Introduction

The ST25DVxxx is a Dual EEPROM device designed to be accessed via two different interfaces: a wired I²C interface and a standard contactless ISO 15693 RFID interface.

One of the features offered by ST25DVxxx is energy harvesting delivery, which consists in transferring part of the RF received energy onto the V_EH output pin.

The level on V_EH is generated by means of RF signal rectification in a non regulated DC voltage that is only limited, below 5.5 V, by the RF input clamping circuit.

Energy harvesting is mainly intended to supply a sensor or a very low power application through a filtering circuit smoothing V_EH level in order to limit the impact of fast consumption switching.

The purpose of this document is to present the way to activate energy harvesting with ST25DVxxx in relation to its possible impact on RF communication.

This application note applies to the products listed in Table 1.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Part number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST25DVxxx</td>
<td>ST25DV04K</td>
</tr>
<tr>
<td></td>
<td>ST25DV16K</td>
</tr>
<tr>
<td></td>
<td>ST25DV64K</td>
</tr>
</tbody>
</table>
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1 Acronyms and notational conventions

The following conventions and notations apply in this document unless otherwise stated.

1.1 Binary number representation
Binary numbers are represented by strings of 0 and 1 digits, with the most significant bit on the left, the least significant bit on the right, and a ‘b’ suffix added at the end.
Example: 11110101b

1.2 Hexadecimal number representation
Hexadecimal numbers are represented by strings of numbers from 0 to 9 and letters from A to F, and an ‘h’ suffix added at the end. The most significant byte is shown on the left and the least significant byte on the right.
Example: F5h

1.3 Decimal number representation
Decimal numbers are represented without any trailing character.
Example: 245

Table 2. List of acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>Amplitude modulation</td>
</tr>
<tr>
<td>DSC</td>
<td>Dual subcarrier</td>
</tr>
<tr>
<td>EH</td>
<td>Energy harvesting</td>
</tr>
<tr>
<td>I²C</td>
<td>Inter-integrated circuit</td>
</tr>
<tr>
<td>ISO/IEC</td>
<td>International organization for standardization / International electrotechnical commission</td>
</tr>
<tr>
<td>HDR</td>
<td>High data rate</td>
</tr>
<tr>
<td>RF</td>
<td>Radio frequency</td>
</tr>
</tbody>
</table>
2 Energy harvesting delivery setting and resetting

ST25DVxxx offers the possibility to automatically activate energy harvesting after boot when ST25DVxxx enters a RF Field. This mode is enabled when the value of bit EH_MODE is 0b. Bit EH_MODE is the lowest significant bit of the EH_MODE register located in the system area.

Programming bit EH_MODE can be done through the RF interface or through the I²C interface.

Note: Access to bit EH_MODE requires that a system password is first presented in RF or I²C.

By default factory setting, the energy harvesting feature of ST25DVxxx is disabled (bit EH_MODE of register EH_MODE is set to 1b). Consequently, after RF boot, the EH_EN bit of the EH_CTRL_Dyn register is reset and the V_EH output remains in the high impedance state.

After boot, V_EH behaves as follows:

- When EH_MODE is set to 0b, V_EH is automatically powered by the captured field after device boot.
- When EH_MODE is set to 1b, V_EH remains in the high impedance state after device boot.

Whatever the value of bit EH_MODE, V_EH delivery can further be activated or deactivated through RF or I²C by means of the EH_EN dynamic bit. This command is not protected by password.

Note: After a setting of configuration bit EH_MODE to 0b, via RF or I²C, the EH_EN bit automatically sets to 1b and energy harvesting is delivered if a RF field is present. On the contrary when EH_MODE is reset to 1b, dynamic bit EH_EN remains set until a RF field is present or until it is reset.

Energy harvesting setting is described in Figure 1 on page 7.
Figure 1. Energy harvesting setting

Initialization via RF
- RF_ON
- Present System PWD
- Write System EH_MODE bit (Config Pointer @02h)

Initialization via I2C
- VCC_ON
- Present I2C PWD (Read I2C_SSO)
- Write System EH_MODE bit (System @0002h)

EH_MODE = 0
- EH enable after boot
- Write dynamic register RF or I2C
- EH_ENABLE bit (Pointer @02h)

EH_MODE = 1
- EH disable after boot
- Write dynamic register RF or I2C
- EH_ENABLE bit (Pointer @02h)

EH_ENABLE = 0
- EH Reset
- V_EH High-Z

EH_ENABLE = 1
- EH Set
- V_EH DC voltage
3 Impact of energy harvesting on ST25DVxxx behavior

The behavior of ST25DVxxx, especially when energy harvesting delivery is expected, depends on the conditions of use.

A part of the received power is used to supply ST25DVxxx activity while the remaining drifts to V_EH output.

The captured energy is a function of the RF field intensity, of the coupling and of the dimensions of the antennas involved.

During RF communication the HF field is modulated by the reader or by the ST25DVxxx. This can induce a temporary reduction of incoming power. The internal tank capacitor protecting ST25DVxxx from resetting when EH is disabled cannot ensure seamless operation across the whole functional domain when EH is active.

Limitations of operating performance occur when the power absorbed on V_EH is high. Consequently the functional domain is limited to a reduced working area when energy harvesting is activated.

The measurement plots provided further show the working area, limited by the maximum available current (Figure 3 and Figure 4 on page 11) or the maximum power delivered power (Figure 5 and Figure 6 on page 12). Beyond these limits, ST25DVxxx stops to communicate with the RF reader.

Note: The working area is narrowed when the reader uses 100% amplitude modulation versus a 10% amplitude modulation, resulting in a higher energy loss during RF command.

When the RF communication is lost due to energy harvesting delivery, it is possible to recover it by increasing the capture energy condition or by turning off the RF field to disable energy harvesting delivery.

The latter is only possible when EH_Mode is reset to 1b. In all other cases, ST25DVxxx reactivates energy harvesting delivery immediately after RF boot.

The sections below present:

- The current delivery capability when ST25DVxxx is set on an ISO class1 antenna with the intrinsic value and the limited value for which RF functionalities are kept.
- The corresponding voltage, current and power characterizing V_EH pin as a function of the RF field.

3.1 Energy harvesting current delivery measurement

Figure 2 and Table 3 show the energy harvesting current delivered by ST25DVxxx soldered on an ISO class1 antenna placed in an RF field:

- The red curve does not take the RF communication capability into account.
- The green curve shows the RF communication border when the driven current is limited.
Figure 2. EH current delivery

Table 3. EH current delivery values

<table>
<thead>
<tr>
<th>H (A/m rms)</th>
<th>I Max (mA)</th>
<th>I Com (mA)</th>
<th>V_EH Imax (V)</th>
<th>V_EH Icom (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.1</td>
<td>0.7</td>
<td>1.8</td>
<td>3.1</td>
</tr>
<tr>
<td>1.5</td>
<td>6.7</td>
<td>0.7</td>
<td>1.8</td>
<td>3.1</td>
</tr>
<tr>
<td>2</td>
<td>6.9</td>
<td>0.9</td>
<td>1.8</td>
<td>3.1</td>
</tr>
<tr>
<td>2.5</td>
<td>7.5</td>
<td>0.9</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>7.5</td>
<td>1.3</td>
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<td>2.9</td>
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<td>4.5</td>
<td>7.9</td>
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<td>2</td>
<td>2.9</td>
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<tr>
<td>5</td>
<td>7.9</td>
<td>2.9</td>
<td>2</td>
<td>2.7</td>
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<tr>
<td>5.5</td>
<td>8</td>
<td>3.3</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
3.2 Energy harvesting delivery measurement

This section presents the results obtained for maximum current delivery with ST25DVxxx connected to an ISO/IEC class 1 Antenna (tuning 13.6 MHz) put on an ISO 15693 tower driven by an RF reader delivering a field $H_{EH}$.

The functional test limit corresponds to the reception of a valid response to an inventory request (AM then DSC HDR).

The following notation is used:
- $V_{EH}$: DC voltage delivered on ST25DVxxx $V_{EH}$ output
- $I_{EH}$: DC current absorbed on ST25DVxxx $V_{EH}$ output
- $P_{EH}$: resulting power delivered on ST25DVxxx $V_{EH}$ output

Table 4 presents the characterization measurement results obtained for $AM = 100\%$ and working RF communication.

<table>
<thead>
<tr>
<th>$H_{EH}$ (A/m rms)</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{EH}$ (V)</td>
<td>3.3</td>
<td>3.35</td>
<td>3.29</td>
<td>3.29</td>
<td>3.23</td>
<td>3.13</td>
<td>3.05</td>
<td>3.03</td>
<td>3.08</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>$I_{EH}$ (mA)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.9</td>
<td>1.3</td>
<td>1.7</td>
<td>1.9</td>
<td>2.3</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>$P_{EH}$ (mW)</td>
<td>2.31</td>
<td>2.345</td>
<td>2.303</td>
<td>2.907</td>
<td>2.907</td>
<td>4.069</td>
<td>5.185</td>
<td>5.757</td>
<td>7.084</td>
<td>8.64</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 presents the characterization measurement results obtained for $AM = 10\%$ and working RF communication.

<table>
<thead>
<tr>
<th>$H_{EH}$ (A/m rms)</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{EH}$ (V)</td>
<td>3.6</td>
<td>3.45</td>
<td>3.29</td>
<td>3.23</td>
<td>3.15</td>
<td>3.13</td>
<td>3.09</td>
<td>2.97</td>
<td>2.78</td>
<td>2.57</td>
<td>2.57</td>
</tr>
<tr>
<td>$I_{EH}$ (mA)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.7</td>
<td>0.9</td>
<td>1.1</td>
<td>1.3</td>
<td>1.5</td>
<td>2.1</td>
<td>3.3</td>
<td>4.5</td>
<td>4.9</td>
</tr>
<tr>
<td>$P_{EH}$ (mW)</td>
<td>0.36</td>
<td>1.035</td>
<td>2.303</td>
<td>2.907</td>
<td>3.465</td>
<td>4.069</td>
<td>4.635</td>
<td>6.237</td>
<td>9.174</td>
<td>11.565</td>
<td>12.593</td>
</tr>
</tbody>
</table>
3.2.1 EH delivery working area limited by I_EH current

*Figure 3* shows the results obtained with AM = 100 %.

*Figure 3. EH delivery working area with AM = 100 % (current limitation)*

*Figure 4* shows the results obtained with AM = 10 %.

*Figure 4. EH delivery working area with AM = 10 % (current limitation)*
3.2.2 EH delivery working area limited by $P_{EH}$ power

*Figure 5* shows the results obtained with $AM = 100\%$.

*Figure 5. EH delivery working area with AM = 100 % (power limitation)*

*Figure 6* shows the results obtained with $AM = 10\%$.

*Figure 6. EH delivery working area with AM = 10 % (power limitation)*
4 RF control recovery

ST25DVxxx offers the possibility to enable or to disable energy harvesting delivery after RF power up. This configuration selection is done by setting system bit EH_MODE respectively to 0b (activate EH after boot) or to 1b (keep EH inactive after boot).

When EH is used and communication is lost between the ST25DVxxx tag and a reader, it is usual that ST25DVxxx cannot interpret incoming instructions properly (this occurs more often when the reader uses AM 100% than when it uses AM 10%).

The only possibility to recover RF control is to return to a situation for which communication and EH delivery are possible; this can be achieved by reducing the working distance in order to increase the incoming power, by reducing the driven current acting on the load or by turning off the RF field to reset Energy Harvesting delivery.

It is recommended to keep bit EH_MODE to 1b thus keeping Energy Harvesting inactive after boot. In all cases, EH delivery is quickly activated by using dynamic bit EH_EN.

In this configuration, after resetting the RF field (RFOFF / RFON), dynamic bit EH_EN will be reset and RF communication will be established again.

Conversely, it can happen that, when Configuration bit EH_MODE is set to 0b, after each RF ramp up, Energy Harvesting is delivered but communication is impossible. In such a case, the only recovery is to modify the physical parameters of system, to increase the RF field or to limit the absorbed current.
5 Characterization results

The characterization is performed as follows:

- Test set up: ST25DVxxx on an ISO antenna, placed on an ISO tower with configuration bit EH_MODE = 1b,
- The H field is emitted by an RF tester/reader driving ISO tower. The field value is controlled by voltage measurement by means of an ISO calibration coil.
- The current loaded on V_EH output is applied by the tester after H field setting and ST25DVxxx boot delay.
- For functional tests, Write Dynamic Configuration and Read Dynamic Configuration commands are exchanged between the ST25DVxxx under test and the tester.
- After each test, the voltage on V_EH during I_EH delivery is reported (values in boxes). When the V_EH driver output is HighZ, V_EH is driven to ~ -0.7 V by the current load.

5.1 Power delivered by energy harvesting

Figure 7 shows the delivered voltage as a function of the EH output level and of the load current.

- Boxes are orange or red where V_EH is not delivered.
- Boxes are green (both dark and light) where V_EH is delivered.
- The red curve indicates the limit of the domain where both EH and RF communication are working at AM = 10 %.
- The yellow curve indicates the limit of the domain where both EH and RF communication are working at AM = 100 %.
Figure 7. Energy harvesting voltage delivery

1. Vertical axis: \( I_{EH} \) pull current on \( V_{EH} \) output in mA.
5.2 RF functional domain with energy harvesting

*Figure 8* shows the various domains as a function of the field level and of the load current.

- Boxes are yellow or red where no RF communication is available.
- The green area (both dark and light) represents the ST25DVxxx RF working domain for energy harvesting: in this region RF communication works properly during V_EH delivery.
Figure 8. Functional domains with energy harvesting

1. Vertical axis: $I_{EH}$ pull current on $V_{EH}$ output in mA.
6 Application schematics

The signal delivered by ST25DVxxx on V_EH output is coming from the full wave rectification of the RF field. The signal level is simply limited by the clamping of the RF input. It is not regulated.

The use of an output filter to smoothen variations before the receiving circuitry is recommended. The dimensioning of the filter is relative to its driving capability, to the admissible ripple on the loading circuit and to the initial setting time required.

In the tests presented in this document, a 10 nF capacitance between V_EH and ground is used.

Several applications demonstrating EH usage of are developed and available for the ST25DVxxx discovery kit:
1. Quantify V_EH output level with different resistive loads.
2. Supply a low power microcontroller through energy harvesting

Figure 9. Application schematics
7 Appendix

7.1 Static registers relative to EH

*Table 6* describes the structure and the programming of the EH_MODE register.

<table>
<thead>
<tr>
<th>RF</th>
<th>Command</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Read Configuration (cmd code A0h) @02h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Write Configuration (cmd code A1h) @02h</td>
<td></td>
</tr>
</tbody>
</table>

**Table 6. EH_MODE register**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Function</th>
<th>Factory value</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>EH_MODE</td>
<td>0: EH forced after boot &lt;br&gt;1: EH on demand only</td>
<td>1b</td>
</tr>
<tr>
<td>b7-b1</td>
<td>RFU</td>
<td>-</td>
<td>000000b</td>
</tr>
</tbody>
</table>

7.2 Dynamic registers relative to EH

*Table 7* describes the structure and the programming of the GPO_CTRL_Dyn register.

<table>
<thead>
<tr>
<th>RF</th>
<th>Command</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Read Dynamic Configuration (cmd code ADh) @00h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Write Dynamic Configuration (cmd code AEh) @00h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast Read Dynamic Configuration (cmd code CDh) @00h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast Write Dynamic Configuration (cmd code CEh) @00h</td>
<td></td>
</tr>
</tbody>
</table>

**Table 7. GPO_CTRL_Dyn**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Function</th>
<th>Factory value</th>
</tr>
</thead>
<tbody>
<tr>
<td>b0</td>
<td>RF_USER_EN</td>
<td>0: disabled &lt;br&gt;1: GPO output level is controlled by Manage GPO Command (set/reset).</td>
<td>0b</td>
</tr>
<tr>
<td>b1</td>
<td>RF_ACTIVITY_EN</td>
<td>0: disabled &lt;br&gt;1: GPO output level changes from RF command SOF to response EOF.</td>
<td>0b</td>
</tr>
<tr>
<td>b2</td>
<td>RF_INTERRUPT_EN</td>
<td>0: disabled &lt;br&gt;1: GPO output level is controlled by Manage GPO Command (pulse).</td>
<td>0b</td>
</tr>
</tbody>
</table>
Table 8 describes the structure and the programming of the EH_CTRL_Dyn register.
### Table 8. EH_CTRL_Dyn

<table>
<thead>
<tr>
<th>RF</th>
<th>Command</th>
<th>Type b0: R always, W – b1 - b7: RO</th>
</tr>
</thead>
</table>
| RF | Command | Read Dynamic Configuration (cmd code ADh) @02h  
Fast Read Dynamic Configuration (cmd code CDh) @02h  
Write Dynamic Configuration (cmd code AEh) @02h  
Fast Write Dynamic Configuration (cmd code CEh) @02h |
| I^2C | Address | E2 = 0, 2002h |
| I^2C | Type | b0: R always, W always  
b1-b7: RO |
| Bit | Name | Function |
| b0 | EH_EN | 0: Disable EH feature  
1: Enable EH feature |
| b1 | EN_ON | 0: EH feature is disabled  
1: EH feature is enabled |
| b2 | FIELD_ON | 0: RF field is not detected  
1: RF field is present and ST25DVxxx may communicate in RF |
| b3 | VCC_ON | 0: No DC supply detected on VCC pin or Low Power Down mode is forced (LPD is high)  
1: VCC supply is present and Low Power Down mode is not forced (LPD is low) |
| b7-b4 | RFU | - |

Depending of power source  
Depending of power source  
Depending of power source
# Revision history

Table 9. Document revision history

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-Mar-2017</td>
<td>1</td>
<td>Initial release.</td>
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