BEAM INTENSITY MONITOR FOR KEK PROTON SYNCHROTRON

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The beam intensity monitor using a "current transformer" was constructed for the precise measurement of the proton beam intensity in KEK synchrotron. The current transformer consists of a toroidal core which is made from the permalloy thin film of 50 μm thickness and whose dimensions are shown in Fig.1. The static permeability μ of the core is 3.5×10^4 and the saturation field is about 7 KG. We adopted a "L/R-integrator circuit" as a detection circuit to obtain a high measuring accuracy and a high stability[1]. In the L/R-integrator in Fig.2 the sensitivity for the beam current is decided by the number of turns of the feedback coil and the feedback resistor if the feedback loop consists of a high gain amplifier. The magnetic field in the core induced by the beam current is cancelled by the feedback current, thus the core saturation does not occur. In order to obtain a high signal to noise ratio, it is necessary to analyze the noise characteristics of the amplifier in the feedback loop. To reduce the amplifier noise in the high frequency range, we used the amplifier whose gain is rolled-off in the manner of -6 dB/oct. in the frequency range higher than $f_A = \omega_A/2\pi$. Using such an amplifier in the feedback loop, the transfer function of the loop has two poles. Thus the careful analysis about the stability of the feedback loop is necessary. The output voltage of the L/R-integrator as shown in Fig.2 is represented by

$$V_3(\omega) = \frac{j\zeta\omega/\omega_0}{1 + j\zeta\omega/\omega_0 - (\omega/\omega_0)^2} \cdot \frac{I_0 R_2}{N_2} , \qquad (1)$$

where ζ is the damping constant given by

$$\zeta = \frac{A_0 L_1 N_2}{N_1 R_2} \left[\frac{\omega_A}{L_1 (1/R_1 + N_2{}^2/N_1{}^2 R_2)} \right]^{1/2}, \qquad (2)$$

and

$$\omega_0^2 = \omega_A / L_1 (1/R_1 + N_2{}^2/N_1{}^2 R_2). \qquad (3)$$

I_0 is the beam current, A_0 is the DC gain of the amplifier, L_1 is the inductance of the pickup coil of the current transformer, and $\omega_A/2\pi$ is the roll-off frequency of the amplifier gain. The lower frequency limit of the system is $\omega_L = \omega_0/\zeta$ and the higher frequency limit is $\omega_H = \omega_0\zeta$. For obtaining a wide frequency range it is desirable to have large A_0 and L_1. The lower frequency time constant $T_L = 1/\omega_L$ must be much longer than the repetition time of the beam acceleration (2.2 sec) to avoid the error based on the droop. In our L/R-integrator A_0 = 75 dB, L_1 = 24 H, T_L = 25 sec, and $\omega_H = 2\pi\times15$ KHz. Using the correction circuit of the droop, we obtained the effective time constant T_L of about 300 sec. Furthermore the feedback amplifier was completely shielded to reject the RF noise. The total error in our measuring system for the beam intensity is within ±1 % and the rise time is about 30 μsec (90 %). As an example the beam current signal is shown in Fig.3 (lower trace). The upper trace in this picture is the particle number signal which is obtained by dividing the beam current signal by the revolution frequency of the acceleration.

References

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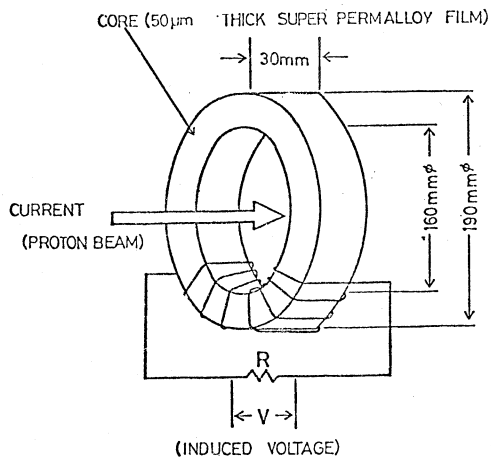


Fig.1 Current transformer.

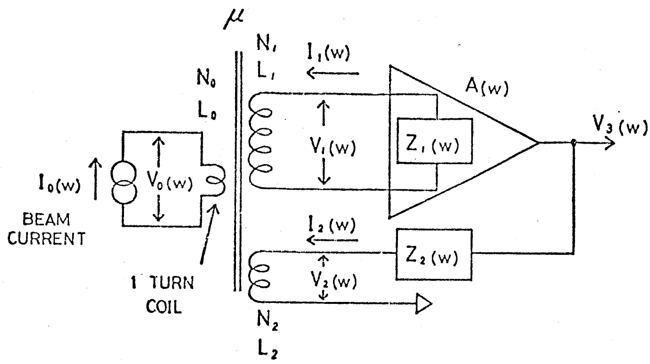
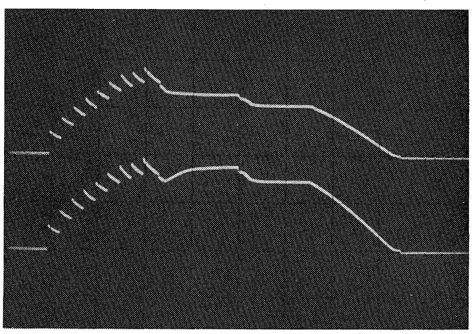


Fig.2 Schematic diagram of L/R-integrator.



Particle number (1.0×10^{12} ppp/div.)

Beam current (100 mA/div.)

Fig.3 Output signal of beam current monitor.