DEVELOPMENT OF WIDE BAND FCT SYSTEM FOR BOOSTER SYNCHROTRON OF INDUS-1 & 2

Prashant Pareek*, Karan singh & R.S. Shinde
Raja Ramanna Centre For Advanced Technology, Indore, India.

Abstract

A precision, non-destructive type wide band FCT for measurement of electron current of Booster synchrotron for Indus-1 & 2 has been developed. This monitoring system is composed of fast and slow FCTs using NiZnCo ferrite toroids, pulse amplifiers and electromagnetic shields. The FCT shows fast rise time (60 ns) large time constant (38 ms), high sensitivity 25 mV/mA at 50 Ω and linearity within 1%. This paper focuses on FCT design, construction and pulse response.

INTRODUCTION

For the fine operation of accelerator it is important to measure beam current and pulse shape so a wide band FCT is required to measure electron beam turn to turn current and stored current accumulation during 1µs pulse injection into booster synchrotron. The parameters required for FCT are 1) fast rise time 2) large L/R ratio 3) high signal to noise ratio 4) good linearity. It is difficult to achieve above characteristics using single large ferrite toroid. So we have developed two FCTs using large Ni-Zn-Co ferrite toroids, housed in a single box with two outputs. One FCT measures the current from 60 ns to 15 µs and another measures from 12 µs to 1 ms. The spacing between two FCT is optimized to reduce mutual coupling .The two outputs are amplified, buffered and then transmitted through 50 Ω characteristic impedance coaxial cable to control room.

CIRCUIT DESCRIPTION

Principle

The FCT picks up the magnetic field generated by electron beam [1]. A simplified equivalent electrical circuit diagram is shown in fig 1.

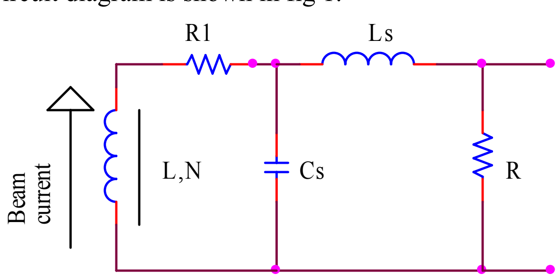

Figure 1: Equivalent electrical circuit diagram of FCT

where

- L, the pickup coil or secondary inductance
- N, the number secondary turns
- R, the load resistance
- R1, the resistance of cable of secondary circuit
- C_s, Stray capacitance between components
- L_s, stray inductance between the components

Due the combination of L_s & C_s results in overshoot and damped oscillation of the output signal. The stray inductance and capacitance influences the rise time. To get fast rise time 60 ns, numbers of turns are reduced in fast FCT and to get large time constant 38 ms, number of turns are increased. Secondary side reflected equivalent circuit diagram is shown in fig 2.

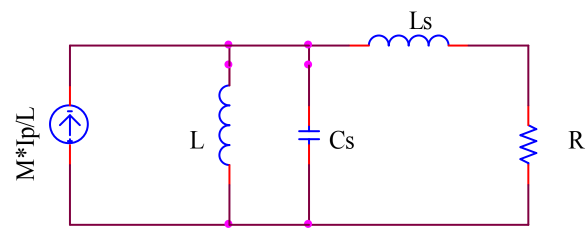

Figure 2: Equivalent secondary side reflected electrical circuit diagram of FCT

Fast FCT

Fast FCT has given 20 turns and terminated with 4.75 Ω resistance, which gives time constant 87 µs. The pickup coil wound on small region of the core, so the leakage inductance cannot be neglected. Therefore, the current transferred to secondary will be equal $M*I_{beam}$ / L_{pickup} instead of I_{beam} / N. M is the mutual inductance between pickup coil and I_{beam} acting as primary. The measured M and coupling coefficient K are 15 µH & 0.6 respectively . The signal across load resistance is amplified by differential video amplifier MC1733. A cable driver LH0033 is used to transmit the signal through 50 Ω characteristic impedance coaxial cable to control room. The electronic block diagram is shown in fig 3.

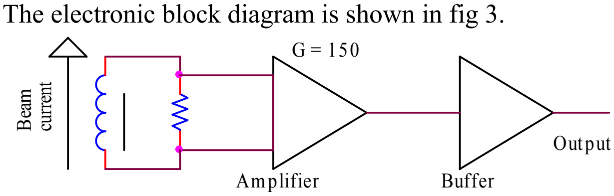

Figure 3: Electronic circuit block diagram for fast type FCT

Slow FCT

Slow FCT has given 350 turns and terminated with 3.2 Ω resistances, which gives time constant 38ms. Here the pickup coil wound on entire region of the core. The measured M and coupling coefficient K are 307 µH & 0.72 respectively. Due to large number of turns, high gain is required which is achieved in three stages using video amplifier and operational amplifier and cable driver LH0033 is used to transmit the signal through 50Ω characteristic impedance coaxial cable [2]. The electronic

*ppareek@cat.ernet.in

block diagram is shown in fig 4 and the parameters of FCTs are shown in table 1.

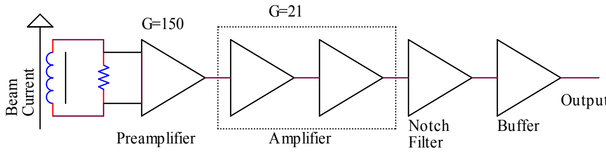

Figure 4: Electronic circuit block diagram for slow type FCT

Table 1: Parameters of FCTs

FCT	Number of Turns	Inductance	Load Resistance	Time constant
Fast	20	417µH	4.75Ω	87µs
Slow	350	124mH	3.2Ω	38ms

CONSTRUCTION

Fig 5 shows the photograph the wide band FCT. The current monitor composed of two ferrite toroids of dimension 120 mm (OD) x 100 mm (ID) x 15 mm thick. These toroids are cut using diamond wafer blade of 0.4 mm thick into two pieces. It is used as non-destructive type. These toroids are fitted into aluminium casing with spacing 10 mm between them to minimize mutual coupling between them. The electronic circuit is also enclosed in 3mm thick enclosure to reduce electromagnetic interference. The complete FCT system is enclosed in Mu-metal enclosure to reduce magnetostatic as well as electromagnetic interference.

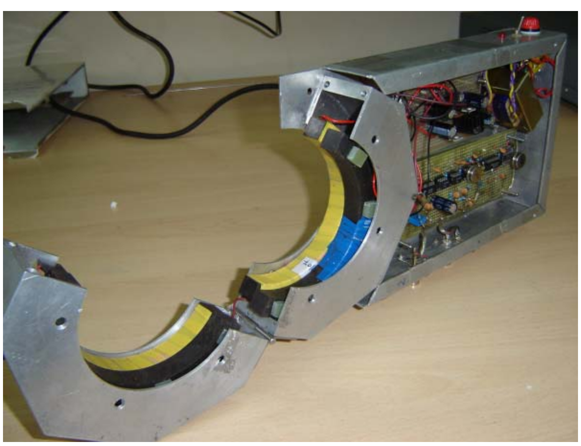

Figure 5: Photograph of Wide band FCT

CALIBRATION

The output voltage of the FCT will be given by, $V = G*R*M*I_{beam} / L_{pickup}$. There is nearly close agreement between measured voltage using calibration setup and voltage by formula. The FCT is calibrated by using pulse generator, single wire as a beam current, matching resistor 50Ω. Pulse current through single wire was measured by fast current probe (Tektronix TCP202) and output of FCT was measured by DSO (Tektronix TDS 540C,500MHz) [3]. Fig 5 and 6 shows the pulse response of the FCTs.

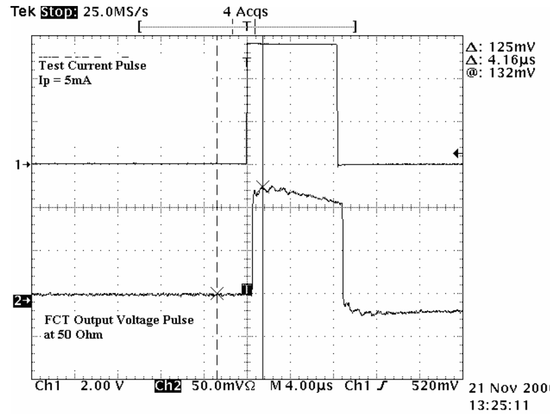

Figure 6: Pulse response of fast FCT

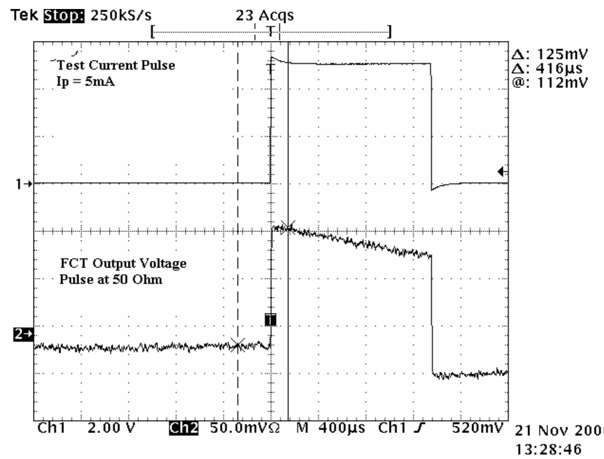

Figure 7: Pulse response of slow FCT

RESULTS

The sensitivity of both the FCTs is observed 25mV/mA with accuracy and linearity better then 1%. The observed droop is 2 %/µs for fast and 13 %/ms for slow type FCT. Large droop in slow FCT is due to notch filter in the electronic circuit. Stability of FCT over long period is measured in our laboratory. It is observed a stable & clean pulse. Now, FCT system is ready for its installation into Booster Synchrotron.

ACKNOWLEDGEMENTS

The authors would like to thank Shri.S. Kotaiah, PM (Indus-2) & Shri. Gurnam Singh, Head IOAPDD for their kind guidance, scientific & technical discussion during FCT developmental works. We express great thanks to Mr. Shiv Bachan & Mr. Lalchand Ghongde for their technical assistance throughout the fabrication of Wide Band FCT system.

REFERENCES

[1] R.S. Shinde "High precision current ferrite monitors", J.PHYS. IV FRANCE 7(1997) , p. C1-159

[2] P. Strehl "Beam Instrumentation and Diagnostics", Springer

[3] P. Pareek , K. Singh , etal "Pulse measurement of FCTs" RRCAT internal note , 2006.