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Chess Pieces Detecting

Abstract

The project attempts to develop a method for detecting positions and types of chess pieces on a chessboard. Using RFID for such tasks is a tempting solution but it is expensive and limits the detection frequency. The proposed approach is to build a resonant LC tag into each piece and to use a matrix of coils under chessboard fields to detect the resonant frequencies. So far a prototype board have been developed and tested using small LC circuits. The tests yielded positive results, allowing to detect and distinguish between the tags.

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1 Introduction

In the KoNaR Student Interest Group, The Robotic Chessboard [2] has been constructed. It allows human players to enter movement commands using PC application or voice commands. Although these methods work well, they are quite inconvenient. Ideally, one would like to move pieces by hand, just as in regular chess games. This project attempts to solve this problem by providing a method for detecting chess piece position and identity using resonant LC tags built into each piece.

2 Proposed solution

Several available solutions for recognizing chess pieces were considered.

One solution would be to use RFID tags built into each chess piece and a receiver under each field. Such a method would be robust and easy to implement as RFID is widely available. The main problem with RFID is the cost of such tags for a whole chessboard (64 fields and 32 chess pieces). Second downside is that RFID communication is relatively slow due to protocol overhead.

Considering problems of RFID usage, a solution based on purely analog pieces recognition has been chosen. By placing a transmitting coil under each field and building small passive LC (coil-capacitor) circuits into pieces it is possible to detect figure presence and measure its identity by finding resonant frequency of the circuit. This is possible due to induction of current in the passive LC circuit which is amplified near the resonant frequency.

To detect chess pieces on the whole field the coils under chessboard can be arranged into a grid and multiplexed. For each coil a frequency-sweeping signal (chirp) would be used to modulate the coil. Simultaneously the response would be demodulated to retrieve the modulation due to resonance in the LC tag. In case of no tag, the resulting signal would be constant and when a tag is above a field, the signal should have a peak at the moment when chirp signal's instantaneous frequency is equal to tag's resonant frequency.

The frequency of a tag can be then easily calculated using the following formula:

$$f_{TAG} = \frac{\Delta t_{TAG} \left(f_{MAX} - f_{MIN} \right)}{T_{CHIRP}} + f_{MIN} \tag{1}$$

where T_{CHIRP} is the time of a full frequency sweep, Δt_{TAG} is the time at which the peek voltage is registered (relative to T_{CHIRP}) and f_{MIN}, f_{MAX} denote the range of chirp frequencies.

3 Circuit design

Based on the measurement technique an appropriate circuit have been designed. A block diagram of the circuit can be seen in the figure 1. The circuit has been divided into the following sections:

- Triangle generator – the generated triangular signal serves as an input voltage to the voltage controlled oscillator and concurrently as a synchronizing signal for the microcontroller.
- Voltage controlled oscillator – to generate chirp, an oscillator should have capability to change the frequency of the generated signal. In this case, the frequency directly depends on the input voltage.

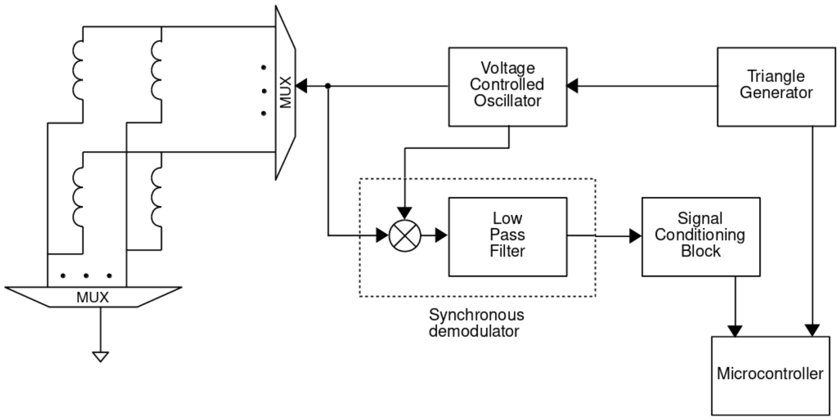


Figure 1: Electronic circuit block diagram.

- Coils matrix with multiplexers – coils should be placed underneath each field and only one coil should broadcast at the specific time. Using multiplexers allows microcontroller to choose which coil has to be operative.
- Synchronous demodulator with signal conditioning – an amplitude of the chirp is modulated by a coupled coil in the LC tag while it is resonating. The task of this module is to extract information about the frequency of occurring resonant.
- Microcontroller unit – gaining all data, the microcontroller is able to detect presence and kind of the LC tag. After collecting data from whole board, one can send this information to the chessboard controller.

The full circuit for a prototype board have been designed along with PCB layout using *KiCad* software and the board have been ordered and soldered.

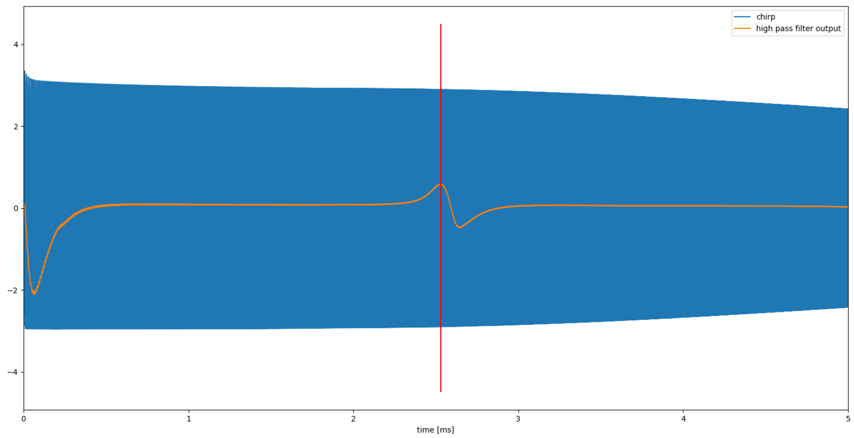
4 Electrical simulation

Before the circuit have been implemented in hardware a simulation in *LTSpice* have been created. This allowed to check the design correctness and detect multiple mistakes early. Detection results can be seen in the figure 2.

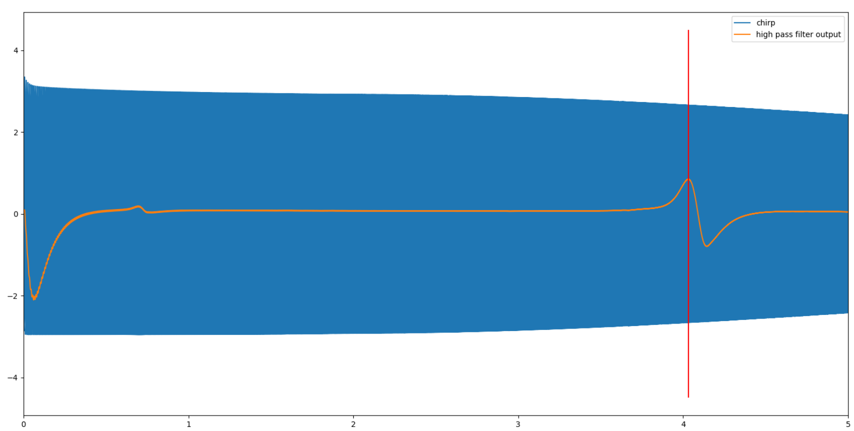
According to the equation 1, the following parameters have been used in the simulation:

- $f_{MIN} = 100kHz$,
- $f_{MAX} = 600kHz$,
- $T_{CHIRP} = 5ms$.

In the figure 2a, the peak occurs after $2.5ms$ (so $\Delta t = 2.5ms$). Computing f_{TAG} gives acceptable accuracy, similarly in the other case (figure 2b).



(a) The tag's resonant frequency is equal to 350kHz



(b) The tag's resonant frequency is equal to 500kHz

Figure 2: Detection results in the simulation. Blue line is the chirp and orange line is the resulting demodulated signal. The peek is marked by the red vertical line.

(a) Tag with 277.5 kHz frequency

(b) Tag with 263.9 kHz frequency

Figure 3: Oscilloscope view of the detection results obtained using the developed prototype board. Yellow line is the sawtooth signal that determines chirp's instantaneous frequency and blue line is the final detection result.

5 Prototype tests

To test the selected method a prototype board have been created. The board contains all the circuits necessary for measurements, excluding multiplexers and the matrix of coils. Instead, a single coil has been used to focus on the detection task.

The circuit have been tested in order to determine consistency between assumed and real parameters of chirp signal. Due to component inaccuracy and limitations the final frequency range of the signal was $f_{MIN} = 152kHz$, $f_{MAX} = 463kHz$. This range, although much smaller than it was assumed in the simulation, appeared to be sufficient for the required number of distinct tag frequencies.

For the resonant tags, small circuit consisting of an inductor and a capacitor have been constructed. The values of the components have been chosen such that each tag had a different frequency in the range of the circuit. The following tags have been used:

- 232.5 kHz
- 263.9 kHz
- 277.5 kHz
- 405.2 kHz

Results of the tests performed using the prototype board and resonant tags can be seen in the figure 3. It can be observed that the difference between the signals obtained from the tags is high enough to be reliably detected using microcontroller, even though the tags' resonant frequencies were very close (frequency of the tag from the figure 3a has been marked with an oscilloscope cursor in both figures).

The wide crest of the signal at the lower frequency range is an unwanted noise. It shrinks the range of frequencies that can be used for pieces detection. This artifact probably corresponds to non-ideal filtering of the chirp signal but it yet has to be investigated.

It should be noted that the peeks of the signal corresponding to resonant frequencies become logarithmically wider with increasing chirp frequencies. This means that the gaps between tag frequencies have to be higher the higher the resonant frequency of a tag is.

6 Future work

So far, many goals have been achieved, these are:

- building pieces substitution using simple LC tags,
- distinguishing LC tags based on its corresponding resonant frequency,
- achieving reasonable measurement frequency for a single field equal to $200kHz$.

The authors are conscious of tasks, which they will have to face. Further development of the project includes:

- building-in the tags into chess pieces,
- creating coils matrix at printed circuit board,
- integrate the solution with the Robotic Chessboard [2].

7 Conclusion

Chosen measurement method has turned out to be well suited for the given issue. It gives satisfactory accuracy and measurement resolution. Moreover, the method is significantly faster than the RFID. In general, the method can be perceived as worth to use in the given case, despite difficulties met during prototyping.

Even though the created device works well, it is not ready to be implement in the Robotic Chessboard yet. To consider the device as ready-to-implement, it is necessary to add support for measurements on a matrix of coils and to establish communication with the chessboard controller.

This paper should be treated as a proof of the concept, therefore the results obtained can be considered satisfactory. Although chess pieces with built-in tags have not yet been constructed and tested, the consistency between simulation and experiment results proves that the method can be used for the selected task.

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