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DESIGN OF A BEAM-POSITION MONITOR CIRCUIT FOR THE KEKB INJECTOR

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Abstract

The PF linac is presently being upgraded for the KEKB project. In this project, stripline-type beam-position monitors (BPMs) are to be installed at every Q-magnet. The beam-displacement signals are to be processed by BPM circuits. The circuit must work with high stability under strong electromagnetic interference. Two types of narrow-band circuits have been investigated: one comprises a band-pass filter of 120-MHz center-frequency with a 3.2-MHz band-width; the other comprises one differentiating circuit and several-stage integrating circuits. The design and performance of BPM circuits as well as the design of the BPM electrode are discussed.

1. Introduction

The PF 2.5-GeV linac is being upgraded in order to meet the requirements of KEKB project. The electron-beam energy is to be increased from 2.5 GeV to 8 GeV, and that of the positron beam from 2.5 GeV to 3.5 GeV. The bunch charge of the positron beam is to be increased so as to be 20-times as intense as the present one. In order to realize this big increase of the positron beam, the primary electron beam must contain 10 nC/bunch. In order to suppress the transverse wakefield due to a high-current beam, the beam must be accelerated in the center axis of the accelerating structures.

BPM electrodes will be installed at every Q-magnet for measuring the beam displacement from the center axis. The BPM circuits are to be used near to the klystron modulators, which generate very strong electromagnetic noise, and must work stably in such an environment. Two narrow-band amplifiers have been studied for this purpose. One comprises a band-pass filter, and the other consist of an RC differentiating circuit and several-stage integrating circuits. In this paper, the latter one is mainly discussed as well as the performance of the BPM electrodes.

2. BPM electrode

The BPM electrode is made of stainless steel with four-fold symmetry; its dimensions are shown in fig. 1. All of the BPM electrodes are calibrated using a precise test bench. A 0.5-mm wire is used to simulate the beam line, and the BPM electrode on a movable stage is scanned in the plane of ±5-mm square around the beam line. The beam position is calibrated using the following formula:

$$X = A_0 + A_1x + A_2y + A_3x^2 + A_4xy + A_5y^2 + A_6x^3 + A_7x^2y + A_8xy^2 + A_9y^3,$$

where $x = \dfrac{V_1 - V_3}{V_1 + V_3}$ and $y = \dfrac{V_2 - V_4}{V_2 + V_4}$.

We have measured all coefficients from A_0 to A_9 for 16 MPM-electrodes which have been installed in the linac system. In these coefficients, A_0 is an offset of the electrode and A_1 is often used for first-order approximation. Typical values for A_0 and A_1 were several ten microns and 8.59 mm, respectively. All coefficients from A_0 to A_9 will be stored in the computer system for calibration purposes.

3. Design of Circuits

The BPM circuits have four channels which measure outputs from V1 to V4. The linearity required in order to measure the beam position with a 0.1 mm accuracy is 1%. This specification is very hard, and none of the circuits described later satisfy this linearity. Further improvements should thus be made. We also consider compensating the linearity using computer software.

The circuits are to be installed under very strong electromagnetic noise, the frequency spectrum of which has been measured. There is very strong electromagnetic noise under 20 MHz. Two types of narrow-band amplifiers with a pass band over 20 MHz have been investigated.

Circuit-type 1

We first designed a circuit which cover 65 dB. Though a 10 nC/bunch is the maximum accelerated charge, the BPM design covers twice this (20 nC/bunch), taking into account future improvements. The minimum charge in the specification is 0.64 nC/bunch for the positron beam, though 0.2 nC/bunch is for positron beam commissioning. Therefore, the dynamic range for the beam intensity is 45 dB, and a dynamic range of ± 10 dB is added to it for beam displacement within ± 7 mm. A dynamic range of 65 dB is divided into three overlapping ranges, each of which has 34 dB. The circuit comprises a band-pass filter, limiting amplifiers, a double-balanced mixer and a sample/hold circuit[1,2]. The dynamic range of the circuit is satisfactorily, but the linearity does not meet our requirement. The linearity will be compensated using a computer.

Circuit-type 2

The circuit described above covers all of the beam modes; a common circuit can be used through the linac. Other possible means is to make two types of circuits which can cover from the beginning of the linac to the positron target (10 nC/bunch-1.28 nC/bunch) and from the positron target to the end of the linac (1.28 - 0.2nC/bunch), respectively. Two types of circuits having different gain levels and the same dynamic range of 35 dB satisfy our requirements. In this alternative, we aim for simplicity and low cost of the circuits; also, a beam displacement within ± 5 mm is assumed. If the circuit is simple and low cost, we can then make the same number of the BPM circuits as the BPM electrodes, and can measure one beam trace with one beam pulse; otherwise, several BPM electrodes will be connected to one common circuit through switches, requiring several pulses of beams to measure one beam trace. A beam-position measurement with one identical beam is very attractive and leads to a second circuit.

This circuit comprises a band-pass filter comprising an RC differentiating circuit and RC integrating circuits. A schematic diagram of the type-2 circuit is shown in fig. 2. The differentiating circuit is followed by three stages of integrating circuits. The output from the band-pass part is amplified and stretched. Figure 3 shows the input vs. output of the circuit. Pulse width of input pulse was 1 ns and horizontal axis shows attenuation of pulse generator. Band pass characteristics of the circuit are also shown in fig. 4. Center frequencies for both differentiating circuit and integrating circuits are 50 MHz. Although the stability of the circuit is satisfactorily, linearity of this circuit is worse than our requirement.

4. Conclusion

We have developed two types of BPM circuits. Type-2 has been investigated very recently, and has some room for improvements. It was very difficult to obtain a linearity better than 1% for both circuits. The linearity will be compensated for using a computer. Both will be tested in a real field from September, 1995.

References

1) A. Lazos, T. Suwada, T. Urano and H. Kobayashi; Proc. 1994 Linear Acc. Conf. Tsukuba, Japan 1994, p. 872

2) H. Kobayashi, T. Urano, T. Suwada and A. Lazos; Proc. 20th Linear Acc. Meeting in Japan Osaka, Japan 1995, p. 245

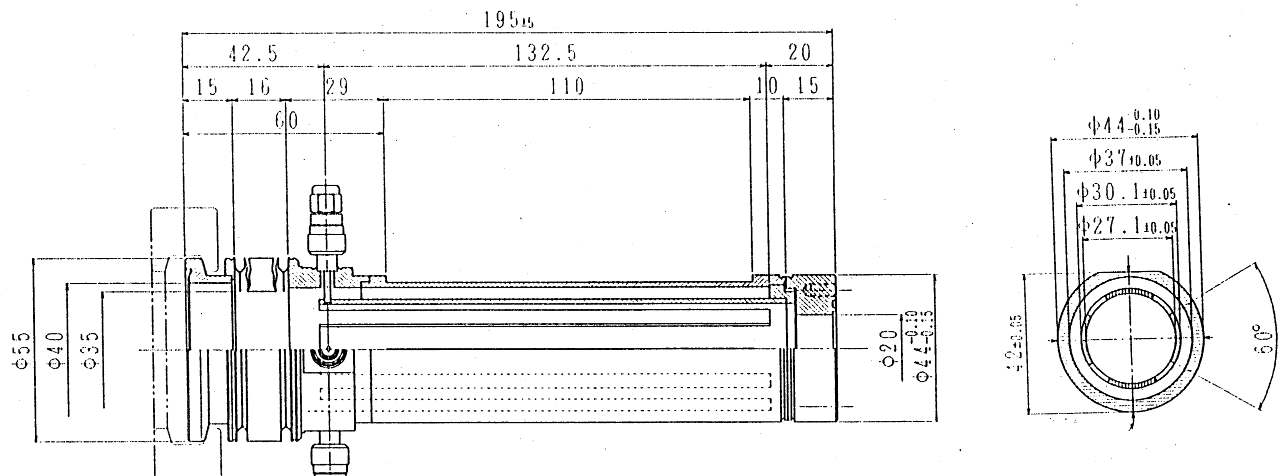

Fig. 1. BPM electrode.

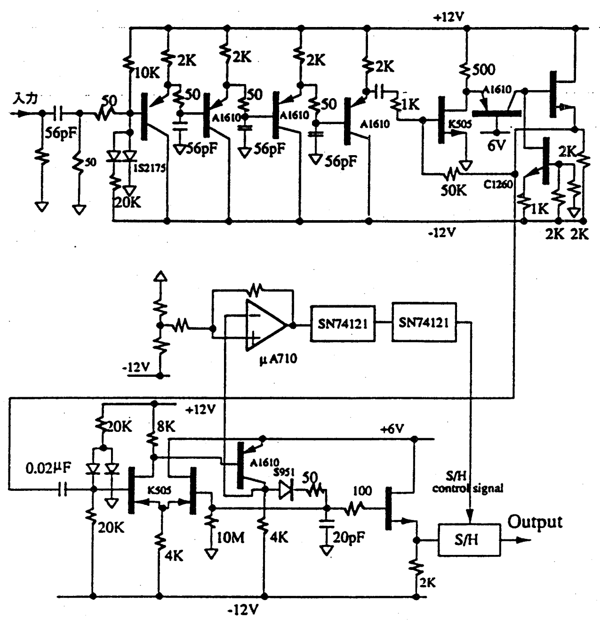

Fig. 2. Diagram of Circuit-2.

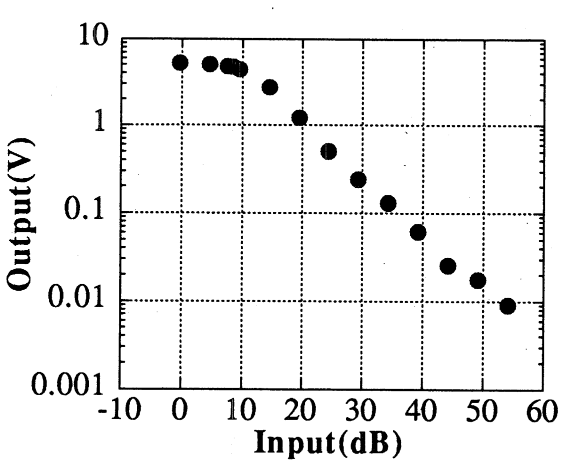

Fig. 3. Input vs. output of Circuit-2.

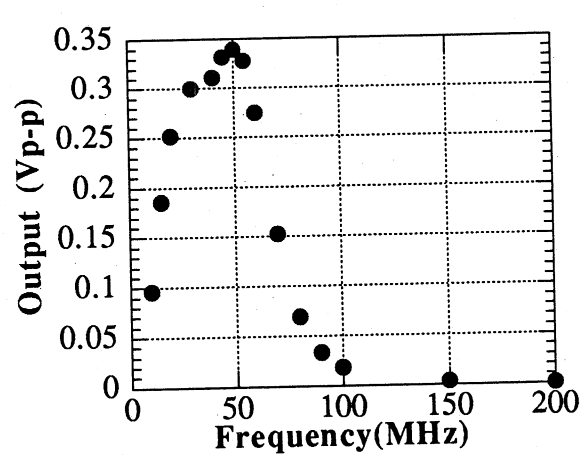

Fig. 4. Band-pass characteritics of Circuit-2.