

# NEW PURPOSED HIGH PRECISION POWER SUPPLY FOR QUADRUPOLE MAGNETS OF ILSF USING LOW RESOLUTION DIGITAL PWM

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## Abstract

A total number of 104 quadrupole magnets, split into 9 families, will be required for the ISLF storage ring lattice. Each quadrupole magnet has own independent power supply. In new design of quadrupole magnets, the output of two synchronized current-fed push-pull converters (one for coarse regulation and another for fine current regulation) will be added together before a synchronous rectification. By using this method, there isn't any requirement to use extra high-current output inductor. Also less power dissipation can be seen on power switches. To produce PWM signals at this design, special switching mode 16-bits microcontroller family from Microchip co was used.

## DESCRIPTION

After finishing the Conceptual Design Report for ILSF and before starting basic and detail design [1], construction of some prototype devices such as power supplies, would be very useful to get a pretty good estimate of domestic capabilities.

Many topologies of power supplies were considered for quadrupole of ISLF storage ring. One of them is series combination of two power supplies which is shown in figure 1.

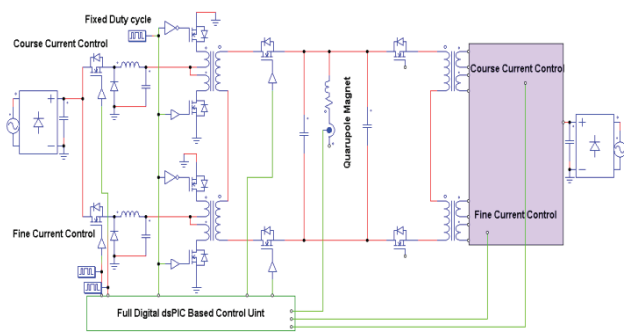


Figure 1: Schematic of 1.2 KW low resolution PWM.

As shown in Figure 1 the power converter consist of 2 main sections. Each section has one buck converter and one push-pull converter. In order to minimize the output current ripple, each MOSFET of push-pull working at 55% on-time duty cycle. At 100A working point, the coarse controller can regulate at 0.1A and fine regulator tune output current to 0.001A steps to reach better than 10-100ppm precision and stability.

The main idea for both regulators comes through current-fed topology. One typical schematic of current-fed topology is shown in figure 2. The current-fed topology can also be implemented as a buck-push-pull circuit. As in the buck-current-fed bridge, the capacitor after the buck inductor L1 is omitted and Q1, Q2 are operated with a deliberately overlapping on time. Only buck transistors Q5A, Q5B are width-modulated. Output inductors are not used. All the advantages of the buck-current-fed bridge are retained. Although off-voltage stress is twice V2 (plus a leakage spike) instead of V2 as in the bridge, that is still significantly less than twice V1 as V2 is bucked down to about 75 percent of the minimum value of V1. This circuit is used at lower power levels than the buck-current-fed bridge and offers the saving of two transistors [2].

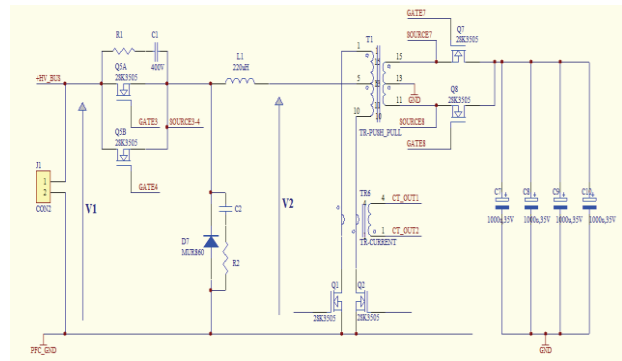


Figure 2: Schematic of current-fed push-pull.

High precision programmable switching power supply, known as its precise feedback system and high resolution PWM generator. In case of using analog PWM controller, high resolution digital to analog (DAC) is essential. As well in full-digital SMPS, high resolution PWM (more than 16 or 18-bit) is required which can be find at advanced DSP with internal special PWM generator.

In this design we have tried to achieve 90 ppm accuracy with full digital components without using high resolution PWM generator. This design was based on DSPIC33FJ16GS504 [3] from Microchip that just used for SMPS design to generate 10 to 12-bit several independent channel PWM at frequency between 10-20 kHz.

## RESULTS AND DISCUSSION

To check the performance of this purposed design, one prototype power supply has been constructed. A 1.5kW power factor corrector (PFC) designed and constructed as Input stage of this power supply. 2SK3505 from FUJI ( $V_{DSS}=500V$ ,  $I_D=14A$ ,  $R_{DS(On)}=350m\Omega$ ) [3] was chosen as switching device for both buck and push-pull converters and IRF3070 from International Rectifier ( $V_{DSS}=75V$ ,  $I_D=210A$ ,  $R_{DS(On)}=2.8m\Omega$ ) [4] was selected for synchronous rectifier stage. DSPIC33FJ16GS504 a 16-bit microcontroller from Microchip also selected as main controller for first design but it will be replaced by DSP from Texas Instruments.

As shown in Figure 3 the fabricated 1.2kW power supply was installed in 3-unit 19 inch rack mount case.



Figure 3: Fabricated 1.2 kW prototype power supply at ILSF using low resolution.

After completing design and fabrication of this power supply, it was necessary to verify the performance of this design. Stability measurement was the most important test, so several tests were done to measure short and long time stability. Figure 4 shows first result of stability measurement on magnetic load. It is chart of output currents vs. time when power supply connected to a magnet load for less than 5 hours.

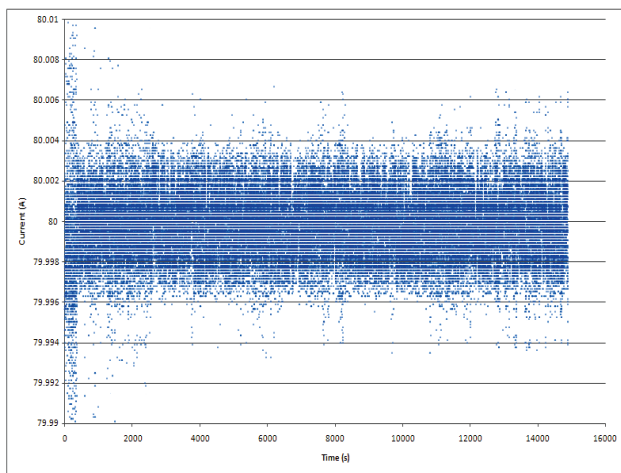


Figure 4: Variation of output current versus time. Measurement was done by using an external DCCT (IT-150S Ultra stable from LEM) and 24-bit 2kHz sigma delta ADC, HI7191 from Intersil [6].

Based on figure 4, the maximum current variation can be seen about 8 mA in 80A which is equal to 100 ppm accuracy.

## CONCLUSION

After finishing design and fabrication of desired power supply, required tests were done which 100 ppm accuracy obtained during first sets of measurement. More measurement should be performed such as line and load regulation to verify exact performance of this power supply and then some new and more advanced algorithms for digital control loop should be used to improve the overall stability of this new design. By the way first results shows, after some modification, this topology potentially could be a good candidate for power supplies of Quadrupole magnets in storage ring or transfer line of ILSF. Authors of this paper hope to improve this design to reach at least 20ppm stability refer to maximum output current.

## REFERENCES

- [1] Conceptual Design Report, Iranian Light Source Facility (ILSF), October 2012
- [2] A.I. Pressman, *Switching Power Supply Design*, (The McGraw-Hill Companies, Inc., 1999), 189.
- [3] [ww1.microchip.com/downloads/en/DeviceDoc/70339A.pdf](http://ww1.microchip.com/downloads/en/DeviceDoc/70339A.pdf)
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