REDUCING OUTPUT CURRENT RIPPLE OF POWER SUPPLY WITH COMPONENT REPLACEMENT

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Abstract

Correction magnets of synchrotron storage ring are served with linear power supplies (correction power supply) with 100 ppm output current ripple in National Synchrotron Radiation Research Center. Reducing output current ripple of correction power supply might reduce perturbation of beam position of storage ring. Replacing correction power supplies with lower output current ripple ones is straightforward but costs lots of money. Without adding any other circuit and electronic component, some components of correction power supply are replaced by ones with more precious and lower output fluctuation; so that the same circuitry structure of correction power supply is kept without increasing its complexity and could reach 25 ppm output current ripple

INTRODUCTION

The control interface of correction power supply is simply based on analog input analog output (AIAO) and digital input digital output (DIDO), the control signals of power supplies are from interface cards of INTRUMENT AND CONTROL (I&C) group and there is some distance between these two electronic systems.

As we know, ground loops exist when two different two electronic systems are connected and the longer distance between them the more series problem will arise, in our case the output current ripple of correction power supply would get larger and how to eliminate ground loops effect is the main concern to reduce output current ripple.

There were several devices of control circuitry replaced, loop gain changed and some re-wiring; each one of them makes obvious contribution on reduction of output current ripple of correction power supply, so measurements will be demonstrated for any procedure.

REFERENCE INPUT STAGE

The control and status read-back interface of correction power supply is a digital interface, current control and read-back are analog signals. Because current control crate of INTRUMENT AND CONTROL (I&C) group and correction power supply are separated by a long distance so that ground loop between these two systems exists. Ground loop at times can be a source of noise, if the magnitude of noise is too large such that circuit operation might be affected and the performance of power supply degrade. The effect of ground loop can be eliminated or at least minimized by isolating these two circuits, isolation can be achieved by transformer, common mode choke, optical coupler, balanced circuitry, frequency selective grounding or isolation amplifier.

There are two current control reference input stages of correction power supply, remote control state and local control state. In normal remote control state the most concern is ground loop effect induced by connection between power supply and control crate of I&C group. The circuitry used as a remote current control analog input stage is an isolation amplifier BURR-BROWN ISO120BG[1]. The performance of isolation ability of BURR-BROWN ISO120BG is undoubted very well, but some parameters(gain、input offset voltage、…etc.) seems like to be not so good that lower output current ripple is not reached. Figure 1 shows output current ripple of correction power supply.

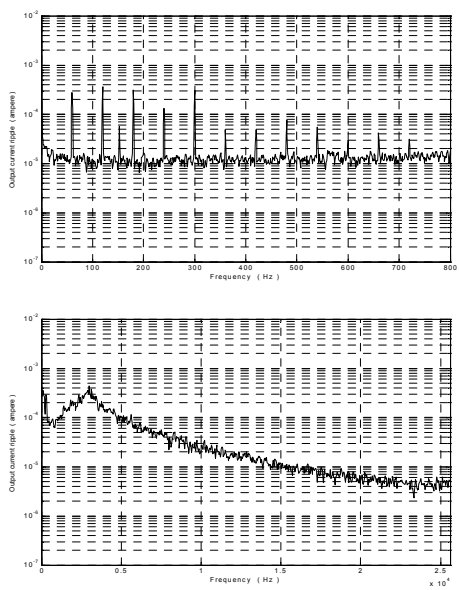
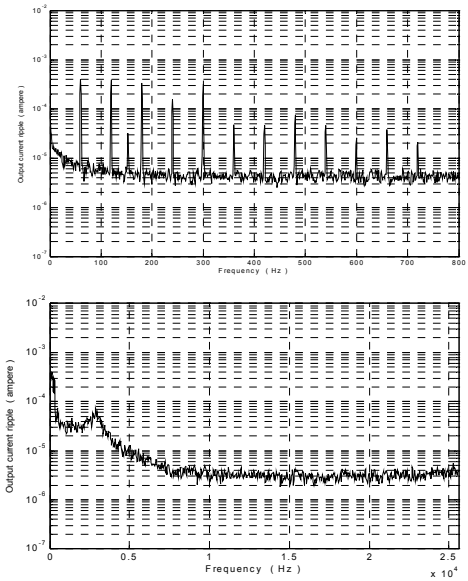


Figure 1 : Original output current ripple
(a) (0~800 Hz) (b) (0~25 kHz)

Instead of an isolation amplifier, the local reference input stage of correction power supply is a differential amplifier composed of four resistors and an OP177, a differential amplifier is also able to eliminate or minimize

the effect of ground loop and minimization ability is dependent on the matching ratio of these four resisters. By changing some wiring the differential amplifier could be used instead the reference input stage of correction power supply and Figure 2 shows output ripple current of correction power supply after reference input stage is changed.



(a)

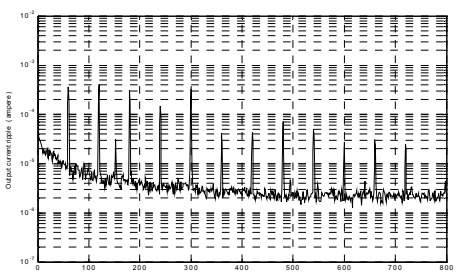
(b)

Figure 2 : Output current ripple of power supply after modification of reference input stage
(a) (0~800 Hz) (b) (0~25 kHz)

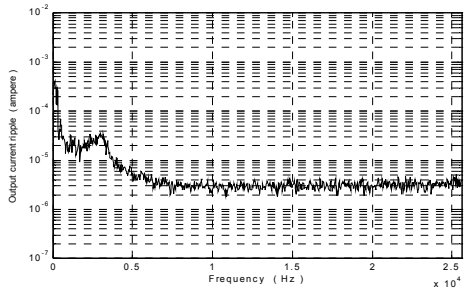
From figure 1 and 2 we can see that background current ripple is reduced from 10^{-5}A to $4*10^{-6}$A and 2.5kHz current ripple envelope is reduced from $4*10^{-4}$A to $7*10^{-5}$A.

INSTRUMENTATION AMPLIFIER OF CURRENT FEEDBACK

The original instrumentation amplifier served for current feedback loop is a BURR-BROWN INA110BG[2] and there is a pin to pin compatible instrumentation amplifier an ANALOG DEVICE AD624CD[3]. Replacement of these two instrumentation amplifiers is very easy and figure 3 shows the performance of correction power supply after usage of an AD624CD as an instrumentation amplifier of current feedback loop.



(a)

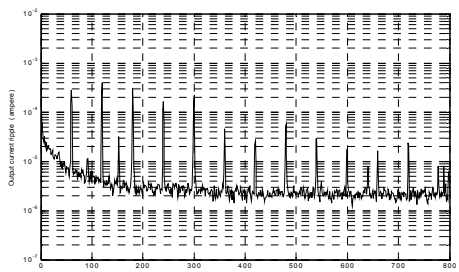


(b)

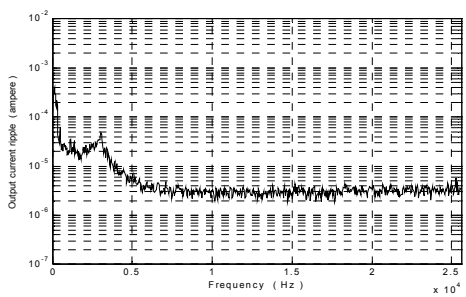
Figure 3 : Output current ripple of power supply after replacement of instrumentation amplifier of current feedback
(a) (0~800 Hz) (b) (0~25 kHz)

Figure 3 show background current ripple is reduced to $2*10^{-6}$A and 2.5kHz current ripple envelope is reduced to $3*10^{-5}$A.

The gain setting of AD624CD and BURR-BROWN INA110BG can be achieved through series and parallel combination of the internal resisters. Instead of setting gain by internal resisters there is a character of AD624CD that BURR-BROWN INA110BG do not has, the gain setting of AD624CD could be set by a external resistor. Instead of using internal resisters, a 5ppm/℃ resistor is used to set the gain of AD624CD to 100.



(a)



(b)

Figure 4 : Output current ripple of power supply after gain setting resistor of instrumentation amplifier of current feedback is replaced by external resistor
(a) (0~800 Hz) (b) (0~25 kHz)

Comparing figure 3 and 4 background current ripple seems not to be lowered down but 60Hz, 300Hz, 420Hz,

540Hz and 660Hz current ripple are reduced half.

REDUCTION OF LOOP GAIN

In original state, correction power supply loop gain is set as high as possible without oscillation on output current and the cut-off frequency of output current frequency response is about 100Hz; but the cut-off frequency of the magnet field of correction magnet is about 4Hz, so reducing loop gain of correction power supply makes not any trouble on performance of storage ring.

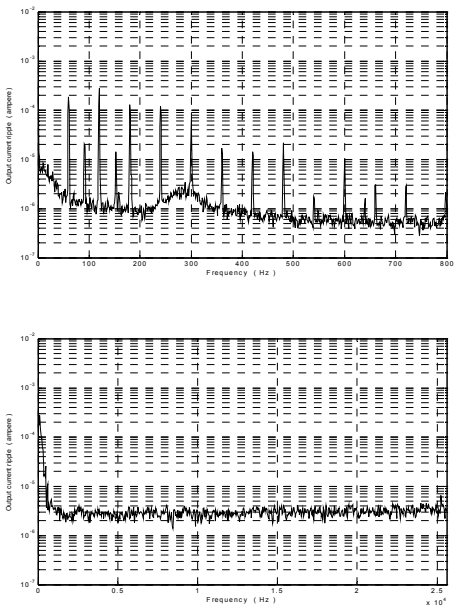


Figure 5 : output current ripple of power supply after loop gain is lowered down 100 times
(a) (0~800 Hz) (b) (0~25 kHz)

Figure 5 shows output current ripple of power supply after loop gain is lowered down 100 times, background current ripple is reduced to $7*10^{-7}$A and 2.5kHz current ripple envelope is disappeared.

REDUCTION OF GROUND LOOPS EFFECT

Ground loops almost can be a source of noise and it is inevitable on the control circuitry of correction power supply, there are multiple signal ground points separated by a large distance and theses points could not be equipotential that an unwanted noise voltage would be induced causes the performance of low-level analog circuits degrade. It is hard to redesign the control circuitry of correction power supply with low impedance ground plane but we tried wiring some signal ground points to main ground point and figure 6 shows output current ripple of power supply reduced when a point is connected to main ground point.

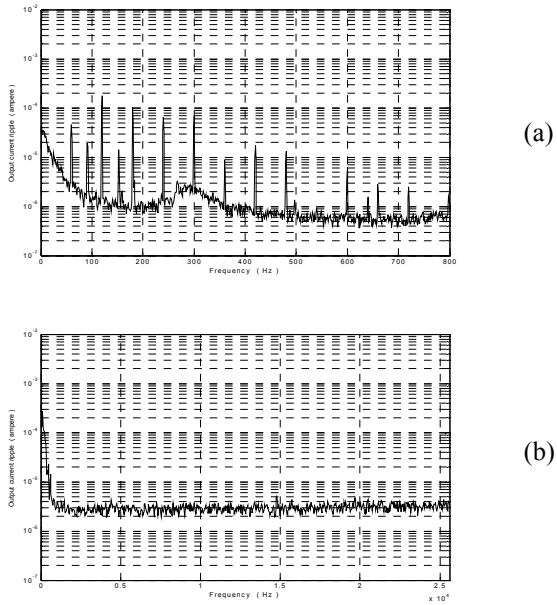


Figure 6 : output current ripple of power supply after signal ground re-wiring
(a) (0~800 Hz) (b) (0~25 kHz)

CONCLUSION

The reduction of output current ripple of correction power supply used at SRRC is reached by utilizing low noise components to replace original ones (include reference input stage OP amplifier, instrumentation amplifier for current feedback), loop gain lowering and signal ground re-wiring.

All experiments are proceed at full power output of maximum 20 amperes output current of correction power supply, this should be the worst case because at this operational condition ground loop noise and transformer magnetic field interference are largest. There are obvious results show every procedure could contribute improvement on output current ripple.

All of improvement procedures are easy and do not need to change the circuitry of correction power supply that could simplify the maintenance work.

REFERENCES

[1] Data book of BURR-BROWN, LINEAR PRODUCTS, 1995.
[2] Data book of BURR-BROWN, LINEAR PRODUCTS, 1995.
[3] Data book of ANALOG DEVICE, LINEAR DATABOOK, 1992.