TPS DIGITAL CORRECTOR MAGNET POWER CONVERTER BASED ON FPGA

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Abstract

This paper is to realize digital corrector magnet power supply based on FPGA. The purpose of the study is to implement digital PID controller by using Xilinx programmable gate array (FPGA), in hope of enhancing output performance and reducing circuit size.

The ±10A/± 48V output corrector magnet digital FPGA power converter uses a full bridge configuration, the switching frequency of power MOSFET is 40 kHz, in which each bridge leg has its own independent PWM controller and the output current bandwidth is 1kHz when connected with the corrector magnet load. Using a DCCT as the current feedback component, the output current ripple of this converter could be lower than 10ppm. In this paper, the hardware structure and control method of the corrector magnet power converter will be described and the test results will be demonstrated.

THE STRUCTURE OF DIGITAL FPGA CORRECTOR MAGNET POWER CONVERTER

The corrector magnet power converter could be roughly divided into three functional sections：Power regulation and filtering 、 Digital FPGA controller 、 high precision current feedback system, as figure 1 shows.[1]

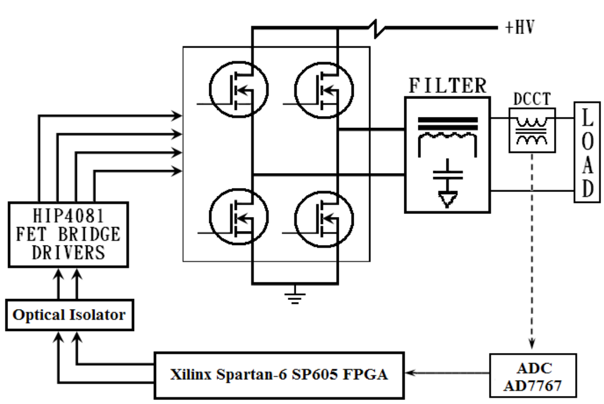

Figure 1: The structure of corrector power converter.

HIGH PRECISION CURRENT FEEDBACK SYSTEM

The key component for the corrector magnet power converter to meet the current output precision requirement is the current sensors. Here we adapt the Danfysik Ultra stab 866-20I DCCT.[2] The analog-to-digital converters we choose is AD7767, which is a high performance, 24-bit, oversampled SAR analog-to-digital converters (ADCs). The AD7767 combines the benefits of a large dynamic range and input bandwidth.

Ideal for ultralow power data acquisition, the AD7767 provide 24-bit resolution. The combination of exceptional SNR, wide dynamic range, and outstanding dc accuracy make the AD7767 ideally suited for measuring small signal changes over a wide dynamic range. This is particularly suitable for applications where small changes on the input are measured on larger ac or dc signals. In such an application, the AD7767accurately gather both ac and dc information.[3]

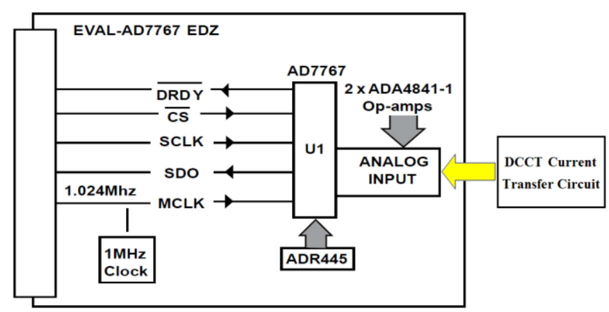

Figure 2: high precision current feedback.

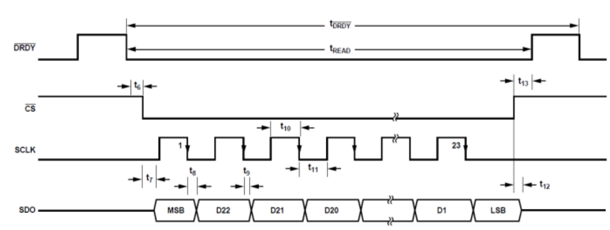

Figure 3:AD7767 Serial Timing Diagram.

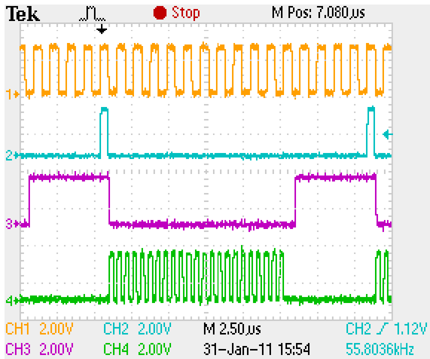

Figure 4:FPGA singal in reading ADC data.

DIGITAL FPGA CONTROLLER

Spartan-6 FPGA delivers is chosen as Digital controller. Because what Spartan-6 FPGA can deliver is an optimal balance of low risk, low cost, and low power for cost-sensitive applications, now with 42% less power consumption and 12% increased performance enabled by ISE Design Suite. Spartan-6 FPGAs offer advanced power management technology, up to 150K logic cells, integrated PCI Express blocks, advanced memory support, 250MHz DSP slices, and 3.2Gbps low-power transceivers.[4]

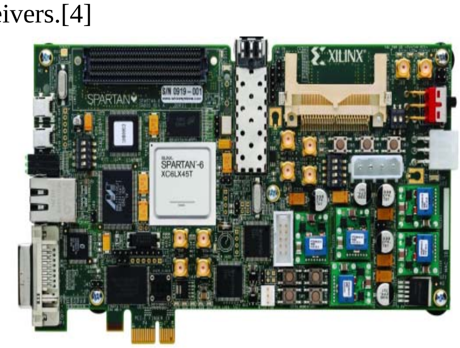

Figure 4:Xilinx Spartan-6 FPGA SP605 Evaluation Kit.

Table 1: Xilinx FPGA SP605 Feature

Device	XC6SLX45T
Logic Cells	43,661
Slices	6,822
Flip-Flops	54,576
Max Distributed RAM	401(Kb)

USE MATLAB SIMULINK TO SIMULATOR CONTROL METHOD

The Matlab Simulink is used to simulate the digital control method, in order to assure feasibility of the high precision control method.[5]

The corrector power converter regulates the output current by controlling the pulse width of an H-Bridge power MOSFETs. The switching frequency is 40kHz. The H-Bridge is shown in Figure 5.

In Figure 5, the P-I compensator generated an error signal from current command and the current feedback signal. The error signal compared with the triangle wave signal to generated PWM signal to control MOSFET.

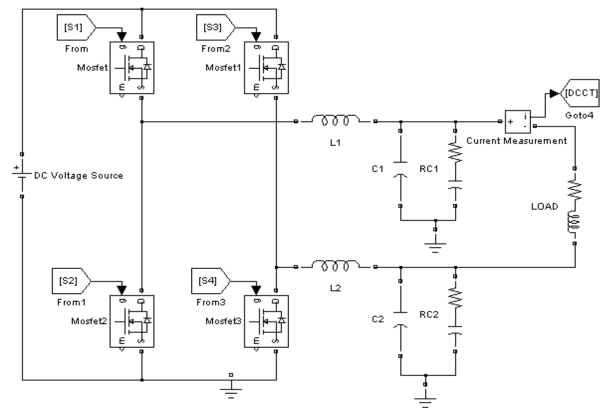

Figure 5:The power regenerator system diagram.

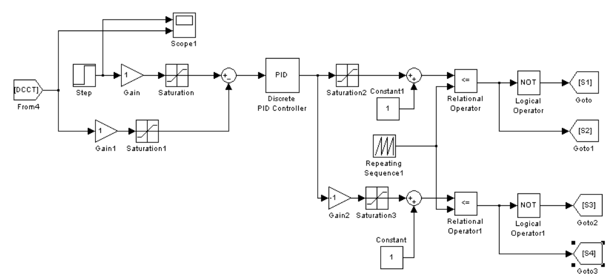

Figure 6: P-I compensator block diagram.

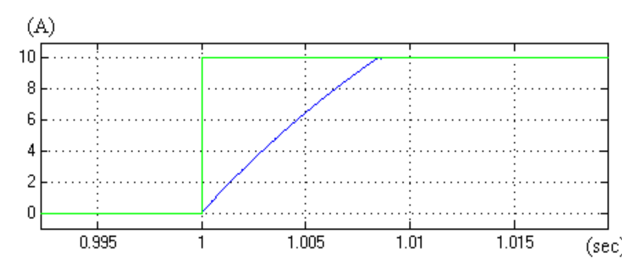

Figure 7: PI Controller Step Response.

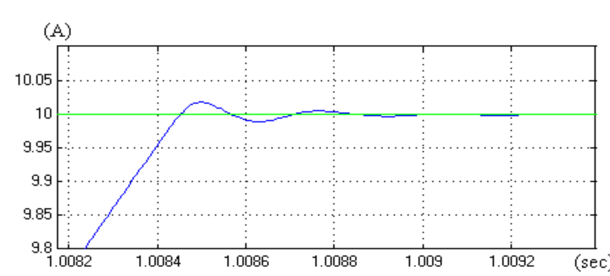

Figure 8: Reset Windup for PI Controllers.

In the Figure 9, top diagram is the simulated 3Hz sin wave input reference command and the bottom is the simulation result of current output.

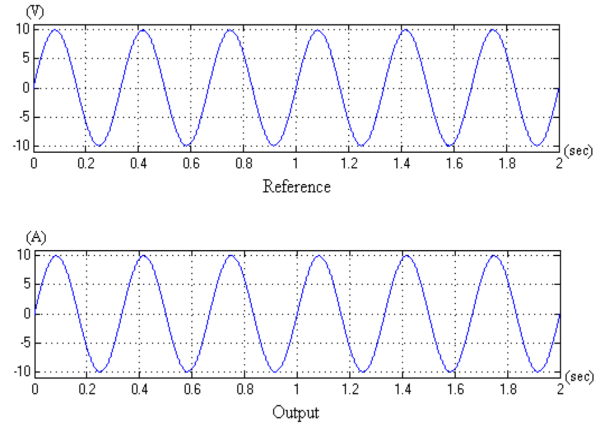

Figure 9: 3Hz sin wave input and current output diagram.

FREQUENCY RESPONSE AND OUTPUT CURRENT STABILITY

In Figure 10, the total ripple current intregated from 0 Hz~1 kHz is about 60uA that is 6ppm for ±10A maximum current output of corrector magnet power converter.

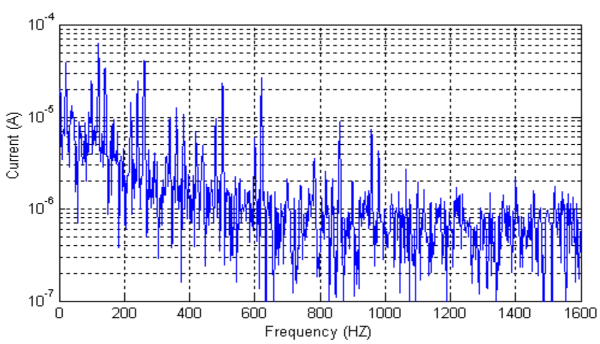

Figure 10: The frequency response of the corrector magnet power converter.

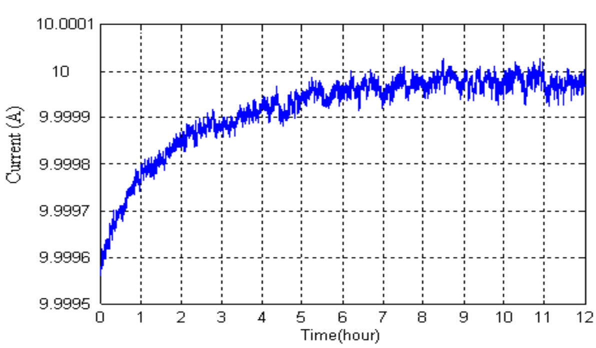

Figure 11: Stability of output current of the corrector magnet power converter within 12 hours.

In Figure 11, shows the output current stability of the corrector magnet power converter with duration of 12hours, and the stability is within 5ppm.

CONCLUSION

Using FPGA to realize a new high performance full digital corrector magnet power converter is fulfilled. In Figure 12, the realized digital corrector magnet power converter based in FPGA is shown.

This digital corrector magnet power converter could output current with 5PPM stability within 12 hours、20uA ripple(0~1kHz). This corrector magnet power converter is versatile to meet any kind of requirements for magnets to be powered within ±10 amperes that include booster ring corrector (horizontal & vertical)、trim coil of storage ring sextupole (include horizontal dipole、vertical dipole & skew quadrupole) and fast feedback corrector.

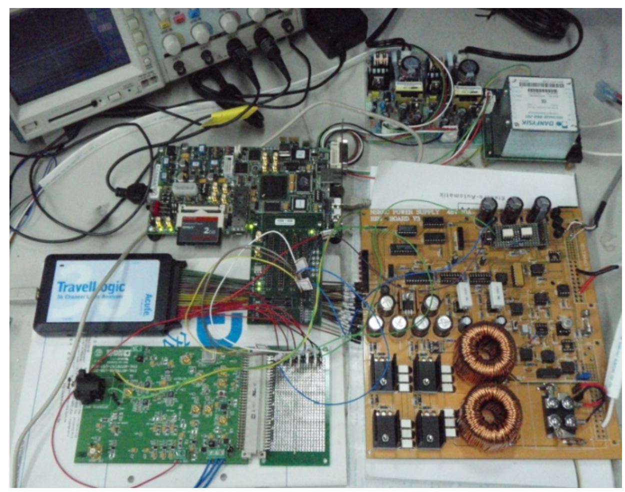

Figure 12: The picture of digital corrector magnet power converter.

REFERENCES

[1] TPS corrector magnet power converter: Kuo-Bin Liu, Yi-Da Li, Kuo-Tung Hsu, Bao-sheng, Wang (NSRRC, Hsinchu, Taiwan), Jimmy Chun-ming Hsu (CMS/ITRI, Hsinchu, Taiwan) IPAC10.

[2] Danfysik Ultrastab 866-20I, http://www.danfysikacp.com.

[3] AD7767 datasheet, Analog Devices.

[4] Spartan-6 FPGA Family. http://www.xilinx.com/

[5] Math Works. http://www.mathworks.com/