# Implementation of Kalmus guidance method for robot navigation

By Kostiantyn Gorbatov

## Introduction

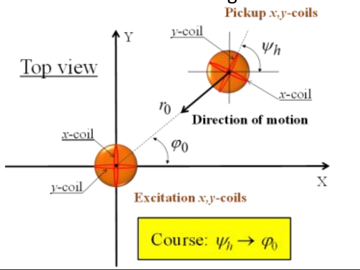
The principle of operation of any position and orientation inductive sensor is based on a detailed mapping of quasistatic magnetic fields induced in free space by a set of miniature coils (or loops) called “magnetic dipoles”. Depending on task, a maximum of 3 coils can be used to produce the required magnetic pattern.
Each coil is energised by a sinusoidal current in the kHz range or a pulse sequence: independently or with a certain phase. The quasistatic excitation means that the electromagnetic wavelength in free space is much larger than any dimensions in the system, including the coil diameters and the distance between the source of magnetic field and the sensor head. The aim is to obtain a unique vector magnetic field (time-dependent) in each coordinate point. Usually, such uniqueness is achieved in a sector (or some sectors) of the coordinate system. The magnetic field in an observation point can be measured by means of a set of miniature coils (or loops) comprising the sensor head which is attached to the tracking object. To recognise the position and orientation of the sensor head, some algorithm has to be proposed that recalculates the magnetic field pattern into the coordinates and the orientational angles. Depending on the design of magnetic source, the characteristics of motion, and the recognition algorithm, the sensor head may also include one, two, or a maximum of three miniature coils in the mutually orthogonal planes

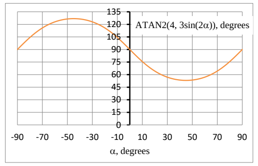
## Objectives

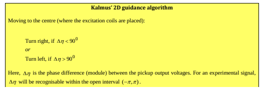
- Development of a low frequency source (KHz range) with two outputs 90 degree shifted to each other to feed excitation coils
- Coil design for excitation and sensor heads
- Development of a low frequency narrow band filter (noise suppression) and a sufficient amplification stage
- Preparation stage where a sinusoidal signal will be translated to digital pulses
- Development of a controller system for translating the voltage phase difference into the motor commands on the driven platform
- Creating or buying appropriate mobile platforms for transmitter and receiver

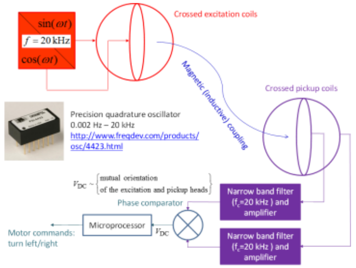
## Principle of operation

The method, first proposed by Henry Kalmus, was originally designed to aid vehicles to follow one another. The two excitation crossed coils are fed from a low frequency source (KHz) in phase quadrature (pi/2-phase shift), as shown in the Figures below. The sensor head placed on a moving platform comprises the two crossed pickup coils and changes its azimuthal orientation with respect to the line of sight between the excitation and sensor heads. It has been shown that the orientation can be determined by measuring the phase difference between the pickup voltages. In robotics, Kalmus’ method could be used to guide a mobile robot or a group of mobile robots.



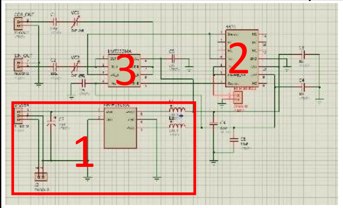




## Implementation

The project consists of two main parts: Transmitter (rc controlled car) and Receiver (Mobile tank)
The schematic for transmitter is implemented on a single circuit:




Excitation circuit schematic

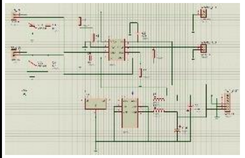
Where:
1 – Voltage converter section
2 - Quadrature oscillator
3 – Buffer and power amplifier
4 – Series LC tuning circuit (for effective power transfer)

Transmitter coil winding in the process. Wooden stick used as a core left until the coil is finished for convenience

Receiver coil ferrite core covered with insulation tape before winding

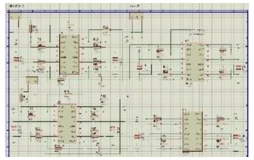
Receiver consists of 4 elements: Input and Power, Filter, Comparator and Controller circuits:

Input and Power circuit



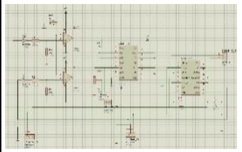
Where:
1 – Voltage converter section
2 – Parallel LC tuning circuit
3 – Buffer and preamplifier

Filter circuit



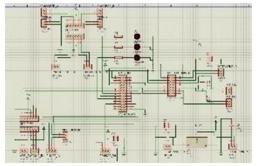
Where:
1 – Narrow bandpass filter for channel 1
2 – Narrow bandpass filter for channel 2

Comparator circuit



Where:
1 – Comparator
2 – Backup circuit

Controller circuit

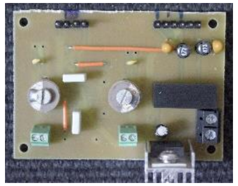


Where:
1 – Voltage converter section
2 – Motor controller
3 – Logic level shifters
4 – DEO-NANO connector

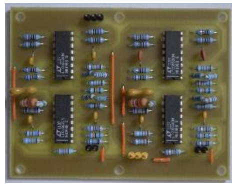
## Results

As a result, all the circuits has been developed and implemented on their respective platforms. Tests has been conducted to assess the performance of each individual circuit before merging them into a single system. Picture of the resultant circuits and platforms are shown below:

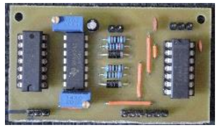
Excitation circuit fully assembled and tested



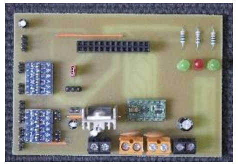
Input and Power circuit fully assembled and tested



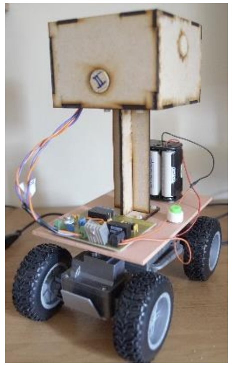
Filter circuit fully assembled and tested



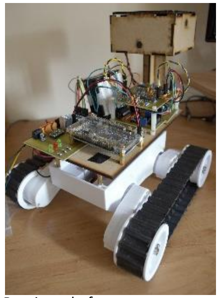
Comparator circuit fully assembled and tested



Controller circuit fully assembled and tested



Excitation platform on a rc controlled car. Box on top is the perpendicular coils with some distance between them to minimise crosstalk



Receiver platform

Transmitter coils

Receiver coils winded on ferrite rods

## Conclusions

The Kalmus’ inductive sensor principle was successfully implemented for a mobile robot using modern components and digital signal processing. Technologies used in the design include a quadrature oscillator chip, operational amplifiers (buffers and amplifiers), analog narrow bandpass filters, comparator, a phase detection algorithm based on FPGA, servomotors and drivers. In the process of implementation, some issues were revealed that need to be addressed in a practical design: more stable oscillators must be used, both tunings should be improved, bandpass should be decreased and amplification increased, motors and electronic circuits must be magnetically shielded, a sensor must be used to avoid a very close proximity between the platform that may result in saturation of some electronic circuits.