RFID technology applied to dosimetry

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2nd WORKSHOP ELICSIR PROJECT, 9-10.03.2021

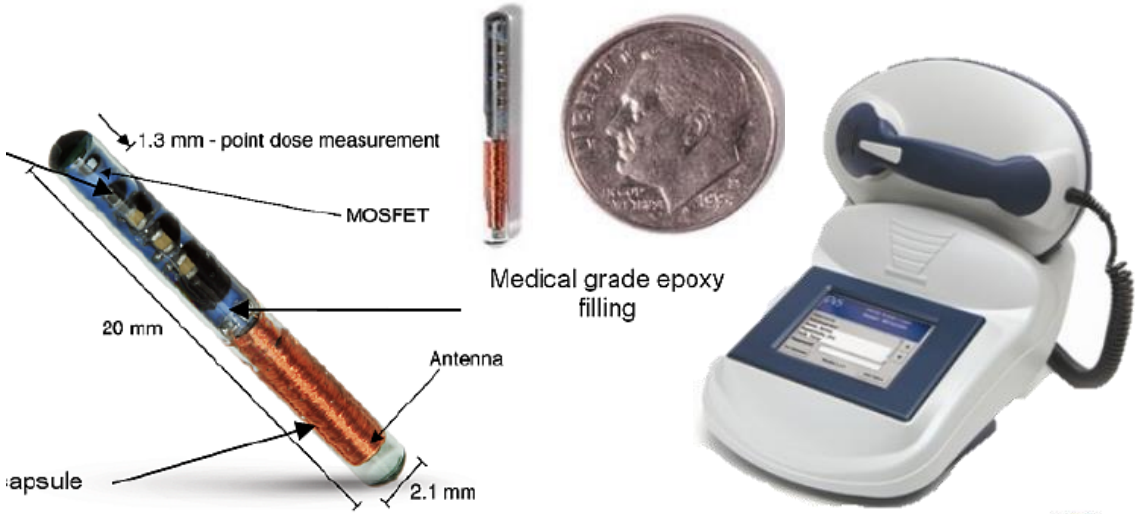
Outline

- Introduction
- RFID Technology
- NFC tag for readout of MOSFET dosimeters
- Conclusions
- Future work

Introduction

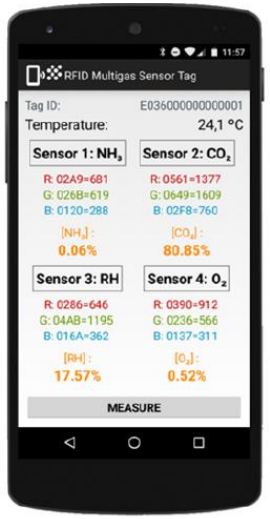
- RFID technologies for implantable medical device identification
- *Q Inside SmartMarker*: implantable RF radiation sensor that provides localization of a tumor and measures radiation dose at the tumor site
- LF band: 30 KHz to 500 KHz

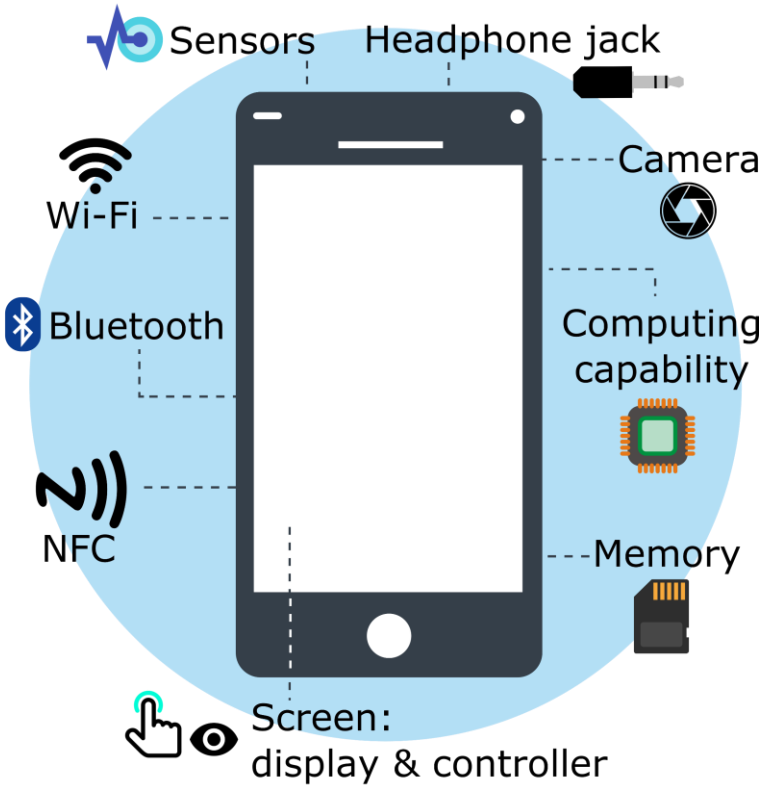
- Dose Verification System (DVS) (Sicel Technologies, Inc., Cary, NC)
- Sicel's Implantable Radiation Dosimeter
- LF band: 30 KHz to 500 KHz



Introduction

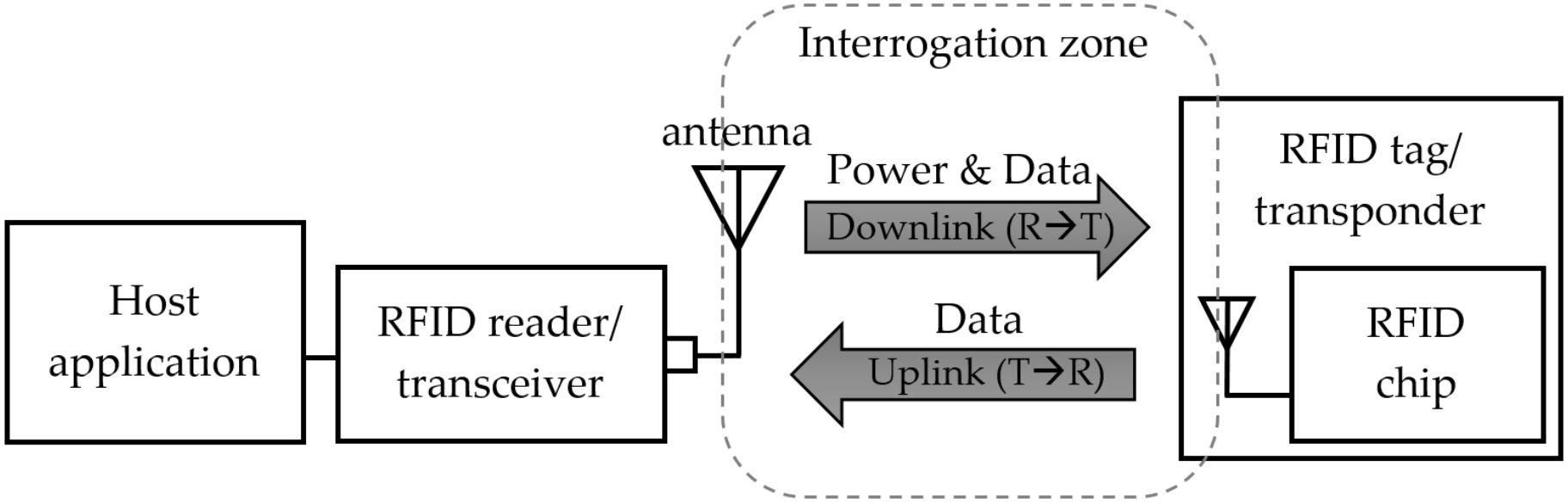
- **Goal**: To develop a passive NFC reader for MOSFET dosimeters
- **Why an NFC reader for MOSFET dosimeters?**
  - Most of smartphones include an NFC reader
  - Passive tags without battery with sensing capabilities
  - Cost saving and easy to use for non-trained users
  - Android devices are very popular





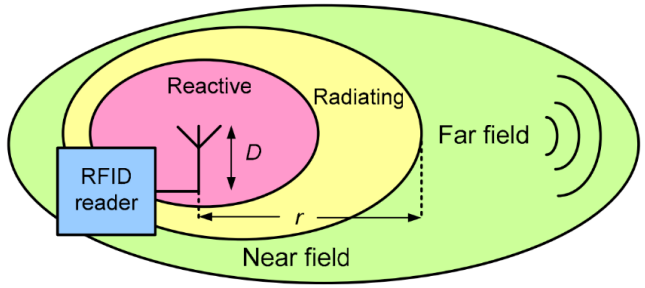
RFID Technology: What is RFID?

- **RFID: Radio Frequency IDentification**
  - Information carried by radio waves
  - It enables product identification and information gathering without contact
  - Overview of a generic RFID system:



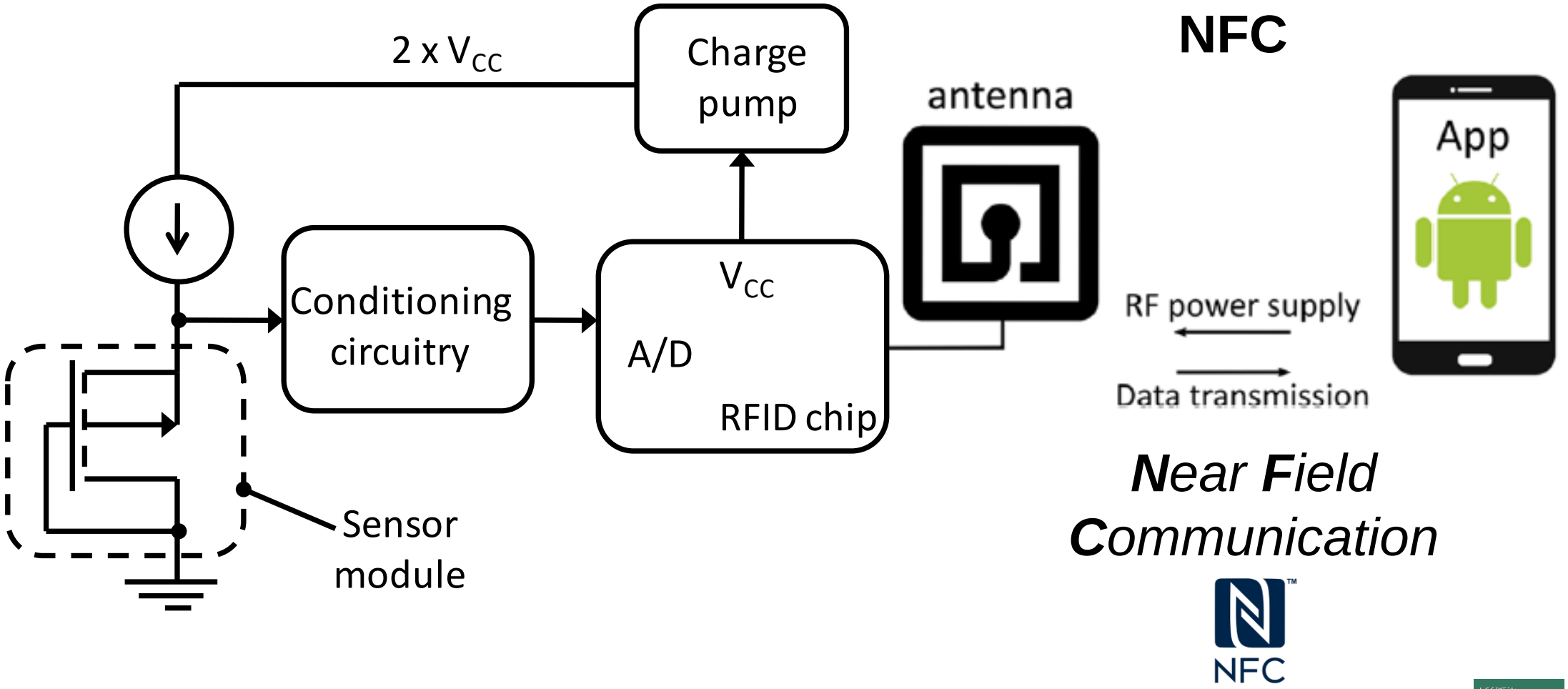
RFID Technology: RFID tag classification

- **Power source**
  - Active
  - **Passive**
  - Semi-passive
- **Operating frequencies**
  - LF, MF, HF, VHF, UHF, SHF
- **Coupling mechanism**
  - Inductive (near field): magnetic field (HF)
  - Radiative (far field): EM wave (UHF)



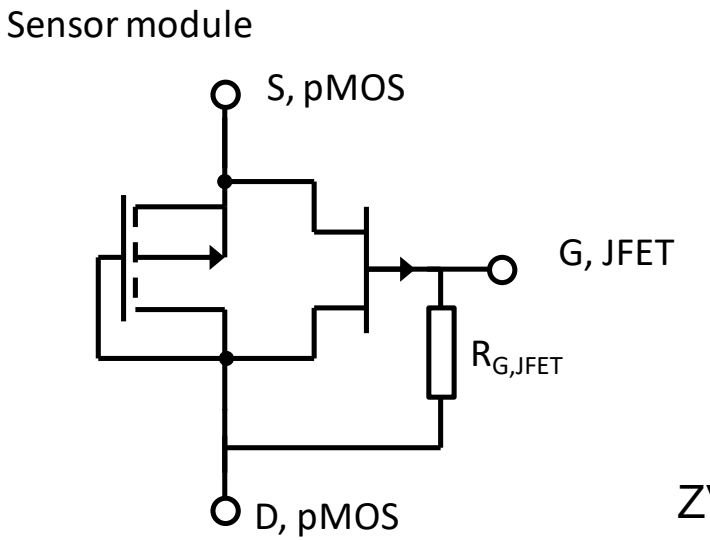
NFC tag for readout of MOSFET dosimeters

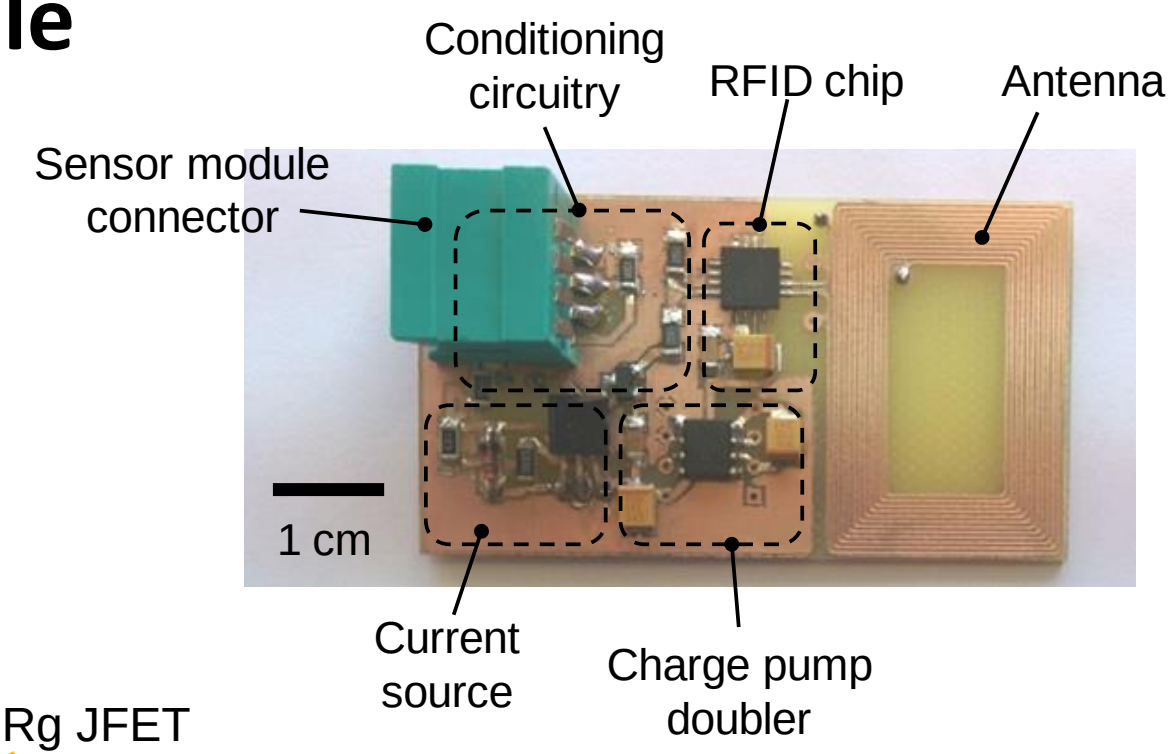
- **Block diagram**

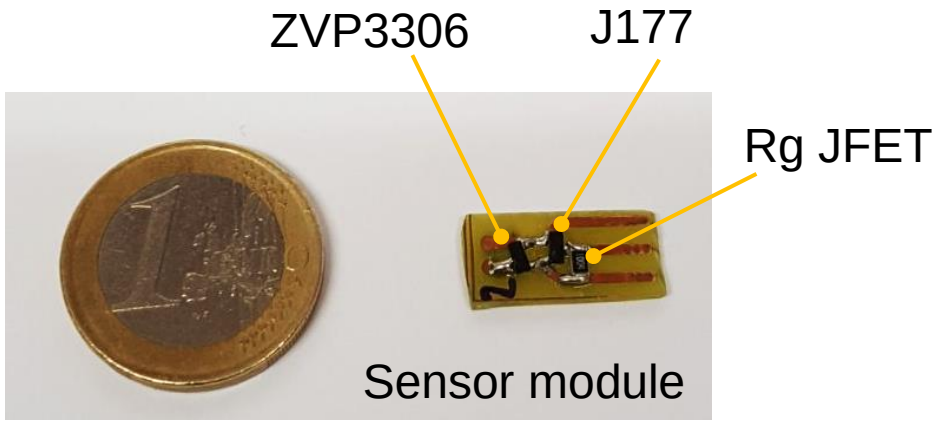


NFC tag for readout of MOSFET dosimeters

- **NFC tag and sensor module**







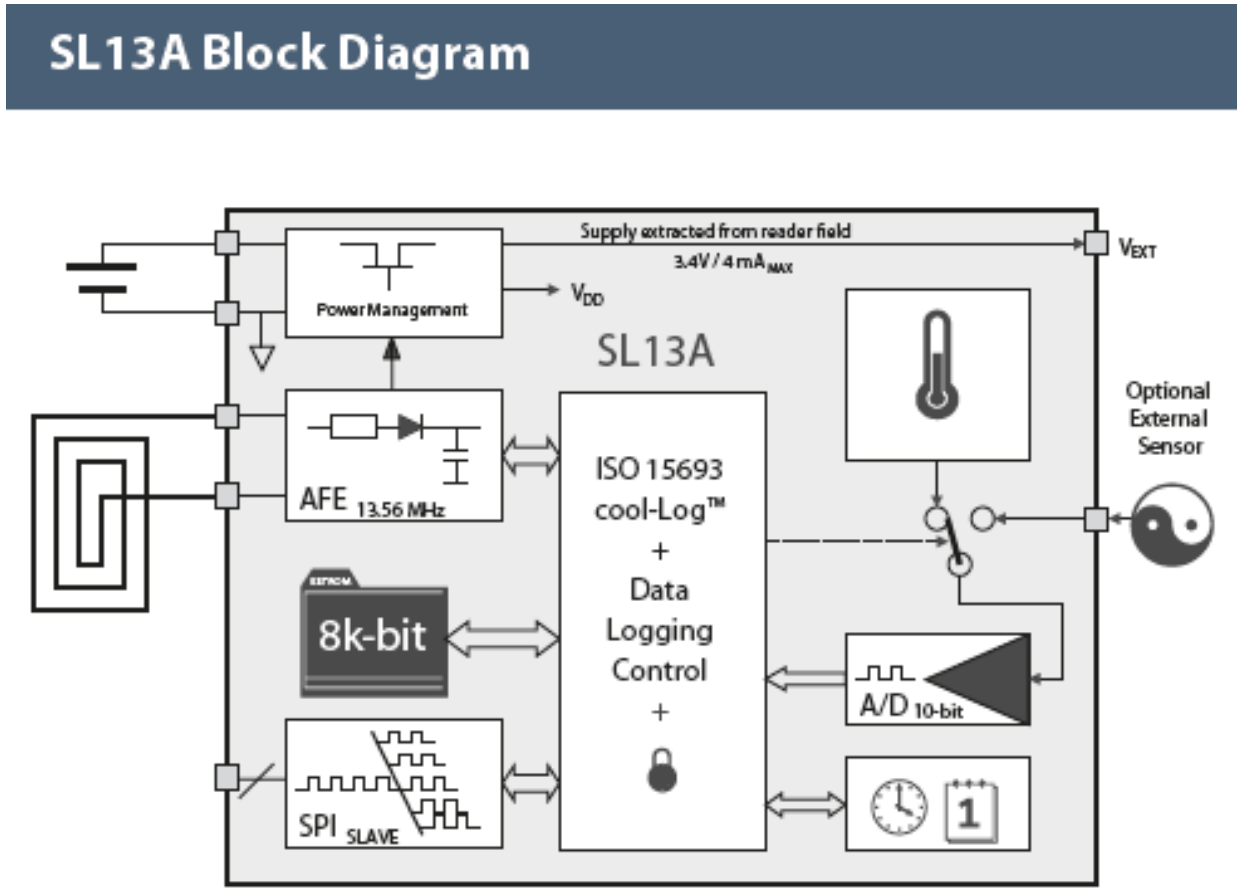
- Compact
- Passive tag: **no battery** is required

NFC tag for readout of MOSFET dosimeters

- **RFID chip**

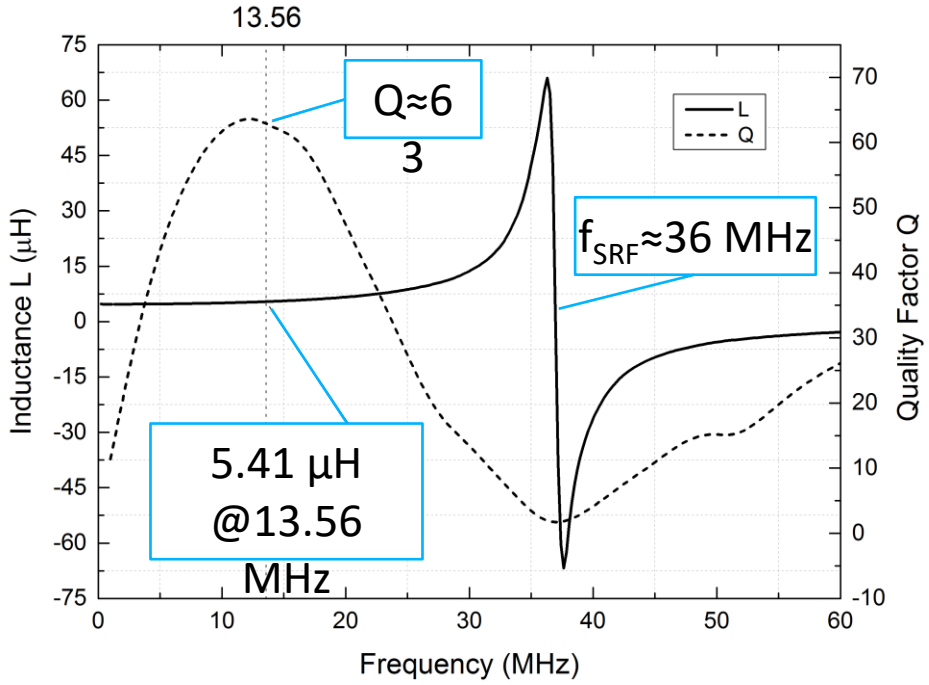
SL13A:

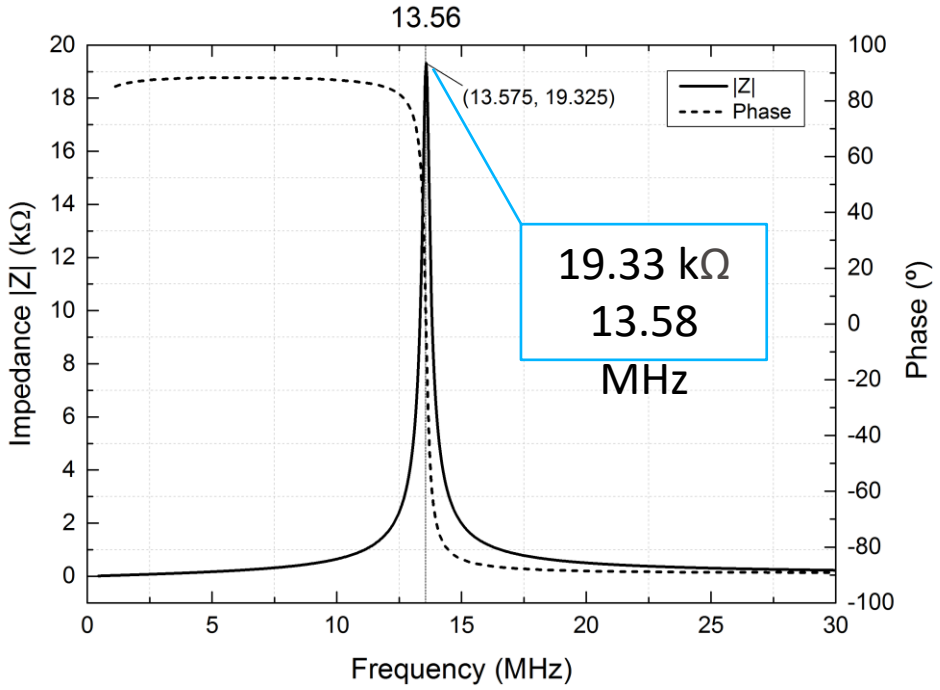
- Manufacturer: AMS (Austria)
- Sensor front end (SFE):
  - ADC 10 bits
  - Input range: 300-600 mV
- EEPROM memory, which can be written and read via NFC
- Supply voltage output:
  - Regulated 3.2 V output, up to 4 mA: 13mW

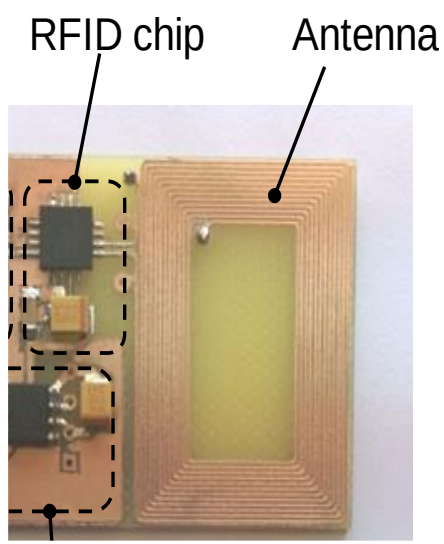


NFC tag for readout of MOSFET dosimeters

- **Antenna:** L_{PCB} || C_{SL13A}
  - C_{SL13A} =25 pF, for resonance at 13.56 MHz → L = 5.5µH
  - $L_{PCB,}$ 12 turns → 5.41µH → Resonance at 13.61 MHz

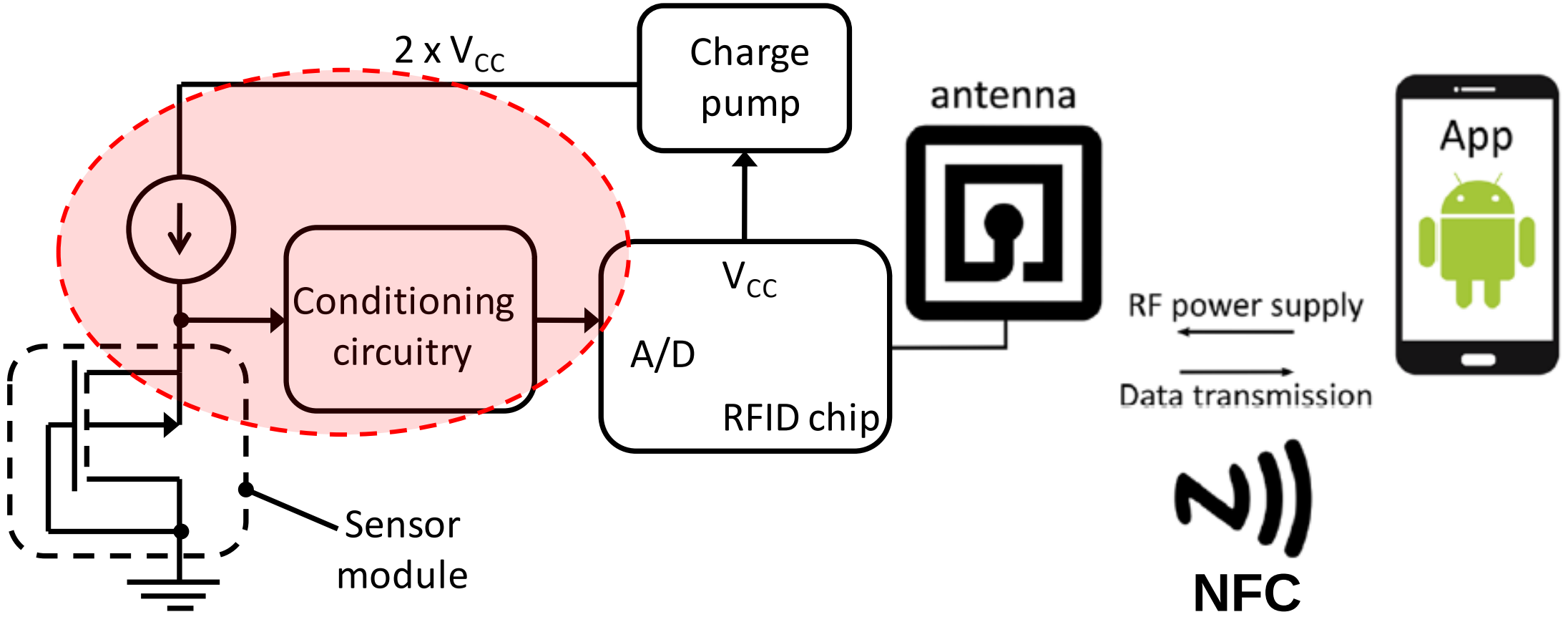






NFC tag for readout of MOSFET dosimeters

- **Analog circuitry:** Current source and buffering



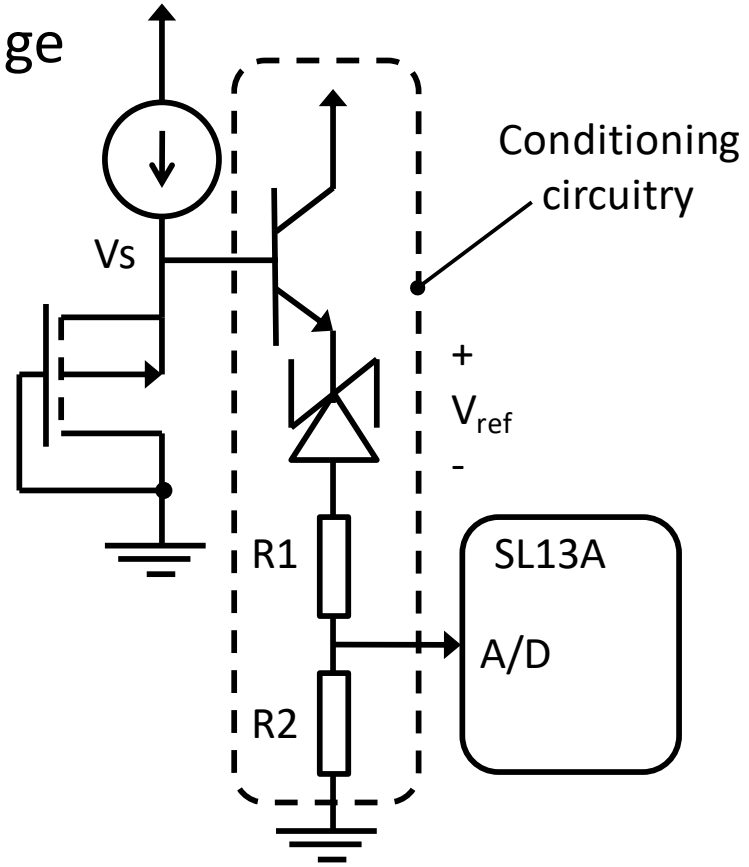
NFC tag for readout of MOSFET dosimeters

- **Analog circuitry:** Buffer and signal conditioning
  - No load the source current
  - To reduce the source voltage down to 300-600 mV range

$$V_{in}^{ADC} = \frac{R_2}{R_1 + R_2}\left(V_S - V_{BE} - V_{ref}\right)$$

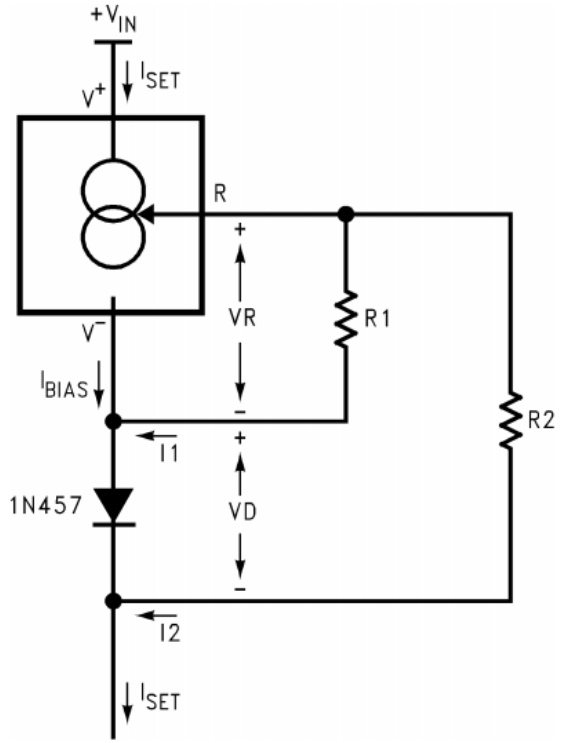
$$\left.\begin{aligned} \Delta V_{in}^{ADC} &= \alpha \Delta T \\ \Delta V_S &= \alpha_S \Delta T \\ \Delta V_{BE} &= \alpha_{BE} \Delta T \end{aligned}\right\} \Rightarrow \alpha = \frac{R_2}{R_1 + R_2}\left(\alpha_S - \alpha_{BE}\right)$$

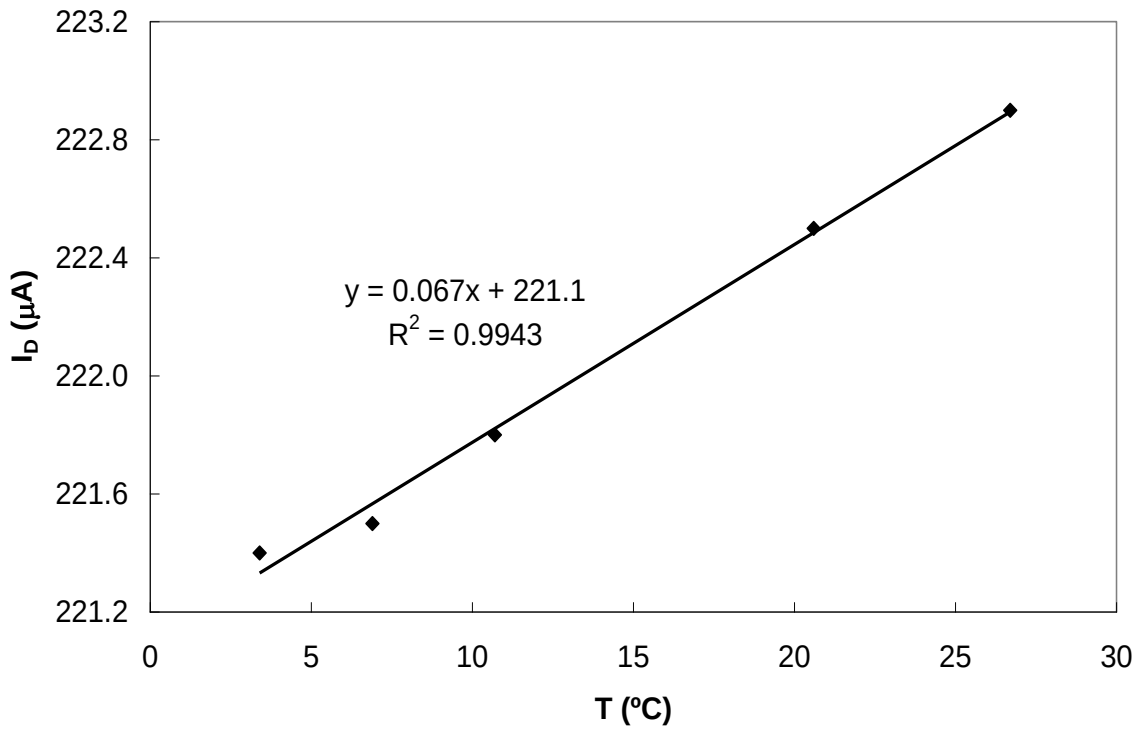
	I (µA)	α (mV/ºC)	Δα (mV/ºC)
VBE_BJT	30	-2.332	0.013
Vs_MOSFET	220	-2.30	0.12



NFC tag for readout of MOSFET dosimeters

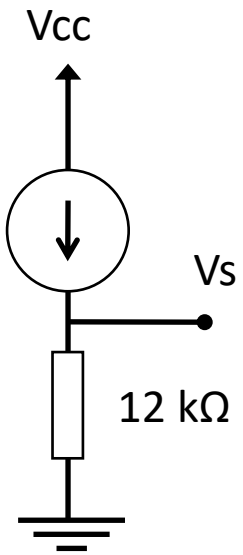
- **Analog circuitry:** Current source
  - Based on LM334 (Texas Instruments, USA)
  - Circuit for thermal compensation suggested by the manufacturer

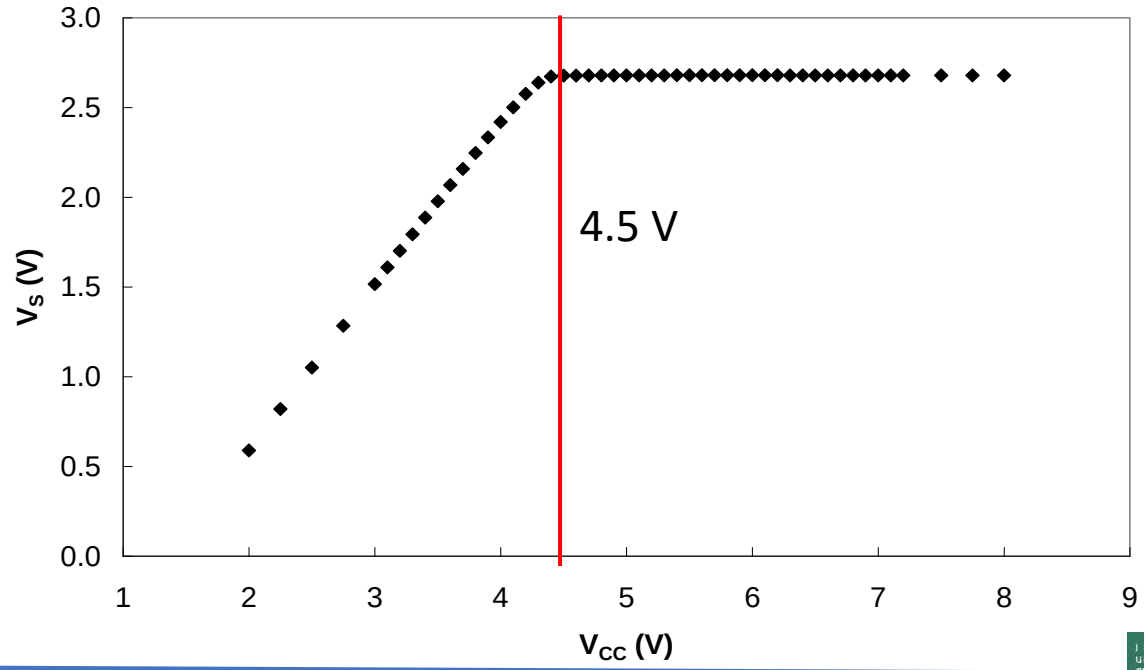




NFC tag for readout of MOSFET dosimeters

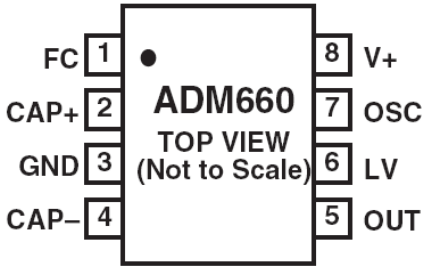
- **Power management:** Supplying the current source
  - Load: Resistor of 12 kΩ, DC source from 2 to 8 V
  - Minimum voltage: 4.5 V.
  - The SL13A does not provide enough voltage
  - Use of a DC/DC up converter

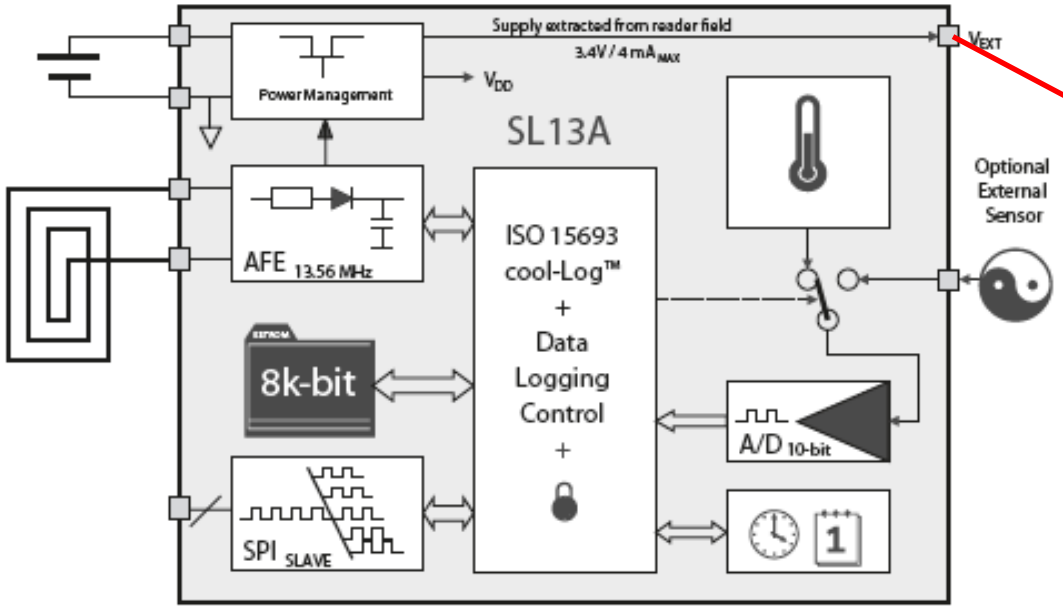




NFC tag for readout of MOSFET dosimeters

- **Power management:** Voltage doubler
  - Charge-pump DCDC converter: low quiescent current (600 µA)
  - ADM660: Voltage doubler, from 3.2 to 6.4 V





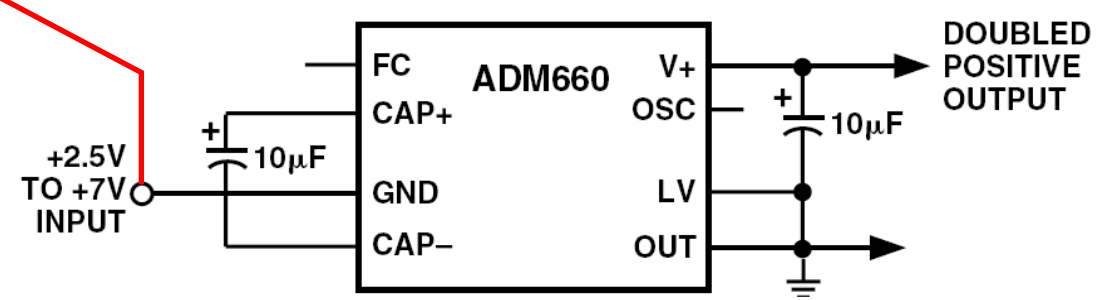
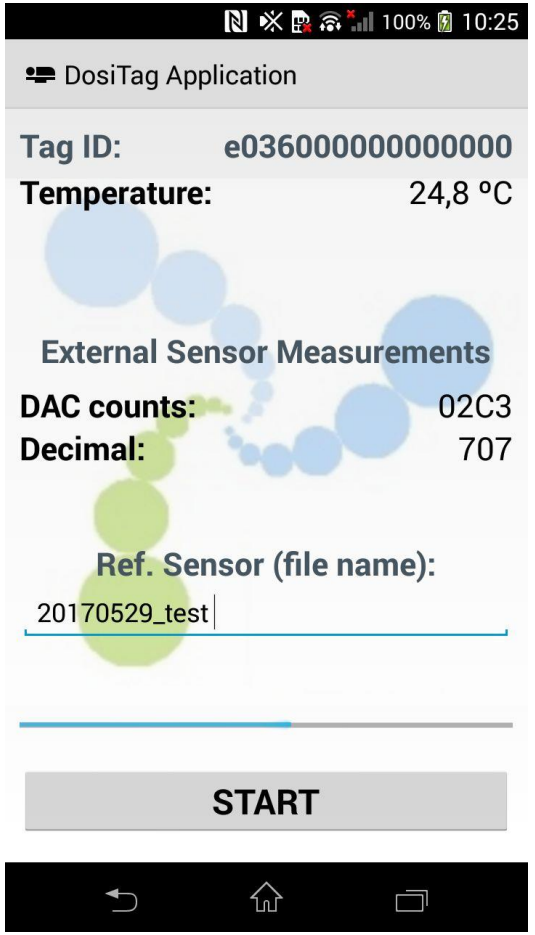


Figure 8. Voltage Doubler Configuration

NFC tag for readout of MOSFET dosimeters

- **Android app:** Measurement protocol

1. The smartphone activates the NFC, then the tag is supplied.
2. The smartphone sends the measurement command to the SL13A
3. The results of A/D conversion is stored in the EEPROM memory of the SL13A
4. The EEPROM memory is read by the smartphone
5. This process is repeated 10 times and storage in a file in the smartphone
6. The NFC of the smartphone is turned off.



NFC tag for readout of MOSFET dosimeters

- **Setup for NFC measurements**

  - Structure made of wood to ensure the inductive coupling:
    - Tag coil and smartphone coil as close as possible and overlapped
    - 3D printing (e.g. PLA) could be used for this purpose

NFC tag for readout of MOSFET dosimeters

- **Dose measurements:** Experimental method

Experimental setup:

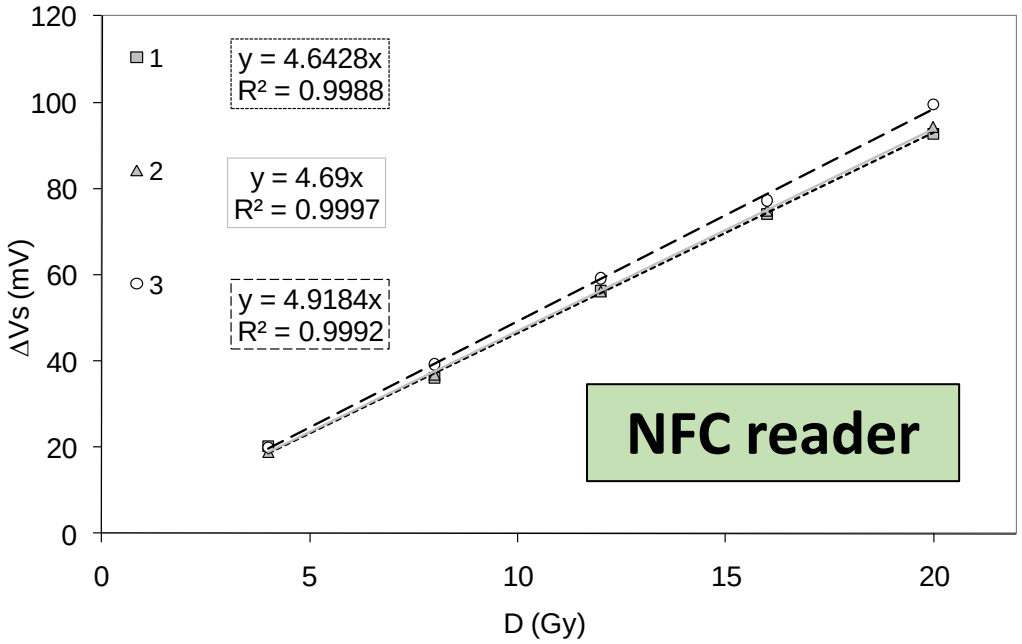
- 3 sensor modules irradiated using a LINAC Siemens Artiste
- Photon beans of 6 MV irradiation field of 10x10 cm^2
- 1.5 cm of solid water as build-up layer
- 5 sessions of 4 Gy each

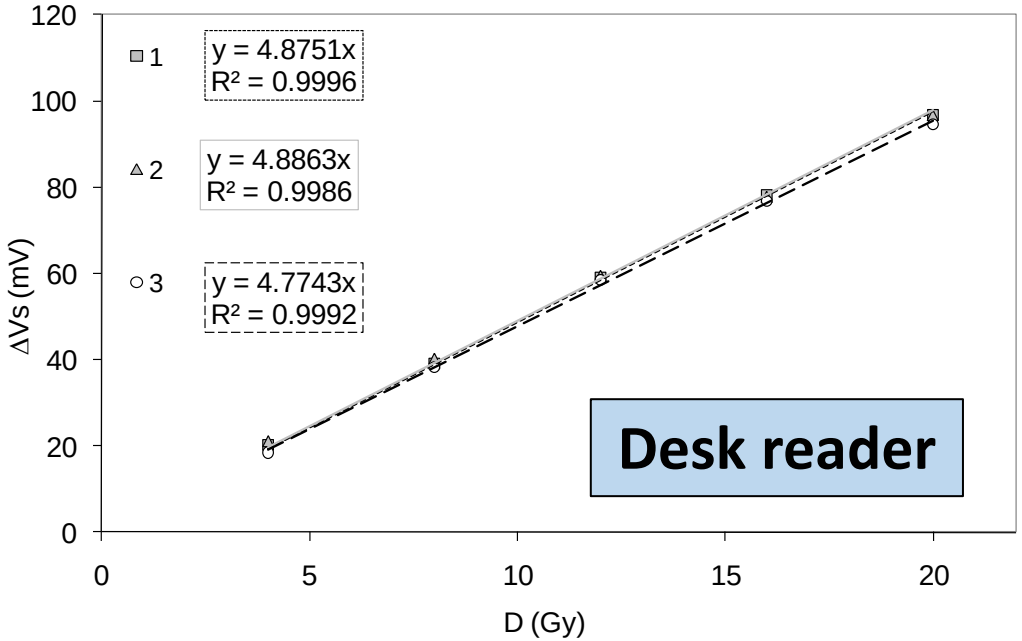
Measurement protocol:

1. The zero was made with NFC reader and with our desk unit
2. The sensor modules were irradiated (Siemens Artiste)
3. After 5 minutes the source voltage was measured again with the NFC reader and the standard unit.
4. Finally the voltage shift was calculated

NFC tag for readout of MOSFET dosimeters

- **Results**





	#1	#2	#3	Average
NFC reader	4.64 ± 0.03	4.69 ± 0.02	4.92 ± 0.03	**4.75 ± 0.15**
Desk reader	4.88 ± 0.02	4.89 ± 0.04	4.77 ± 0.03	**4.85 ± 0.07**

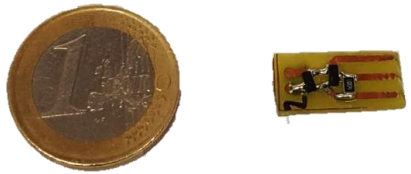
Conclusions

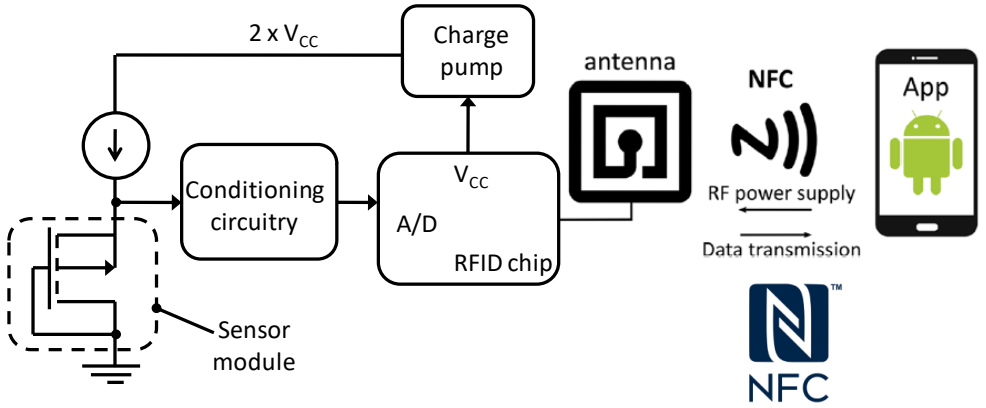
- **NFC tag for readout of MOSFET dosimeters**
  - A compact and passive tag is presented to dose measurements with sensor based on MOSFETs.
  - The NFC reader topology is suitable for dose measurements.
  - A very good inductive coupling is necessary to harvest enough energy.
  - Good linearity has been found

Future work

- **NFC tag for readout of MOSFET dosimeters**

  - Irradiation of the whole NFC tag (reader and sensor module) to check the viability of radiation tag.
  - Design and fabrication of a structure using 3D printing technology for compatibility with different models of smartphones.





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THANK YOU FOR YOUR ATTENTION- QUESTIONS?