DEVELOPMENT OF BIPOLAR TRIANGULAR WAVE CURRENT REGULATED POWER SUPPLY (±75A, ±50V) FOR HIGH FIELD ION BEAM SCANNING MAGNET

S.K.Suman, Rajesh Kumar, A.Mandal
Inter University Accelerator Centre, New Delhi-110067, India

Abstract

High field scanning magnets are used in the phase-II material science beam line at the IUAC for ion irradiation experiments with high energy ion beams. The scanning magnets are dipole magnet used to scan the ion beam in X-Y plane on target. Two separate dipole magnets are used for scanning in horizontal (X) and vertical (Y) plane. The ratio of operating frequency for X and Y magnets is 100:1. To scan the beam in a paintbrush pattern on targets these magnets are fed with current regulated triangular wave having no cross over distortion and non-linearity. The problem faced with magnetic scanner is its high inductance which causes large impedance and inadequate phase margins to the A.C power supplies used to energise these magnets. To accomplish such requirement a high power bipolar transconductance amplifier based on linear series pass technique with class-A output stage has been designed, which provides current regulated triangular wave output having no cross over distortion and non-linearity. Two power supplies have been fabricated for X and Y plane, delivering programmable current regulated triangular wave of 0 to ±50 A for X-axis at 50 Hz and 0 to ±75 A at 0.5 Hz for Y-axis. The power supplies can be programmed locally and remotely by a ±10 V triangular wave signal. The paper presents the layout plan and regulation scheme of the power supply.

LAYOUT OF THE POWER SUPPLY

The photograph and block diagram of the power supply are shown in figure 1 and 2, respectively. The power supply is housed in a 19" rack mount cabinet and mainly consists of two sections: control electronics and power section. The power supply's control electronics has been designed in modules for easy maintenance.

Figure 1: Photograph of scanning magnet power supply

The power supply is controlled locally through front panel and remotely through CAMAC interface. The remote/local control interface module interfaces the selected control to the power supply. The regulation module compares the control input signal with current feedback and regulates the output via the power output stage.

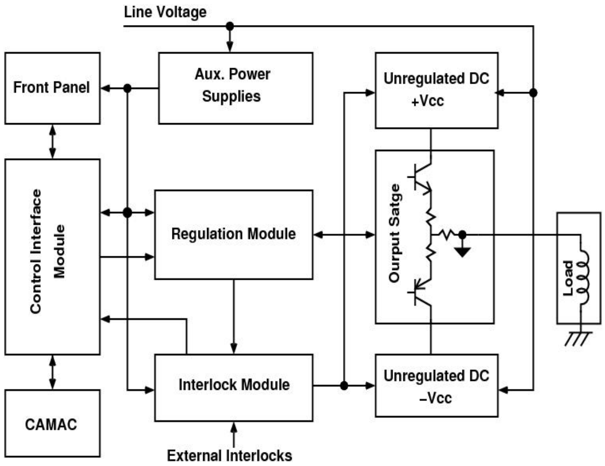

Figure 2: Block diagram of power supply

The interlock module processes all the required signals from different sections of the power supply for monitoring and to generate interlocks. The generated interlocks protect the power supply in case of a failure condition, by automatically switching off the main contactor. It also provides interlocks information to the front panel for local monitoring and to the CAMAC for remote read back.

The output stage is a complimentary push-pull stage having power transistors mounted on water cooled heat sinks. Two unregulated DC sources (+VCC and -VCC) are generated and connected back to back to make a bipolar supply to power the output transistor stage. These two DC sources are identical in design, where the main AC input supply is fed to a step down transformer, rectified and filtered using a LC low pass filter.

REGULATION SCHEME

The simplified schematic diagram of the regulation scheme is shown in figure 3. The power supply is a linear bipolar amplifier having limited band width. It provides current regulated triangular wave output without cross over distortion and non-linearity to inductive loads in response to a ±10 V signal control signal. The power supply design is based on linear series-pass technique, configured as transconductance bipolar amplifier with class-A output stage. The regulation circuit has two control loops operating simultaneously: quiescent current control loop and output current control loop. The output stage is a complimentary push-pull stage. As the push-pull stage has crossover distortion because of nonlinear input characteristics of the transistor. In order to minimize crossover distortion, the transistors are biased in class-AB mode, where a small standby current (quiescent current) flows through push-pull output stage at zero input signal.

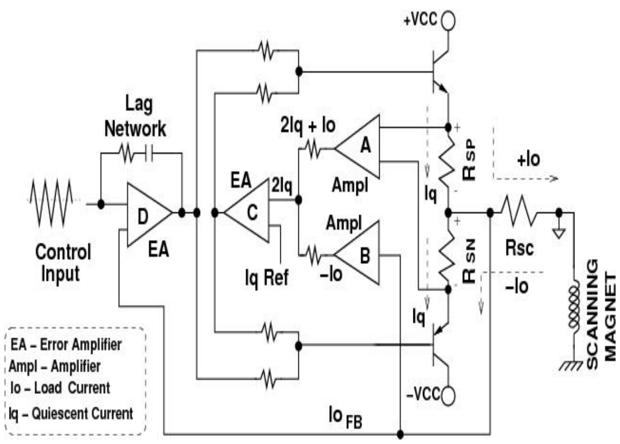

Figure 3: Simplified schematic of regulation scheme.

Amplifiers-A, amplifier-B and error amplifier-C (shown in figure 3) controls the quiescent current. This loop regulates a constant current through the power stage, regardless of the magnitude and direction of the load current. The no load quiescent current (Iq) is sensed by the current sensing resistors R_{SP} and R_{SN}. The resulting voltage drop corresponds to 2Iq is compared with a reference 'Iq Ref' and the error signal drives both the power stages, resulting in a constant current through both the transistors. Under load condition, the resulting voltage drop is corresponds to '2Iq + Io'. To keep a constant Iq flow through output stage, the Io factor is subtracted, leaving difference voltage always corresponds to 2Iq, irrespective of the magnitude and direction of the load current.

The output current is regulated by regulating the voltage drop across the sensing resistor (R_{SC}) in series with the load. The error amplifier-D compares the voltage drop across the sensing resistor (R_{SC}) with the input control signal and the resultant error signal controls the output current through the bipolar output stage.

The conventional large output capacitors at the output of power supply are not used to achieve fast slew rate. This results in inadequate phase margin for feedback loop stability, which is compensated by introducing a lag network across the current error amplifier-D.

TEST RESULTS

Initially, the power supplies have been tested with resistive load for required specifications as listed in table 1. The -3db corner frequency measured for resistive load is 4 kHz. After successful functional testing, the power supply has been connected to actual load (a dipole scanning magnet of inductance 4 mH and resistance 50 mΩ). The lag network used across current control error amplifier-D has been adjusted to stabilise the loop with inductive load. The lag network has been calculated in such a way that load's corner frequency is below the amplifier's corner frequency. The linearity of 50 Hz, ±50 A triangular wave recoded on a pen-recorder was better than 1 % with actual load.

Table 1: Specifications

Parameters	**X-axis PS**	**Y-axis PS**
Output current (programmable bipolar triangle wave)	0 – ±50 A	0 – ±75 A
Maximum output voltage	±50 V	±10 V
Output frequency range	0-50 Hz	0-5 Hz
Transconductance (Gm = A/V)	5	7.5
Bandwidth (dc to -3db) (resistive load)	4 kHz.	4 kHz.

CONCLUSION

The homogeneity of scanner was tested using 120 MeV silver ion beam on the quartz sample and was found to be satisfactory. The power supplies are in regular use with large area scanning magnet in phase-II material science beam line at the IUAC. After successful testing, four more power supplies have been assembled which will be used in other ion irradiation facilities at the IUAC. The power supply can also be used for scanning of ion beam in the industrial and medical applications.