Upgrade of the Analog Integrator for EAST Device

Y. Wang*, Z.S. Ji, Z.C. Zhang, S. Li, F. Wang, X.Y. Sun

Institute of Plasma Physics, Chinese Academy of Sciences

P.O.Box 1126, Hefei, Anhui 230031, P.R.China

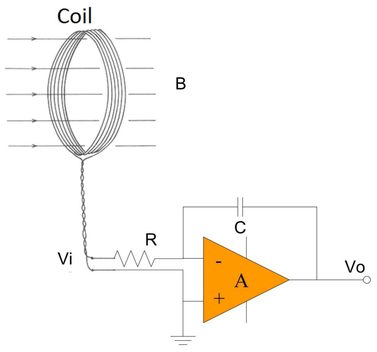
*Corresponding Author, Email: wayong@ipp.ac.cn

ABSTRACT : Integrators are fundamental instruments to recover differential signals from magnetic probes in Experimental Advanced Superconducting Tokamak (EAST) experiments. While previous analog integrators are single-ended input, which has low common mode rejection ration (CMRR), a kind of difference integrator is introduced which has the same structure as the standard difference amplifier. The linear fitting method is used for determining the effective drift slope, then the plasma control system (PCS) use the drift slope to rectify the integration signal in real time. To improve the maintainability and testability of the integrator system，a new integrator controller was developed，which uses an ARM micro-controller and the lightweight IP protocol stack to realize the network control. The tests show that the upgraded integrator works well, its CMRR is high up to 125 dB when the common voltage is 1.5 V, and the processed integration drift is about 200 uVs /1000 s, which is much better than the previous integrator.

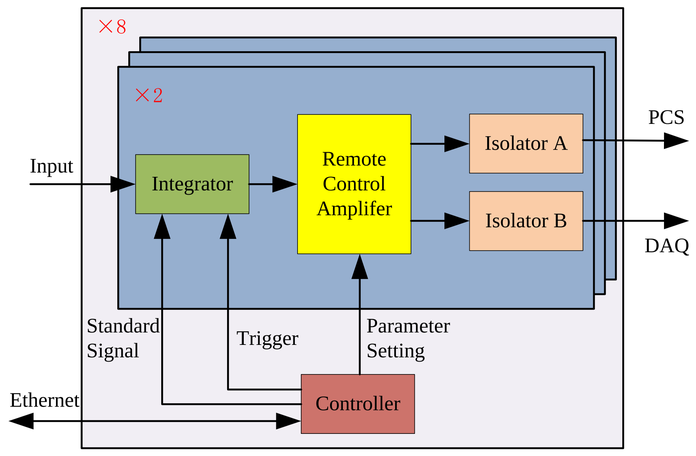
Introduction

There are more than 600 channels of integrators has been used for EAST about 10 years. The main purpose of the upgrade of the analog integrator are as follow:

- To optimize the system structure and improve the maintainability and testability
- To improve the common mode rejection ration (CMRR)
- To reduce the integration drift.



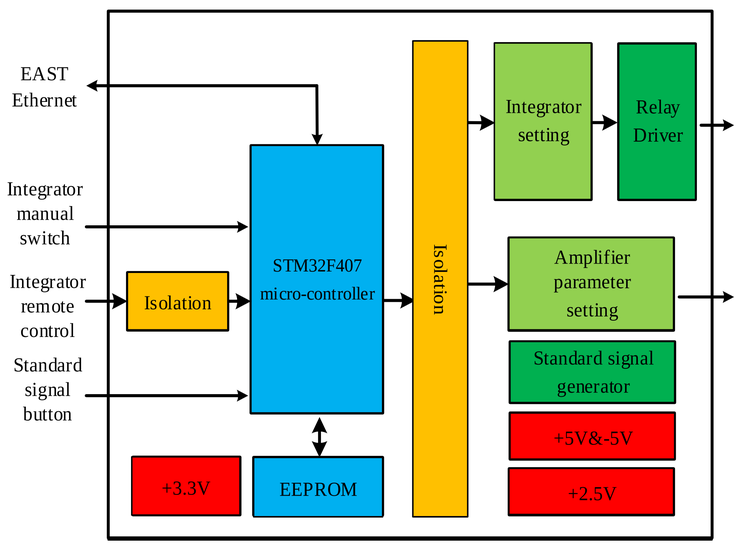
System Structure



This new integrator system mainly consists of four parts: integrators, isolators, remote control amplifiers and controller.

The input of the integrator is a magnetic signal or a standard test signal. There are two outputs, one is to the Plasma Control System (PCS), and the other is to the Data Acquisition System (DAS). Before transit the signals to integration results, each path will go through isolators and remote control amplifiers.

Controller

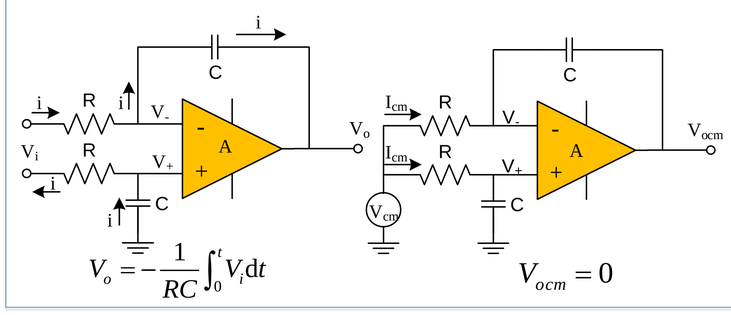


- ARM Cortex-M4 micro-controller STM32F407ZGT6
- The control signals control the relays on integrator modules by ULN2803
- The controller receives instructions via Ethernet
- 1 manual switch for local control
- 1 BNC interface for remote control
- 1 manual button for standard signal

The program on STM32F407ZGT6 has realized TCP communications based on LwIP.

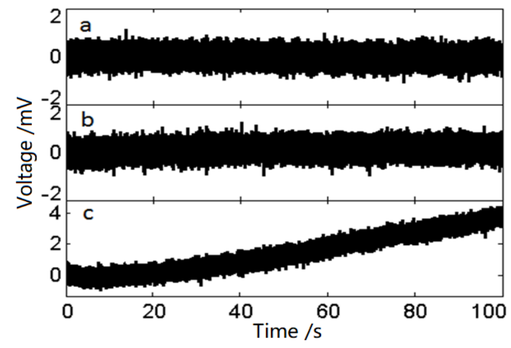
Instruction	Description
ALLd;d;d;d;d;d;d;d;d;d	Set the gain for all channels
READAll	Read the gain of all channels
RCd	Set the gains on one module
INTEd	Set the same gain for all channels
Initialization	Initialize to normal mode
StandardSignal	Integration of a standard signal
PulseSignal	Integration of a pulse signal (extended to 1s)
IntHold	Hold the integration value
NET X.X.X.X;X.X.X.X;X.X.X.X	Modify IP，MASK，GATEWAY
QUIT	TCP disconnected

Difference Integrator



The difference integrator has the same structure as the standard difference amplifier, in which two resistors are replaced by two capacitors, which has high CMRR.

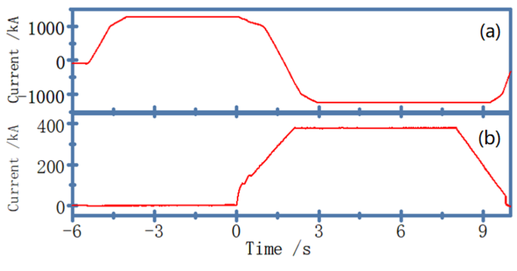
Performance



The common mode voltages are 0 V (a), 0.13 V (b) and 1.5 V (c).

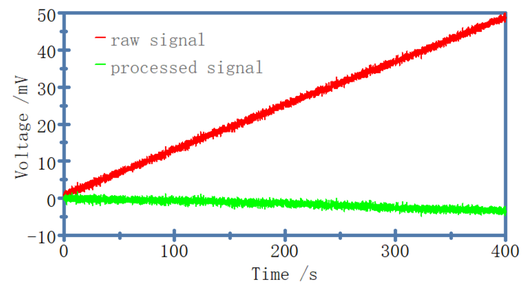
RC=20 ms, T=100 s

$$20\lg\frac{1.5\mathrm{V}\times 100\mathrm{s}}{4\mathrm{mV}\times 20\mathrm{ms}} \approx 125\mathrm{dB}$$



When the terminal of a magnetic probe touches the wall inside the tokamak，the integration signal (a) is wrong by the single-ended integrator.

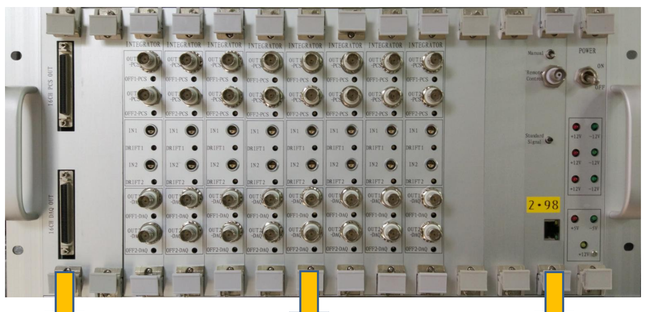
While the integration signal (b) turns out to be right when using the difference integrator.



A reference shot is used for calculating the drift rate, then the plasma control system use the drift slope to rectify the integration signal in the following shot in real time.

The raw signal drift is about 50 mV / 400 s, while the processed signal drift is about 4 mV / 400 s, that is 200 uVs /1000 s (RC=20 ms).

System Pictures



Interface module

Integrator module

Control module

Eight integrator modules, one control module and one interface module are assembled in one chassis.

Each integrator module has two channels, so there are 16 channel integrators in one chassis.

Additional, there is an interface module, which can connect the 16ch outputs to the digitizer directly through SCSI interface, such as PXI-2022 and PXIe-6368.

32ch outputs of two integrator chassis can be combined together and connected to the D-TACQ digitizer without additional BNC panels.

Conclusion

Compared with the previous integrators, the upgraded has following features:

(1) Lower drift, < 200 uVs / 1000 s

(2) higher CMRR, 125 dB when the common voltage is 1.5 V

(3) higher integration and better maintainability

Acknowledgment

This work is supported by National Key R&D Program of China (Grant No: 2017 YFE0300500, 2017YFE0300504).