Design of NFC System for Low Power Applications

Monisha J R[1], Dr. S G Srivani[2]

[1]PG Student, Department of Electrical and Electronics Engineering, RV College of Engineering, Bengaluru
[2]Professor, Department of Electrical and Electronics Engineering, RV College of Engineering, Bengaluru

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Abstract - *Near Field Communication (NFC) is a short-range wireless standard used in data exchange and transaction applications. The NFC standard establishes the connectivity with counterpart with a touch. The NFC technology is evolved from the existing contactless identification and interconnection technologies. This paper presents an NFC system design using NXP PN5190 reader IC. An antenna with symmetrical matching is designed for 13.56 megahertz. The NFC system is designed to operate in Low Power Mode to minimize the current and power utilization. A Flyback converter present in power supply unit of NFC system is designed to operate for low power applications. The Flyback converter achieves an output voltage and output current of 3.3V and 0.1A respectively from the input supply of 12V. The NFC system designed finds its application in access control, point-of-sale (POS) and Internet-of-things (IOT).*

***Key Words*: Near Field Communication (NFC), Low Power Mode, proximity, Radio-frequency Identification (RFID), Load Modulation, Rectangular Antenna**

1. INTRODUCTION

Near Field Communication (NFC) is a wireless standard for data transmission within a short-range at high frequency based on Inductive coupling. This technology has evolved from existing Radio-frequency Identification (RFID) technology. This technology is opted when there is a need to transfer data immediately and fast. The basic principle of operation is "touch to communicate" which indicates that bringing NFC enabled devices in close proximity to each other establishes connection for data transmission. The transmission range of the NFC standard is close to 10cm and frequency of operation is 13.56 megahertz. The rate of data transmission offered by NFC is in the range of 106 Kbit/s to 424 Kbit/s [1]-[8].

The NFC comprises of a poller and at least one listener. The poller/initiator has the ability to power up the passive listener/target device by generating RF field actively. The NFC technology allows an NFC enabled device such as mobile to accept data from a tag that is in close proximity to the poller. The NFC passive tag consists of a silicon chip and an antenna. The passive tag does not contain an internal power source rather it makes use of the RF field generated by the reader to power up its inner circuitry. The average power consumption of the NFC system is increased due to reading of such passive tag [1]-[8].

NFC is just not an interface to exchange data but also provides a way to transfer energy to the communication partner called the transponder. Communication with such transponder increases the average power consumption of the system consisting of NFC Reader, Wireless communication channel and a transponder. The NFC finds its application in lock/unlock and ignite car, payments, transportation, door access etc.

The integration of NFC into devices has the drawback of increasing the device's energy consumption. Especially when the NFC Reader is a smart phone, during the reading process the average power consumption of NFC-Reader increases by up to 107%.

Using NFC systems for applications like wireless payment, it is mandatory to add security. All the weak spots must be secure to prevent attackers from gaining unauthorized access to the system. To secure the wireless transmission, encryption algorithms like Advanced Encryption standard (AES) can be used. The usage of such algorithms leads to an increased energy consumption during transmission.

2. THEORY

2.1 Near Field Communication (NFC)

Radio Frequency Identification (RFID) technology incorporates wireless radio communication technology for unique identification. Both NFC and RFID work on same principle of inductive coupling at 13.56 megahertz. NFC technology has shorter transmission range of 4cm to 10cm compared to RFID range of 100cm. NFC technology provides communication solution to non……-self-powered device (passive). The NFC technology can be complementary to other wireless technologies like Wi-Fi, Bluetooth etc. to increase the data transmission range. The main advantage of NFC is the ability to save energy. Currently various devices like smart phone and smart wearables are equipped with NFC feature for use cases like data transfer between two devices and mobile payments. The smart phone applications like Samsung Pay and Google Pay facilitates contactless payment feature. NFC finds its use case in Transportation access, like in the public Metro transport ticketing where the coin has NFC tag incorporated in it [1]. The figure 1 gives an overview of NFC Domain.

The three operating modes of NFC are shown in figure 1, namely read/write mode, peer-to-peer mode and card emulation mode. The Card Emulation Mode consists of an active NFC reader and a Passive NFC card in the communication setup. The NFC reader reads the information stored in the passive tag. In Read/Write Mode the NFC enabled device can read data from tag or writes information to the NFC tag. The NFC tag is powered by the magnetic field and sends response to the request. In Peer-to Peer Mode two NFC enabled devices communicate with each other. The Peer-to-Peer mode enables devices to connect and interact with each other to exchange data, money transfer and social networking.

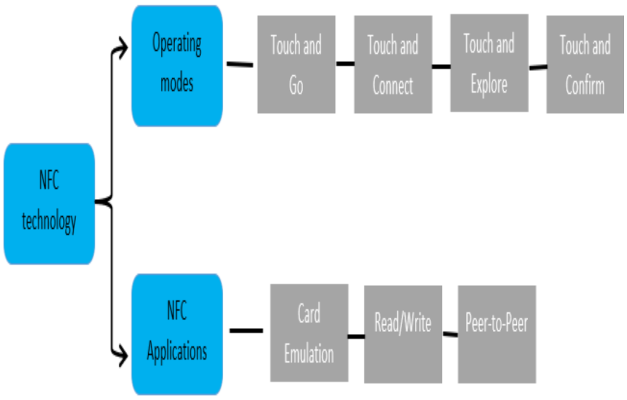

Fig -1: NFC Domain

The basic NFC System is shown in figure 2. The NFC system consists mainly of three components – a Tag, a Reader and a Controller. A Tag, also called a pulse transceiver consists of a semiconductor chip and an antenna. An electronic control module, RF module and an antenna is present in the reader device. A controller component of the NFC system is usually a PC [1].

NFC communication establishment involves three activities –

- Power transfer for communication by RF field of the NFC Reader.
- Modulation of the field.
- Load Modulation of the field.

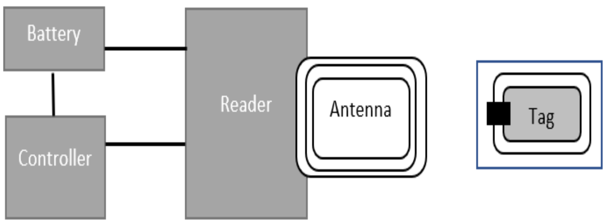

Fig -2: NFC System

2.2 Power Management in Embedded System

The critical issue in embedded devices is the power utilization due to which there is a need for extended battery life. The two scenarios in which systems power consumption can be considered are when the system is in use and when the system is in idle state. The solution to this problem is the deployment of the low power CPU modes. The power management in embedded systems can be achieved either by firmware power management or peripheral power down.

- *Firmware Power management* – The two measures firmware can into consideration to keep the power utilization minimum are to switch off the system peripherals when it is not in use and to regulate the voltage and frequency of the CPU based on the performance needs.
- *Peripheral Power Down* – The very common approach to save energy in embedded system is to switch it off. The complete system turn off when not in use is not recommended because a fully powered down device may take some time to start up. So, the embedded system should be designed such a way that the peripherals and subsystems may be turned on or off by firmware temporarily. Therefore, an alternate to the system power down is the low power modes.

The proposed NFC reader include low voltage power domains into their architecture and offer when it is associated with power modes, embedded power states. The low power mode of operation to reduce the energy consumption is chosen by a command in application running on the system [2].

3. SYSTEM DESIGN

The Block diagram of the NFC System proposed is shown in figure 3.

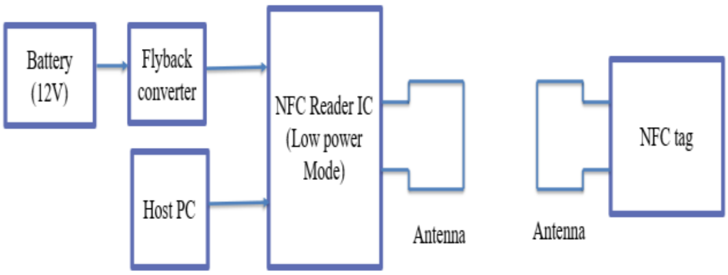

Fig -3: Block Diagram

The tag and a reader in the NFC system have radio frequency communication between them. Each tag consists of unique identification number and an antenna. The NFC Reader will use unique identification number of the tag to establish communication. The read distance of the NFC reader dependent on the antenna parameters such as the shape, size, frequency etc., surrounding environment and others [1].

The NFC Reader communicates with host PC via host interfaces, which can be either of I2C, SPI, USB or serial UART. In the proposed system the Reader IC is considered to be PN5190 IC. The reader IC can be customized to operate in low power mode in order minimize current consumption via a software application flashed on to it. The various low power modes in which reader IC could operate are such as Standby mode, Suspend mode and ultra-low power card detection mode. The reader IC have several other features and interfaces accommodated in the chip to meet the requirements of different use cases. The NFC Reader comprises of an antenna which is chosen to be rectangular patch antenna. The main issue in the design of the NFC system is the antenna alignment with the reader [1].

3.1 Design of an Antenna

The choice of right antenna depends on the application requirements. In the process of choosing the right antenna there are trade offs between applications requiring maximum read distance (consumes large power) and applications with strict power budgets (results in short read range). The balance between the two extremes can be achieved with a blend of power efficiency and performance, which can be met with the latest high-performance readers featuring ultra-low power card detection. In the proposed system a rectangular antenna is chosen because it is a symmetrical antenna with equal power distribution. The bill of material and the number of components is reduced. The figure 4 gives an example of rectangular antenna and dimensions. The inductance of antenna can be calculated using following formulas:

$$L_a = \frac{\mu_0}{\pi} \cdot [x_1 + x_2 - x_3 + x_4] \cdot N_a^{1.8} \quad (1)$$

$$d = \frac{2(t+w)}{\pi} \quad (2)$$

$$a_{avg} = a_0 - N_a(g + w) \quad (3)$$

$$b_{avg} = b_0 - N_a(g + w) \quad (4)$$

$$x_1 = a_{avg} \cdot \ln\left[\frac{2a_{avg}b_{avg}}{d\left(a_{avg} + \sqrt{a_{avg}^2 + b_{avg}^2}\right)}\right] \quad (5)$$

$$x_2 = b_{avg} \cdot \ln\left[\frac{2a_{avg}b_{avg}}{d\left(a_{avg} + \sqrt{a_{avg}^2 + b_{avg}^2}\right)}\right] \quad (6)$$

$$x_3 = 2[a_{avg} + b_{avg} - \sqrt{a_{avg}^2 + b_{avg}^2}] \quad (7)$$

$$x_4 = \frac{a_{avg} + b_{avg}}{4} \quad (8)$$

where:

a_0 = length in mm

b_0 = width in mm

t = track thickness in mm

w = track thickness in mm

N_a = number of turns

The above-mentioned parameters are calculated to design an antenna for NFC reader. The antenna dimensions are a_0= 45mm, b_0= 45mm, N_a= 3, w = 200µm, g = 400µm, t = 35µm. The inductance value of an antenna obtained by the above-mentioned equations is 1.2837µH.

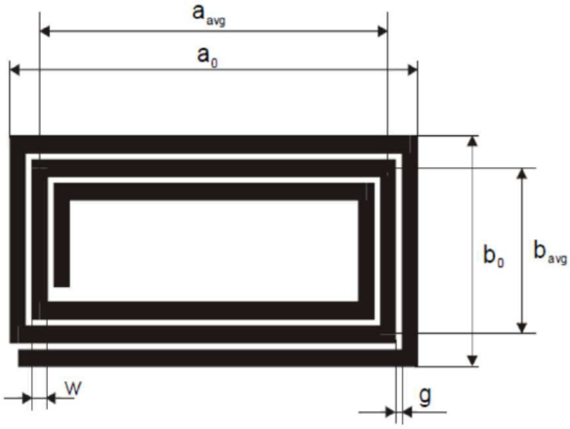

Fig -4: NFC Antenna

3.2 Converter Design

The power supply unit of the NFC system comprises of a battery of 12V and a flyback converter has been incorporated for DC-DC conversion. The flyback converter will step down the battery supply voltage to 5V/3.3V. The flyback converter is a DC-DC converter topology like boost converter having similar structure and performance. The converter stores energy when current flows using an inductor and supplies energy when the power is removed [9].

Flyback switch mode power supply is most commonly used SMPS circuit for low output power applications. The flyback converter has two operation phases: when the power from input side is being transferred to the output when the primary side switch is off and when the primary side switch is on and the output do not receive power from primary side. The basic flyback design has few low-cost material requirements just like the other dc-dc converters: the capacitor, the MOSFET as the primary switch, the diode as the secondary switch and inductor is being replaced by the flyback transformer or simply transformer [9]. The simple flyback converter circuitry is shown in Figure 5.

The necessary equations required for the design of the flyback converter are given below. The duty cycle calculation of the converter is required to determine the conduction ratio of the circuit The converter is designed for an output voltage of 3.3V from an input voltage of 12V. The duty cycle calculated from the below mentioned equation (9) is 45%.

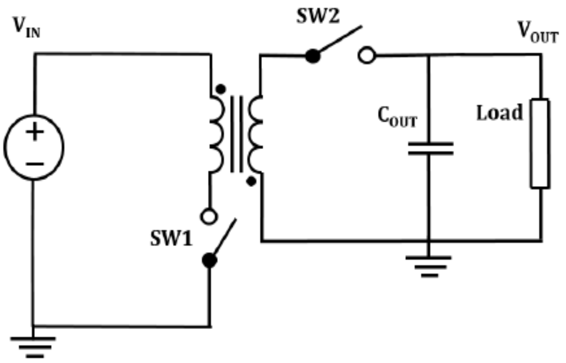

Fig -5: Simple Flyback converter

The transformer ratio $^{N_1}/_{N_2}$, in this design is set as 3.

$$\frac{N_2}{N_1} = \frac{V_0}{V_S}\left(\frac{1-D}{D}\right) \tag{9}$$

The load resistance R calculated with the output current of 0.1A in equation (10) is 33Ω.

$$R = \frac{V_0}{I_0} \tag{10}$$

In the converter design the switching frequency is taken as 100KHz with Imin as 0.06A. The value of inductance L calculated in (11) is 22.5mH.

$$L = V_{in}\frac{D}{\frac{2I_0}{1-D} - 2I_{min}f} \tag{11}$$

The computed value of capacitance C in (12) is 6.81µF.

$$C = \frac{DV_{in}}{8rV_0Lf^2} \tag{12}$$

The simulation circuit of flyback converter using PSIM tool is shown in Figure 6.

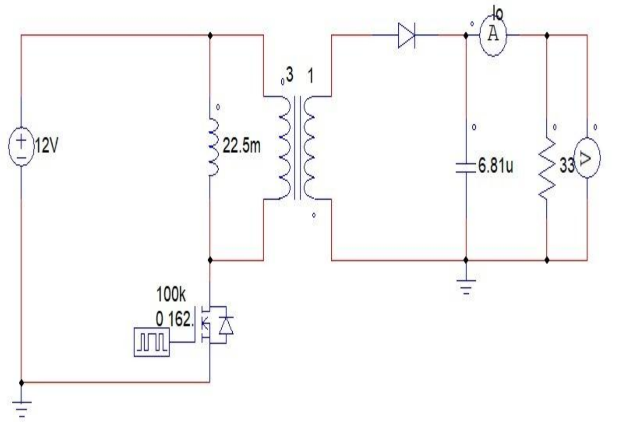

Fig -6: Flyback converter

The schematic of the flyback converter comprises of a MOSFET, which acts like a switch, a transformer, a diode operating complementarily to MOSFET, an inductor and a capacitor. The pulse generator module is used for the control of duty cycle of the circuit by turning on and off the MOSFET switch. The converter circuit components are positioned to achieve the desired output condition of 3.3V output voltage and 0.1A current.

The waveforms generated by the designed flyback converter are shown below. The figure 7 depicts the waveform of 3.3V output voltage obtained by the designed converter
circuit.

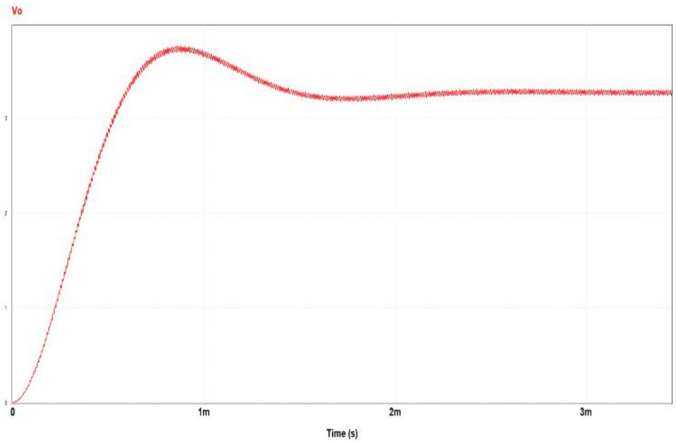

Fig -7: Output Voltage Waveform

The output current of 0.1A waveform is as shown in Figure 8.

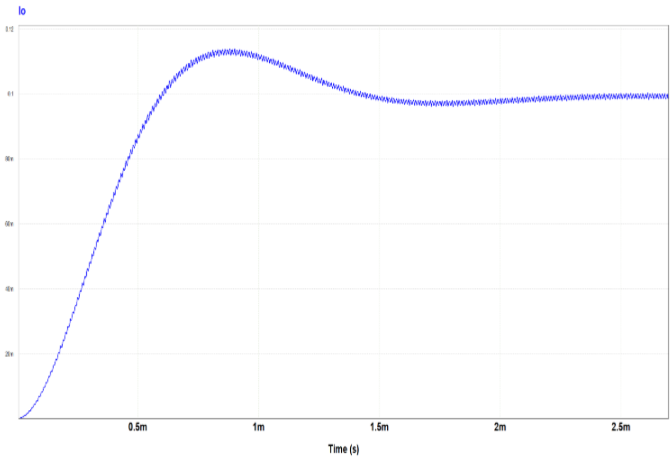

Fig -8: Output Current Waveform

4. CONCLUSION

An NFC system design has been proposed, which incorporates an antenna operating at 13.56MHz. A rectangular antenna with inductance of 1.2837µH has been designed. The power supply unit of the proposed NFC system incorporated a flyback converter. The flyback converter design is presented and simulated in PSIM tool to obtain an output of 3.3V with output current 0.1A from supply of 12V. The switch in the flyback converter conducts for 0.45 duty ratio. The flyback converter is a viable choice for use cases requiring low voltage and power such as a portable device. The credit payments, data transfer, access control and vending machines are the various use cases of the proposed NFC system.

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