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1. Overview

- This Document describes the RF exposure Calculation for the Rechargeable Philips Power Toothbrush (**Cairo Models**) with NFC ST25R100 operating at 13.56MHz.
- The NFC hardware / Firmware used for calculation is production equivalent and tuned for better performance of the NFC in the product.

2. Terminology & Abbreviations

Terminology & Abbreviations	Description/Definition
RF	Radio Frequency
NFC	Near Field Communication
IC	Integrated Circuit
RC	Resistor–Capacitor circuit
LC	Resonant circuit, Inductor and Capacitor circuit
EC	European Commission
Hz	Hertz
mA	Milli Ampere
mW	Milliwatt
N/A	Not Available
mm	Millimeter
msec	Milli seconds
MHz	Megahertz
v	Volts
ASK	Amplitude-shift keying
HF	High Frequency
PTB	Power toothbrush
BH	Brush Head

3. References

Reference	Title / additional remarks
REF-1	st25r100 data Sheet
FCC Part 1.1310	Radiofrequency radiation exposure limits
KDB 447498 D01	RF Exposure Procedures and Equipment authorization policies for Mobile and Portable devices.
RSS -102	Radio Frequency exposure compliance
ST25R100 -N26102-REV0	Antenna Matching from Supplier

4. General Product Information

- The Philips PTB uses HF reader/ NFC transceiver (ST25R100) IC for the NFC communication.
- Battery-powered, portable standalone device with a rechargeable 4.1 V battery
- Philips uses proprietary antenna on the products.

5. Antenna Details

Details	Description/Definition
Make	Philips Proprietary
Antenna Transmission Range	12mm Max
Antenna type(s)	loop/Coil Antenna
Antenna Topology	Single Ended
Antenna Connection Type	Integral

6. Modulation Scheme

- ASK modulation is employed in the transmit carrier.

7. Nominals Transmit Frequency and Tools details

- NFC Operating Frequency: 13.56 MHz
- Tool used – Tektronix oscilloscope calibration due on 31 July 2026.
- All the measuring equipment are calibrated.

8. Device Under Test





Figure 1

9. NFC Operation Details

9.1 General Information

- NFC is operational only in **Standby mode** of the power toothbrush.
- The Standby Mode is active only for **30sec** of time interval once the handles are woken up from sleep or after the brushing session has been completed, basically this is the time when the user selects the options on the handle before starting the brushing session or the brushing session data is recorded in the BH for efficacy of the product.
- The NFC is triggered periodically in the Application to check if any operation needs to be performed while the Power toothbrush is in standby state.
- Below Snippet shows the call rate of Nfc in the application (**Nfc trigger Time**).

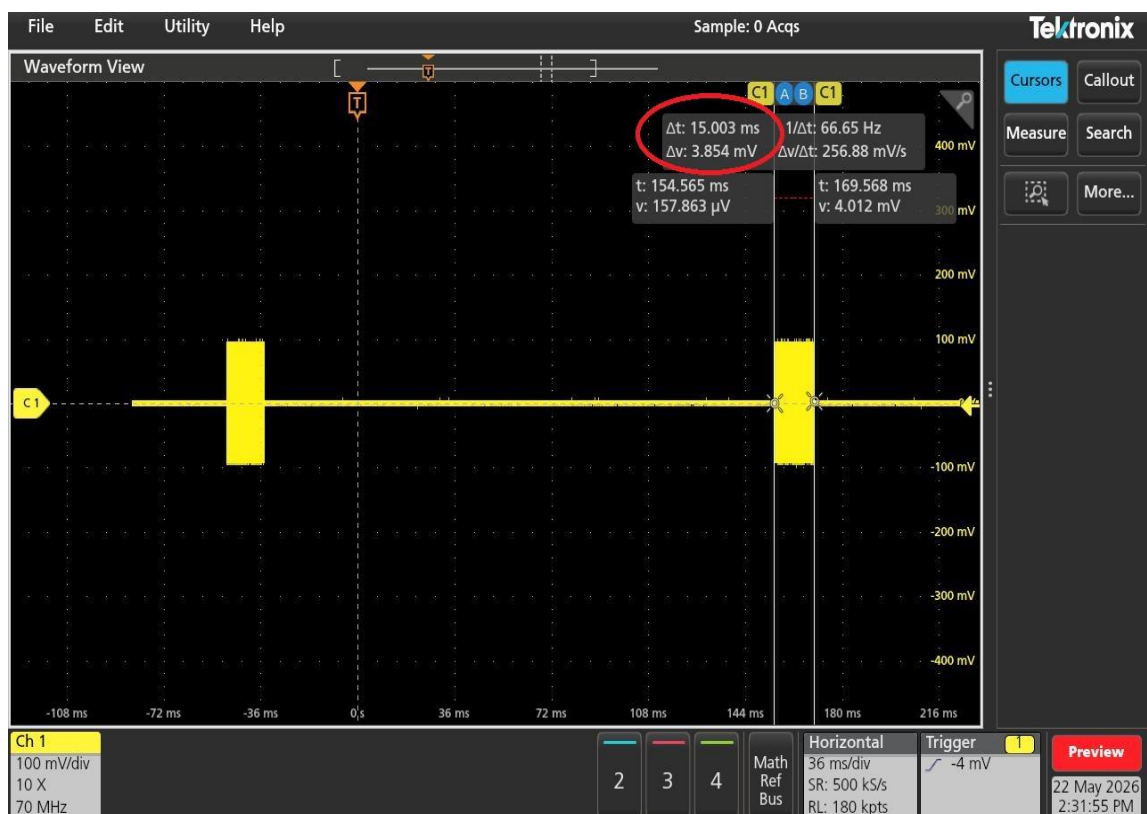
```
#define NFC_POLLING_PERIOD_MS      200      // Poll for NFC tag every so often.
```



Figure 2

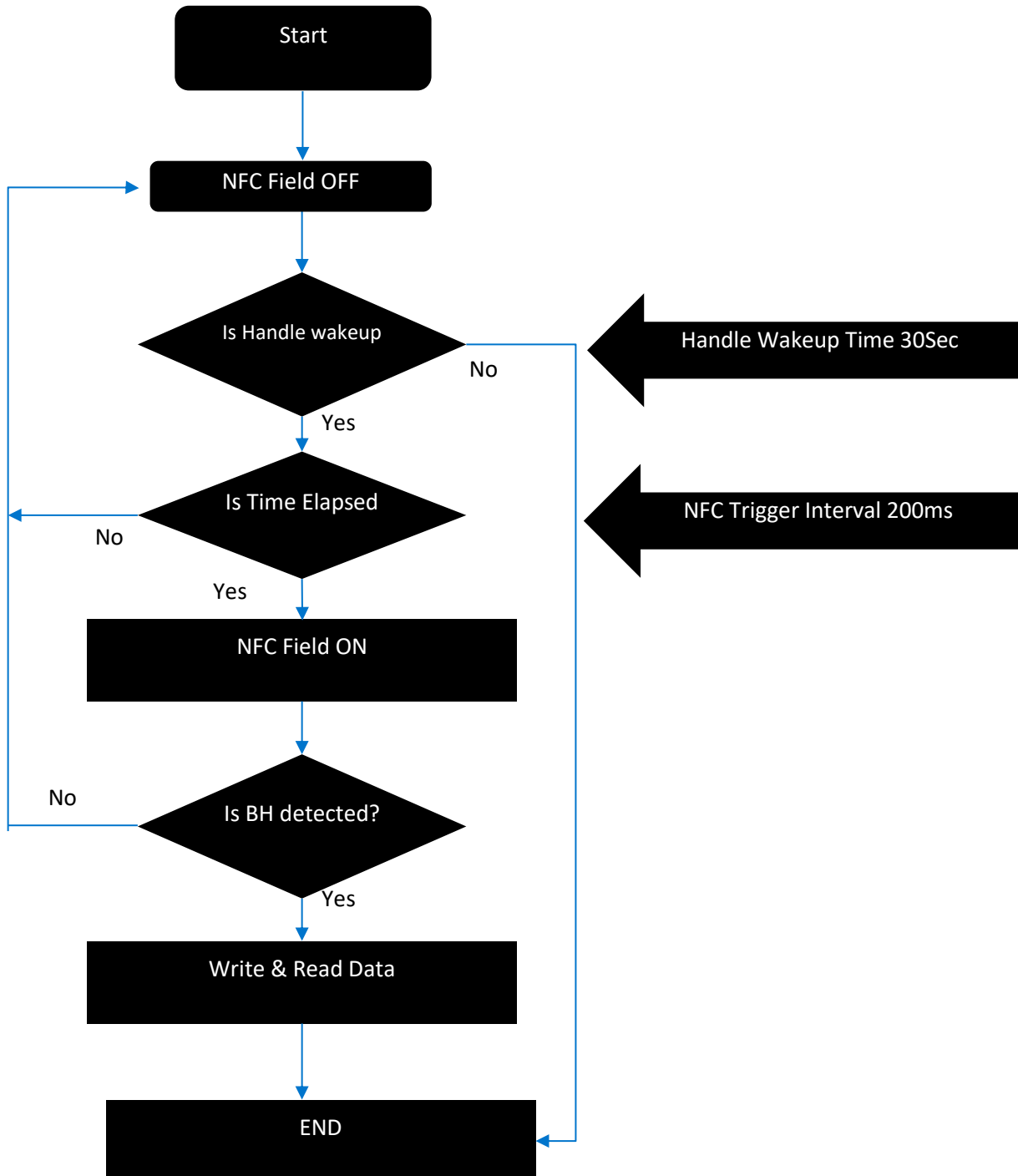
- The transmission (Tx) and reception (Rx) bit rates configured are both set to 106 Kbps (Kilobits per second).
- The NFC module takes approximately **15 msec** to complete to check if it needs to carry out any write / read operation. This time doesn't include any write / read operation time i.e. we consider this as the **NFC idle transmission Time** as shown in the below image.

Figure 3



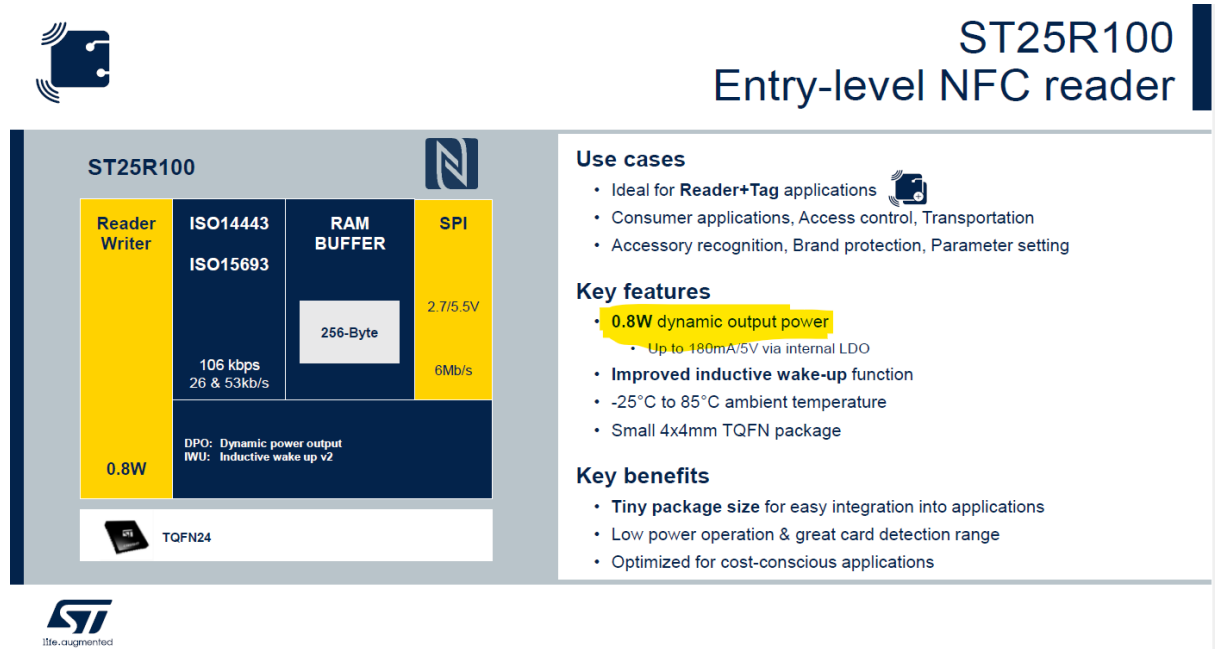
9.2 NFC Operation Flow Chart

The Below flow diagram shows the general operation of the NFC



10. RF Exposure Calculation for ST25R100 NFC IC

- As per the ST data sheet we have **0.8-watt** as the max output power the IC can generate in **Differential output configuration of the antenna** for the ST25R100 nfc chip.
- Attached snippet from the ST data sheet



ST25R100
Entry-level NFC reader

Use cases

- Ideal for Reader+Tag applications
- Consumer applications, Access control, Transportation
- Accessory recognition, Brand protection, Parameter setting

Key features

- 0.8W dynamic output power**
 - Up to 180mA/5V via internal LDO
- Improved inductive wake-up function
- 25°C to 85°C ambient temperature
- Small 4x4mm TQFN package

Key benefits

- Tiny package size for easy integration into applications
- Low power operation & great card detection range
- Optimized for cost-conscious applications

ST25R100 Block Diagram:

Reader Writer	ISO14443 ISO15693 106 kbps 26 & 53kb/s	RAM BUFFER 256-Byte	SPI 2.7/5.5V 6Mb/s
DPO: Dynamic power output IWU: Inductive wake up v2			

TQFN24

- Philips NFC antenna Design **doesn't use the Differential output topology rather it uses single ended driver mode** please refer [Antenna Details](#) for more details. So, the output power would be obviously less than the mentioned value i.e. **0.8w** which also mentioned in the data sheet.

Using the single driver mode the number of the antenna LC tank components (and therefore the cost) is halved, but also the output power is reduced. In single mode it is possible to connect two antenna LC tanks to the two RFO outputs and multiplex between them by controlling the *IO configuration register 1* bit rfo2.

As per the SAR power exclusion limit we need to have power less than 308mW for a period of exposure for 30 mins as per regulation FCC Part 1.1310 for the (KDB 447498 D01) attached snippet below (depends on the operating frequency and the Distance measured)

We need also apply the equation in the section 4.3.1 to get the threshold.

Appendix C

SAR Test Exclusion Thresholds for < 100 MHz and < 200 mm

Approximate SAR test exclusion power thresholds at selected frequencies and test separation distances are illustrated in the following table. The equation and threshold in 4.3.1 must be applied to determine SAR test exclusion.

MHz	< 50	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	mm
100	237	474	481	487	494	501	507	514	521	527	534	541	547	554	561	567	mW
50	308	617	625	634	643	651	660	669	677	686	695	703	712	721	729	738	
10	474	948	961	975	988	1001	1015	1028	1041	1055	1068	1081	1095	1108	1121	1135	
1	711	1422	1442	1462	1482	1502	1522	1542	1562	1582	1602	1622	1642	1662	1682	1702	
0.1	948	1896	1923	1949	1976	2003	2029	2056	2083	2109	2136	2163	2189	2216	2243	2269	
0.05	1019	2039	2067	2096	2125	2153	2182	2211	2239	2268	2297	2325	2354	2383	2411	2440	
0.01	1185	2370	2403	2437	2470	2503	2537	2570	2603	2637	2670	2703	2737	2770	2803	2837	

As per the **RSS-102 — Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)** we need to have section 6.3 SAR exemption limits

Table 11: Power limits for exemption from routine SAR evaluation based on the separation distance

Frequency (MHz)	≤ 5 mm (mW)	10 mm (mW)	15 mm (mW)	20 mm (mW)	25 mm (mW)	30 mm (mW)	35 mm (mW)	40 mm (mW)	45 mm (mW)	> 50 mm (mW)
≤ 300	45	116	139	163	189	216	246	280	319	362
450	32	71	87	104	124	147	175	208	248	296
835	21	32	41	54	72	96	129	172	228	298
1900	6	10	18	33	57	92	138	194	257	323
2450	3	7	16	32	56	89	128	170	209	245
3500	2	6	15	29	50	72	94	114	134	158
5800	1	5	13	23	32	41	54	74	102	128

The exemption limits in table 11 are based on measurements and simulations of half-wave dipole antennas at separation distances of 5 mm to 50 mm from a flat phantom, which provides a SAR value of approximately 0.4 W/kg for 1 g of tissue.

For limb-worn devices where the 10 gram of tissue applies, the exemption limits for routine evaluation in table 11 are multiplied by a factor of 2.5.

5.2.2 SAR

The SAR limits are summarized in table 3 .

Table 3 : SAR basic restrictions limits (100 kHz to 6 GHz)

Body region	Uncontrolled environment average SAR (W/kg)	Controlled environment average SAR (W/kg)	Averaging time (minutes)	Averaging mass (g)
Whole body	0.08	0.4	6	whole body
Localized head, neck and trunk	1.6	8	6	1
Localized limbs	4	20	6	10

10.1 FCC Part 1.1310

- We have the limits for FCC as per Appendix C calculated for 13.5MHz frequency and distance less than 5 mm as define below.
- **SAR T1 = [(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] x [vf(GHz)] ≤ 3.0 for 1-g SAR, and ≤ 7.5 for 10-g**
- f(GHz) is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before calculation³¹
- The result is rounded to one decimal place for comparison
- The values 3.0 and 7.5 are referred to as numeric thresholds in step b) below
 - **SAR Power Threshold = [(SAR T1 x [1 + log(100/f(MHz))]) x 0.5].**
 - **SAR Power Threshold < 7.5**

10.2 RS 102 section 6.3

- PTB is a handheld device and primary point of contact with the person would be his palms, so we need to have the multiplication factor of **2.5**.
- Mechanical constraints limit the user's ability to access the NFC radiated power.
- There is Housing tube and Brush head which is attached on top of the NFC ring.
- Total Power Exemption as per table is considering the Physical limitation is
 $45 * 2.5 = \mathbf{112.5mW}.$

10.3 Max Power output from the NFC IC calculation at a given point of time

- The NFC IC output power is directly proportional to its input supply voltage.
- Although the battery can reach a maximum voltage of 4.15 V, firmware-controlled charging limits prevent it from attaining full charge to account for system tolerances. For power calculations, an idle battery voltage of 4.0 V is assumed, representing the condition under which the NFC IC delivers its maximum output power.
- NFC output power is determined using the voltage measured at the RFO (VRFO) pin and the supply current (IVDD).
- All measurements presented in this document were obtained using the Cairo PTB platform after the NFC antenna was tuned for optimum performance.
- Power of the IC is **PWRNFC = VRFO x Iantenna.**
- **Iantenna = Ivdd – IRD** (IRD = Current consumed by the IC when Field is off)
- For additional details regarding antenna tuning and optimization, please refer to the antenna tuning guidelines provided by the NFC IC supplier.

Transmitter

The transmitter incorporates the drivers, which drive the external antenna through pins RFO1 and RFO2. Both single-ended and differential antenna configurations are supported. The transmitter block also generates the OOK or AM modulation of the transmitted RF signal.

The transmitter can either operate RFO1 and RFO2 independently to drive up to two antennas in single ended configuration or operate RFO1 and RFO2 combined to drive one antenna in differential configuration. The drivers are designed to directly drive antenna(s) integrated on the PCB as well as antennas connected with 50 Ω cables.

8	VDD_DR	AO3	Regulated driver supply for antenna
9	RFO1	AO	Antenna driver output
10	RFO2	AO	Antenna driver output



ST25R100

Electrical characteristics

Table 93. Electrical characteristics ($V_{DD} = 3.3$ V, $V_{DD_IO} = 3.3$ V)

Symbol	Parameter	Conditions ⁽¹⁾	Min	Typ	Max	Unit
I_{RESET}	Supply current in reset mode	$T_{jun} = -25^{\circ}\text{C}$ to 25°C ⁽²⁾	-	0.15	1.2	μA
		$T_{jun} = 85^{\circ}\text{C}$ ⁽²⁾⁽⁷⁾	-	0.6	5	
		$T_{jun} = 125^{\circ}\text{C}$ ⁽²⁾	-	5	24	
I_{PD}	Supply current in power-down mode	$T_{jun} = -25^{\circ}\text{C}$ to 25°C ⁽³⁾	-	1.4	2.7	μA
		$T_{jun} = 85^{\circ}\text{C}$ ⁽³⁾⁽⁷⁾	-	4.1	16	
		$T_{jun} = 125^{\circ}\text{C}$ ⁽³⁾	-	21	67	
I_{WU}	Supply current in wake up mode	$T_{jun} = -25^{\circ}\text{C}$ to 25°C ⁽⁴⁾	-	2.0	4.5	μA
		$T_{jun} = 85^{\circ}\text{C}$ ⁽⁴⁾⁽⁷⁾	-	4.5	17	
		$T_{jun} = 125^{\circ}\text{C}$ ⁽⁴⁾	-	21	68	
I_{RD}	Supply current in Ready mode	⁽⁵⁾	-	4.8	11	mA
I_{ALL}	Supply current all active	⁽⁶⁾	-	13	25	mA
R_{RFO}	RFO1 and RFO2 driver output resistance	$V_{RFO}=150$ mV ⁽⁷⁾	-	1.5	3	Ω
R_{RFI}	RFI input resistance	⁽⁷⁾	8	11	15	$\text{k}\Omega$
V_{POR}	Power on reset voltage	⁽⁷⁾	0.3	0.75	1.3	V
V_{AGD}	AGD voltage	⁽⁵⁾	1.4	1.5	1.6	V
t_{RESET}	Time between RESET pin in high state to device reset	⁽⁷⁾	10	-	-	μs
t_{BOOT}	Time between power On/RESET high-to-low transition and first SPI operation	⁽⁷⁾	500	-	-	μs

⁽¹⁾ The minimum and maximum values are tested in production at 25°C, and other temperature values are extrapolated by

CAIRO POWER TOOTHBRUSH NFC DETAILS

Reference point from schematic from where the V_{RFO} measurements were made

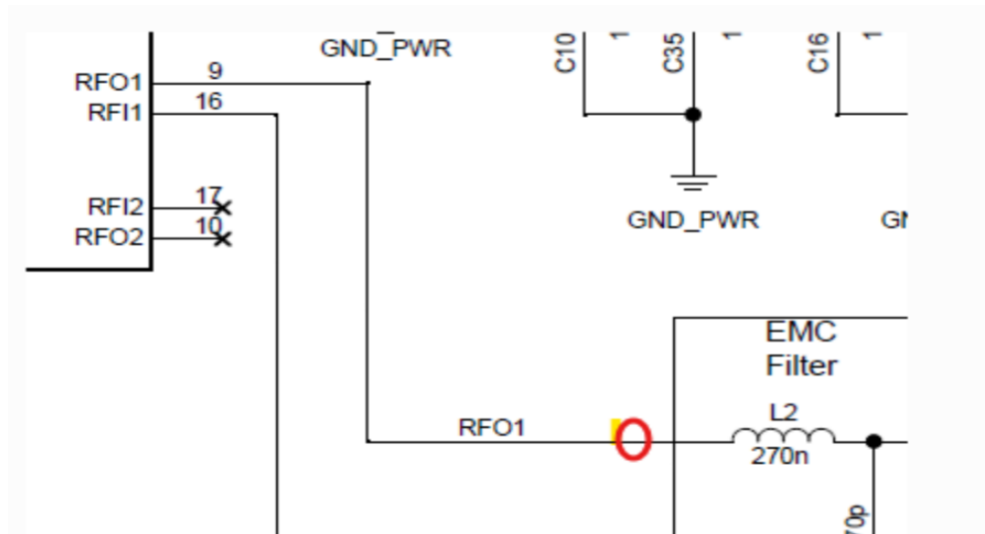


Figure 4

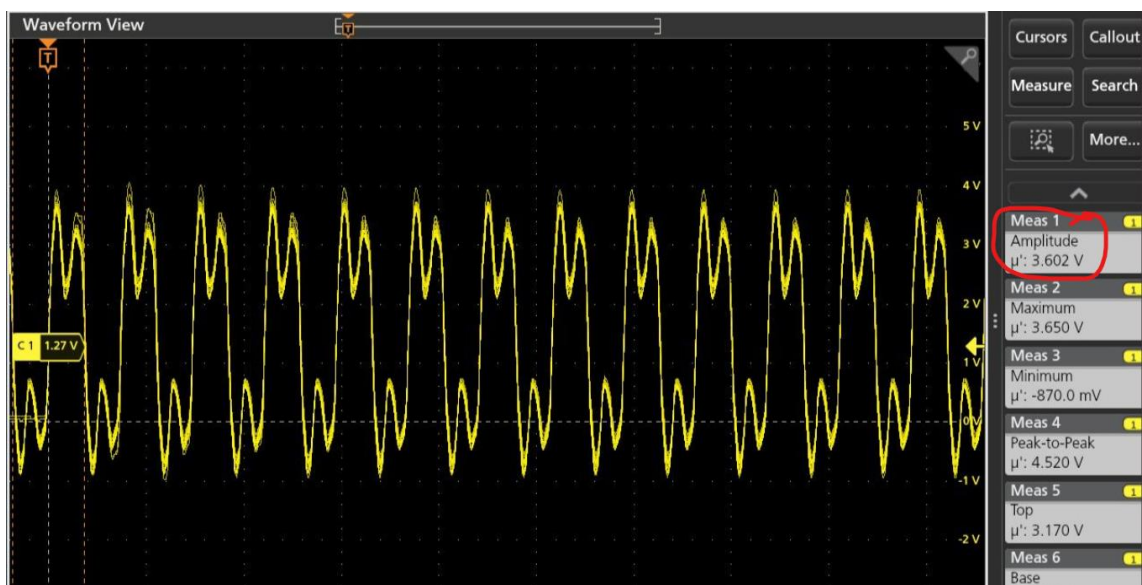




Figure 5

- The **IRD** current as per Figure 5 is **IRD = 6.238mAmp**
- The **Ivdd** current as per the data is **Ivdd = 36.4mAmp**.
 - 34.6 mA without tag
 - 36.4 mA with a tag
- Total current **Iantenna** = 36.4 – 6.238 = **30.162mAmp**
- The Voltage at the RFO as per Figure 4 is **VRFO = 3.6v**
- The average output power from the ST25R100 **PWRNFC** = **VRFO x Iantenna = 108 mW**.
- Now the main thing to note here is as mentioned above the NFC would remain ON only in the standby state which is worst case scenario **1 min** during a brushing session and this time frame is minimal from exposure point of view.



Antenna Matching
Cairo_PTB with ST25R



ST25R100.pdf



st25r200-r100-produ
ct-presentation.pdf

FCC Part 1.1310 threshold calculation

Please refer to the Section [FCC Part 1.1310](#) in this document for the calculation formulae.

$$\text{SAR T1} = ([108\text{mW} / 5\text{mm}] \times \sqrt{0.01356}) = 2.5$$

$$\text{SAR Power Threshold} = [[2.5 \times [1 + \log (100/13.56)]] \times 0.5] = 2.33.$$

$$\text{SAR Power Threshold} < 7.5$$

RSS -102 threshold Calculation

Please refer to the section [RS 102 section 6.3](#) in this document.

SAR Limit is 112.5 mW

Output Power of the IC is 108mW

11. Conclusion

As per the above calculation at any point in time the maximum power the NFC chip can output is around 108 mW and 2.33 numerical

This value is lower than the threshold of 112.5 mW and 7.5.