

Electronics

Advanced electronics are part and parcel of all modern scientific research and at CERN they are behind almost everything from the operation of the accelerators, to the collection of the experimental data and to its subsequent analysis. The volume of electronics involved is very high but standardization has been achieved to a considerable extent — through the NIM system and more recently through the CAMAC system (see vol. 8, page 314) which has simplified life for the users and for the electronics industry.

A particular CERN requirement is for very high speeds. Nanosecond timescales are called for when carrying out measurements on high energy particles. For example the new detectors, such as multiwire proportional chambers and drift chambers, have a voracious appetite for collecting data on particle events and the speed of the associated electronics is an important aspect of their abilities. In general, high energy physics is still pushing for faster instrumentation. It has been one of the first fields where integrated circuits have been used on a large scale and has called for devices to achieve ultra fast switching at nanosecond or even sub-nanosecond speeds.

An example of instrumentation developed for special requirements is a device called the Digitron to be used in the 'g-2' experiment (E24 Multi-channel time recorder — Digitron). The experiment requires the precise timing of electrons emerging from the decay of muons orbiting a small storage ring. From this timing, via a series of steps which is beautiful physics all the way (see vol. 6 page 152), it is possible to deduce the g-2 value of the muon to an accuracy of few parts per ten million and thus to test rigorously the theory of quantum electrodynamics and to probe the nature of the mysterious muon.

Many time measurements are required and conventional systems of scalers would be complex and expensive. The Digitron circumvents this by using only four scalers and a buffer memory. It can make 200 time measurements with a precision of ± 5 ns. The timing precision comes from a crystal-controlled 100 MHz clock which runs continuously. Its pulses are counted by the scalers controlled by a recirculating shift-register which has a single bit and three zeros. Thus only one scaler counts at a time. The arrival of a signal due to an electron being detected stops the scaler, thus recording a time interval, and the shift register moves on to start the next scaler. The shift takes place between two clock pulses which avoids losing a count; this is covered by having the input signals also pass via a time-quantizer which assigns them to the nearest 10 ns time-bin.

When a scaler is stopped, its timing information is passed to a buffer memory the transfer taking 500 ns. Thus several scalers can be queuing to pass their information to the memory. However, the chance that all four scalers are so occupied is likely to be very small in most applications. (Further information from I. Pizer.)

The refined use of electronics in data analysis equipment is illustrated by a special digital to analogue converter built for the ERASME system for measuring tracks on film from the 3.7 m European bubble chamber, BEBC. ERASME looks for tracks on the film with a cathode ray tube flying spot and the spot is made to scan the film by powering two deflection coils. High performance digital to analog (DAC) converters control the currents to the two coils (E12 High speed 16 bit digital to analogue converter and digital deglitcher).

Since 12 bit DACs could easily be

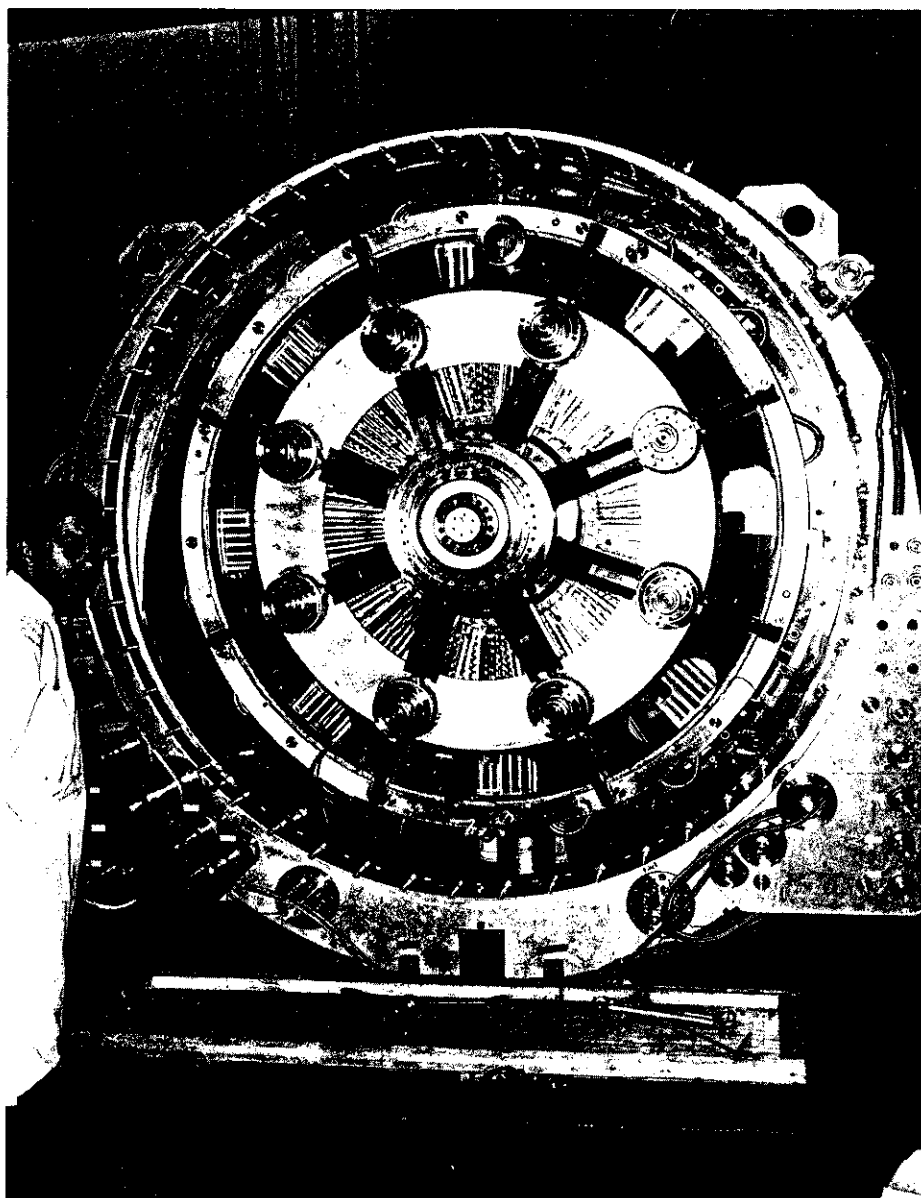
purchased, it was decided to build the required 16 bit devices by adding units designed and built at CERN to cope with the 4 most significant bits. The full converter then includes a high speed 12 bit DAC, an ultra high stability voltage reference, four fast switches, a high stability resistor network (using metal film technology) and an amplifier with high slew rate and very fast settling.

With 16 bits an accuracy of 1 in 65 000 is possible, corresponding to 150 μ V in 10 V output, but special precautions have to be taken to achieve such accuracy. A 12 bit DAC with low cross-talk between digital and analogue signals was necessary and, throughout the converter, special care had to be taken with component positioning, ground distribution, minimizing white noise and electromagnetic radiation and with thermal stability.

It has also been important to suppress 'glitches' — a sort of bounce of the output when many bits in the DAC are changed at the same time. A digital 'deglitcher' has been built which removes the problem by introducing delays between a synchronous counter and the DAC to compensate for the delays of each bit and the lack of symmetry of positive and negative edges. (Further information from J.C. Wolles.)

Another 16 bit DAC is involved in a different application at the Intersecting Storage Rings (E10 Precision reference source). The need is for a very precise, ultra stable voltage reference for the power supplies to the ISR magnets since the stability of the currents in the magnets is crucial for the good performance of the ISR.

The reference source is suitable for any application where a power supply must give ultra high performance. It is designed as a self-contained unit which can be readily incorporated



The rotary capacitor which will be used to provide the 600 MeV synchro-cyclotron with radio-frequency power to accelerate a more intense beam of protons. It gives a time varying capacitance so as to cover a frequency range from 30 MHz to 17 MHz and has to handle up to 50 MVA of r.f. power. The electronic and mechanical problems involved were not easy to solve.

The latest equipment of this type is the rotary capacitor which is to be incorporated in the radio-frequency system of the 600 MeV synchro-cyclotron presently undergoing a series of improvements. (E28 The new SC radio-frequency system: essential technological features of its rotary capacitor.)

It is required to provide a time varying capacitance, with a rotor carrying 3 rows of 16 teeth moving between 4 rows of stator blades, and has to handle up to 50 MVA. The rotor-stator gap is 1.1 to 4 mm with a tolerance of 0.1 mm. The rotor speed is 2200 rpm.

CERN and AEG confronted the problems of building such a device to operate in high vacuum, free of hydrocarbon vapour, and in high r.f. fields. Water cooling is necessary for the system, including the rotor, which for r.f. reasons could only be supported by a cantilevered shaft so as to leave one side free. The high mechanical tolerances make it necessary to use pre-stressed ball-bearings which have to be lubricated, cooled and protected from r.f. currents.

The lubrication and cooling is done by pumping oil with an automatic centrifugal system brought into action by movement of the rotor. The oil has to be prevented from entering the high vacuum region and a special steel and carbon-ceramic seal has been developed. The problem of r.f. current flowing through the bearings is removed by establishing a capacitance bridge with the bearings in one of the balance arms. The bridge is set so as to be in balance at the centre of the frequency range covered by the rotary capacitor. (Further information from H. Berger, A. Fiebig, R. Hohbach or S. Talas.)

in any system, being either set locally or set remotely by computer. At the ISR, the control computer sends its requirements as digital signals which emerge from the unit as an analogue reference voltage.

It is a completely solid state, electronic device with no mechanically moving parts. From 10 V to zero its output can be varied in steps of 150 μ V thus giving steps of 15 parts per million in selecting the reference voltage. As with the DAC mentioned above, special care is needed in the design and construction to achieve such accuracy and some additional measures were taken to reduce output variations with temperature to as little as 7.5 parts per million.

A new technique, which recently emerged from the aerospace industry, is used to ensure precise switching. Electronic components do not give such a distinct difference in the 'on' and 'off' situations as mechanical

relays but positioning several of them in parallel in shunt positions, rather than in series in the resistor network, results in switching errors of less than 1 part per million. A second new technique is to compensate for changes due to temperature by changing the 10 V primary reference voltage in the opposite direction. Thus if higher temperatures are tending to drift the output reference voltage upwards, the primary reference voltage is lowered to keep the output steady. This works to accuracies of better than 4 parts per million over a 30 °C range. (Further information from J. Pett.)

To put alongside the lilliputian world of transistors, integrated circuits and so on, CERN has also been involved in large-scale electronic systems, in particular in order to provide high power radio-frequency systems for the acceleration of charged particles.