A low frequency RFID temperature data logger

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Abstract – **In this paper, the design and implementation of an RFID-like temperature data-logger prototype, based on ISO11784/11785 standard is presented. It was designed to communicate through an inductive coupling with a 134.2 kHz ISO compliant reader, similar to those regularly employed for livestock traceability. It uses a low power – low cost microcontroller and several discrete circuit elements for the activation signal detection, signal transmission and temperature measurement.**

I. INTRODUCTION

SEVERAL industrial applications, especially in the agribusiness field, require a reliable tracking of temperatures. In any supply chain involving the movement of perishable or temperature sensitive articles such as food or medicines for example, it is important (and increasingly being regulated) to have a precise temperature tracking of the goods in transit. But also in environmental monitor for precision agriculture, or kiln drying of wood among other processes, there exist a need for low-cost temperature tracking in a large amount of nodes. Several commercial products exist for the task, using the so called temperature data logger devices which periodically measure the temperature, store the data and easily transmit the information to a computer [1]-[5]. For a practical use the communication must be fast, and in some applications it is preferable to be of no physical contact between the two devices. A survey of products in the market reveals most of them have an elevated cost to be massively adopted in the traceability of food or the agribusiness industry. Besides, some of them involve a physical connection between the reader and the transponder, which means an impractical utilization. However, the trend exists to develop simple, contactless, ultra low-cost temperature loggers to monitor and track assets, goods and environment, especially in the agribusiness industry.

It should be mentioned that currently the cost of a microcontroller to measure temperature is only a few cents, and the limit to develop a data logger is the wireless communication of the data. In this work, a low frequency RFID approach is proposed because of two reasons: first because its simplicity enables developing low-cost applications, and secondly because 134.2 KHz RFID protocol and devices are being incorporated in our country for the livestock traceability.

Radio Frequency Identification (RFID) is a widely used method to track pieces, lots, animals, in diverse production systems [6][7][8]. It is normally based in a contactless data transfer between a transponder (Tag) capable to store information up to several Kbytes, and a reader unit. The Tag consists on an integrated circuit, an antenna and a few discrete components, hermetically sealed in a plastic piece. To achieve minimum cost tags, its supply energy is usually obtained from the reader by means of a coupling coil or an antenna. In addition, there are several frequency bands and standards for the communication protocol [8]. Battery powered tags are known as 'active' ones; they are much more expensive because of the battery and the complexity necessary to implement a communication protocol.

A. *ISO 11784/11785 standard*

According to the ISO11784/11785 standard [9], adopted also by ICAR [10], cattle identification tags work at 134.2 kHz frequency. This standard was also adopted by most national regulations about RFID for livestock traceability. At such low frequency, instead of RF waves, the communication link should be better described as an inductive coupling phenomenon between the reader and transponder antennas [11]. Two different communication protocols are defined in ISO11784/11785, for two different types of passive tag: half duplex (HDX) and full duplex (FDX). In this work an active tag was implemented using ISO HDX protocol, since according to a previous work it was shown to be a more robust and simple to tune circuit [11]. The reading process for an HDX Tag starts when the reader creates a 134.2 kHz activation field during a 50 ms activation period. After it finishes, the reader waits for the response of a Tag during 3 ms. If no HDX message header is received, the activation shall be resumed. If a valid header is received within the 3 ms period, the rest of the message is decoded during a 20 ms maximum period. The activation is resumed if it is not received a valid message including a valid CRC. The data from the tag is FSK modulated at 124.2 kHz for a digital '1', and 134.2 kHz for a digital '0', at approximately 8 Kbits/s. At least, every HDX message starts with a '01111110' header, contains 64 bits of data and 16 bits for the CRC check [9].

B. *The proposed device*

The prototype to be presented is a proof of concept for the strategy; the long term objective is to integrate all the system in a single ASIC except for the battery, antenna coil, and decoupling capacitors. The idea is to provide a wireless RIFD data transfer to a temperature logger, with a minimum cost for the link. The prototype was designed to measure and

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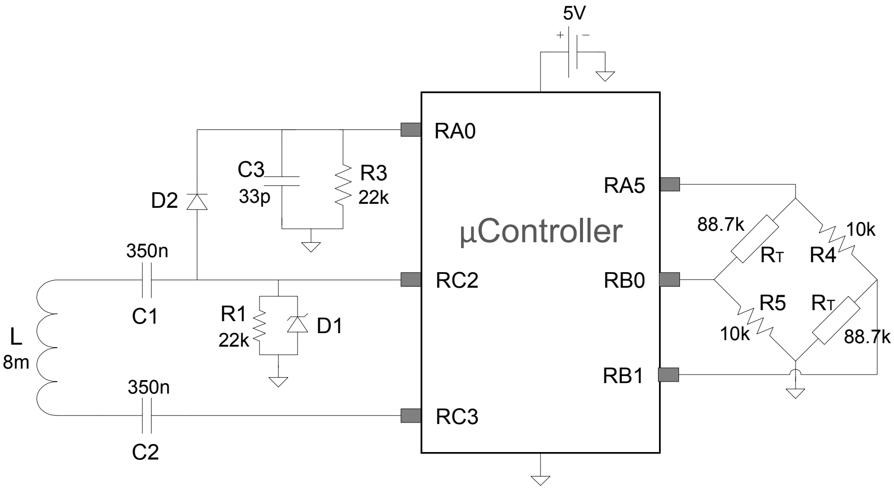

Figure 1. Complete circuit diagram of the developed prototype.

store the temperature in its surroundings between fixed successive time intervals, and transmitting all the data to a reader unit through an ISO compatible HDX RFID link. Only a PIC16F886 microcontroller was used with the addition of several discrete components, including two NTC thermistors for temperature measuring and a coil antenna to establish the inductive coupling. A photograph of the developed prototype is shown in Figure 2, while the complete circuit diagram is shown in Figure 1. The same sub-circuit on left side of Figure 1 is used both for transmission and reception, changing the state of the nodes connected to the microcontroller's pins.

II. ACTIVE RFID TEMPERATURE DATA-LOGGER

The device periodically measures its surrounding temperature and stores the information in the microcontroller's EEPROM. When not measuring, it enters in reception mode, waiting for the presence of a reader within its active range. 1 ms after an activation signal is detected, it automatically responds with the FSK modulated message containing the stored data. Every transmitted bit lasts 16 cycles of the carrier signal of 124.2 kHz or 134.2 kHz, depending if it is a binary 1 or a binary 0.

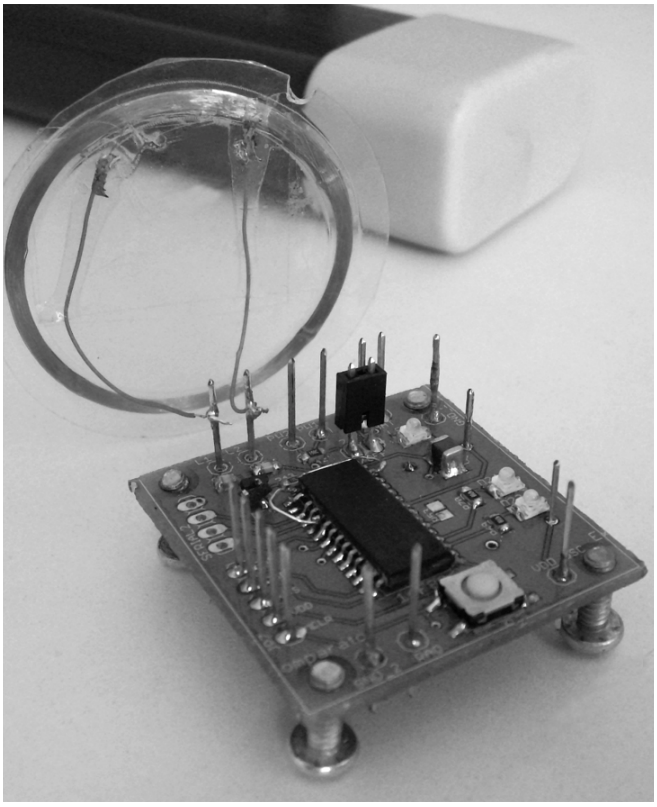

Figure 2. Photograph of the developed prototype. Behind it, the reader unit.

A. *Temperature measurement*

A Wheatstone bridge circuit with two 10 kΩ NTC thermistors was used for the temperature measurement (right side of Figure 1). The temperature operating range of the thermistors is -40ºC to +125ºC. The bridge is powered when microcontroller's pin RA5 is set high, and the imbalance caused by changes in the environment's temperature is A/D converted trough pins RB0 and RB1, and stored in memory.

B. *Activation signal detection circuit*

The activation signal from a reader is demodulated by means of a diode and an RC parallel, and detected with a microcontroller's internal comparator. The circuit on the left side of **Figure 3**Figure 1 enters in detection mode when the microcontroller's pins RA0 and RC2 are set as high-Z inputs and pin RC3 is grounded. The reception equivalent circuit is shown in Figure 3. The 134.2 kHz activation signal appears in terminals of the coil L during the 50 ms activation period. This signal is rectified by the schottky diode D_2 and low-pass filtered by the R_3C_3 parallel, resulting at pin RA0 a pulse signal as shown in Figure 4. The peak value of this pulse is A/D converted and compared to a reference value V_{REF}, which determines whether an activation signal is taking place or not. Zener diode D_1 is used to protect the microcontroller from high voltages that may be induced by large magnetic fields close to the antenna coil, while R_1 is used to provide a path for the current during half the period the signal is rectified by D_2.

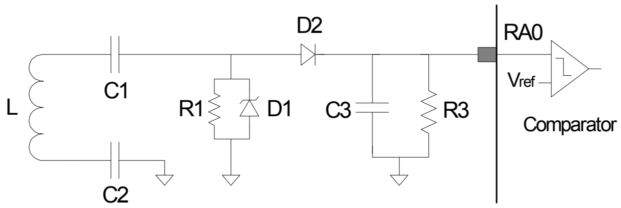

Figure 3. Activation signal reception circuit.

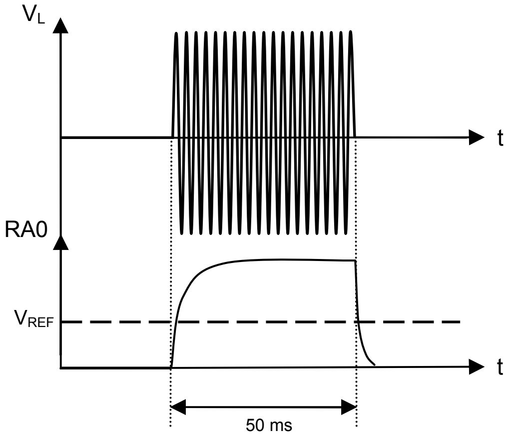

Figure 4. A 50 ms activation signal.

C. *Data transmission circuit*

Setting pin RA0 as high-Z input, and pins RC3 and RC2 as outputs in Figure 1, the system enters in transmission mode. Its equivalent circuit is shown in Figure 5. No current passes through D1 since microcontroller's output voltage does not exceed the diode's breakdown voltage; however, a small additional current consumption occurs due to R1 when transmitting (Figure 1). The message is transmitted in series using FSK modulation, alternatively changing the state of RC3 and RC2 pins between high and low state, either at 134.2 kHz or 124.2 kHz. The frequency determines whether a binary 1 or a binary 0 is being transmitted. The coil used was obtained from a disassembled RFID Tag. Capacitors C_1 and C_2 were chosen so that the resonance frequency of the circuit is close to the middle of the FSK transmission band, in order to maximize the current through the circuit and the transmission distance range.

D. *Power consumption*

Temperature log does require a permanent power supply, so the energy is provided by a 3.3 V lithium primary battery. To enable the use of very low cost batteries, it is necessary to minimize current consumption and to avoid large current consumption peaks.

A high current is demanded from the battery when the microcontroller's comparator is turned on, to compare the activation signal peak value to the reference voltage. Thus, when the device enters reception mode after completion of the temperature measurement, the reception circuit is not continuously waiting for the presence of an activation signal. Instead, it makes an input comparison every 20 ms, and after that it is turned off. Also the Wheatstone bridge used for temperature measuring is turned off when not used, setting to low microcontroller's pin RA5 (Figure 1). In addition, the microcontroller enters sleep mode during the time no temperature measurements, reception or transmission take place.

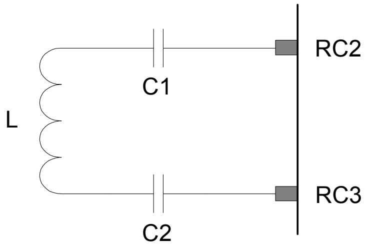

Figure 5. Transmission circuit.

III. MEASUREMENTS

The developed prototype was tested. It properly measured temperature, and communicate with a 134.2 kHz standard reader unit with a reliable link well above 20cm distance. For all the measures an ISO compliant reader was used [11]. The reader first sends the activation field and waits for a tag reply.

A. *Activation signal*

In Figure 6 is shown a 134.2 kHz activation signal coming from the reader measured at the transponder coil's terminals, and then rectified and low-pass filtered by the reception circuit, measured at microcontroller's pin RA0 (Figure 1). It lasts 50 ms; and after 3 ms of no reply the activation signal is resumed.

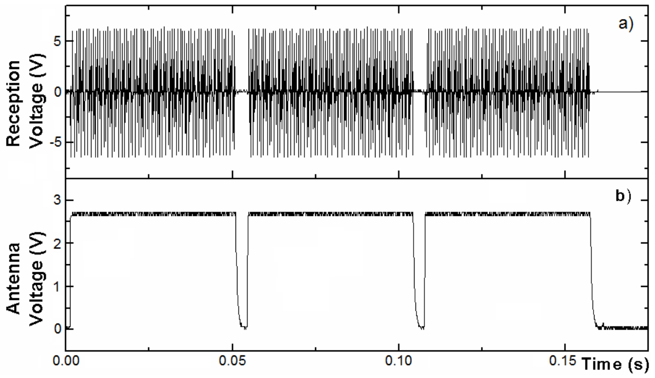

Figure 6. Activation signal measured a) at coil's terminals, b) at microcontroller's input. After 3 ms of no Tag's response, the activation signal is resumed.

B. *Reception circuit range*

Varying the distance between the reader and the Tag, the amplitude of the filtered activation signal at microcontroller's pin RA0 behaves as shown in Figure 7. In order to protect the integrity of the microcontroller, this amplitude is limited for the Zener diode D_1 breakdown voltage (Figure 1).

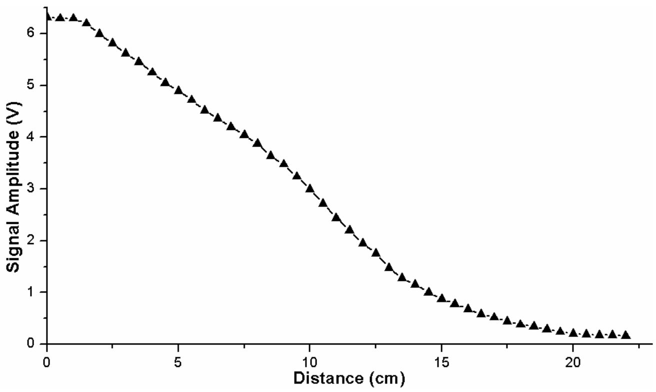

Figure 7. Amplitude of the received activation signal at the input RA0, varying the distance between the Tag and the reader.

C. *HDX message transmission*

In Figure 8, an HDX message read from the reader while being sent by the Tag is shown. The first graph corresponds to the voltage from one terminal of the Tag's antenna referred to ground, while the second to the decoded bits read from an internal node of the reader unit. The amplitude of the signal at the Tag's antenna varies depending whether is being transmitted a digital '0' or '1' due to the inexact tuning of the LC pair.

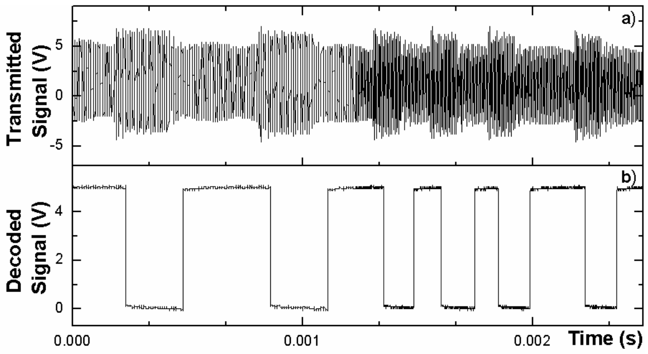

Figure 8. Transmitted signal a) at the Tag's antenna, b) decoded by the reader.

IV. CONCLUSIONS

The design and operation of an RFID temperature logger prototype compatible with ISO11784/11785 data transmission standards has been presented. It was implemented using only low-cost, of the shelve circuit elements. This work represents a first approach to a future integration of the whole circuit, except for the battery, antenna and decoupling capacitors. The low-speed communication link reached an acceptable reading range, while maintaining a low current consumption compatible with commercial low cost batteries. Electrical specifications of the developed device are found in Table 1**Table 1.**

Table 1

ELECTRICAL SPECIFICATIONS

Current consumption	
Waiting for an activation signal	8.15 mA
During communication	9.10 mA
While measuring temperature	8.30 mA
Average current consumption*	~12.50 µAh
Communication distance	~ 25 cm

*Average current consumption is estimated considering ten temperature measurements and one data transmission every five hours.

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