consumption values.*

In this state, shown in the figure below all functions of ST25DV-I2C are available.

Figure 3. Waking up from ultra-low power state



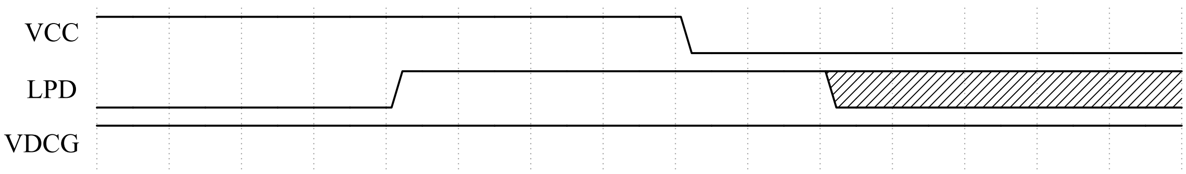
3.3 Entering ultra-low power state

After I_2C access or fast transfer mode is finished, the microcontroller can shut down the ST25DV-I2C to save power. This is done by setting the ST25DV-I2C's V_{CC} pin voltage to less than 1.4 V.

To avoid any reboot during V_{CC} transition from high to low, the microcontroller must first set the GPIO connected to the ST25DV-I2C's LDP pin to high-level output. Then it can safely set the GPIO connected to the ST25DV-I2C's V_{CC} pin to low-level output or in high impedance mode.

The figure below show the low-power state phase.

Figure 4. Entering ultra-low power state



Note: After an I^2C write in EEPROM memory, the microcontroller must wait the end of the programing cycle before entering in ultra-low power mode to avoid any risk of interrupting the programing. Refer to the datasheets Dynamic NFC/RFID tag IC with 4-Kbit, 16-Kbit or 64-Kbit EEPROM, fast transfer mode capability and optimized I^2C(DS13519) and Dynamic NFC/RFID tag IC with 4-Kbit, 16-Kbit or 64-Kbit EEPROM, and fast transfer mode capability (DS10925) for more information on EEPROM programing cycle.

On ST25DVxxKC version, a GPO interrupt is available to signal to the microcontroller the end of the I^2C EEPROM programming cycle during write programming cycles.

For 8-pins versions of ST25DV-I2C, as LPD pin is not available, the ST25DV-I2C cannot be set in low-power mode prior to removing V_{CC} power supply. It is recommended to use the low-power mode of 12-pin version, but it is also possible to use ultra low power mode on 8-pins versions. To achieve this, V_{CC} fall and rise time must be increased. When V_{CC} fall time and rise time is long enough. The risk of rebooting the device is considerably lowered.

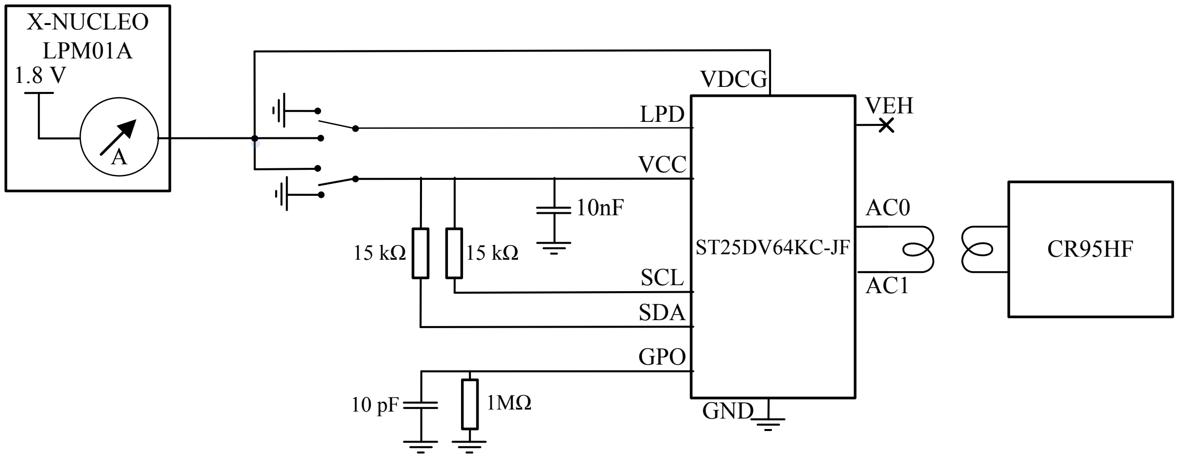
To achieve this, a minimum 10 µF capacitor can be connected between the V_{CC} pin and ground, this ultimately increases the time to exit the ultra-low power state.

Another difference with a 12-pins version is that the GPO pin must be permanently tied high with a pull-up resistor to allow GPO interrupts.

4 Measurements

An example of the possible achievable power consumption measurements have been made on the following setup.

Figure 5. Measurement setup



The measurements are done on a ST25DV64KC-JF Dynamic Tag. The ST25DV64KC's V_{CC} and LPD pins are connected to switches that allow to leave them floating, to connect them to a power source or to ground.

The ST25DV64KC's V_{DCG} pin is permanently powered. The ST25DV64KC's GPO pin is driving to a 1 MΩ load (oscilloscope probe) and its output value changes depending on the RF events, active high.

The main power source is a supply provided by a X-NUCLEO-LPM01A. This board is delivering 1.8 V to the ST25DV64KC to V_{CC}, LDP and V_{DCG} pins, and can measure a static current drawn with a precision down to 1 nA. The measures are done at an ambient temperature of 24 °C.

A CR95HF RFID reader is used to provide the RF field power when required for the measurements. The current is measured with and without the RF field presence.

Measurements are made in:

- I^2C ready mode:
  - ST25DV64KC is powered through V_{CC} and is ready to receive I^2C commands.
- low-power mode:
  - LPD is high and V_{CC} is still connected to the power supply source.
- ultra-low power mode:
  - V_{CC} is grounded or left floating. This mode is entered and exited as described earlier in this document.

Note: All the measurements described below reflects measurements on one sample only, at ambient room temperature, and are given as examples only. Values may vary from one part to another and in function of the temperature. For maximum and typical power consumption figures, refer to the datasheets Dynamic NFC/RFID tag IC with 4-Kbit, 16-Kbit or 64-Kbit EEPROM, fast transfer mode capability and optimized I^2C (DS13519), and Dynamic NFC/RFID tag IC with 4-Kbit, 16-Kbit or 64-Kbit EEPROM, and fast transfer mode capability (DS10925).

Table 1. I^2C ready mode measurements

Voltage on V_{CC} (V)	Voltage on LPD (V)	Voltage on VDCG (V)	GPO output voltage (V)	RF field	Current drawn on 1.8V (µA)
1.8	0	1.8	0	Not present	51
1.8	0	1.8	0	Present	60
1.8	0	1.8	1.8	Present	60

Table 2. 3 Low power mode measurements

Voltage on V_{CC} (V)	Voltage on LPD (V)	Voltage on VDCG (V)	GPO output voltage (V)	RF field	Current drawn on 1.8V (µA)
1.8	1.8	1.8	0	Not present	0.440
1.8	1.8	1.8	0	Present	0.392
1.8	1.8	1.8	1.8	Present	0.645 (1)

1. • *With GPO output driving 1 MΩ load. The GPO pin is active high (1.8 V) for maximum 301 µs down to minimum 37 µs.*

Table 3. Ultra-low power mode measurements

Voltage on V_{CC} (V)	Voltage on LPD (V)	Voltage on VDCG (V)	GPO output voltage (V)	RF field	Current drawn on 1.8V (µA)
0	0 or 1.8	1.8	0	Not present	≤0.001
0	0 or 1.8	1.8	0	Present	≤0.001
0	0 or 1.8	1.8	1.8	Present	0.254 (1)

1. • *With GPO output driving 1 MΩ load. The GPO pin is active high (1.8 V) for maximum 301 µs down to minimum 37 µs.*

5 Conclusion

In ultra-low power application, the ST25DV-I2C can be shutdown in an advantageous and safe mode when not in use by the microcontroller. While at the same time its RF communication and the microcontroller wake-up capabilities are kept. During the waked-up phase for short I_2C accesses, the power consumption of the ST25DV-I2C is very limited, and only for a very short time periods. During longer shut down periods its power consumption is null.

Revision history

Table 4. **Document revision history**

Date	Version	Changes
20-Oct-2021	1	Initial release.

Contents

List of tables

List of figures

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