

Drift Self-compensating Type Flux-meter for Automatic Magnetic Flux Measurement

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In magnetic flux measurement, output voltage drift of electronic integrator is an essential problem. In this work, we have developed a new kind of Miller type integrator using a sample and hold amplifier. Input bias current was measured and this value was hold in the sample and hold amplifier, after that input bias current of Miller integrator was compensated automatically using the value which holds in the sample and hold amplifier. Developed flux-meter shows the drift of flux-meter are smaller than 10^{-5} Wb/min in full scale of 10^{-2} , and we could also measure multi-channel magnetic flux simultaneously.

Key words : magnetic measurement, flux-meter, integrator, drift

1. Introduction

For the measurement of magnetic flux, search coil and integrator have been used using Faraday's induction law. Electronic integrators using Miller type analog integrator or voltage to frequency converter and frequency counter type digital integrator have drifted due to the input bias current or offset voltage of operational amplifier [1, 2]. This drift directly influence to the uncertainty of measurement. Before measurement of magnetic flux using the flux-meter, we must adjust the drift of the flux-meter manually or automatically.

In this work, we have constructed a new kind of flux-meter which is suitable to apply multi-channel flux-meters such as nuclear fusion research [3]. The drift of flux-meter could be compensated automatically using a sample and hold amplifier and micro-controller.

2. Construction of the Drift Self-compensating Flux-meter

Fig. 1-(a) shows a typical Miller integrator which is used in electronic flux-meter. For the ideal case of operational amplifier, the relation between input voltage $V_i(t)$ and output voltage $V_o(t)$ is as follows

$$V_o(t) = -\frac{1}{RC} \int V_i(t) dt \tag{1}$$

But there is always input bias current i_b , and this input bias current is also integrated to the output voltage. The

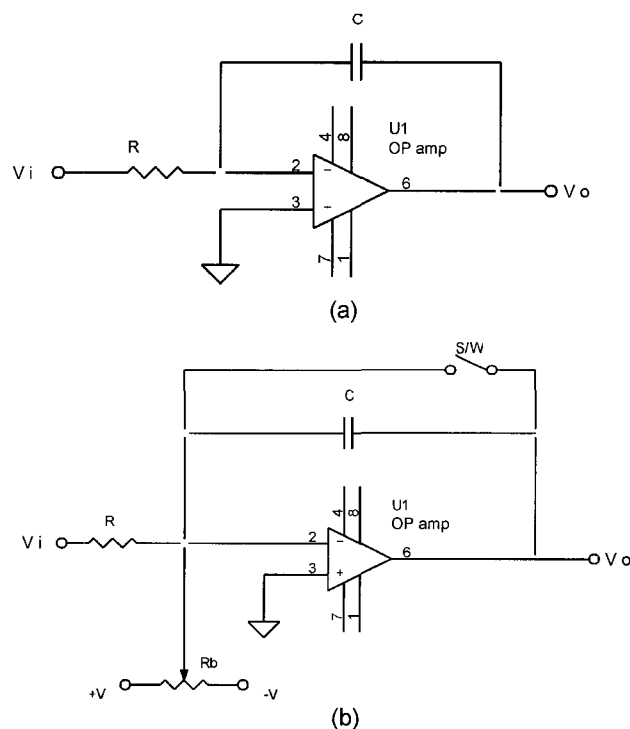


Fig. 1. Miller type integrator (a) and compensation of input bias current of integrator (b).

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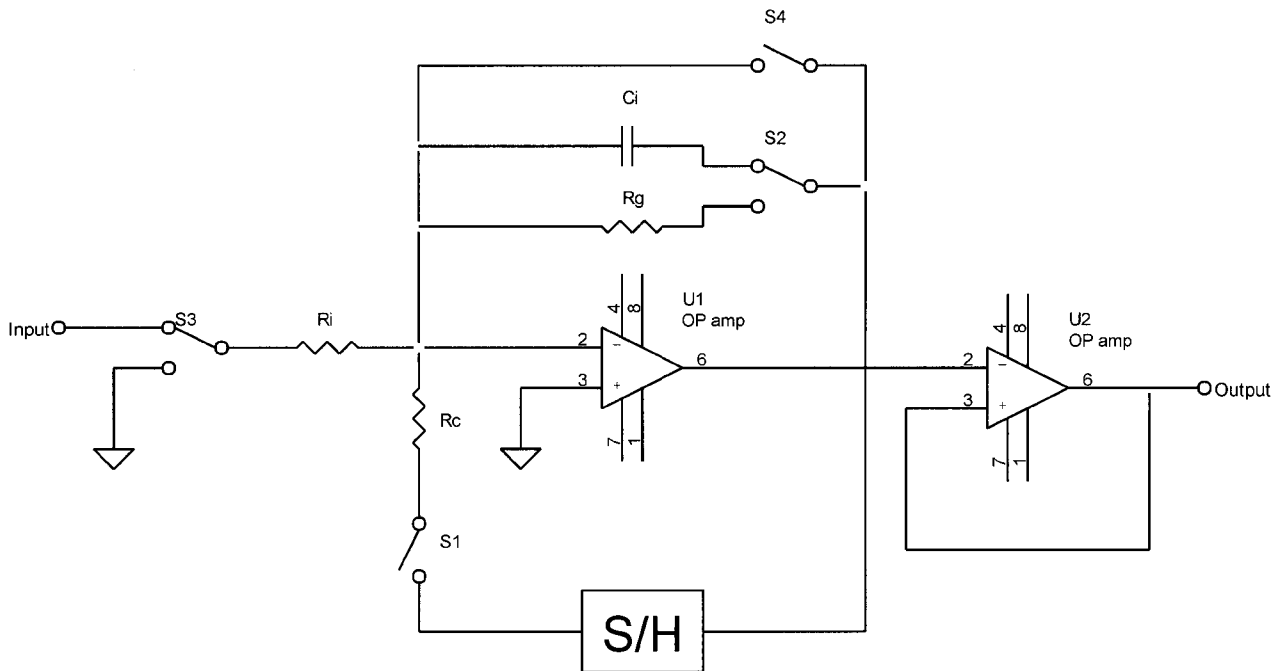


Fig. 2. Schematic diagram of the drift self-compensating flux-meter developed in this work.

relation between input bias current i_b and output voltage $V_b(t)$ is

$$V_b(t) = -\frac{1}{C} \int i_b dt \tag{2}$$

and this output voltage gradually increase or decrease when input bias current is constant within certain time interval.

To reduce this drift, we can input additional offset voltage which can be adjustable for the minimization of output voltage drift as shown in Fig. 1-(b). Just before measurement we should adjust input bias current, and integrator could be reset using a switch. after that we can measure magnetic flux. If we measure multi-channel magnetic flux simultaneously, we can not adjust integrator's drift in many channels simultaneously and manually. To overcome this problem, we have constructed a new kind of flux-meter as shown in Fig. 2.

To measure input bias current, we let position of S_1 , S_2 , S_3 , and S_4 to open, R_g , common, and open respectively. The output voltage becomes

$$V_o = -i_b R_g \tag{3}$$

If we measure and hold this voltage of sample and hold amplifier, this voltage could be used as compensation of input bias current. For example, after the switch S_1 in closed, the compensating current i_c becomes

$$i_c = -\frac{R_g}{R_c} i_b \tag{4}$$

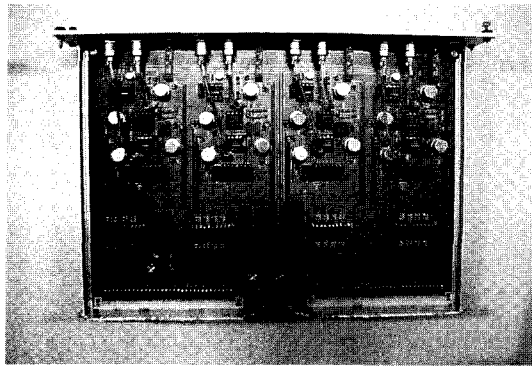
If $R_g = R_c$, i_c becomes $-i_b$ and input bias current becomes completely compensated.

For the proper operation of drift self-compensating flux-meter, we have classified 5 different modes of switch operations; "Power ON", "Offset Measurement", "Offset Compensation", "Reset", and "Trigger".

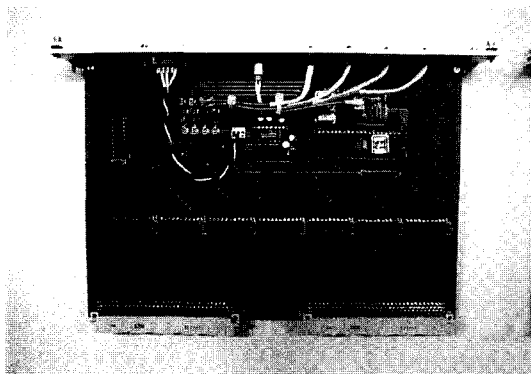
Switch positions of each mode are shown in Table 1. Operation of 4 switch for 5 different modes are carried out using 8 bit micro-controller (89C51). Fig. 3-(a) shows constructed 4-channel drift self-compensating flux-meter board and Fig. 3-(b) shows 8 bit micro controller board for switch operation by computer using RS-232C interface. For Flux-meter panel in computer monitor, we have used VEE. The completed 4-channel drift self-compensating flux-meter is shown in Fig. 4.

Table 1. Relation between integrator modes and switches

| Power on "PR" | | | | offset meas "OM" | | | | offset compensating "CM" | | | | Reset "RS" | | | | Trigger "MS" | | | |
|---------------|-------|-------|-------|------------------|-------|-------|-------|--------------------------|-------|-------|-------|------------|-------|-------|-------|--------------|-------|-------|-------|
| S_1 | S_2 | S_3 | S_4 | S_1 | S_2 | S_3 | S_4 | S_1 | S_2 | S_3 | S_4 | S_1 | S_2 | S_3 | S_4 | S_1 | S_2 | S_3 | S_4 |
| off | R_g | GND | ON | off | R_g | * | off | on | R_g | * | off | on | C_1 | * | ON | ON | S_2 | * | S_4 |



(a)



(b)

Fig. 3. Photography of the developed drift self-compensating flux-meter; (a) 4-channel integrator board and (b) micro-controller board.

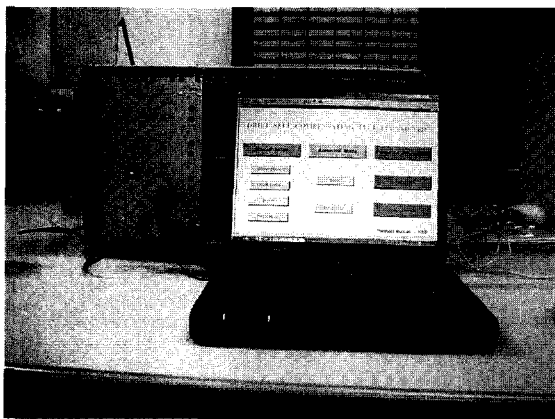


Fig. 4. Photography of the developed drift self-compensating flux-meter and control software.

3. Experimental Results

For the test of developed flux-meter, we have used $R = 1 \text{ k}\Omega$ and $C = 1 \mu\text{F}$ for Miller integrator. This means that full scale of this flux-meter is $\pm 10^{-2} \text{ Wb}$ which corresponds to ± 10 volt output. Fig. 5 shows the flux-meter output drift, the output voltage drift was smaller

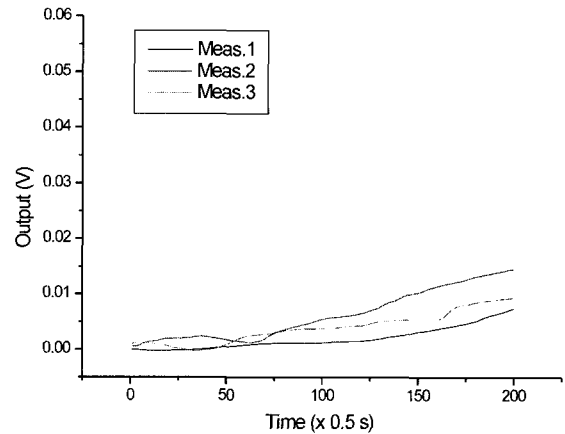


Fig. 5. Output voltage drift of the developed drift self-compensating type flux-meter.

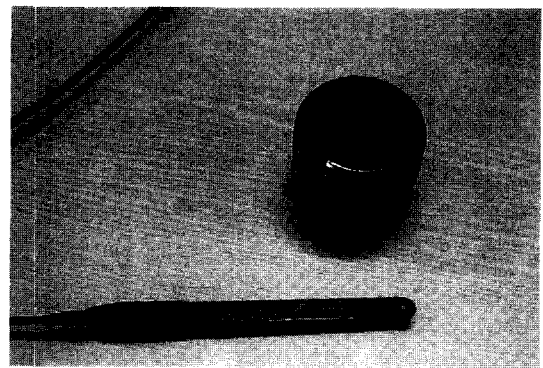


Fig. 6. Reference magnet and search coil for the test of developed flux-meter.

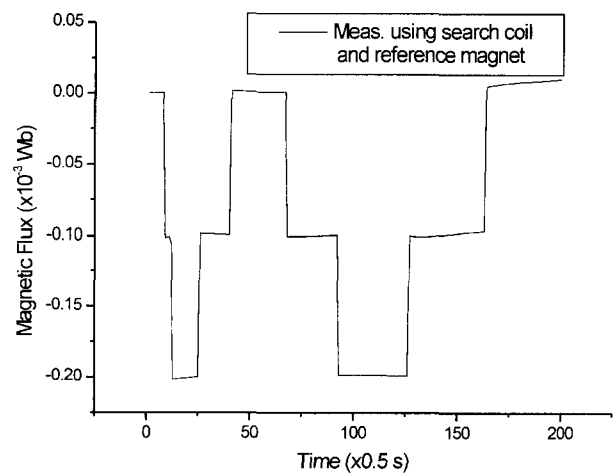


Fig. 7. Flux-meter output depending on the changes of magnetic flux of 1.1×10^{-4} .

than 10^{-2} V/min which corresponds to 10^{-5} Wb/min , and this condition was satisfied the requirement of nuclear fusion experiments.

To demonstrate flux-meter performance, reference magnet of $B=0.0998$ T and area turns of search coil $NA = 1.10 \times 10^{-3}$ m² was used as shown in Fig. 6. Fig. 7 shows experimental results. The search coil is inserted into the reference magnet, and the drift of the flux-meter is compensated. After the search coil was pull out, magnetic flux was changed 1.1×10^{-4} Wb, and search coil was up side down, the search coil was put into reference magnet, magnetic flux was changed another 1.1×10^{-4} . This experiment was done during 100 seconds, we can see that our developed the drift self-compensating flux-meter could be applicable to magnetic flux measurement within the limit of 10^{-5} Wb/min of drift.

4. Conclusion

In this work, we have developed a new kind of the drift

self-compensating type of flux-meter which could be applicable to simultaneous multi-channel magnetic flux measurements. Input bias current of Miller integrator was measured and this value was stored in sample and hold amplifier and this value was used as compensating input bias current of Miller integrator. Drift of the developed flux-meter was smaller than 10^{-5} Wb/min in full scale of 10^{-2} Wb.

References

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