AN4913

Application note

Energy harvesting delivery impact on ST25DV-I2C Series behaviour during RF communication

Introduction

The ST25DV-I2C Series 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 ST25DV-I2C Series 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 ST25DV-I2C Series in relation to its possible impact on RF communication.

This application note applies to the ST25DV-I2C Series Dynamic NFC Tags and is now referred to as ST25DV-I2C.

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

Table 1. Applicable products

Reference	Part number
ST25DV-I2C Series	ST25DV04K
	ST25DV16K
	ST25DV64K
	ST25DV04KC
	ST25DV16KC
	ST25DV64KC

1 Acronyms and notational conventions

Table 2. List of acronyms

Acronym	Definition
AM	Amplitude modulation
DSC	Dual subcarrier
EH	Energy harvesting
I^2C	Inter-integrated circuit
ISO/IEC	International organization for standardization / International electrotechnical commission
HDR	High data rate
RF	Radio frequency

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

2 Energy harvesting delivery setting and resetting

ST25DV-I2C offers the possibility to automatically activate energy harvesting after boot when ST25DV-I2C 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 I^2C interface.

Note: Access to bit EH_MODE requires that a system password is first presented in RF or I^2C.

By default factory setting, the energy harvesting feature of ST25DV-I2C 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:

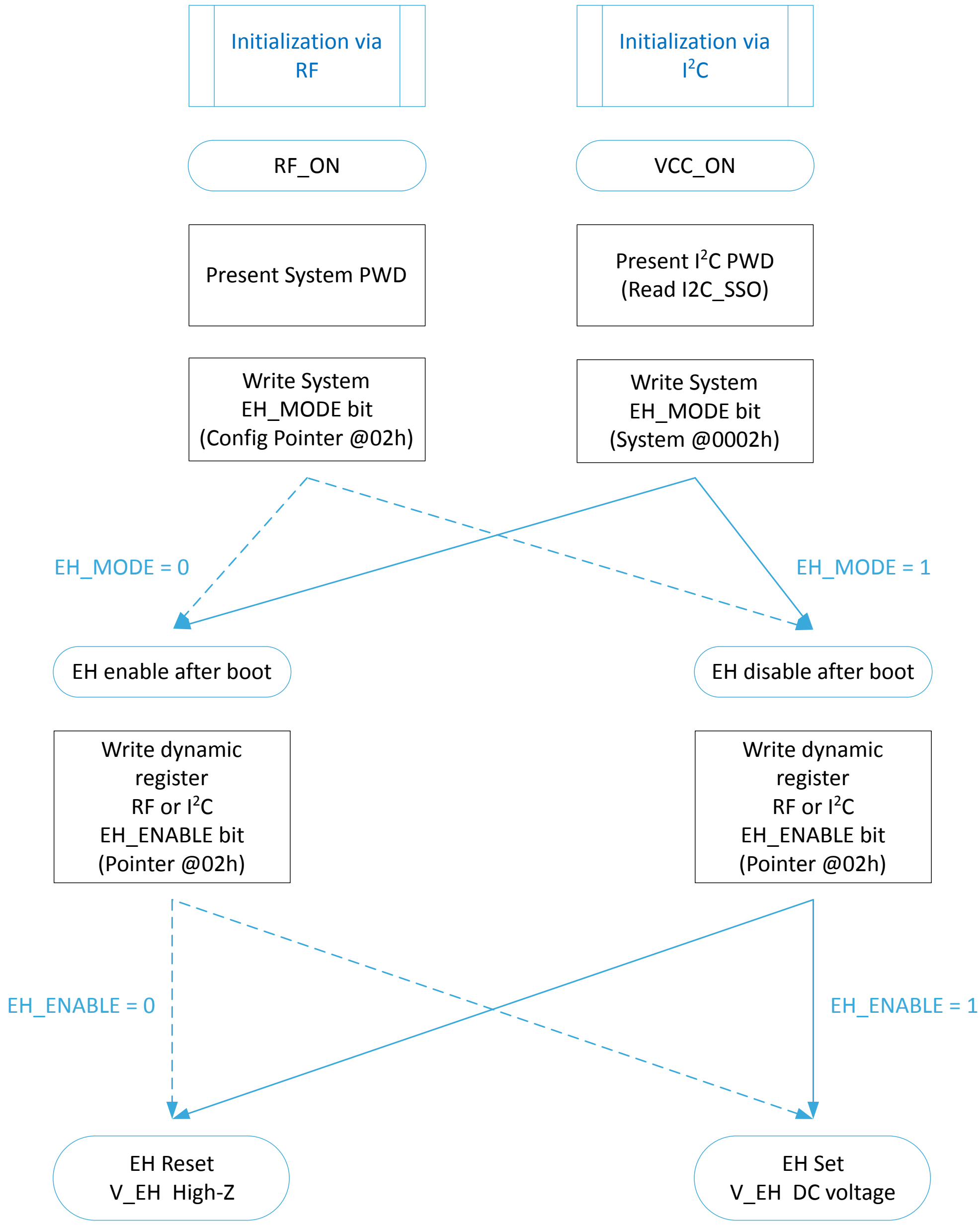
- When EH_MODE is set to 0b, V_EH is automatically powered by the captured field after device boot.
- When EH_MODE is set to 1b, V_EH remains in the high impedance state after device boot.

Whatever the value of bit EH_MODE, V_EH delivery can further be activated or deactivated through RF or I^2C 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 I^2C , 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.

Figure 1. Energy harvesting setting



3 Impact of energy harvesting on ST25DV-I2C behavior

The behaviour of ST25DV-I2C, especially when energy harvesting delivery is expected, depends on the conditions of use.

A part of the received power is used to supply ST25DV-I2C 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 ST25DV-I2C. This can induce a temporary reduction of incoming power. The internal tank capacitor protecting ST25DV-I2C 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) or the maximum power delivered power (Figure 5 and Figure 6). Beyond these limits, ST25DV-I2C 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, ST25DV-I2C reactivates energy harvesting delivery immediately after RF boot.

The sections below present:

- The current delivery capability when ST25DV-I2C 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 ST25DV-I2C 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**

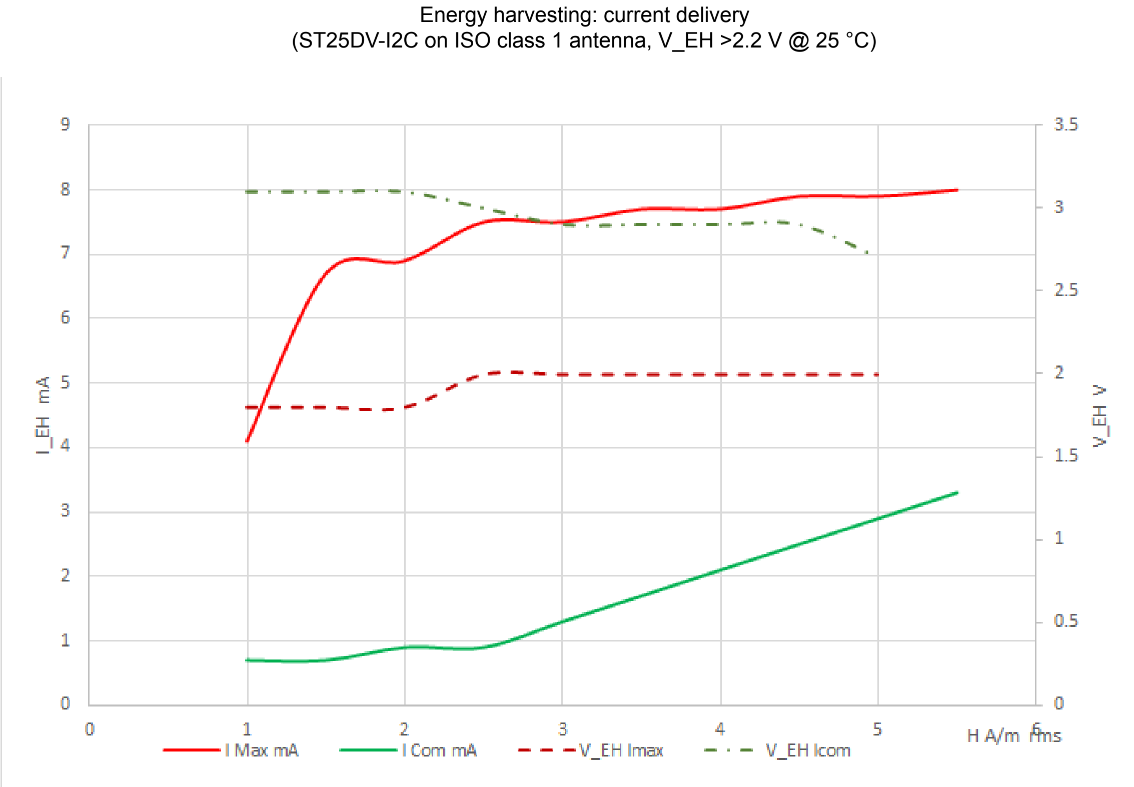


Table 3. **EH current delivery values**

H (A/m rms)	I Max (mA)	I Com (mA)	V_EH Imax (V)	V_EH Icom (V)
1	4.1	0.7	1.8	3.1
1.5	6.7	0.7	1.8	3.1
2	6.9	0.9	1.8	3.1
2.5	7.5	0.9	2	3
3	7.5	1.3	2	2.9
3.5	7.7	1.7	2	2.9
4	7.7	2.1	2	2.9
4.5	7.9	2.5	2	2.9
5	7.9	2.9	2	2.7
5.5	8	3.3	-	-

3.2 Energy harvesting delivery measurement

This section presents the results obtained for maximum current delivery with ST25DV-I2C 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 ST25DV-I2C V_EH output
- I_EH: DC current absorbed on ST25DV-I2C V_EH output
- P_EH: resulting power delivered on ST25DV-I2C V_EH output

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

Table 4. Energy harvesting measurements with AM = 100 %

H_EH (A/m rms)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
V_EH (V)	3.3	3.35	3.29	3.29	3.23	3.23	3.13	3.05	3.03	3.08	3.2
I_EH (mA)	0.7	0.7	0.7	0.7	0.9	0.9	1.3	1.7	1.9	2.3	2.7
P_EH (mW)	2.31	2.345	2.303	2.303	2.907	2.907	4.069	5.185	5.757	7.084	8.64

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

Table 5. Energy harvesting measurements with AM = 10 %

H_EH (A/m rms)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
V_EH (V)	3.6	3.45	3.29	3.23	3.15	3.13	3.09	2.97	2.78	2.57	2.57
I_EH (mA)	0.1	0.3	0.7	0.9	1.1	1.3	1.5	2.1	3.3	4.5	4.9
P_EH (mW)	0.36	1.035	2.303	2.907	3.465	4.069	4.635	6.237	9.174	11.565	12.593

3.2.1 EH delivery working area limited by I_EH current

Figure 3. EH delivery working area with AM = 100 % (current limitation) shows the results obtained with AM = 100 %.

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

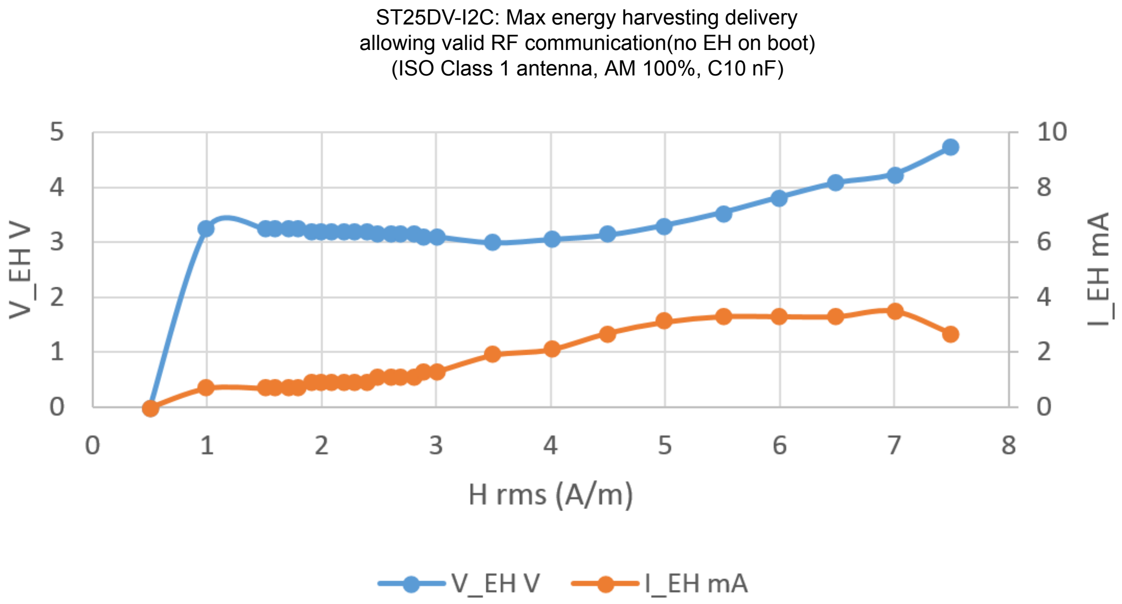
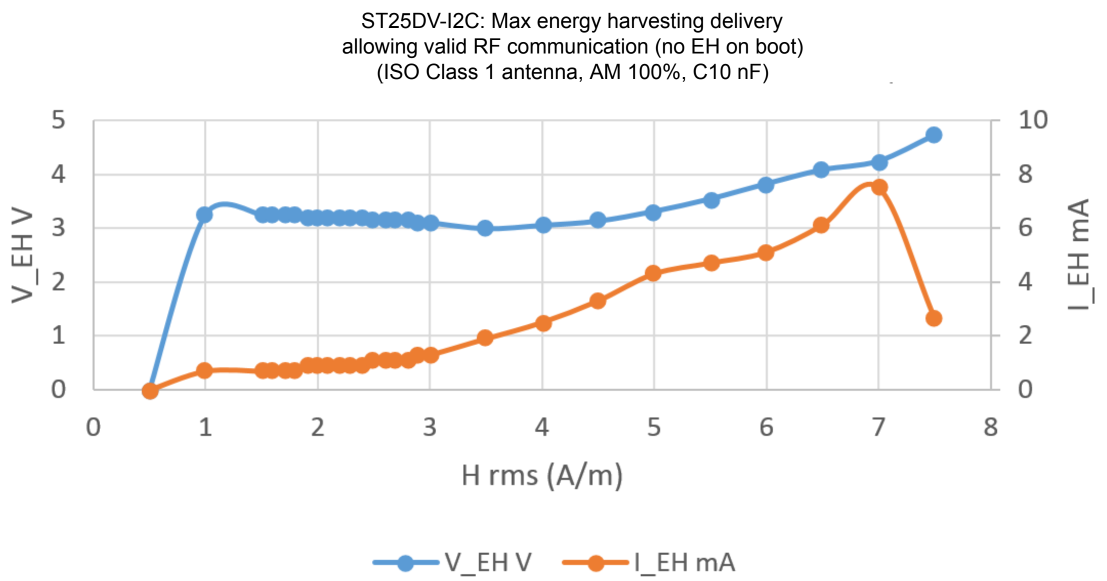


Figure 4. EH delivery working area with AM = 10 % (current limitation) shows the results obtained with AM = 10 %.

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)

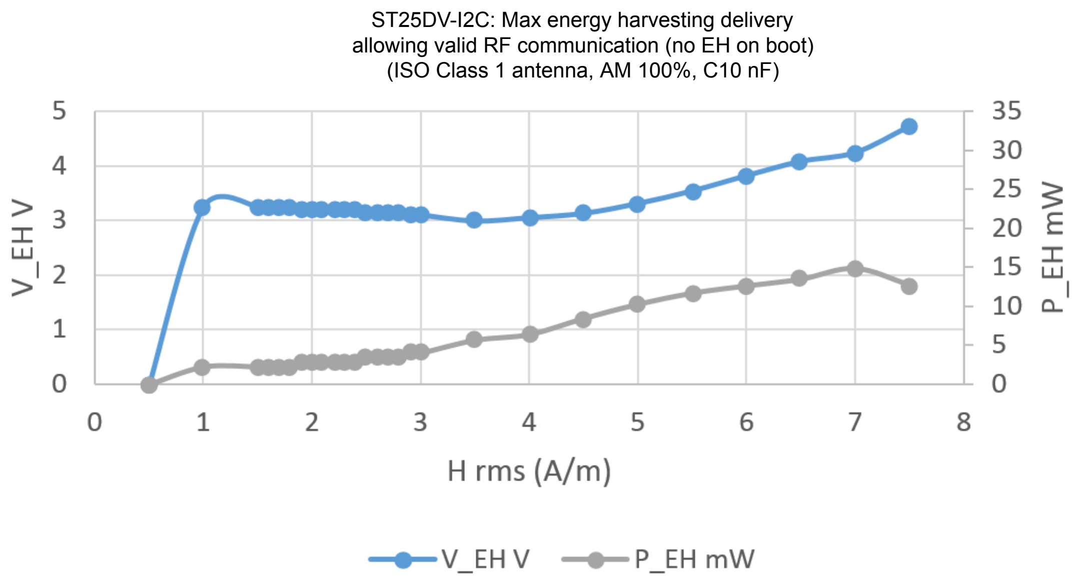
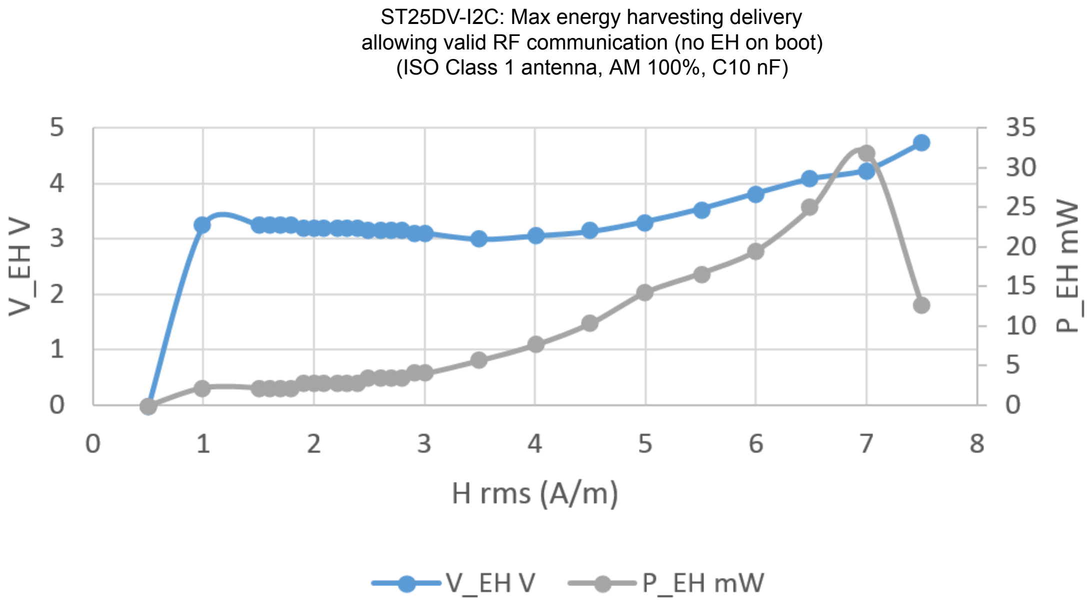


Figure 6 shows the results obtained with AM = 10 %.

Figure 6. EH delivery working area with AM = 10 % (power limitation)



4 RF control recovery

ST25DV-I2C 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 ST25DV-I2C tag and a reader, it is usual that ST25DV-I2C 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 reseting 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:

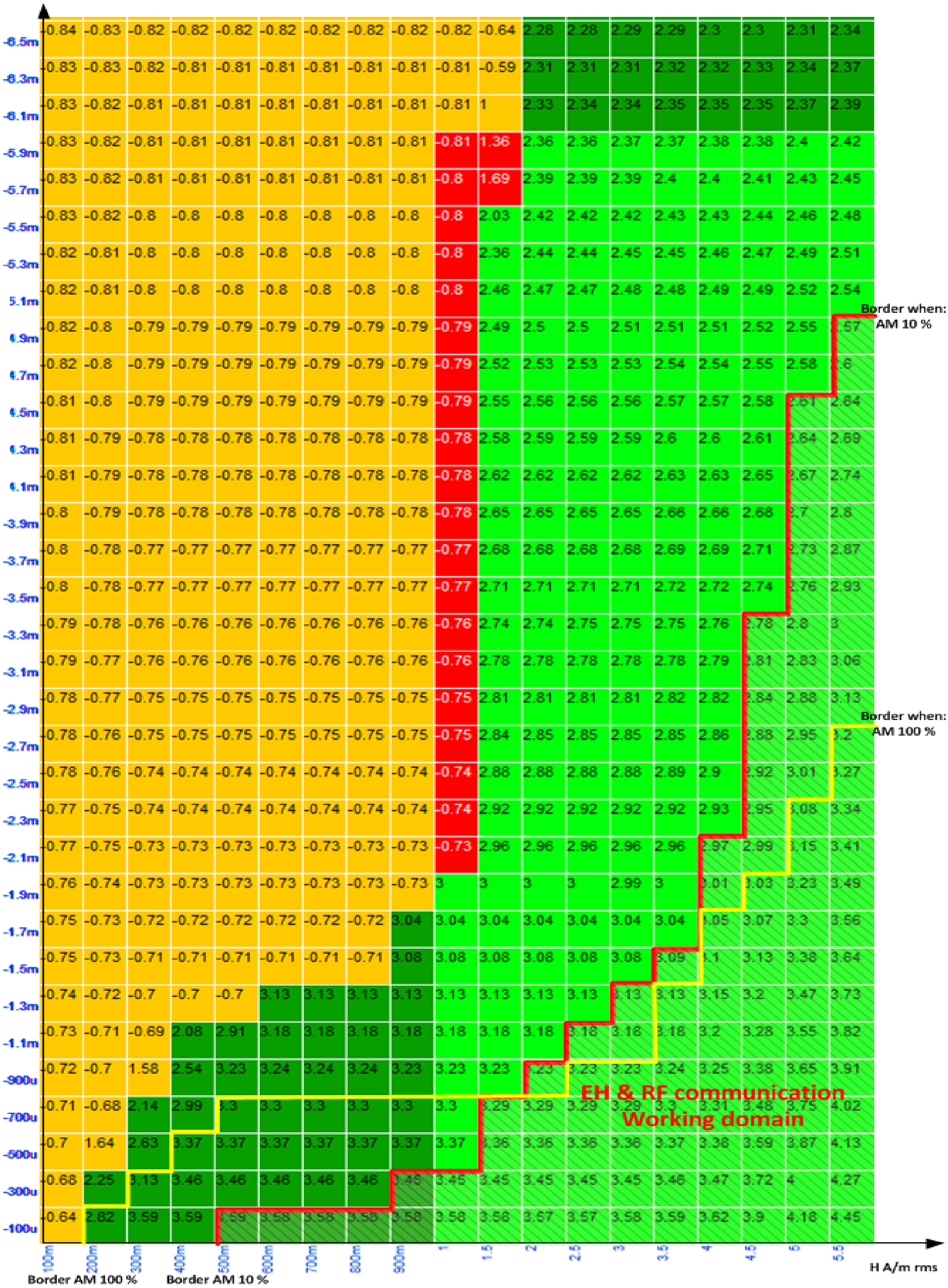
- Test set up: ST25DV-I2C on an ISO antenna, placed on an ISO tower with configuration bit EH_MODE = 1b,
- The H field is emitted by an RF tester/reader driving ISO tower. The field value is controlled by voltage measurement by means of an ISO calibration coil.
- The current loaded on V_EH output is applied by the tester after H field setting and ST25DV-I2C boot delay.
- For functional tests, Write Dynamic Configuration and Read Dynamic Configuration commands are exchanged between the ST25DV-I2C 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



Comment : antenna=0014633a-17; tuning=13.7mhz at por; stcfg="62"

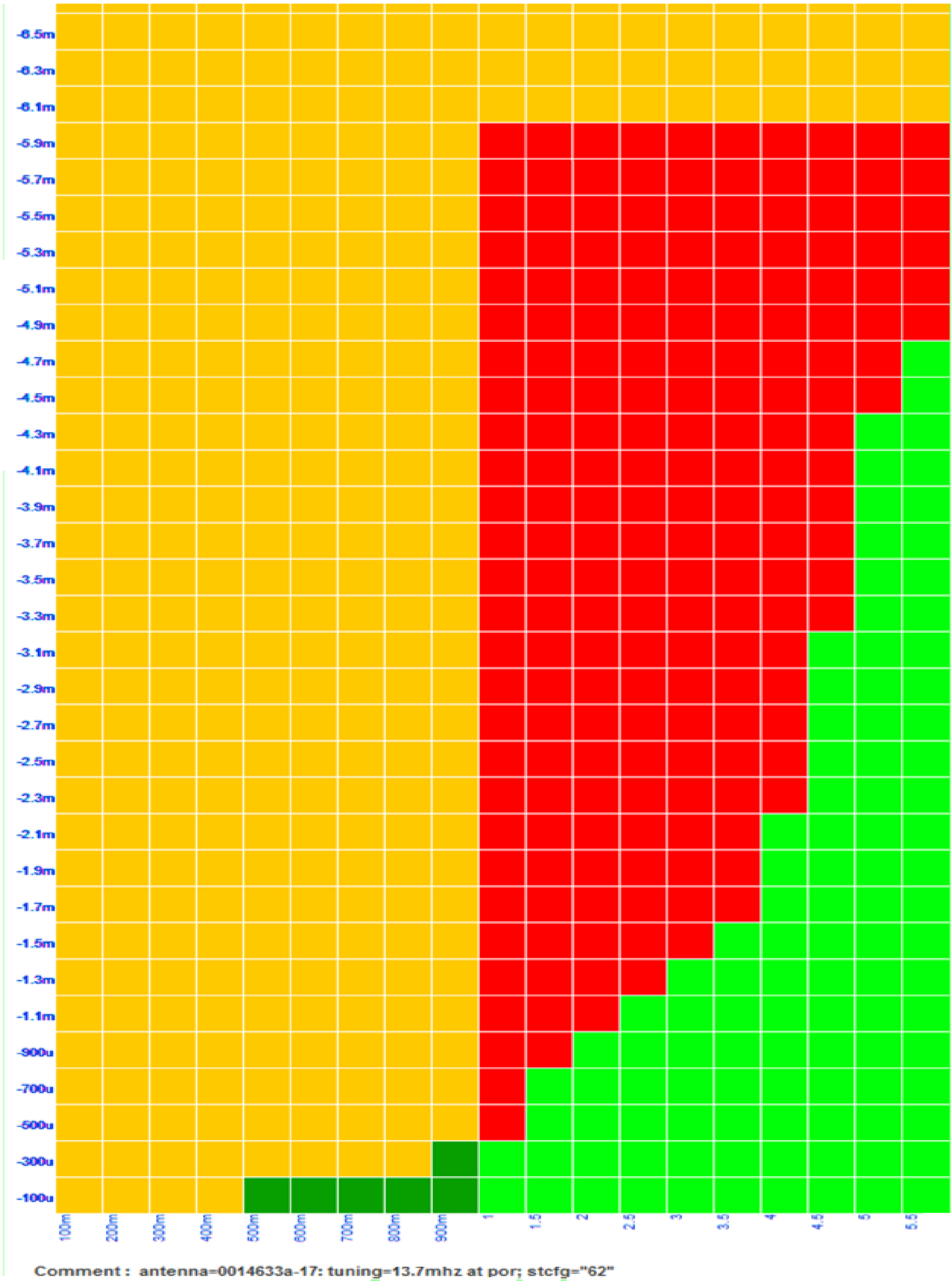
1. Vertical axis: I_EH pull current on V_EH output in mA.
2. Horizontal axis: ambient H field of ST25DV-I2C antenna in A/m rms.

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 ST25DV-I2C 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.
2. Horizontal axis: ambient H field of ST25DV-I2C antenna in A/m rms.

6 Application schematics

The signal delivered by ST25DV-I2C 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.

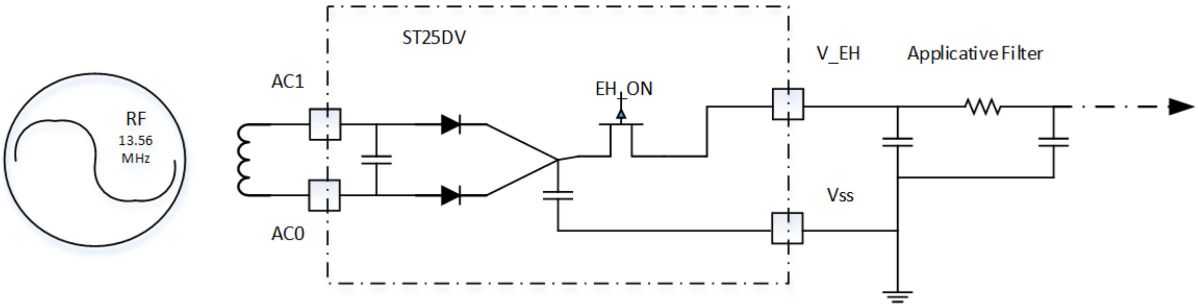
The use of an output filter to smoothen variations before the receiving circuitry is recommended. The dimensioning of the filter is relative to its driving capability, to the admissible ripple on the loading circuit and to the initial setting time required.

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 ST25DV-I2C 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



Appendix A

A.1 Static registers relative to EH

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

Table 6. EH_MODE register

RF	Command	Read Configuration (cmd code A0h) @02h Write Configuration (cmd code A1h) @02h	
	Type	R always, W if RF configuration security session is open and configuration not locked	
I2C	Address	E2 = 1, 0002h	
	Type	R always, W if I2C security session is open	
Bit	Name	Function	Factory value
b0	EH_MODE	0: EH forced after boot 1: EH on demand only	1b
b7 - b1	RFU	-	0000000b

A.2 Dynamic registers relative to EH

Table 7 and Table 8 describes the structure and the programming of the GPO_CTRL_Dyn register.

Table 7. GPO_CTRL_Dyn for ST25DV04K, ST25DV16K and ST25DV64K

RF	Command	Read Dynamic Configuration (cmd code ADh) @00h Write Dynamic Configuration (cmd code AEh) @00h Fast Read Dynamic Configuration (cmd code CDh) @00h Fast Write Dynamic Configuration (cmd code CEh) @00h	
	Type	RO	
I2C	Address	E2 = 0, 2000h	
	Type	b0-b6: RO - b7 : R always, W always	
Bit	**Name**	**Function**	**Factory value**
b0	RF_USER_EN	0: Disabled 1: GPO output level is controlled by Manage GPO Command (set/reset)	0b
b1	RF_ACTIVITY_EN	0: Disabled 1: GPO output level changes from RF command SOF to response EOF	0b
b2	RF_INTERRUPT_EN	0: Disabled 1: GPO output level is controlled by Manage GPO Command (pulse)	0b
b3	FIELD_CHANGE_EN	0: disabled 1: A pulse is emitted on GPO, when RF field appears or disappears	1b
b4	RF_PUT_MSG_EN	0: disabled 1: A pulse is emitted on GPO at completion of valid RF Write Message command	0b
b5	RF_GET_MSG_EN	0: disabled 1: A pulse is emitted on GPO at completion of valid RF Read Message command if end of message has been reached	0b
b6	RF_WRITE_EN	0: disabled 1: A pulse is emitted on GPO at completion of valid RF write operation in EEPROM	0b
b7	GPO_EN	0: GPO output is disabled. GPO is High-Z (Open Drain) or 0 (CMOS) 1: GPO output is enabled. GPO outputs enabled interrupts	1b

Table 8. GPO_CTRL_Dyn for ST25DV04KC, ST25DV16KC and ST25DV64KC

RF	Command	Read Dynamic Configuration (cmd code ADh) @00h Write Dynamic Configuration (cmd code AEh) @00h Fast Read Dynamic Configuration (cmd code CDh) @00h Fast Write Dynamic Configuration (cmd code CEh) @00h	
	Type	RO	
I2C	Address	E2 = 0, 2000h	
	Type	b0-b6: RO - b7 : R always, W always	
Bit	**Name**	**Function**	**Factory value**
b0	GPO_EN	0: GPO output is disabled. GPO is High-Z (Open Drain) or 0 (CMOS) 1: GPO output is enabled. GPO outputs enabled interrupts	1b

Table 9 describes the structure and the programming of the EH_CTRL_Dyn register.

Table 9. EH_CTRL_Dyn

RF	Command	Read Dynamic Configuration (cmd code ADh) @02h Write Dynamic Configuration (cmd code CDh) @00h Fast Read Dynamic Configuration (cmd code AEh) @02h Fast Write Dynamic Configuration (cmd code CEh) @02h	
	Type	b0: R always, W – b1 - b7: RO	
I2C	Address	E2 = 0, 2002h	
	Type	b0: R always, W always b1-b7: RO	
Bit	**Name**	**Function**	**Factory value**
b0	EH_EN	0: Disable EH feature 1: Enable EH feature	0b
b1	EN_ON	0: EH feature is disabled 1: EH feature is enabled	0b
b2	FIELD_ON	0: RF field is not detected 1: RF field is present and ST25DV-I2C may communicate in RF	Depending of power source
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)	Depending of power source
b7-b4	RFU	-	0000b

Revision history

Table 10. **Document revision history**

Date	Revision	Changes
02-Mar-2017	1	Initial release.
01-Jun-2021	2	Replace in whole document SR25DVxxx with ST25DV-I2C. Updated , Table 1. Applicable products Added Table 8. GPO_CTRL_Dyn for ST25DV04KC, ST25DV16KC and ST25DV64KC

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