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DESIGN OF EXPERIMENTS FOR THE FEEDBACK CIRCUIT OF POWER DRIVER AMPLIFIER WITH MAGNETIC BEARINGS

Shuqin Liu , Feng Xu , Changzhi Lu , Zhongguo Bian
Magnetic Suspension technology Laboratory, Shandong University of Science and Technology,
Jinan, Shandong, 250031, China
Lshuqin@jn-public.sd.cninfo.net

ABSTRACT

In order to increase efficiency of the power driver amplifier, a switching power amplifier is used in electromagnetic bearings. The output characteristic of the switching power amplifier is primarily determined. In this paper the switching power amplifier with the negative feedback circuit have been studied. We have compared and evaluated the performances of the voltage negative feedback and current negative feedback. The experiments have been tested on the electromagnetic bearing test rig built at the Magnetic Suspension Technology Laboratory of Shandong University of Science and Technology. The advantage of the switching power amplifier with negative feedback compared with the properties of a switching power amplifier without feedback is also shown by experimental measurements. We have compared and evaluated the performances of the voltage negative feedback and current negative feedback. The difference between voltage and current negative feedback is the rate. This paper also presents a new methodology of experiment-aided integrated power amplifier for the full bridge design. Integrated PWM amplifier requires substantially less heat-sinking, board space and provide an attractive power amplifier solution. In our experiment we choose H-bridge SA60. The direction of load current can be controlled by analog input. The experimental result has proved its feasibility.

1. INTRODUCTION

Active Magnetic Bearings (AMB) provide numerous advantages compared with other types of bearings, since they are not subjected to wear and do not require any maintenance or lubrication. However, it consumes electrical energy for supporting. In the case of big rotors, large current power is supplied. In order to increase efficiency of the power driver amplifier, a switching power amplifier is used in electromagnetic bearings. We have studied the influence of voltage and current of driving amplifier on the rotating speed and control precision [1]. In switching amplifiers, high voltage and high current is present in the control devices only during the switching operations. The comparatively small switching losses are proportional to the supply voltage, and proportional to the switching-transition period and frequency. Beside the advantage of small power losses of a switching amplifier there is also some disadvantage such as high current distortion. The fundamental and the circuit of MPW amplifier [2, 3] are studied. In this paper, we will realize the linear of output voltage and current. To achieve this goal the voltage negative feedback and current negative feedback were all studied. A PID controller designed for a negative feedback circuit is the new method. The output characteristics of power driver amplifier have relation with the parameters that control the quantity of a feedback. The rate of the output characteristic curve is proportional to the quantity of a feedback.

2. HALF-BRIDGE POWER AMPLIFIER

In our approach we use current control for the bearing magnets and the load current is supplied by switching power amplifiers. Switching power amplifiers are mostly composed of pulse width modulator, driving circuit, main circuit of power amplifier and feedback circuit. In our experiment, two kinds of main circuit of power amplifier—half bridge circuit and H-bridge circuit were been used. The function of pulse width modulation is to produce pulse whose duty-cycle can vary in certain range according to the result of control signal. Two kinds of driving circuit are used widely. The first kind is to make use of the high frequency transformer in order to insulate; the second is optocoupler driving circuit. The disadvantage of transformer is that it is easy to cause noise. Feedback may be voltage feedback, current feedback, flux feedback and so on. The power amplifier with voltage feedback, current feedback and without feedback all did in our experiments.

Voltage negative feedback

The power amplifier with voltage negative feedback is shown in Fig. 1. The duty-cycle of the driving pulse reduce when the feedback signal increase and the duty-cycle of the driving pulse will increase when the feedback signal reduce. That is the duty-cycle is in proportion to the superimposed sum of the control signal V_c and the feedback signal.

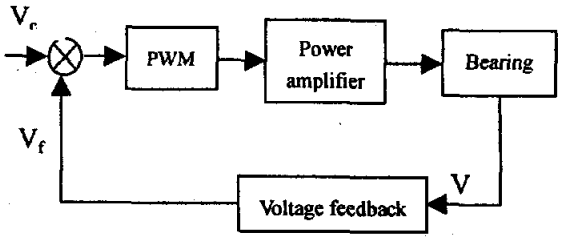

Fig. 1 Power amplifier with Voltage feedback

The advantage of the switching power amplifier with negative feedback compared with the properties of a switching power amplifier without negative feedback is also shown by experimental measurements. Fig. 2 shows the output current curves. The output current when without feedback is grievous distortion. The other cures are output current when voltage feedback, they are linear. Design parameters of feedback circuit are often referred as factors and the design parameter include the PID feedback gains can have many levels. The rate of the output characteristic curve is proportional to the quantity of a feedback.

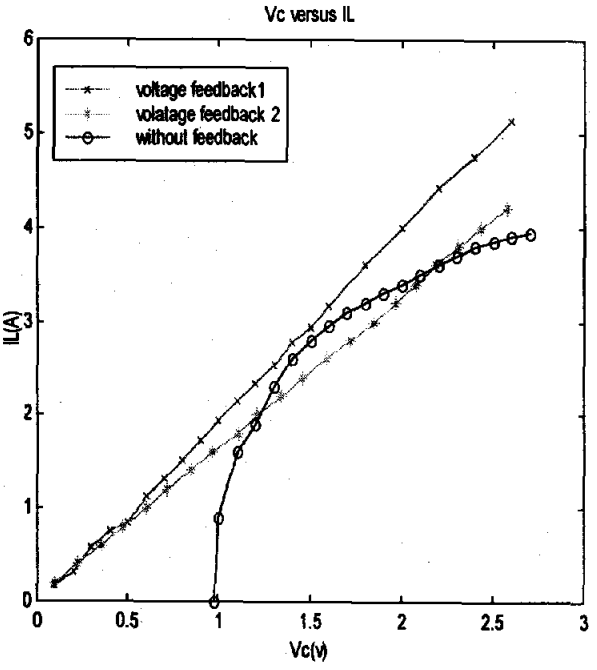

Fig.2 Output current(voltage feedback)

A bias current Io is necessary for high dynamic forces. It improves the linearity of transfer characteristics of the magnets. In our experiment, Io is 2.5 A. The experimental result shown that switching power amplifier with negative feedback is easy to realize the linear of output voltage and current.

Current negative feedback

The power amplifier with current negative feedback is shown in Fig. 3. The output current characteristic curves are shown in Fig. 4. In current feedback

experiment, current sample could be measured by use of resistor, but because the current of AMB bearing coil is relative larger the losses in resistor is much more. In our experiment a new kind measure device—current sensor is used. This kind of measure method disconnects amplifier circuit with measure circuit, so they do not affect each other.

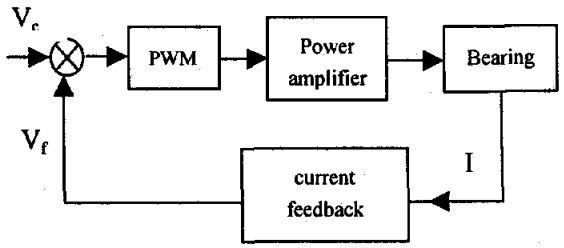

Fig. 3 Power amplifier with current feedback

The output current when without feedback is grievous distortion. When The power amplifier

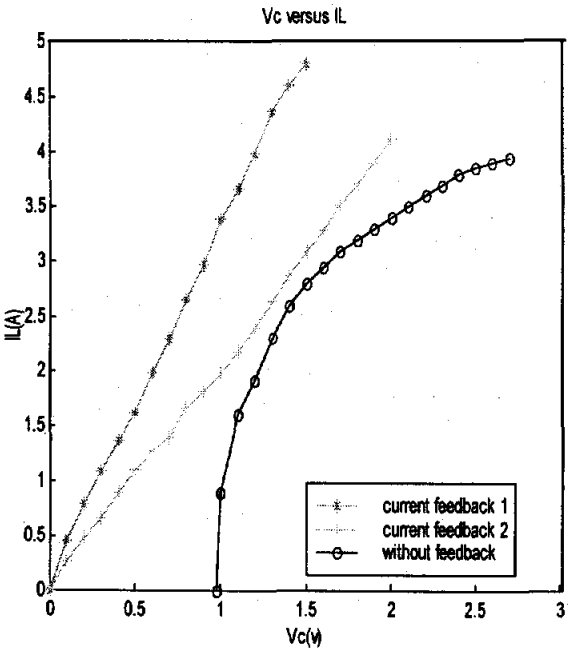

Fig. 4 Output current(current feedback)

contained current negative feedback, the output current cures are also linear. The rate of the output characteristic curve is proportional to the quantity of a feedback. We can compare and evaluate the performances of the voltage negative feedback and current negative feedback. The difference between voltage and current negative feedback is the rate. The current negative feedback needs smaller driving voltage than voltage negative feedback for the same output current.

3. H-BRIDGE POWER AMPLIFIER

The switching amplifier consists of two transistor switches and two diodes arranged to form an H-bridge with the bearing coil. See the Fig. 5. The two transistors make up of one pair of switches that allow energy to be increased in the bearing coil. The diodes form the other pair of switches that allow energy to be reduced in the bearing. The transistors are the only switches that have to be actively controlled. The diodes are passive switches that become conducting whenever the coil voltage becomes greater than the supply voltage. This guarantees the current direction in the bearing coil and that the current in the coil will not become open circuited. The duty-cycle is controlled by a pulse width modulator.

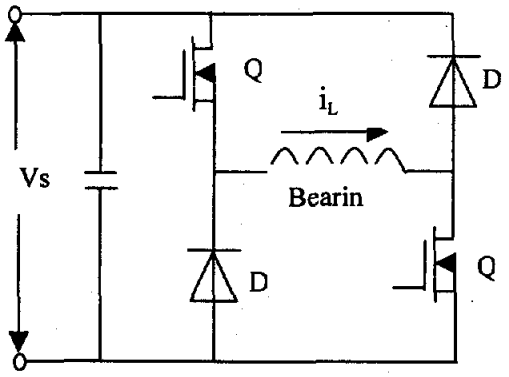

Fig. 5 H-bridge power amplifier

The pulse width modulator (PWM) can be controlled by the control signal and feedback signal. Insulative driving can use optocoupler or high frequency transformer. In our experiment, optocoupler driving has been used. The duty-cycle of driving pulses can

vary from 0% to 100%. During operation at constant current, the amplifier duty-cycle is nearly 50%. When the coil current is increasing the duty cycle increases (See the Fig. 6). The feedback signal is shown in Fig. 7. The feedback loop maintains the bearing current or magnetic flux in proportion to the PID control signal by means of the pulse width modulator.

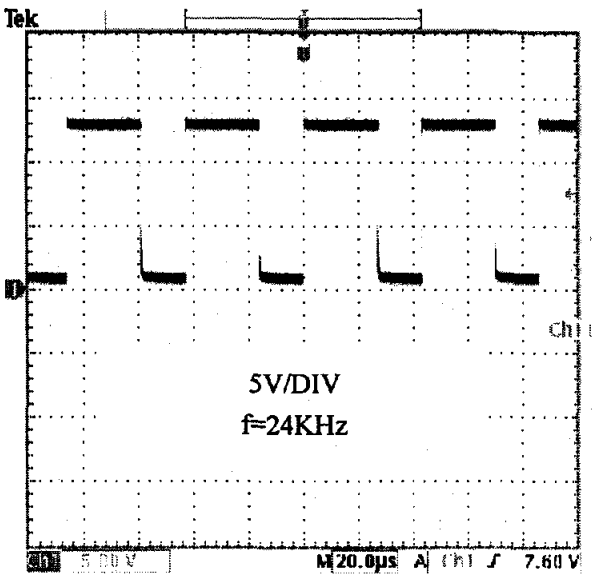

Fig. 6 The duty cycle of driving pulse

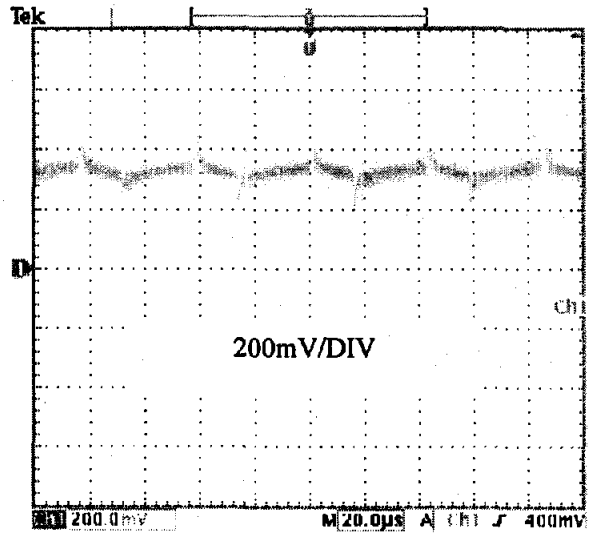

Fig. 7 Feedback voltage

The magnetic bearing wave form is shown in Fig. 8. The frequency of driving pulse is 24KHz. The

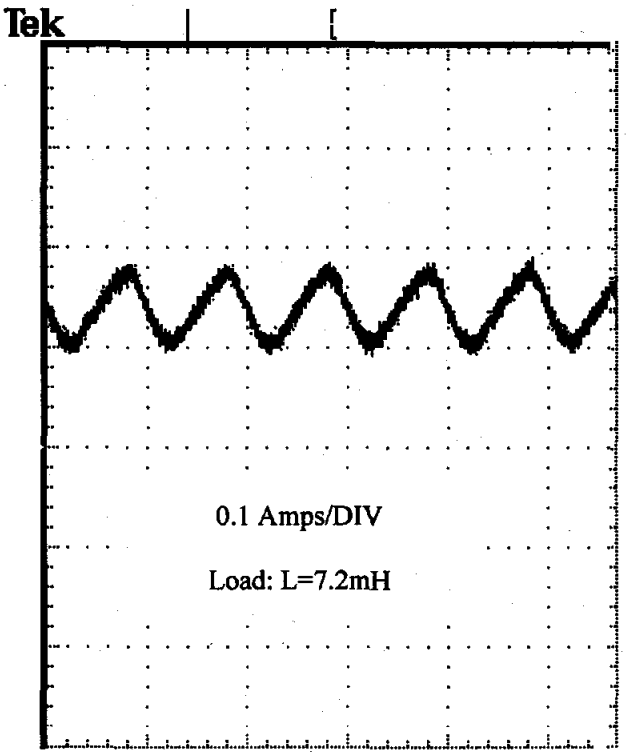

Fig. 8 Load current driven by power amplifier

switching ripple is about 0.18 Amps, which is superimposed on a DC current(4 Amps).

The rate of current of H-bridge switching power amplifier (di/dt) make a great progress than that of half bridge switching power amplifier. The power losses in the amplifier can be divided into two categories, static loss and dynamic loss. The static loss is caused by the transistor, capacitor and the forward biased voltage drop of the diodes. The dynamic loss results from the fact that the transistor switches do not start and stop conducting current instantaneously. In order to minimize the switching losses in the amplifier, the transistor switches must be selected to switch as quickly as possible. The power amplifier with H-bridge is the form of voltage control current, and half bridge switching power amplifier is the form of voltage control voltage.

Integrated power amplifier

When circuit design requires power levels in excess of 200W, the heat-sinking, board space and component count requirements increase dramatically. Integrated PWM amplifier are typically up to 95% efficient and offer a complete package, including protection circuitry thus they require substantially less heat-sinking and provide an attractive alternative to a discrete or hybrid linear power amplifier solution. In our experiment we have used integrated power amplifier. Apex's current model offerings for this product line start with the SA50 rated at 5A on an 80V supply with a resulting 400W of total power delivery, up to the Apex SA06 rated at 10A on a 500V supply with resulting power delivery of 5000W. A number of models are available in either full or half bridge design. The SA60 has some good feature to suit for AMB. The direction of load current can be controlled by analog input. When the analog input vary from 1/3 Vcc to 1/2 Vcc, the direction of the current is countercurrent with the analog input vary from 1/2 Vcc to 2/3 Vcc. The SA60 is a pulse width modulation amplifier that supplies 5A current to the load in our experiment, but it can supply peak current 15A. In our experiment we choose H-bridge SA60, and the experimental circuit is shown in Fig. 9.

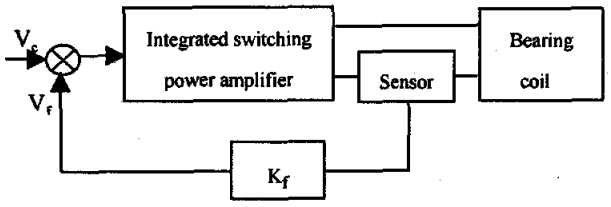

Fig .9 Integrated power amplifier

Our experiment indicated that the noise of load current is reduced very apparently compared with switching amplifier of discrete devices, which is very useful for system control.

4. CONCLUSIONS

In this paper, a feedback controller is researched to a active magnetic bearing test rig with switching power amplifier. A detailed experimental method was developed using in Half-bridge, H-bridge and integrated power amplifiers. Experimental results show that feedback controller is desirable to reduce distortion in the bearing current.

(1) The experimental result shown that switching power amplifier with negative feedback is easy to realize the linear of output voltage and current.

(2) The output characteristics of power driver amplifier have relation with the parameters that control the quantity of a feedback. The rate of the output characteristic curve is proportional to the quantity of a feedback.

(3) The current negative feedback needs smaller driving voltage than voltage negative feedback for the same output current.

(4) The rate (di/dt) of current of H-bridge switching power amplifier can make a great progress than that of half bridge switching power amplifier.

5. REFERENCES

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