

IMPROVEMENT OF BEAM LIFETIME MEASUREMENT SYSTEM AT TRISTAN

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Abstract

A new beam lifetime measurement system has replaced an old one. The new system consists of a micro-computer CAMAC module and a 16 bits ADC module, while the old one consisted of an accelerator control computer(HIDIC-80) and a 12/13 bits ADC at TRISTAN Accumulation Ring(AR)/Main Ring(MR). Using the micro-computer system, we can get precise beam lifetime with quick response and reduce software load of the accelerator control computer.

Introduction

Beam lifetime is a one of the significant parameters of a storage ring. The beam lifetime measurement requires preciseness and quick response. An accelerator control computer(HIDIC-80) and a 12/13 bits ADC module had been used for calculation and measurement of beam lifetime in TRISTAN Accelerators. Disadvantages of this system are 1)It cannot increase sampling rate of measurement of current, because the accelerator control computer has many other software loads. 2)It cannot improve the precision, because of the restriction of resolution of ADC. From these reasons, result of calculation of beam lifetime had errors. Though averaging method was tried to eliminate the errors, this resulted in sacrifice of response. We have developed a new beam lifetime measurement system, using a micro-computer CAMAC module and a newly developed 16 bits ADC. It can eliminate disadvantages of the former system.

Calculation

In a storage ring, decrease of the stored current is given by the following equation:

$$I = I_0 \exp(-t/\tau q), \quad (1)$$

or

$$\tau q = -t/\ln(I/I_0), \quad (2)$$

where I_0 is the initial current, t is the time, and τq is the beam lifetime. In this calculation, the time variation of beam current is approximated by linear line in logarithm scale as shown in fig.1. Theoretically, calculation of beam lifetime is derived from current decrease during a given time interval. Actually we fit many measured current values I_1, I_2, \dots at the times t_1, t_2, \dots to eq.(2) using the least square method.

The practical equation is

$$\tau q = \frac{\sum_{i=1}^n (t_i - t_0)^2}{\sum_{i=1}^n (t_i - t_0) \ln(I_i/I_0)}, \quad (3)$$

where n is the number of data, which decides precision and response. If n is large, the calculation is precise but its time response is poor. If n is small contrary, its time response is good but the precision is poor. Actually, validity of data is limited by the quantum error of the ADC, so this error has to be small. Moreover, because the current loss rate is very small in the ordinal operation of a storage ring, the sampling interval(Δt) has to be small enough so as not to miss the moment of current change corresponding to the 1 digit of the ADC(Δi).

Hardware

Hardware of the new system is shown in fig. 2. It consists of a toroidal DC beam current transformer, a 16 bits ADC, a microcomputer, an ACC and a memory module.

Toroidal DC beam current transformer: Beam current is measured with a system combining a second harmonic magnetic modulator with an active current transformer in an operational feedback loop.1)2) Specification of this system is shown in table 1.

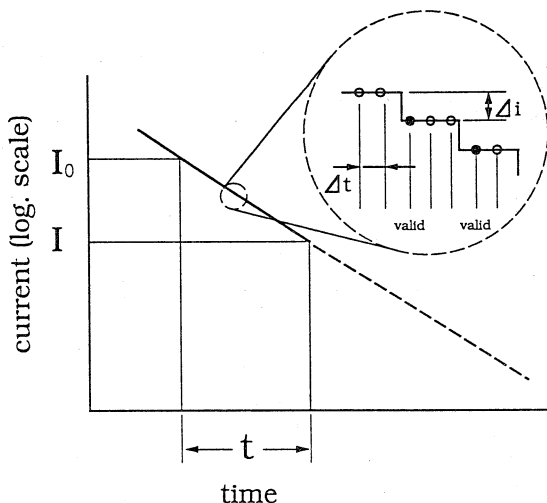


Fig. 1 beam life time calculation

16 bits ADC: A 16 bits ADC CAMAC module is developed for this system. The ADC requires high resolution and small differential linearity error. Even if an ADC has a high resolution, we cannot use it, if its differential linearity error is not small enough, like a successive approximation type and an auto range type ADC. Finally we have selected ADC800, a dual slope type ADC made by Datel Co.. It has 16 bits resolution and small differential linearity error(max.±1/2 LSB). Although catalog data of its conversion time is 400msec, it too slow for this purpose, we doubled the recommended clock frequency of this IC to obtain 200msec conversion time. It behaved well under this condition; we get linear input/output characteristics. The circuit diagram of the CAMAC module of this ADC is shown in fig.3. Resolution of current detection using a new(16 bits) ADC and an old(12/13 bits) ADC in AR and MR is compared in table 2. It should be noted that the accuracy of the ADC now exceeds that of the DC beam current transformer. To attain further improvement of lifetime measurement, refinement of the front part is essential.

Micro-computer, ACC and Memory : Micro-computer CAMAC module(CMS5203 Meisei Co.) consists of Z80 cpu, 64k bytes memory, SIO, CTC, etc.. We can use CAMAC commands to start the cpu, stop the cpu and read/write the memory from HIDIC-80 through the serial crate controller(SCC). This module is connected to an auxiliary crate controller(ACC) module(CMS5204, Meisei Co.) by STD bus so that it is able to access other modules in the

Table 1
Specification of
the toroidal DC beam current transformer

	max. current	output voltage	accuracy	frequency range
AR	80 mA	5 V	200 μ A	DC~500Hz
MR	50 mA	10 V	20 μ A	DC~100Hz

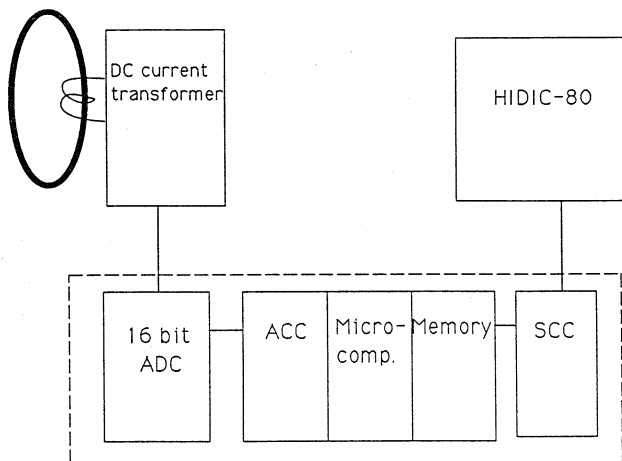


Fig.2 Block diagram of the new beam lifetime measurement system

crate. 3) A memory module (3821 Kinetic Systems) has 4k words. It has four independent address counters to communicate with SCC and ACC independently.

In this system, beam current is sensed and converted to voltage value by the DC beam current transformer. The voltage value is converted to digital value by the 16 bits ADC module. The micro-computer module and the ACC module read the digital value at the interval less than 100msec. The microcomputer module calculates beam lifetime when 1 digit decrease from previous digital data is recognized. It then writes the result to the memory module. HIDIC-80 reads the memory module. This action is independent of the behavior of the micro-computer module.

Software

The micro-computer program is written in Pascal MT+, of its ability writing on ROM, floating point calculation and its easiness in coding. The flow chart of the program is shown in fig.4. It consists of three parts.

a) Initialize routine : This routine first resets the system timer. During a beam is injected in the storage ring, it waits until the current reaches its peak value. The reset action again occurs at the end of acceleration in order to reject the influence of the flux change of bending magnets.

Table 2
Resolution of current detection by ADC

	measurement range	resolution of ADC	value of LSB
AR	0~80 mA	12 bits	40 μ A (2.5mV)
		16 bits	2.5 μ A (.15mV)
MR	0~50 mA	13 bits	12.5 μ A (2.5mV)
		16 bits	1.5 μ A (.31mV)

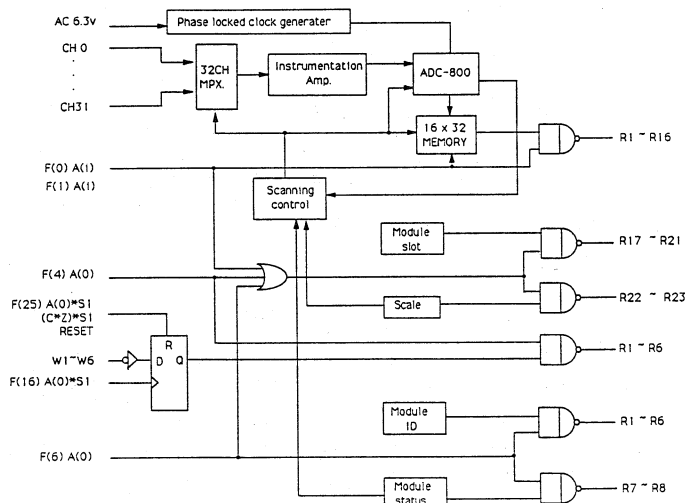


Fig. 3 16 bits ADC CAMAC module

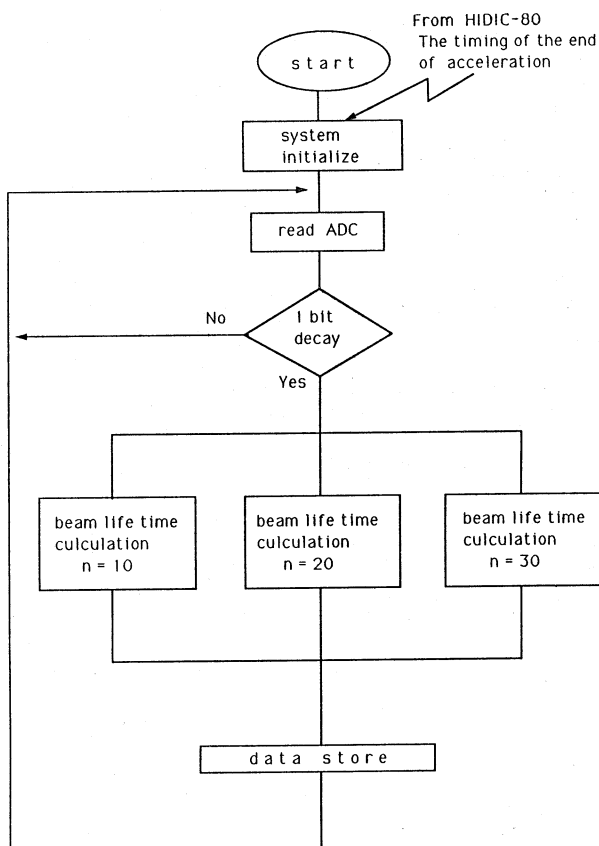


FIG. 4 Flow chart of the micro-computer code

b) Calculation routine: A beam lifetime is calculated when the measured data decreases by 1 digit from the previous data, according to equ.(3), where n decides precision and response. Three beam lifetimes, for $n=10, 20, 30$, are available for various purposes. These lifetimes are shown in fig.5.

c) Data store: Three beam lifetimes and current values are stored in the memory module. Software on HIDIC-80 selects which lifetime should be used.

An example of the time variation of beam lifetime is shown in Fig.6. In this case, the time variation of beam lifetime responds well to the variety of current.

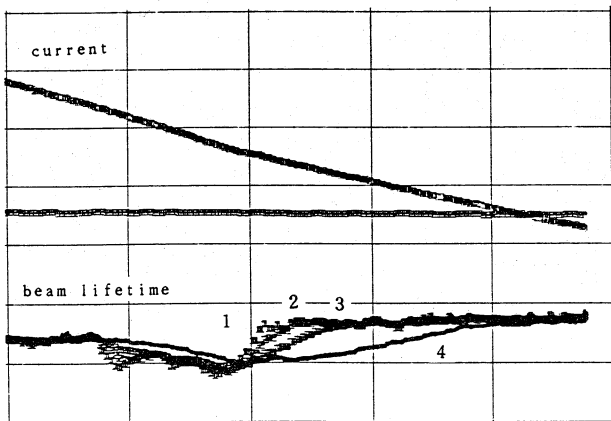


Fig.5 Behaviors of fitted beam lifetime calculated in the case of $n=10$ (1), $n=20$ (2), $n=30$ (3) are compared to calculation of HIDIC-80(4).

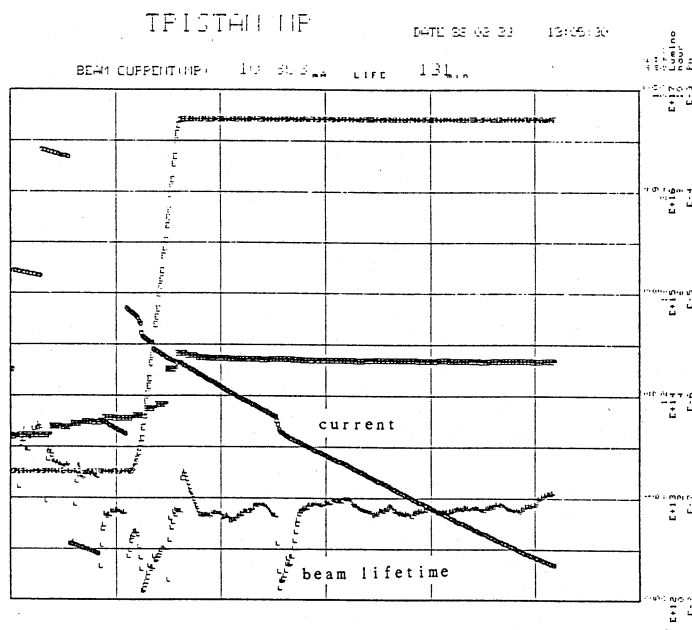


Fig.6 An example of the time variation of beam lifetime

Conclusion

A new system has attained the following improvements:

- Time interval to read ADC data is decreased from 1 sec to 100 msec.
- Resolution of ADC is improved from 12/13 bits (AR/MR) to 16 bits.

The accuracy of the beam lifetime measurement is now limited by the accuracy of the DC beam current transformer. The LSB of ADC corresponds to $1.5\mu A$, while the accuracy of the DC beam current transformer is $20\mu A$ in MR. Refinement of the front part is essential for further improvement.

Acknowledgment

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