MT25

三峡大学

CHINA THREE GORGES UNIVERSITY

College of Electrical Engineering
& New Energy

Research on magnetic field measurement system based on distributed magnetic field sensing and numerical integration method

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Catalogue

1 Introduction

Commonly used methods of magnetic field measurement:

Hall sensor: saturation, nonlinearity, temperature stability.

Magnetoresistive effect: nonlinearity, saturation.

Magneto-optic effect : Complex structure, temperature stability.

Electromagnetic induction coil: sensitivity is limited by the coil size.

Besides: big size, mainly one-dimensional.

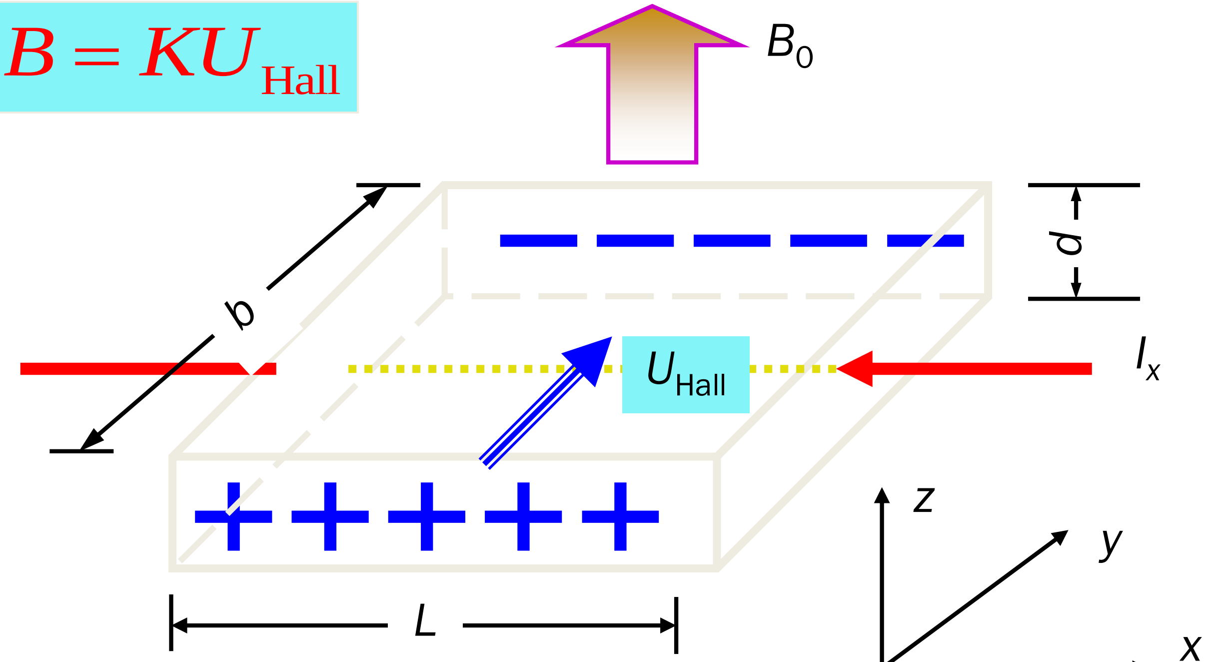
Hall effect: E. H. Hall

$$U_{\mathrm{Hall}} = \frac{R_{\mathrm{Hall}}}{d} \cdot I_x \cdot B$$

$$B = KU_{\mathrm{Hall}}$$

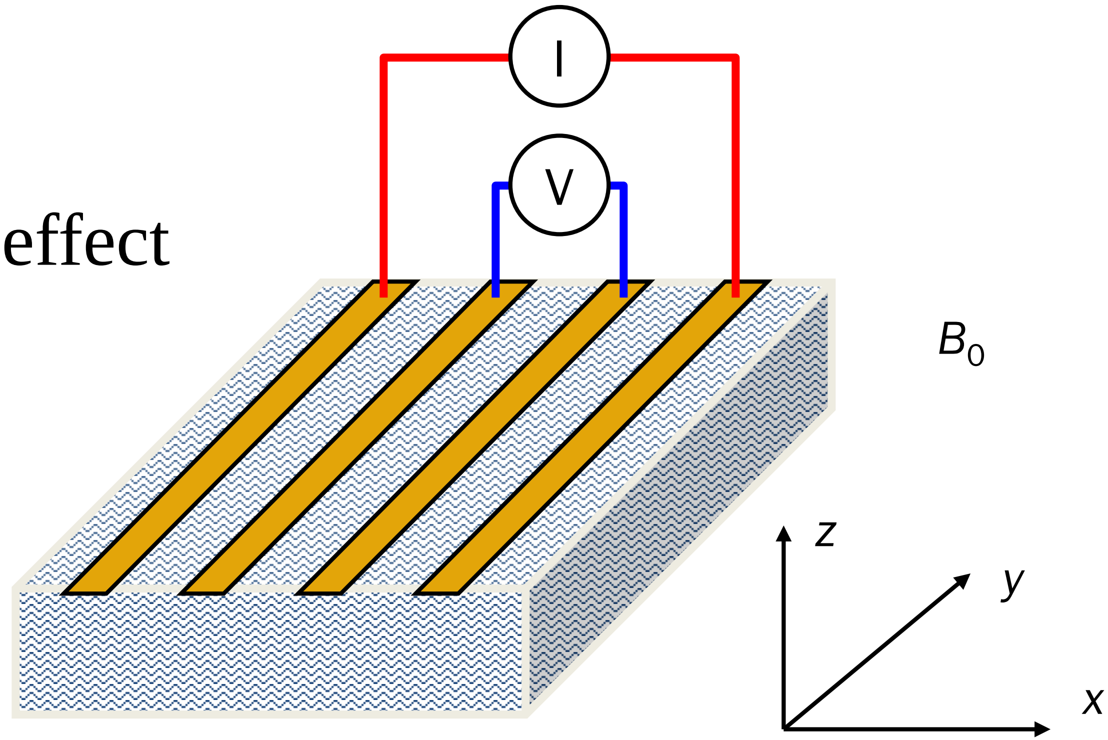
$$K = \frac{d}{R_{\mathrm{Hall}} \cdot I_x}$$

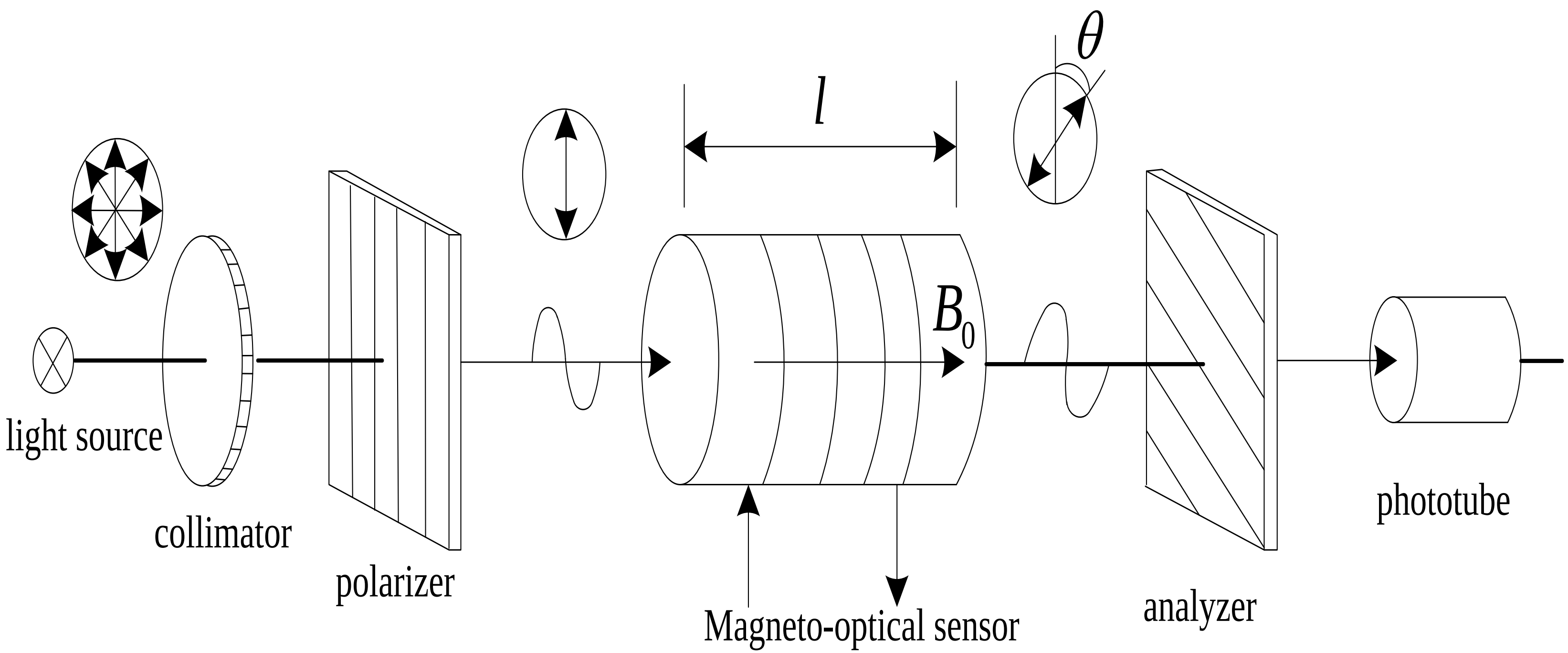
$$R_{\mathrm{Hall}} = \pm \frac{1}{ne}$$



$$B = KU_{\text{Res}}$$

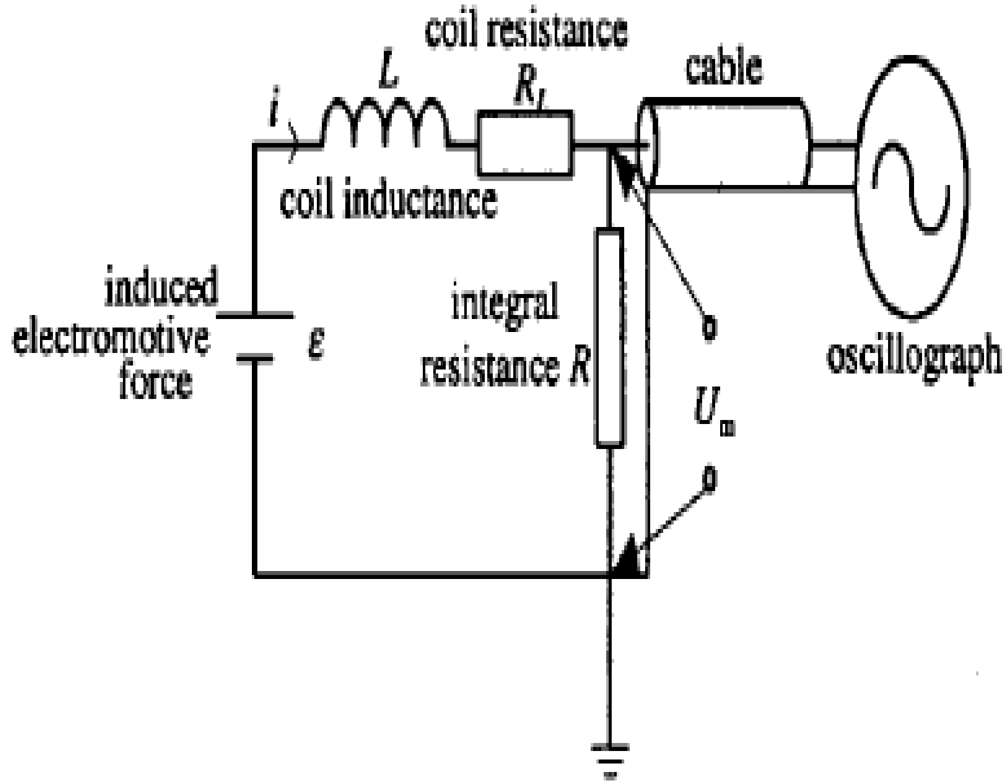
Magnetoresistive effect





Faraday magneto-optical effect

Rogowski coil



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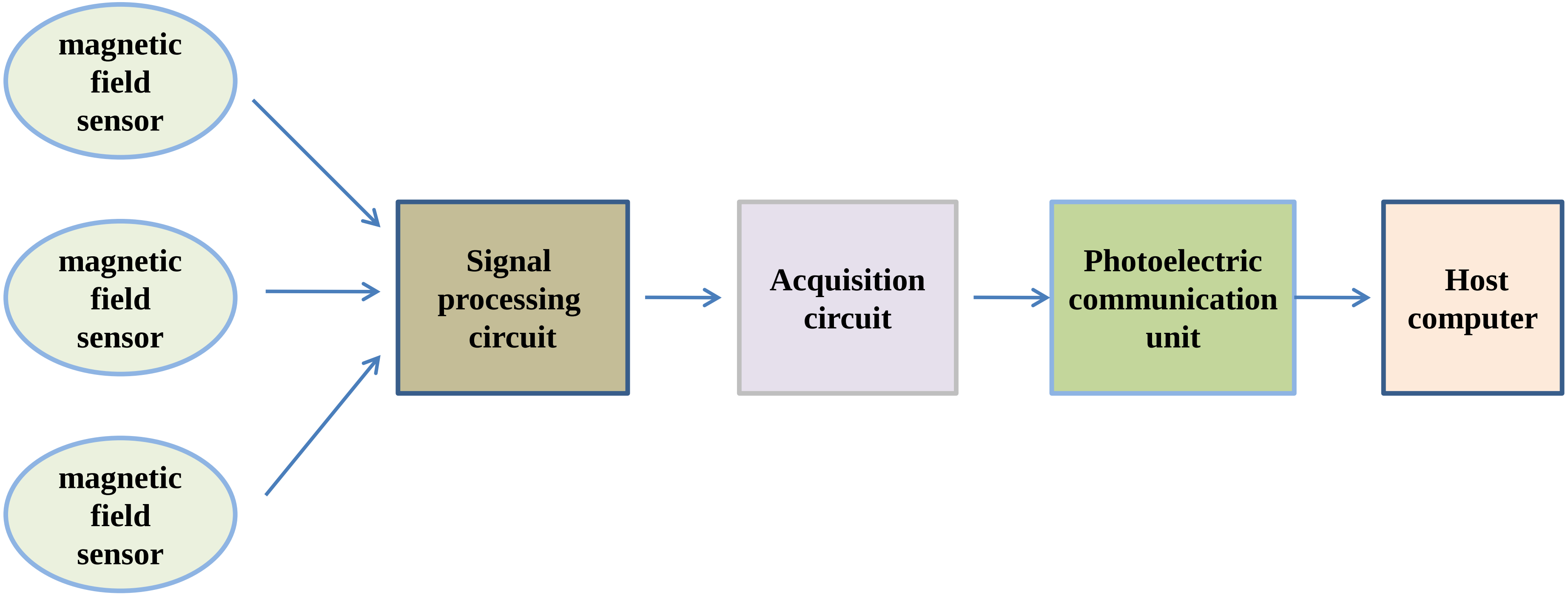
2 Structure of the measurement system



Structure diagram of the magnetic field measurement system

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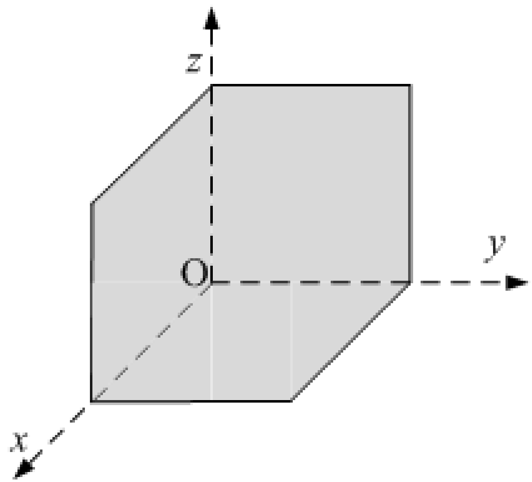
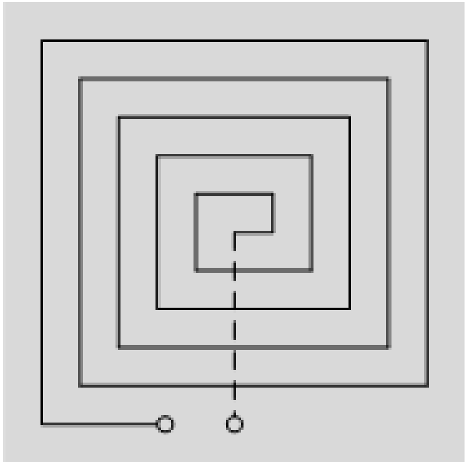
3 Key technologies

3.1 The sensor

Distributed magnetic field sensors:

1) three small coil sensors
2) single cube structure
3) three sensors are closely linked and perpendicular to each other





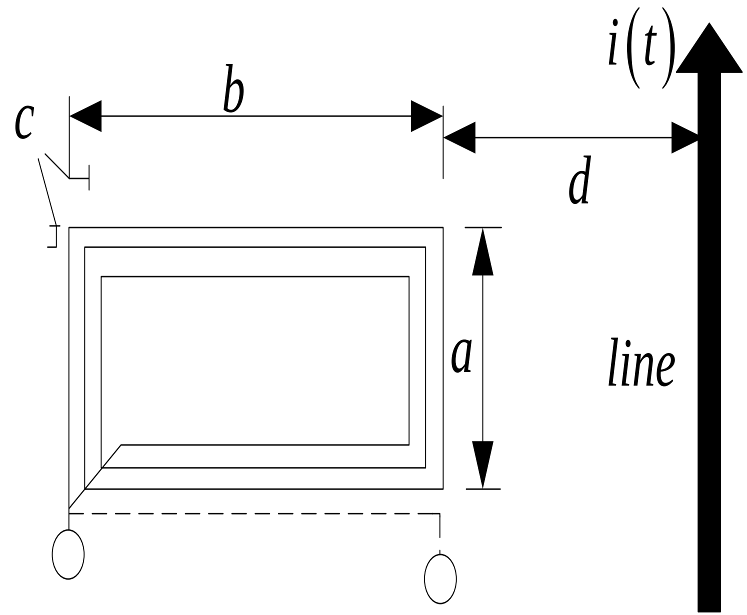
Magnetic field sensors based on Rogowski coil

3 Key technologies

3.1 The sensor

1) n is the number of coil turns
2) a, b, c and d are the size of the coil

$$M(d)=\int_{d}^{d+b}\frac{\mu_0}{2\pi x}a\,dx$$
$$+\int_{d+c}^{d+b-c}\frac{\mu_0}{2\pi x}(a-2c)\,dx$$
$$+\cdots$$
$$+\int_{d+(n-1)c}^{d+b-(n-1)c}\frac{\mu_0}{2\pi x}\left[a-2(n-1)c\right]dx$$



Small coil sensor

3.2 Digital integrator

transfer functions of common algorithms

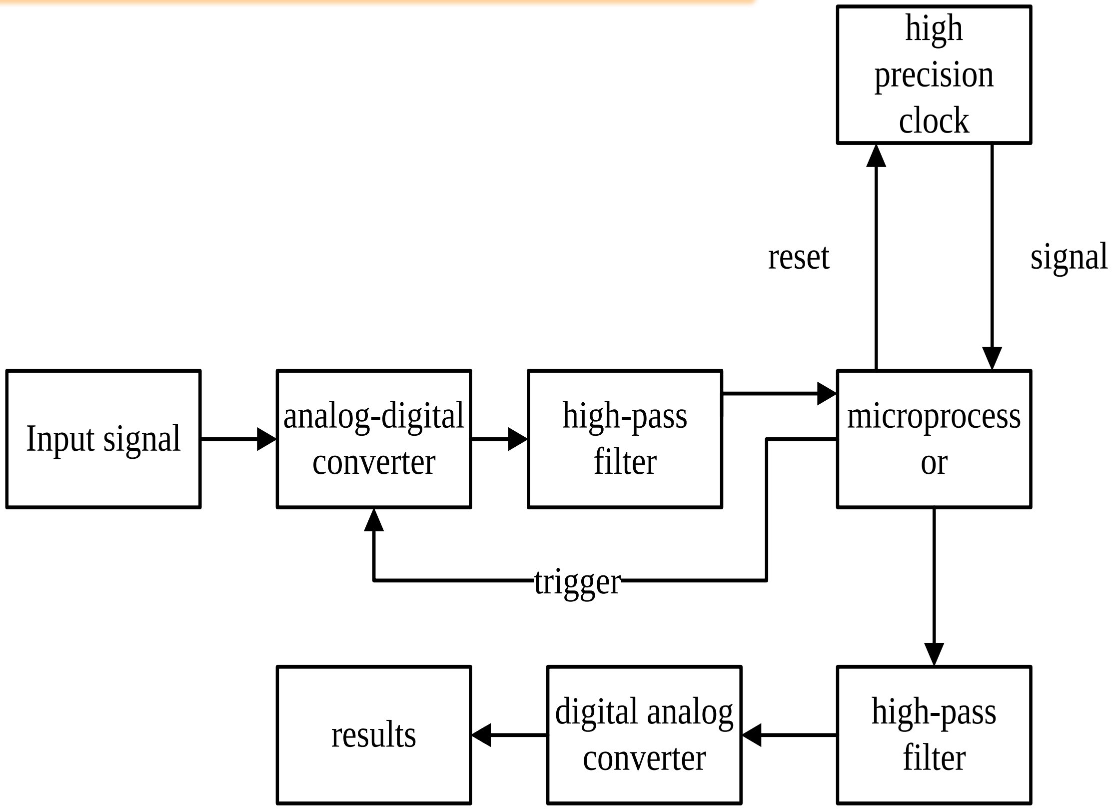
$$\begin{cases} H_T(z) = \dfrac{T}{2}\dfrac{1+z^{-1}}{1-z^{-1}} \\ H_s(z) = \dfrac{T}{3}\dfrac{1+4z^{-1}+z^{-2}}{1-z^{-2}} \\ H_r = T\dfrac{z^{-1}}{1-z^{-1}} \end{cases}$$

Gauss two points formula

$$\int_a^b f(x)dx \approx \frac{b-a}{2}\int_{-1}^{1} f\left(\frac{b-a}{2}+\frac{b+a}{2}t\right)dt$$

$$\int_{-1}^{1} f(x)dx = f\left(-\frac{1}{\sqrt{3}}\right) + f\left(\frac{1}{\sqrt{3}}\right)$$

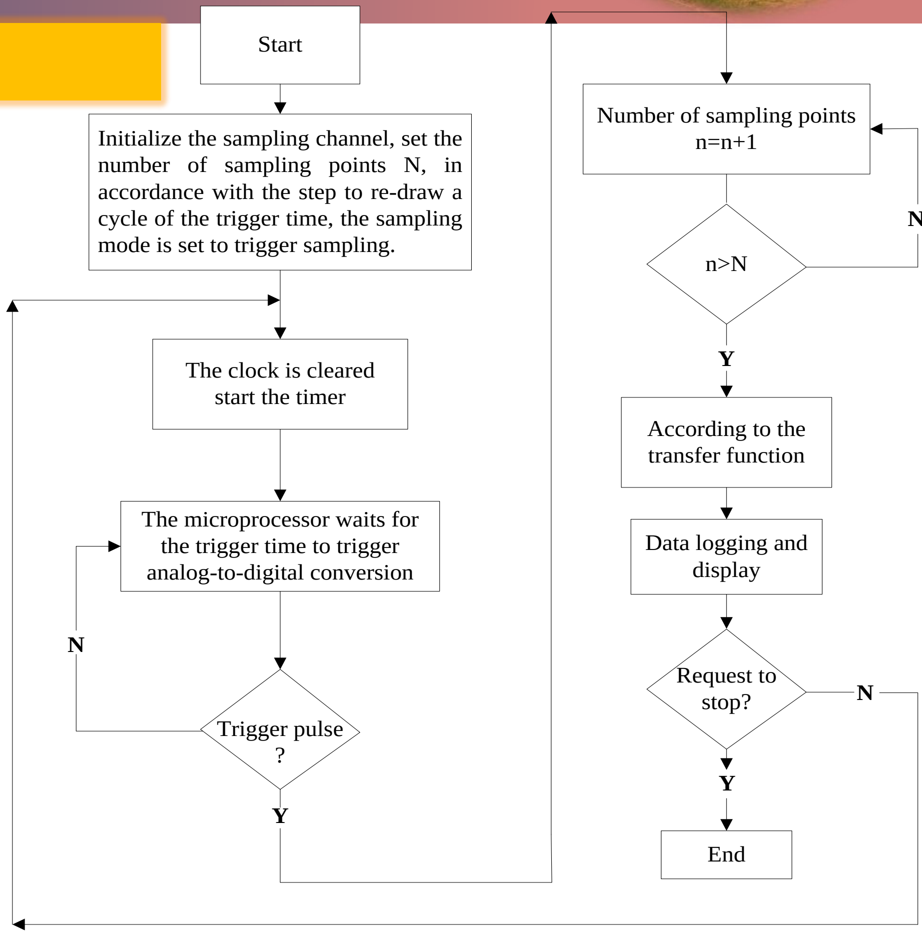
3.2 Digital integrator



The new digital integrator structure

3.2 Digital integrator

1) Generating vector a=0:0.02/N:(0.02-0.02/N)
2) Generating vector b=0.02/N: 0.02/N:0.02
3) Generating vector t=±3-0.5(b-a)
4) The elements in the vector t are combined into a new vector according to the numerical and arrangement. And it is the triggering time.



Software process

3 Key technologies

3.2 Digital integrator

The composite error is calculated with 80 points sampled in a cycle and is shown in table I. In addition, 20 sampling points and 40 sampling points are set in a cycle. The composite error is compared with each other.

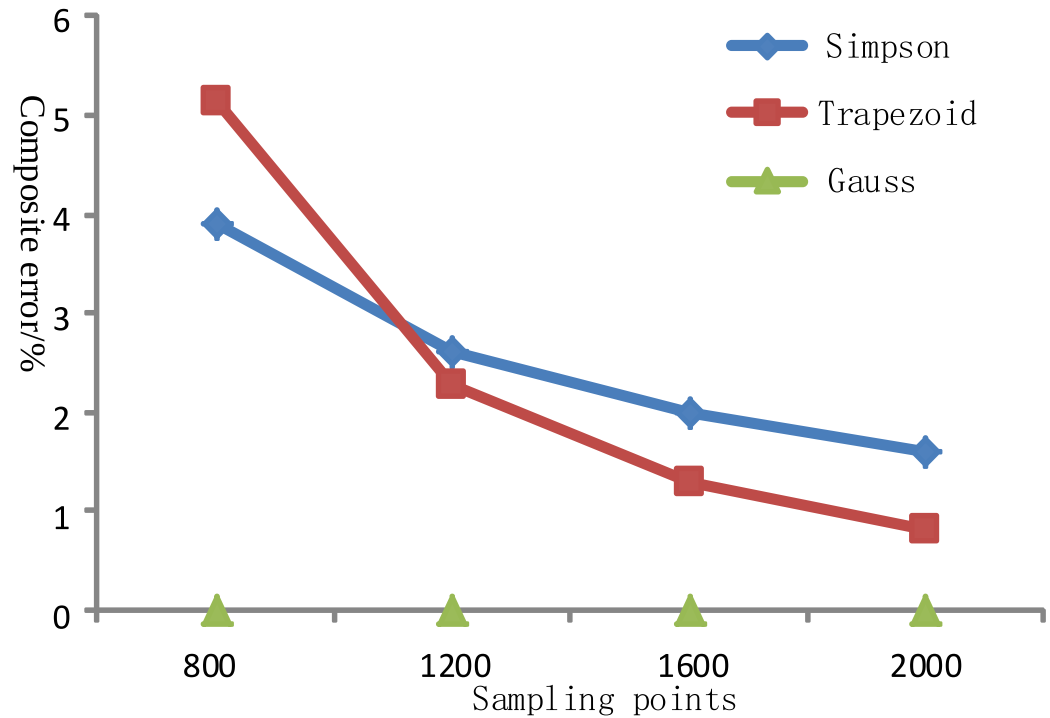
Table I shows that Gauss algorithm has an advantage over other algorithm with the same sampling points under stability condition.

TABLE I
COMPOSITE ERROR WITH DIFFERENT ALGORITHM

Algorithm type	Composite error (%)
Gauss(20)	2.26×10^{-2}
trapezoid	5.14
Gauss(40)	1.41×10^{-3}
Simpson	3.9
Gauss	8.81×10^{-5}

3.2 Digital integrator

The number of sampling points is 80, 120, 160, and 200 respectively in unit period. The result of the three integration algorithms is shown in this figure.

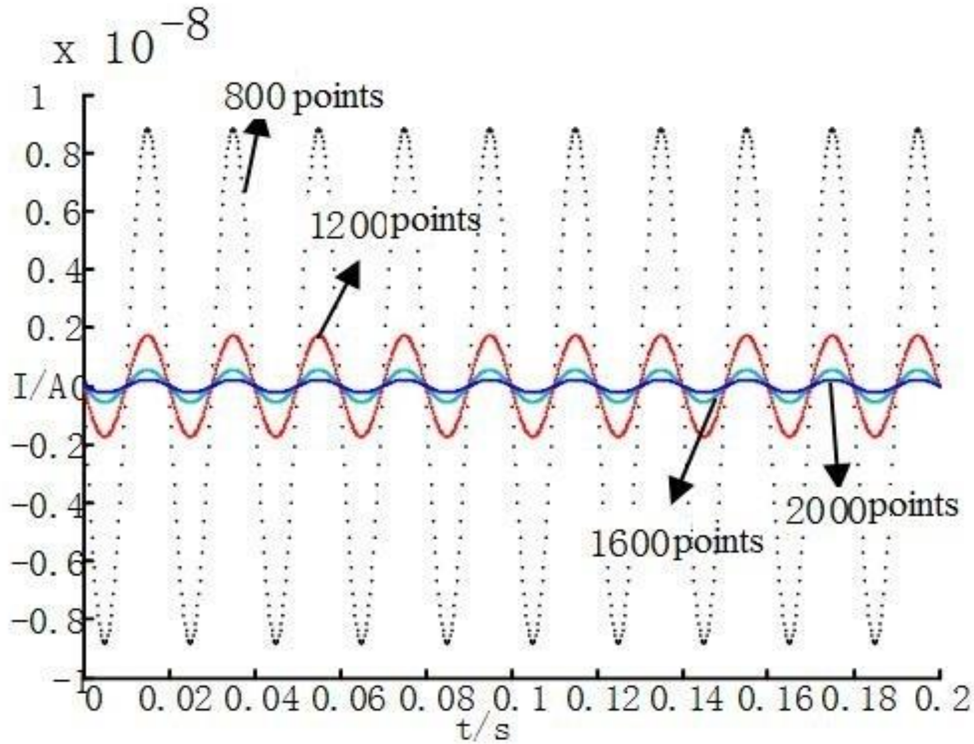


Effect of sampling points number for the composite error

3.2 Digital integrator

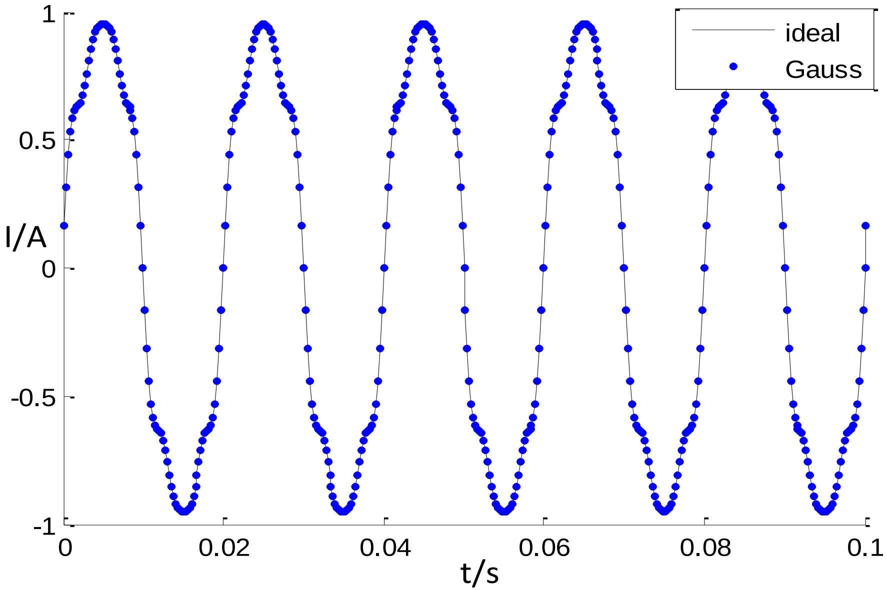
The relationship between the absolute error of the Gauss integral algorithm and the sampling points of the unit period is shown in this figure.

The results show that the higher the sampling frequency is and the more sampling points are, the less error of the trapezoid and the Simpson integral algorithm is for the standard power frequency sine wave signal. Gauss integral algorithm is not affected by number of the sampling points. The absolute error and the range of the composite error are very small, so it can be ignored.



Effect of sampling points number for the absolute error

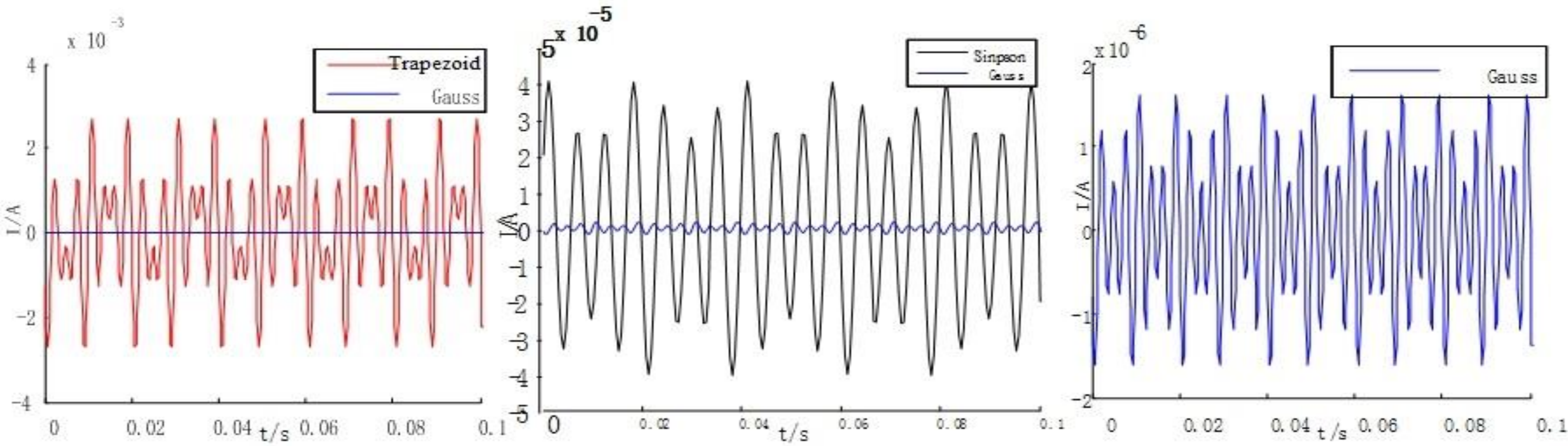
3.2 Digital integrator



Test with harmonics

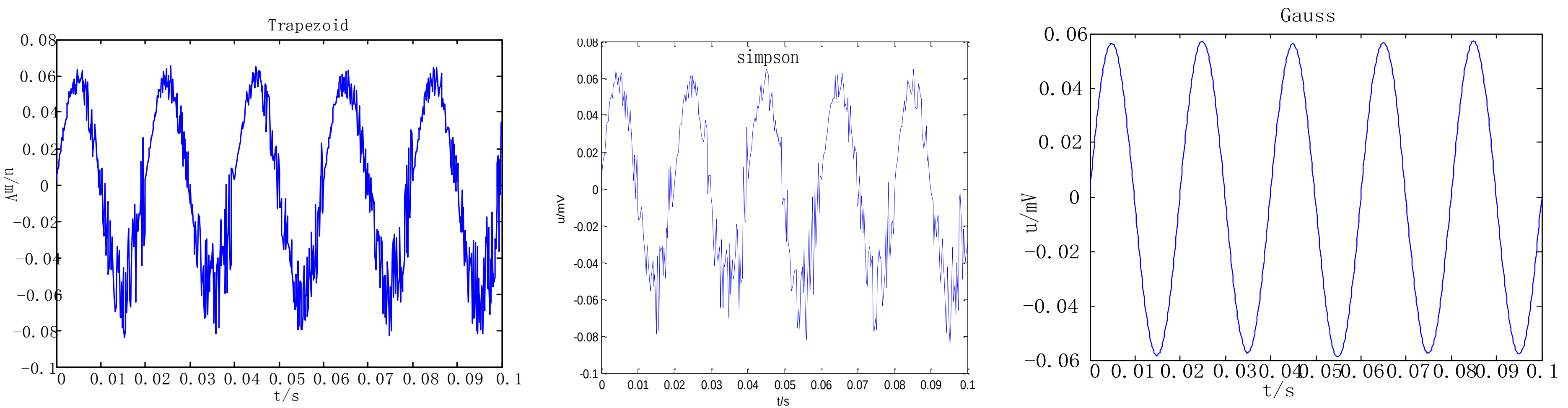
The test is conducted when these 3times harmonic, 5times harmonic, 7times harmonic exist at the same time.

3.2 Digital integrator



Comparison of absolute error of different integral algorithm

3.2 Digital integrator



The effect of noise

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4 Performance test

To verify the system performance, Test was carried out. Table II shows that the system error is less than 5% in the range of 0.05T~5T.

TABLE II
ACCURACY TEST

Serial number	Calibrator (T)	B_x of the system (T)	B_y of the system (T)	B_z of the system (T)	Final value of the system (T)	Relative error (%)
1	0.052	0.047	0.026	0.004	0.054	3.579
2	0.254	0.248	0.079	0.017	0.261	2.690
3	1.018	1.018	0.162	0.027	1.031	1.293
4	2.012	1.994	0.388	0.126	2.035	1.158
5	5.023	4.996	0.694	0.526	5.071	0.962

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5 Conclusion and Prospect

Conclusion

- ◆ A magnetic field sensor is designed, which can measure the magnetic field strength in three directions
- ◆ Test results indicate that the error of the magnetic field measurement system is less than 5% in the range of 0.05T~5T

Prospect

- Tests of anti-jamming performance
- Smaller size, larger dynamic range and wide frequency band

Thanks for your listening !