Rutherford Laboratory
Technical leaflet

A30

AN ELECTRO-MAGNETIC MONITOR FOR THE EXTERNAL PROTON BEAM

This is a toroidal current transformer used to measure the external beam pulse current, the beam acting as a single turn primary.

Particular advantages of this type of monitor are, negligible beam disturbance and ease of calibration.

Current transformers are used to monitor the injector beam of Nimrod, where beam currents down to 10µA are monitored, with a maximum pulse length of 1mSec. The induced current pulses are amplified and displayed on a suitable oscilloscope, together with a calibration pulse of known amplitude, which is fed into a one-turn winding on the transformer.

However, in the case of the external proton beam, the mean beam pulse current may be less than 1µA, and the corresponding pulse length (spill time) as much as $\frac{1}{2}$ sec. This combination of long pulse and small current presents a difficult monitoring problem. At the other extreme, the pulse length may be 1 mSec and the mean pulse current over 100µA.

For good low frequency response, the transformer must have a large inductance, and the secondary load impedance must be small. The latter is conveniently obtained by using feedback, as in Fig. 1, where the lowest impedance obtainable is limited only by the resistance of the secondary winding. When very long time constants are required, as in the present application, the winding may be included in the feed-back loop, thus eliminating the effect of the winding resistance.

Fig. 2 shows the arrangement.

The current transformer

The transformer core comprises 8 strip-wound cores of very high permeability Mu-metal stacked together, the aim being to obtain the largest practicable core cross-section. The size of the core window is dictated by the beam aperture required.

The secondary winding has 2000 turns, split at the centre in order to provide d.c. isolation between the bases of the input transistors, giving an inductance of 2000 H. The feedback winding has 200 turns.

With such a large inductance, the transformer is extremely susceptible to interference. Considerable attenuation of external magnetic fields is provided by the screening can, consisting of alternate layers of mu-metal and copper. The can is fitted with anti vibration mountings, but since the transformer must form part of the beam vacuum system, there will be some unavoidable transmission of vibration via the beam line.

The amplifier

Because of the very low minimum input current and extended low frequency response, it is essential to minimise low frequency noise and drift rate. As the amplifier will be inaccessible during operation, long term drift is also a problem. Differential stages are used throughout, with matched transistors and resistors where necessary, and the input circuit transistors are operated at as low a current level as is compatible with the required frequency response.

The first section of the amplifier (Fig. 3) is direct-coupled, and provides the required voltage gain of approximately 10^5, the output voltage being fed back to the transformer via RF.

A dual transistor is used for the input stage. This is a pair of closely matched silicon planar transistors mounted on a common header. The resulting differential drift with temperature is compared with a small part of that of a germanium diode, and the overall drift reduced to below $1\mu V/^oC$.

To minimise the rate of temperature change, and hence the drift rate, the input circuit is enclosed in an inner die-cast box.

Stabilization against h.f. oscillation is achieved by step networks, and by using local feedback around the input circuit, thus reducing the loop gain required around the main feedback loop.

The second section of the amplifier provides a voltage gain of 50, raising the minimum signal to a level suitable to be sent to the control room. The input circuit uses a droop-compensating network, this reducing the input impedance required, and hence drift due to variations in capacitor leakage currents and transistor base currents. The resulting differential output drift duals temperature in about $1mV/^oC$, and this can be compensated for in the control room, if necessary.

The overall sensitivity of the amplifier is 100 mV out per $1\mu A$ beam, the pulse rise time 0.1 mSecs, and the 'droop' on a $\frac{1}{2}$ sec. pulse 5%.

The exhibit shows the system operating with a simulated beam pulse.

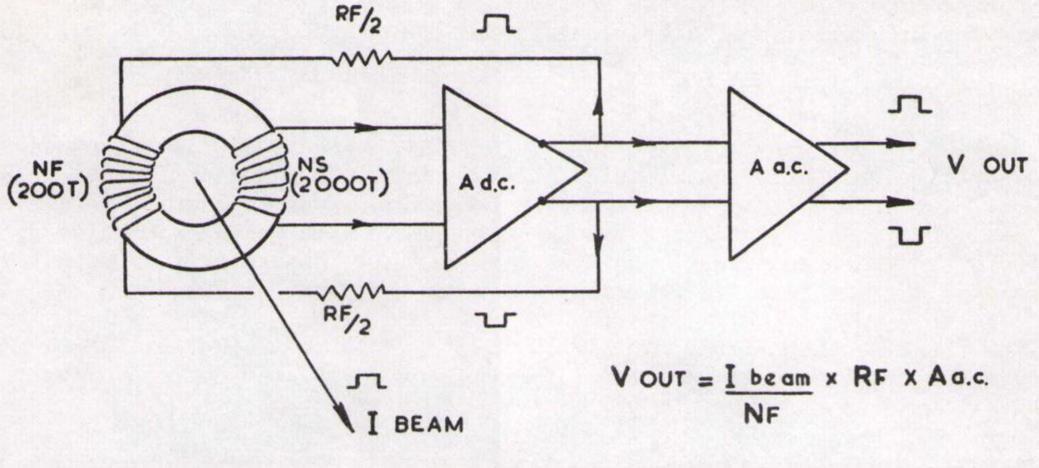

FIG 2. E.P.B. MONITOR ARRANGEMENT

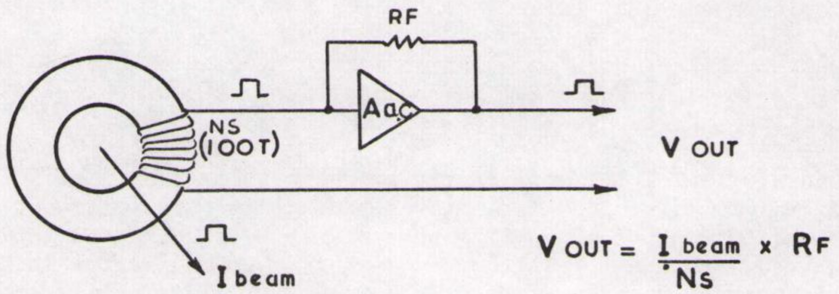

FIG I INJECTOR MONITOR ARRANGEMENT

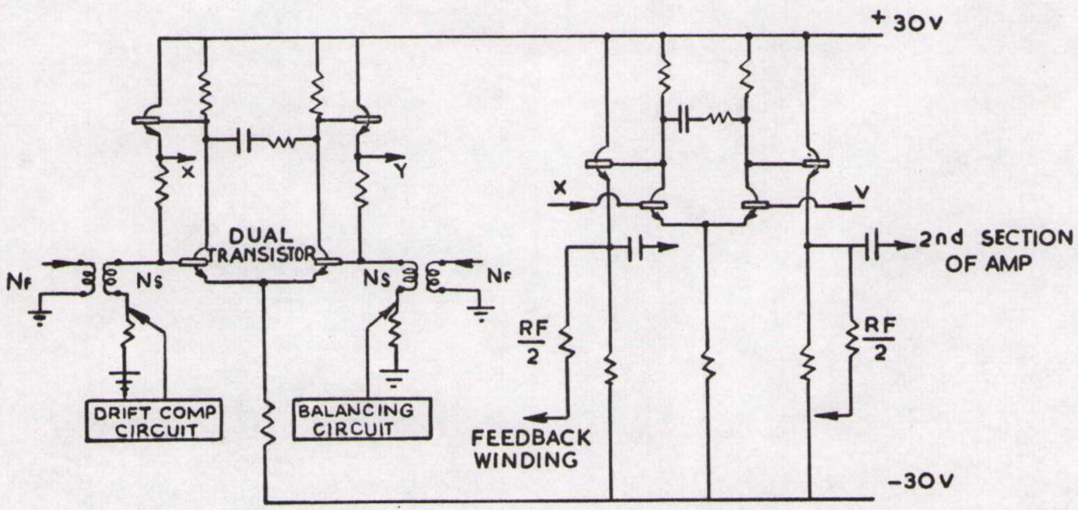

FIG 3 1st SECTION OF AMPLIFIER