A FAST SCANMAGNET FOR IRRADIATION PURPOSES WITH AGOR BEAMS.

O.C. DERMOIS, K. GERBENS, C. HERREMA, S. LETTINGA.
Kernfysisch Versneller Instituut, Zernikelaan 25, 9747 AA Groningen, Netherlands

For the purpose of irradiation, e.g. proton therapy, a fast scanning magnet is being built. The scanning procedure makes use of a 200 Hz fast beam chopper installed in the AGOR injection line. The chopper makes that the beam is on and off both during 2.5tmsec. The scanmagnet will be controlled by the chopper in such a way that during the off time the field changes in about 1 msec and is then constant during the next 4 msec. For the powersupply the switched mode principle is used. The magnet is made from a standard transformer core with a lamination of .05 mm. The design of the powersupply, the magnet and the chopper instrumentation will be shown.

1 General requirements and layout

To get a well defined dose distribution over a volume of irregular shape it might be of an advantage to use a pencil beam which scans the volume on a point to point basis. If one knows the beam profile the distance between the points which make up the grid can be choosen such that a homogeneous dose distribution is realized.
It is even possible to change the dose between subregions in a defined way.

To realize this goal a scanmagnet and powersupply is designed and built. The magnet will bend a 200 MeV proton beam over +5 to -5 degrees in steps of 0.5 degree or less. Each step takes 1 msec after which the angle is kept constant during the rest of the period of 5 msec.
The timing is controlled by the beamchopper discussed in [1]. During the step the beam is switched off.
There will be two of these magnets to scan a two dimensional surface and they may become part of a gantry for proton therapy.

2 The magnet

The magnet is made of standard commercially available C shaped transformer cores, Tellmac 210c, with a lamination thickness of 0.05 mm. From each of the four C cores one of the legs is machined in the right shape and after machining the burs on top of the machined surface are removed by etching.
To make a current step in one msec the inductance of the coils should be kept as small as possible. This means one must compromise between current and number of turns. Each of the two coils has 54 windings. The maximum current needed for the 5 degree bendingpower is 360 A and the inductance of both coils in series is 13 mH. For a step of 30 A in 1 msec one needs 390 V but to keep the current constant at 360 A only 12 V is needed.
Figure 1 shows the core of the magnet.

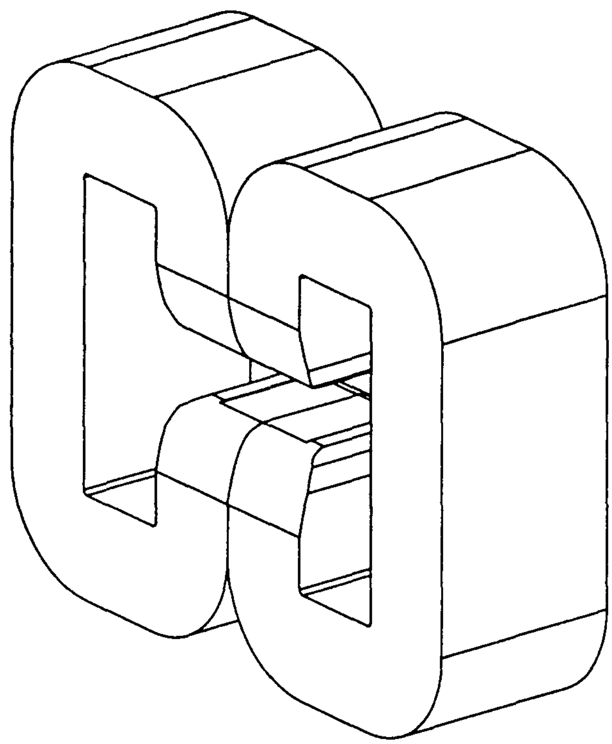

Figure 1. The magnet core.

3 The powersupply

The large difference between the voltage needed to make the current step and the voltage needed to keep the current constant means that the most suitable power supply is a switched mode type.

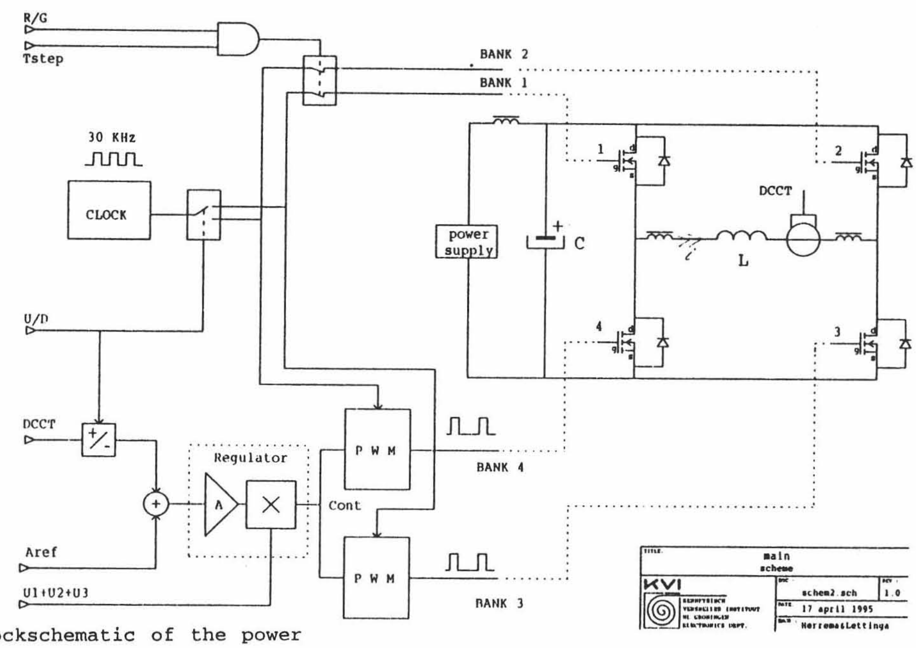

Figure 2. blockschematic of the power supply.

Because the magnet should bend over ±5 degree it must be possible to change polarity. The circuit schematic is shown in figure 2.

The coil called "L" represents the magnet. There are four switch banks, each equiped with 12 fast powerfets in parallel, numbered 1 to 4. The powersupply which charges the capacitorbank "C" is an adjustable constant voltage supply. The voltage of this supply is set to the value needed to make the currentstep of 1 msec in L.

The total time-period to bend the beam from zero to +5 to zero to -5 and back to zero can be divided into 4 subperiods. During subperiod 1 the current in L rises in 1 msec to its new value in the positive direction, as shown in fig. 3, and is kept constant the rest of the switchperiod. In subperiod 2 the procedure is the same but the current decreases in each step. It still flows in the positive direction. In subperiods 3 and 4 the same happens but the current flows in the the negative direction.

In the 1 msec currentstep in subperiod 1 bank 1 is conducting and bank 3 is switched with 100% dutycycle. In the following 4 msec the current is kept constant and flows mainly through the diodes parallel to bank 2 and returns via bank 1 . Bank 3 is then switched into conductance only to keep the current close to setvalue. Thus the combination of bank 1 2, 3 and L works as a Buckconverter. The switchfrequency is 30 kHz and the control is done by pulsewidth modulation. The DCCT with a bandwidth of 100 kHz measures the current which is compared with a reference value. The difference controls the pulswidth modulator.

In subperiod 2 the current should decrease in steps of 1 msec. The resistive powerloss in the circuit is too low to accomplish this. The stepdown is forced when bank 1 is switched out of conductance which forces the current to flow via the diodes parallel to bank 2 and 4 into the capacitor C.

During subperiods 3 and 4 bank 2 and 4 take over from bank 1 and 3 and the current flows in the opposite direction. Also the polarity of the DCCT is changed. Figure 3 shows the timing diagram.

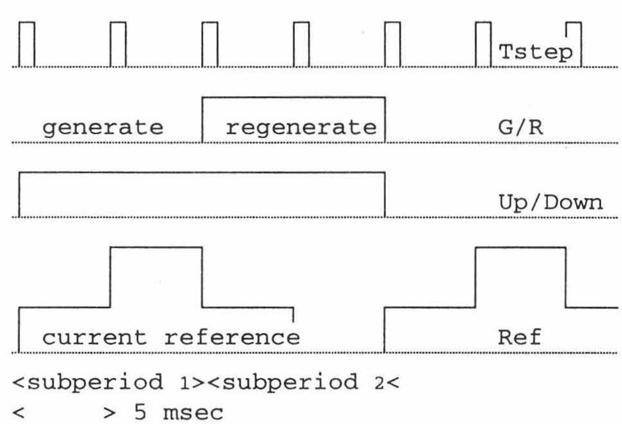

Figure 3. Timing diagram of the control and reference

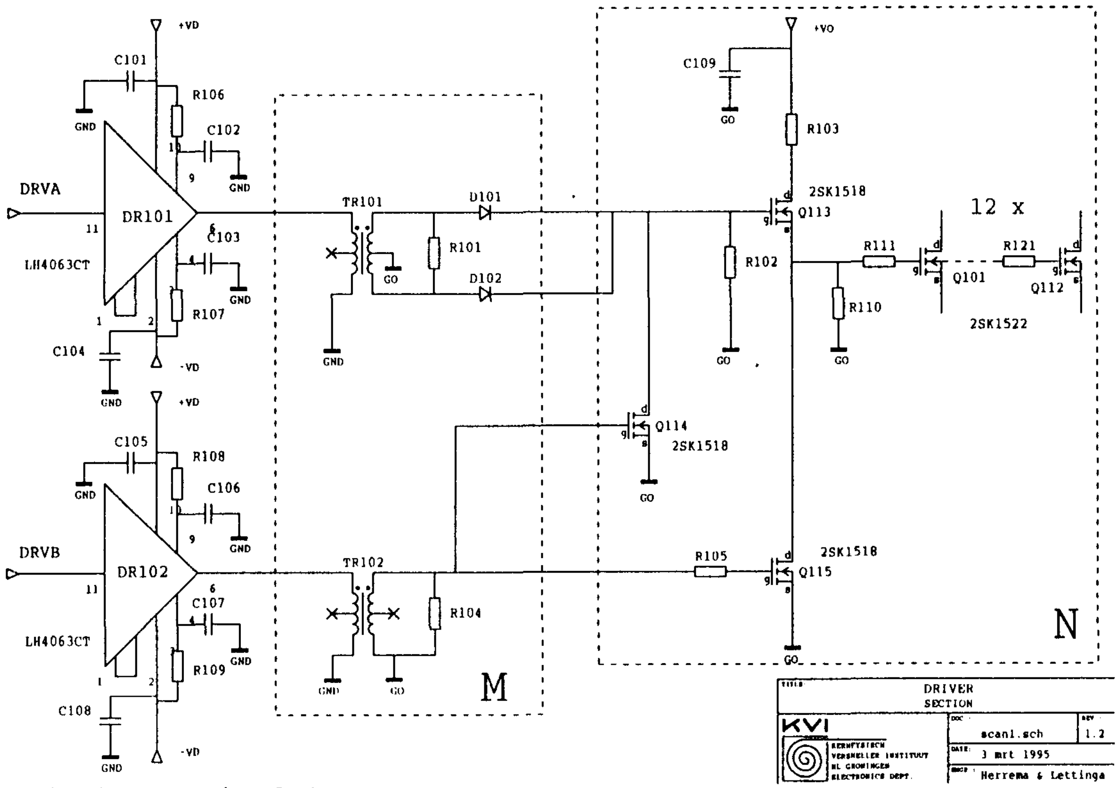

Figure 4. Circuit schematic of the fetbank control.

The "Tstep" pulses control the current-step and are 1 msec wide. The distance between them is 4 msec. The UP/Down controls the current direction, the G/R controls subperiods 1 and 2 and 3 and 4. The "Ref" is the reference control voltage.

The circuit schematic of the fetbank control is shown in figure 4. The driver DRVA supplies a bipolar pulse to the transformer. This pulse is rectified and switches the fetbank into conduction. To force the bank out of conduction a short pulse is given to DRVB. This brings Q114 into conduction and shortly after that Q115.

The control logic is at present hard wired and the analog part of the control is conventional.

4 Present status

The powersupply is designed and build by two students as a project for their final examination. The first tests indicate that the powersupply works as expected. The status of the control electronics is still provisional because of a lot of last minute changes. The power part as shown in fig. 2 and 4 does not need a redesign. It has been built according to the "design rules" of switched mode converters and that seems to work out well.

The magnet is completed and used in the tests. Field measurements still have to be done to see if eddycurrents are suppressed sufficiently.

The timing of the system as a whole, including the beamswitcher, can be changed when desired.

Acknowledgments.

The cooperation with the firm VICTRON, a producer of UPS equipment in Groningen, was essential to get this project realised in time. They provided us with the fast switching components and puls capacitors which otherwise have a long delivery time. They also shared some of their experience with the students.

References

1. O.C. Dermois et al, Non intercepting beam-current and position monitors for the AGOR beamlines. This conference proceedings.