

# Contactless power transfer application for devices identification

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**Abstract.** This paper deals with the problem of non-contact power transfer systems to identify components based on infrared signatures reading. This approach enables the distinction of a larger number of different devices situated in a relatively small area, compared to RFID technology. Moreover, the presented infrared contactless identification is resilient to natural environmental infrared perturbations. The advantages of this approach are demonstrated in a simple use-case: continuously identifying low consumption chess pieces on a custom chessboard. This approach can be further instantiated for high consumption devices such as electrically charging small autonomous guided vehicles.

## Introduction

The idea of automatic identification came with the development of IoT systems and was improved over time. At present, we have hundreds of types of identification systems, most of them based on bar / QR code [1], RFID (radar, IFF for long range [2]) and NFC (for short range) [3] IRID (for short and medium range) . If in case of barcode and QR code are not required to power supply the tags, for RFID and NFC, this is a mandatory condition. On the other hand, barcodes and QRs are impossible to secure, [4] which is why RFID and NFC are used in applications where security is important.

The Industry 4.0 concept has brought the need for diversification of tagging process and improvement of the hardware systems for the protocols used to identify the component parts of a product.

The simplest RFIDs are passive. Instead of containing batteries, they operate entirely by responding to the radio waves received from the scanner or transmitter. There is enough energy in these radio waves to activate the RFID chip. Passive labels send and receive signals only a few centimeters, but no more [5].

NFC technology is the safest because the protocol is software secured, data transfer is improved and is immune to known attack methods [6].

IRID technology is proposed but not large scale implemented. It is a promising alternative for radio frequency identification system in order to provide powerful solutions in many situations, i.e., to overcome radio frequency interference [7].

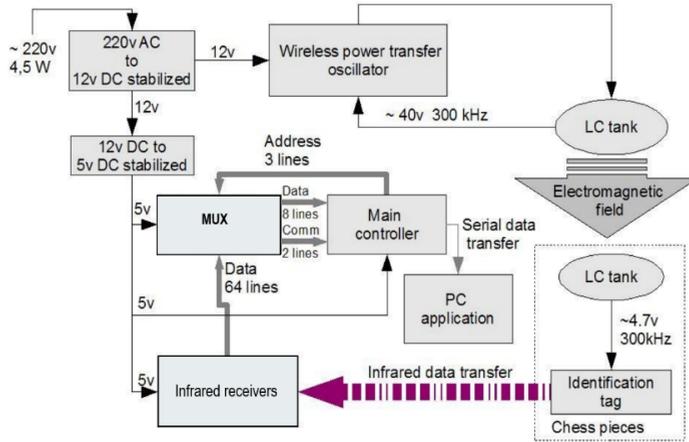
To prove the IRID concept, we build a standard size chess board, that can power the identification tags integrated into chess pieces through contactless power transfer system.

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For the communication between chess pieces and chess board we use infrared transmission, using the simplest possible protocol Fig. 1.

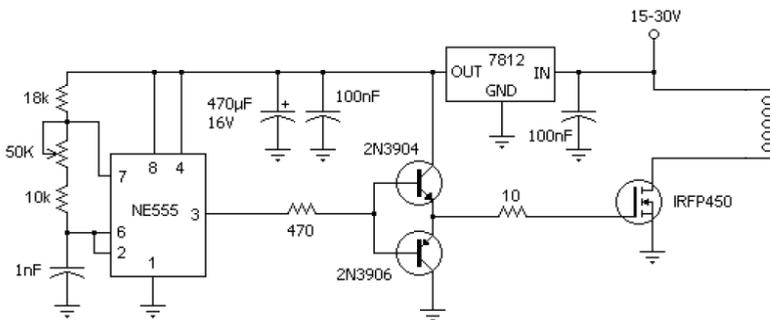
This system is atypical because the generator antenna is formed from a matrix of 64 identical coils being connected 8 parallel x 8 series. The oscillator is a simple one with few pieces, easy to build and easy to use. Due to the fact that the oscillator is fly-back, it is highly efficient, being self-resonant. After its construction and testing, the contactless transmission system has been confirmed to be safe and efficient.



**Fig. 1.** The overview of physical and logical structure of the chess board.

## 1 Experimental methodology

To demonstrate the operation of such a system, it was initially build and simulated in Matlab, Simulink), after that a single coil oscillator was physically built. Prior to this oscillator model we tested several models of oscillators with external synchronization Fig. 2.



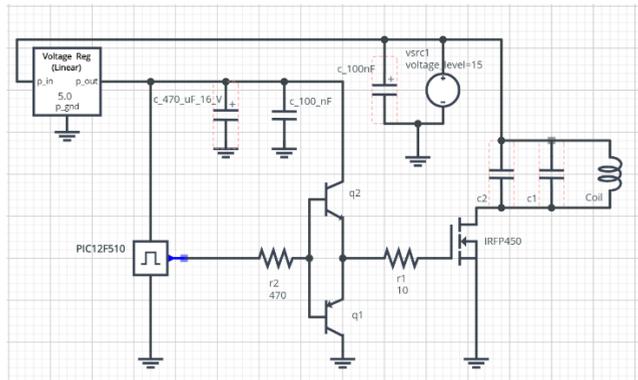
**Fig. 2.** Initial version of oscillator based an LM555 timer.

The generated rectangular pulses control the MOSFET transistor, through a pair of transistor. To transform a rectangular signal to a sinusoidal one a frequency tunable filter is necessary. Efficiency of the oscillator is quite low because MOSFET transistor had only two states: open and close. The main problem was that the oscillator frequency could not set too high. Duty cycle at high frequencies could not be brought lower than 5% because LM555 timer operation became unstable. At the frequency of 100 kHz and 6% duty cycle the oscillator consumed 80 W.

To have better control over the frequency and duty cycle was chosen after that, a signal generator based on the PIC12F510 microcontroller *Fig. 3*.

This microcontroller was able to better control the duty cycle and frequency because those were digitally set. New problems appeared when LC tank entered into resonance, at short pulses, the autoinduction phenomenon was present. Dirac pulses generated when switching MOSFET transistor lead to its destruction because of overvoltage. This version of the oscillator consumes 65 W.

We initially proposed using 64 oscillators driven by a single microcontroller. The disadvantage of this structure it was difficulty to adjust the frequency of the external clock. Any change in the magnetic permeability of the environment near the LC tank ran into a desynchronization. For example, if the circuit resonated with a single piece on the chess board, when all the pieces were placed on the board, the whole system was desynchronized and the energy transfer between the board and chess pieces was drastically reduced.



**Fig. 3.** Second version of oscillator.

## 2 Results

Because the external oscillators proved to be difficult to implement, I have recourse to the use of an analogical flyback oscillator that has proved to be sufficiently stable and safe to operate.

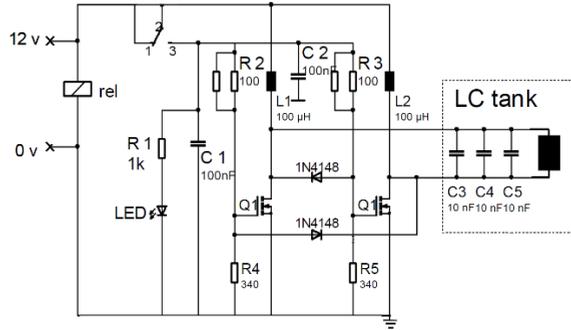
### 2.1 Contactless power transfer generator

To convert the power from the 12 v DC power source, into high frequency AC was used an analogical, half bridge, self resonant oscillator. It worked on two power MOSFET transistors Q1 and Q2, model IRFP450 N channel, two compensation coils RFC, two fast diodes 1N4148 for transistors control. This oscillator was perfectly symmetrical and produced pure sine wave *Fig. 4*.

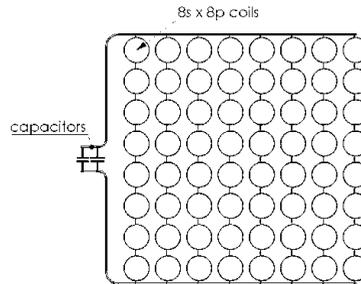
The LC tank was composed of 64 coils, one for each of the 64 squares of the chess board. The 64 coils were connected 8s x 8p, each coil having 12 turns of copper wire

winding with the section of 0.7 mm. To reduce the unwanted effects (radio emission) of high frequency electromagnetic field, the coils were connected in antiphase, so the magnetic field was closing from a coil to another neighbor coil.

It has been experimentally determined that this configuration leads to a reduction of up to 25% of the contactless energy consumption compared to the configuration with the phase connected coils. For easy tuning, but also for the current distribution were used many polyester capacitors connected in parallel Fig. 5.



**Fig. 4.** Flyback oscillator schematics.



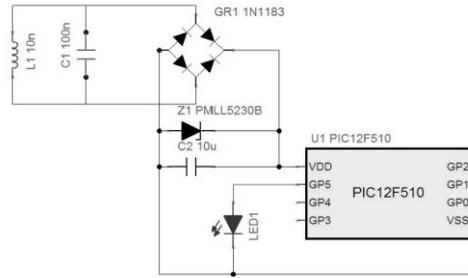
**Fig. 5.** Graphical representation of LC tank.

## 2.2 Contactless power transfer receiver

We chose to use an active identifier, with infrared response, based on (PIC12F510) MCU from Microchip. For this reason electronic ID system requires a power source. Using rechargeable batteries suppose a complicated system and extra costs of use.

The main advantage of contactless receiver is simplicity to use and provides a constant supply voltage for identifiers, situated in the chess pieces. As power source was used an LC system consisting of inductor (L1), copper wire of 0.4 mm section, with 30 turns, and capacitor (C1), with the resonance frequency of 300 kHz, ( Fig. 6)

This frequency has been chosen because it has been experimentally demonstrated that the electronic circuits situated in the chess board have been disturbed beyond the permissible limit.

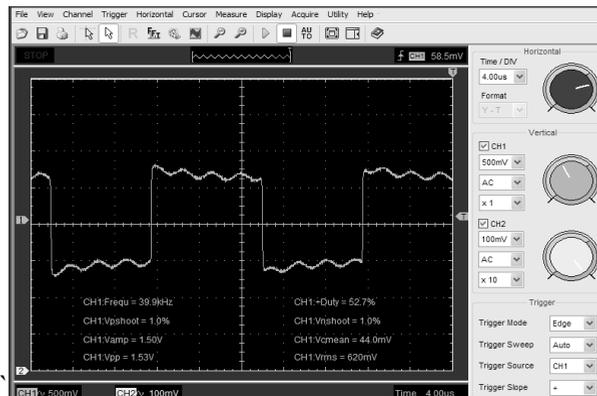


**Fig. 6.** The infrared identifier tag schematics.

The frequency was chosen after several attempts. Restrictions came from the dimension of the coil. A low frequency involved a coil too large. A high frequency decreased coil size, but was much difficult to tuning the system and keep it tuned. Voltage from the LC filter was alternative with amplitude of 16 V, without a consumer at the distance between coils of 10 mm. To power the infrared identifier, the sinusoidal voltage must be rectified and filtered. That was done by using a fast bridge rectifier (GR1). For filtration and energy storage, a 10µF 25 V electrolytic capacitor (C2) was connected. Also the zener diode (Z1) acts as voltage limiter. Output pin of MCU, GP5, was connected at the LED1 (CQY37N), with infrared wavelength of 950 nm, used as transmitter.

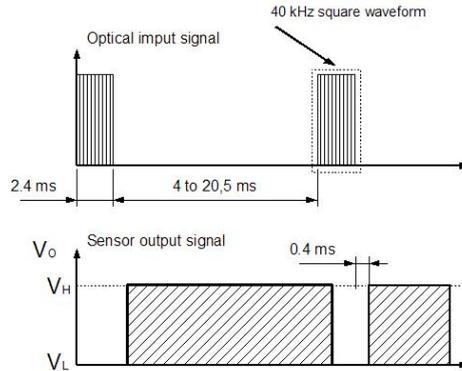
### 2.3 Working principle of the chess piece ID

Once with putting the chess piece on the chessboard, LC filter located in bottom of the chess piece will resonate with the contactless system located in the chess board.



**Fig. 7.** The shape of the supply voltage for infrared LED.

Alternating voltage generated by LC filter will be rectified, by the rectifier bridge, output voltage being 4 volts DC. If it is powered, the microcontroller will reset and begin running the program stored in it. In this case it generates PWM pulses with 50% duty cycle and frequency of 40 kHz, according to the protocol requested by the infrared receiver. Because in this case infrared LED is a large consumer it was necessary to use a capacitor, for storage energy, produced by the LC tank while the LED is off. For a better understanding of the phenomenon, shape of the supply voltage of the LED is shown in Fig. 7.



**Fig. 8.** Effects of the optical signal input at the infrared sensor output.

Here we can clearly see the effect of capacitor energy storage but also the effect of wireless power supply. The infrared receiver switches "low" only in the presence of a signal frequency of 40 kHz. The infrared signal absence leads to switch in "high" state. The piece type is encoded according to how long the sensor has output in the "high" Fig. 8.

## 2.4 Reading chess board based on microcontroller

### About ECIO28P

ECIO28P is a development board based on microcontroller PIC18F2455. This way of implementation was chosen because the controller is fast (60 MHz), reliable, has USB 2.0 on chip and preprogrammed bootloader for rapid development of project. Programming was done in Flowcode, a graphical programming mode.

### Reading chess board protocol

UML representation of the protocol

Fig. 9 is implemented in the software, that runs on the main controller ECIO28P.

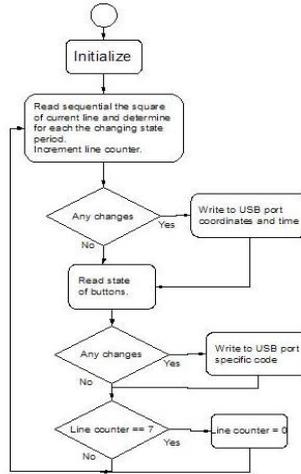
- It starts a timer that increments a counter 2930 times per second.
- The address value is put on the address lines.
- The lines of data corresponding to the pointed square of the board is read in a loop.
- For pointed square of chess board, the time elapsed between the rising edge and falling edge is calculated according to value of counter.
- A string that contains the coordinates of the square and the value of counter corresponding to the square selected is sent on the USB port.
- Address value is incremented.
- The button state is read after each complete reading chess board. Each of the two buttons has a state variable and this is sent at press event only.

## 2.5 Development of computer application

Graphics application is developed in C #, in the Microsoft Visual Studio developing environment. For displaying configuration of the chess board a dynamic library was used. Graphic update is done in the timer event at 100 ms., only if configuration changes in the chess board appear.

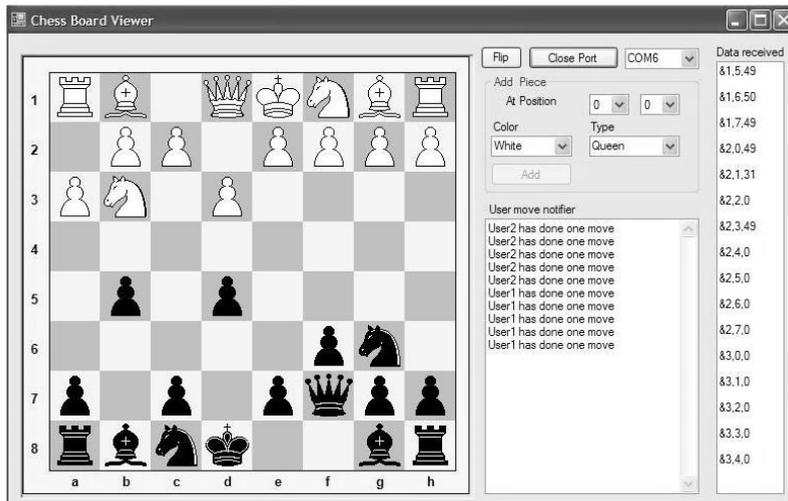
### Graphic refresh

The graphical interface Fig. 10 is updated using a timer. Updating is done only if there is any change in the configuration of the chess board. For this, the board configuration is stored in an array.



**Fig. 9.** The protocol for reading the type of each chess pieces

Each address-value pair is compared with existing date in the matrix at the same address. If this value is equal no change occurs and the graphic display does not refresh. If it is not equal, then the graphics representation refreshes and also the digital model of the chess board.



**Fig. 10.** Graphic interface for computer software.

### 3 Conclusions

The installation is working as expected. The signals are not affected by the electromagnetic disturbances produced by the wireless power supply system. Infrared receivers have increased immunity to ambient light even with chess plate exposed to direct sunlight due to the filter used.

#### *Advantages*

Low development and deployment costs due to the simplicity of the electronic circuits used.

Reliability in operation tested in more than 300 hours of continuous operation.

Calculated scalability up to 36x36 squares for current coil sizes. The limitation is due to the coil desynchronization, the occurrence of large currents in the feed lines, and lose efficiency.

Higher power up to several hundred watts if the number of coils is reduced. Low power consumption if the system works in resonance.

#### ***Disadvantages***

Scalability limited by coil geometry, oscillation frequency, and oscillator end stage power.

Due to reduced frequency (300kHz) power transmission is done over short distances (20mm).

For higher powers and frequencies, the effects of Eddy currents resulting in excessive heating of electro-conductive and ferromagnetic materials must be taken into account.

Also, the increase in current and frequency through the coil conductor increases the skin effect, which decrease the efficiency. A solution to this problem is the use of a multifilament conductor.

For the next project we are going to develop a contactless system for higher power consuming devices (approx. 60w), with higher frequency (1 MHz) for greater distance (150 mm).

Acknowledgements: This work is supported by the DiFiCIL project (contract no. 69/08.09.2016, ID P\_37\_771, web: <http://dificil.grants.ulbsibiu.ro>), co-funded by ERDF through the Competitiveness Operational Programme 2014-2020.

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