UDK621.3:(53+54+621+66), ISSN0352-9045 Informacije MIDEM 31(2001)4, Ljubljana

MULTIDIMENSIONAL CAPACITANCE MEASURING SYSTEM

Vinko Kunc

Faculty of Electrical Engineering, University of Ljubljana, Slovenia

Key words: position measuring, capacitance measuring, multidimensional capacitance measuring, patent applications, CMOS technologies, distance measurements, angular position measuring, linear position measuring, absolute positions, practical results

Abstract: A patent pending principle for multidimensional capacitance sensing system was developed and tested using standard CMOS technology. The described principle is suitable for a number of applications such as absolute angular or linear position , distance measurements, joystick pick-up or any position control in one or more axes. The test chip implementation comprised two dimensional sensing system which was used as absolute angular position sensor . The sensor resolution was limited only by external PCB limitations.

Večdimenzionalni kapacitivni merilni sistem

Ključne besede: merjenje položaja, merjenje kapacitivnosti, merjenje kapacitivnosti večdimenzionalno, prijave patentne, CMOS tehnologije, merjenje razdalj, merjenje položaja kotnega, merjenje položaja linearnega, položaji absolutni, rezultati praktičnii

Izvleček: Članek opisuje patentirani sistem za večdimenzionalno merjenje kapacitivnosti, ki smo ga razvili in preizkusili v standardni CMOS tehnologiji. Opisani sistem je primeren za številne aplikacije, kjer potrebujemo meritev razdalje ali položaja v eni ali več oseh. Testno vezje ki smo ga razvili smo uporabili za realizacijo absolutnega kotnega merilnika. Ta testni sistem je omogočal 8 bitno resulucijo, ki je bila omejena samo z tehnologijo izdelave tiskanega vezja za merilne elektrode.

1. Introduction

A number of capacitance based position measuring systems are known. The vast majority of them is based on differential principle where a ratio of two excitation signals having a 180 degree phase difference is used. Our system solution is unique since it uses two 90 degree shifted signals which are summed and subtracted to generate four excitation signals. These excitation signals are fed to 4 excitation plates on external PCB. The arrangement of these plates defines the position measurement system range (360 degree or any chosen angle).

The sensing plate is located on separate PCB which is placed over the excitation plates PCB and can be freely rotated. The electrical pick up from sensing plate is done using a capacitor between the excitation and sensing PCB. This capacitor can be realised as a metal rim on both plates. Such arrangement requires no wire connection to rotating sensing plate what makes the system very easy to use and robust.

In the chip the signal from sensing electrode is processed to determine the ratio of both excitation signals. Due to the fact that there are four excitation signals we can determine the amplitude and polarity of both basic excitation signals thus knowing the absolute position of the sensing plate in respect to four excitation quadrants.

Fig. 1 presents the basic layout of the two PCBs and the cross-section of mechanical system.

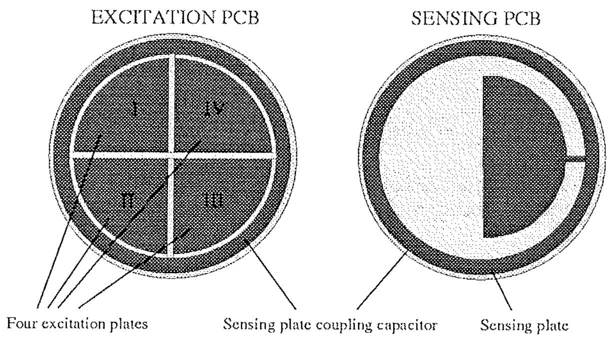

Fig. 1a: PCB layout for absulute 360 degree angle mesurement system

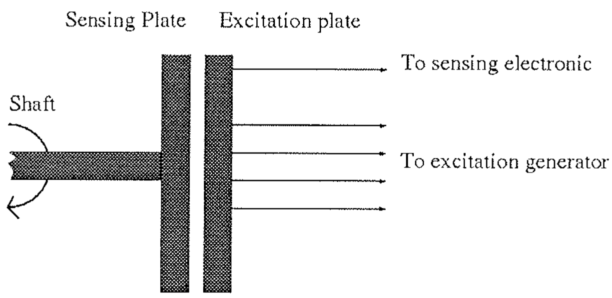

Fig. 1b: Cross-section of mechanical assembly

2. Electrical system

The system electronic can be divided in two main blocks . The excitation signals generation and the sensing signal processing.

The excitation signal generation uses internal RC oscillator to generate the basic frequency. This frequency is divided down to generate two 90 degree shifted signals. In case more than two dimensional system is required an additional pair of 90 degree shifted signals can be generated using a factor of two higher or lower frequency than the basic one. The two 90 degree shifted signals (called A and B) are fed to four summing points where the combinations A+B, A-B,-A+B,-A-B are generated. Those four combination present the four excitation signals needed for absolute position measurements.

The receive signal on sensing node is first amplified using a low noise amplifier having a capacitor in the feedback. To ensure correct DC potential a high ohm resistor (~10Meg Ohms) is needed. If the technology does not provide this possibility also so called "house keeping cycle" system can be used. In this case the DC potential is restored by discharging the feedback capacitor in a special clock cycle during which the measurement system is not operating. Since these cycles can be generated every 64 or 128 normal clock cycles they do not degrade the measurement system.

The amplified signal is fed to two phase selective rectifiers controlled by the two 90 degree shifted excitation signals. In case more dimensional system is used also the number of phase selective amplifiers is increased to match the number of basic excitation signals. The two (or more) phase selective rectifiers outputs directly present the level of each excitation signal content (which is used to control the rectifier) in the receive signal . The signal generated by the 90 degree shifted excitation signal is suppressed by further low pass processing of the rectifier output using integration.

To ensure perfect linearity the integrator output voltages of both channels are chopped by their excitation signals and fed back to the low noise amplifier input. There they are summed with the receive signal. This close loop configuration keeps the output of input amplifier and both phase selective rectifiers at zero signal level.

The signal representing the measurement value is displayed in the output voltages of the two integration blocks needed to keep the "zero signal state". Since there is always zero signal voltage in the most critical part of receive channel it quarantines perfect linearity.

Fig2. presents the basic schematic of excitation and receive block.

3. Conclusion

The described system was realised in 0.8μm standard CMOS technology. The test chip was evaluated both as stand alone electrical system and in combination with external PCB and mechanical assembly as absolute angle measurement system. The achieved resolution of angle measurement system was 8 bit. The limiting factor was not the electrical characteristic of measurement system but the precision of PCB manufacturing.

The electrical characterisation of capacitance measurement system yielded excellent results:

- measurement gain 1V/pF, 10V/pF, 20V/pF
- output spot noise 1.5μV/root(Hz) or 0.075aF/root(Hz)
- output offset <5mV
- output temperature drift <2μV/degree
- signal to noise ratio 110dB in 100Hz bandwidth

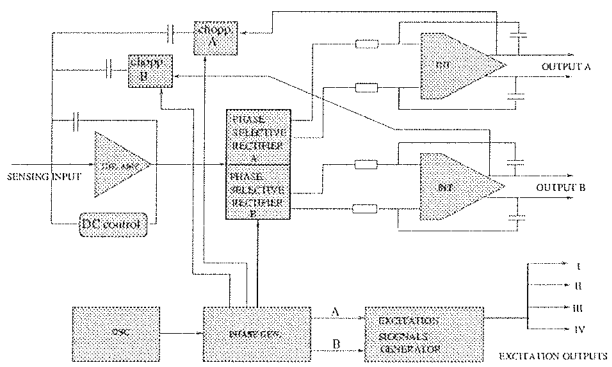

Fig. 2: Basic electrical shematic of test chip

References

/1/ Kunc V., Trontelj J., "Kapacitivni merilnik položaja", patentna listina št.: 9800108, Urad RS za intelektualno lastnino, Ljubljana, 1999

/2/ Kunc V., Trontelj J., "Integrirani kapacitivni merilnik nanometrskih razdalj", patentna listina št. 9600141, Urad RS za intelektualno lastnino, Ljubljana, 1997

/3/ Štern A., "Analiza kapacitivnosti integriranega senzorja pozicije", diplomska naloga, Fakulteta za elektrotehniko Ljubljana, 1998

Vinko Kunc
Faculty of Electrical Engineering
Tržaška 25, 1000 Ljubljana, Slovenia
E-mail: vinko@kalvarija.fe.uni-lj.si

Prispelo (Arrived): 26.10.01 *Sprejeto (Accepted): 10.12.01*