

# INCREASING OUTPUT CURRENT STABILITY BY ADDING AN EXTERNAL CURRENT CONTROL LOOP

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## Abstract

The Agilent 6682A[1] power supply is used as a dipole magnet power supply of Booster to storage ring (BTS) transport-line, its output current stability is less than 100 ppm although specification is 1000 ppm. The performance of Agilent 6682A is quite good for TLS operational requirement but not suitable for less than 10 ppm output current stability general requirement of power supplies of TPS. Circuitry modification of Agilent 6682A to reach less than 10 ppm output current stability is hard to implement, but utilize analog programming function of Agilent 6682A with adding an external current control loop the output current stability of Agilent 6682A could be improved to be less than 10 ppm.

## INTRODUCTION

There are six dipole magnets at Booster to Storage ring transport-line, and each dipole magnet is powered by three paralleled Agilent 6682A power supplies. Utilizing the auto-parallel function of Agilent 6682A power supply, we can just control the master power supply and the other two slave power supplies would follow the master one to provide operational current to a dipole magnet. The real performance of Agilent 6682A power supply could reach less than 100 ppm output current stability ( although it's specification is 1000 ppm ) that is quite good for TLS operational requirement.

The general output current stability requirement of power supplies of TPS is less than 10ppm, so Agilent 6682A power supply couldn't be used at TPS without modification. It's difficult to modify the circuitry of Agilent 6682A power supply but we could utilize analog programming function of Agilent 6682A to improve it's performance.

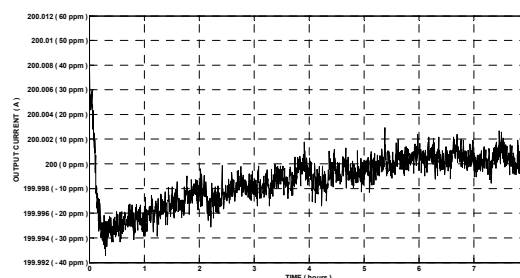
Adding an extra external control loop circuitry formed by an error amplifier circuit, Danfysik ULTRASTAB 866 DCCT[2](w/wo VOM), VISHAY 7.5  $\Omega$  burden resister[3] with 5ppm/ $^{\circ}\text{C}$  temperature coefficient that could let the output current stability of Agilent 6682A to reach less than 10 ppm.

This external control loop circuitry is operated at current feedback mode and its output signal could import to current or voltage programming port of Agilent 6682A to let Agilent 6682A to operate at current mode

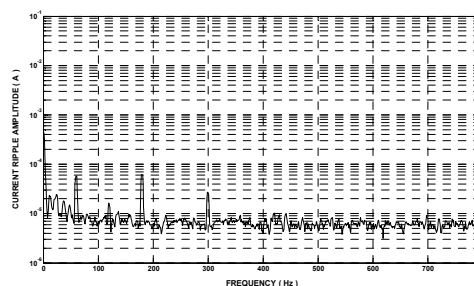
or voltage mode. In this experiment we change some conditions of this external control loop circuitry and the performance improvement will be demonstrated.

## ORIGINAL PERFORMANCE OF AGILIENT 6682A

The output current stability specification of Agilent 6682A power supply is 1000 ppm and figure 1 shows its actual performance.



(a)



(b)

Figure 1: The performance of Agilent 6682A before the external current control loop is operated (a) 8 hours long-term stability (b) Spectrum of output current ripple

Figure 1(a) shows the output current long-term stability is about 60ppm, and 1(b) shows the maximum ripple current are 60&120 Hz 60uA that is 0.3ppm.

## THE CIRCUITRY OF THE EXTERNAL CURRENT CONTROL LOOP

Figure 2(a) listed the circuitry of the external current control loop for Agilent 6682A power supply and figure 2(b) shows the connection setup between Agilent 6682A power supply, Danfysik ULTRASTAB 866 DCCT and

the external current control circuit, Agilent 6682A power supply could operated on current mode or voltage mode depends on the output signal of external current control loop circuit is connected to current programming port or voltage programming port of Agilent 6682A.

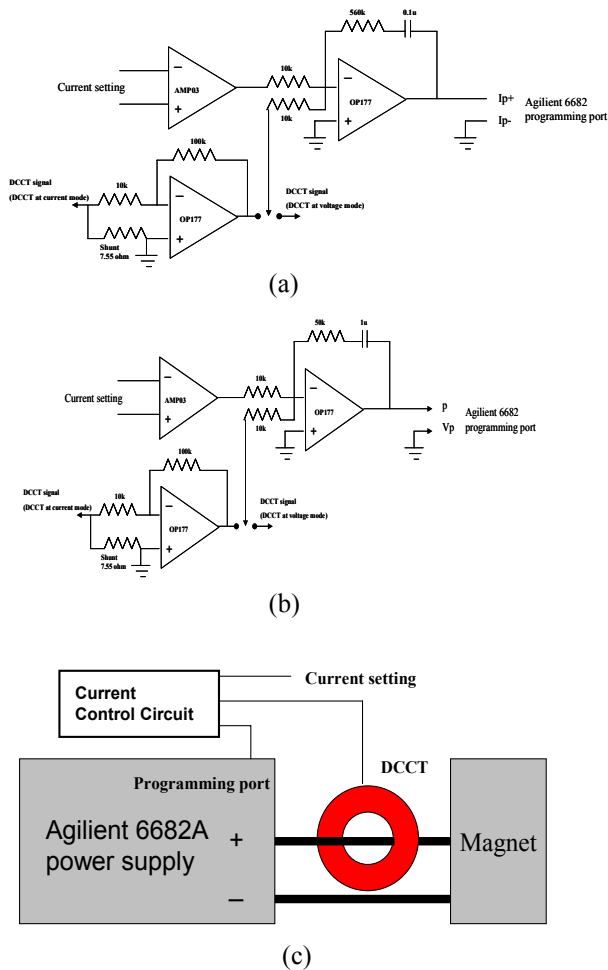


Figure 2: (a)&(b) Circuitry of the external current control loop for Agilent 6682A power supply (c) Setup for current control loop circuit for Agilent 6682A power supply

## IMPROVEMENT OF STABILITY BY ADDING AN EXTERNAL CURRENT CONTROL LOOP

Based on the setup listed at figure 2, the external control loop circuit is a current feedback control loop so it's output signal will control output current of Agilent 6682A to follow the current setting reference but Agilent 6682A could operate at current mode or voltage mode depends on the output signal of external current control loop circuit is exported to current programming port or voltage programming port of Agilent 6682A.

### Agilent 6682A is Operated at Current Programming Mode

#### Accelerator Technology - Subsystems

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Danfysik ULTRASTAB 866 DCCT with VOM output voltage signal and compared with current setting reference at error amplifier that output error signal export into the current programming port of Agilent 6682A. Figure 3 shows the result after the external current control loop circuit is operated.

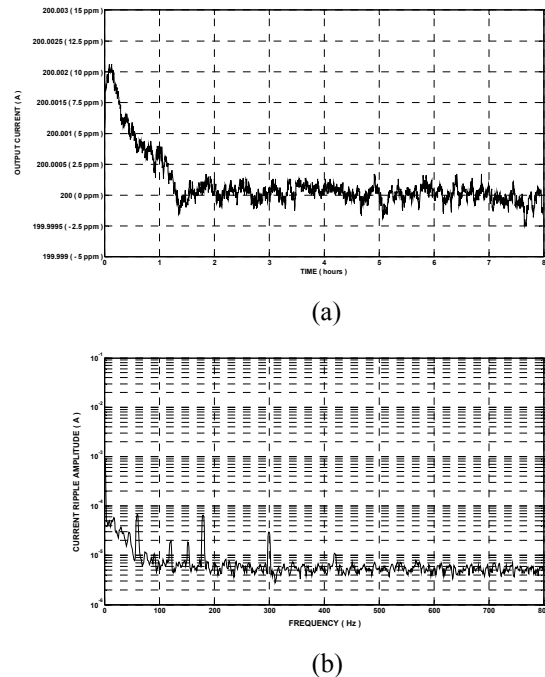


Figure 3: The performance of Agilent 6682A after the external current control loop is operated and Agilent 6682A is at constant current mode (a) 8 hours long-term stability (b) Spectrum of output current ripple

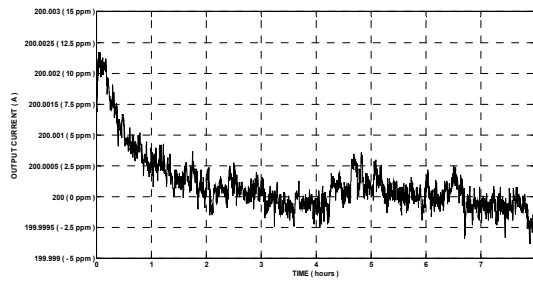
Based on figure 3, output current long-term stability is improved to be about 10ppm, after 1 hour warm-up long-term stability could be within 5ppm. The spectrum of output current ripple is almost the same as before without external current control loop circuit. The external current control loop circuit is well functioned and the improvement of output current long-term stability is obvious.

### Agilent 6682A is Operated at Voltage Programming Mode

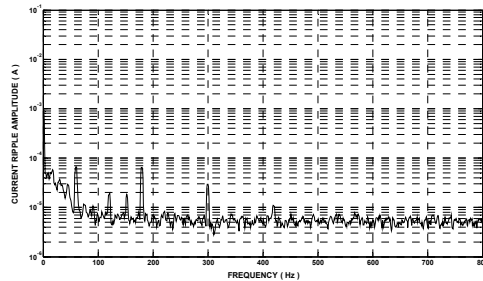
Instead of operating Agilent 6682A at current programming mode, the output signal of the external current control loop circuit is exported into the voltage programming port of Agilent 6682A.

Figure 4 shows the result. The output current long-term stability is about 10 ppm and after 1 hour warm-up long-term stability could be within 5ppm the same as Agilent 6682A is operated at current programming mode, but the short-term stability is a little worse than that Agilent 6682A is operated at current programming mode. The spectrum of output current

ripple is almost the same as that without external current control loop circuit.



(a)



(b)

Figure 4: The performance of Agilent 6682A after the external current control loop is operated and Agilent 6682A is at constant voltage mode (a) 8 hours long-term stability (b) Spectrum of output current ripple

### IMPROVEMENT OF STABILITY BY ADDING AN EXTERNAL CURRENT CONTROL LOOP WITH DCCT AT CURRENT MODE

Danfysik ULTRASTAB 866 DCCT could be operated at voltage mode or current mode depends on VOM(Voltage Output Module) is installed inside DCCT or not. The output current stability improvement of Agilent 6682A demonstrated in previous paragraph is based on DCCT with VOM. Here we will try some experiments the same as previous paragraph the external current control loop circuit output signal would be imported into current and voltage programming port of Agilent 6682A; but DCCT is operated at current mode. When DCCT is operated at current mode, there need a burden resistor to convert DCCT output current signal into voltage signal, the burden resistor used in this experiment is a VISHAY 7.5 ohm resistor with 5ppm/°C temperature coefficient.

The long-term output current stability and current ripple are measured and the performance are the same as before no matter what Agilent 6682A is operated at current or voltage programming mode.

### CONCLUSION

The performance of Agilent 6682A is quite good and under 100ppm output current stability but not suitable for TPS less than 10 ppm output current stability general requirement.

Without any modification on circuitry of Agilent 6682A, in this experiment we adding an extra external control loop circuitry formed by an error amplifier circuit 、 Danfysik ULTRASTAB 866 DCCT(w/o VOM)、 VISHAY 7.5  $\Omega$  burden resistor with 5ppm/°C temperature coefficient that is operated at current feedback mode and its output signal is exported to current or voltage programming ports of Agilent 6682A, under the operation of this external current feedback control loop circuitry and no matter what Agilent 6682A is operated at current mode or voltage mode output current long-term stability and ripple of Agilent 6682A could reach less than 10 ppm.

### REFERENCES

- [1] Operational Manual of Agilent 6682A
- [2] Manual of Danfysik ULTRASTAB 866 DCCT
- [3] Data book of VISHAY resistor