current formed by rotating high-energy electrons. Because the charge-to-mass ratio of the assembly depends on the relative numbers, charges and masses of the ions and electrons, it can be much larger than that of the ions alone. Therefore the complete system is not only relatively easy to accelerate, but the ions have an energy ($M/\gamma m_0$) times as large as that of the electrons after acceleration, where M is the ion mass and γm_0 the initial mass of the relativistic electrons.

In practice, the process takes place in several stages. First there is the production of a several hundred ampere pulse of electrons with an energy of a few MeV using a linear induction accelerator. The electron pulse is then injected into a region containing a transverse magnetic field where it is trapped and curled up to form a ring current. Next, the magnetic field is increased to compress the ring adiabatically. This process also increases the energy of the constituent electrons because of the invariance of the orbital angular momentum of the electrons. Finally, ions are introduced into the ring and the system is extracted and accelerated to a high energy.

Christofilos suggests a new technique for reducing the radius of the ring, a process which is necessary in order to increase its electrostatic field and therefore to diminish the length required for subsequent acceleration. Straightforward adiabatic compression has several disadvantages. First, the increase in electron energy, although improving the stability, reduces the energy gain ($M/\gamma m_0$) by the compression ratio. Second, the compressor must be essentially a variable-radius betatron, an expensive machine with an operating frequency that limits the pulse repetition rate of the complete accelerator. By contrast, Christofilos suggests a two-stage compression cycle involving an axial acceleration of the ring in a decreasing magnetic field, with the ring radius held constant, followed by deceleration in an increasing magnetic field which compresses the ring. The advantages are that the compression is achieved by a static field and the initial and final electron energies are identical. The cost of the compressor is minimized, the energy gain remains high and the accelerator repetition rate is now dependent only on that of the electron injector. In principle, several such compression cycles may be cascaded, allowing the radius of the ring to be reduced until the limit of stability is reached.

Christofilos tabulates possible parameters for an accelerator which would use a 1,000 MeV, 1,000 ampere electron injector followed by two stages of ring compression to produce pulses of 1,000 GeV protons. No doubt many problems remain to be solved before the 1,000 GeV collective-ion accelerator becomes a practical proposition, but the prospect of beams of such high energy at a cost which promises to be less than astronomical is enough to generate more than a passing interest among high-energy physicists.

COMPUTERS

Help for Designers

from a Correspondent

A SYMPOSIUM on computer aided design techniques (CAD) for electronic circuits was held on May 28 and 29 at the Northern Polytechnic, London. The purpose was not so much to provide an opportunity for the exchange of information, but to increase the extent of informed opinion.

CAD demands mathematical representations of components before any satisfactory start can be made, as several speakers pointed out, in particular Mr G. Mayo (Kingston College of Technology). He talked about network synthesis and device modelling, illustrating how several types of model can be devised from a discrete set of measurements. Mr W. S. Meadows (Racal Research Ltd) illustrated the simplicity with which higher level computer languages can be applied if designed specifically for a particular technology.

Mr P. Rzevski (Kingston College of Technology) pointed out the value of the state variable as an approach to network characterization and analysis. Defining the state variable as the minimum information necessary to characterize the future behaviour of a system, he illustrated the generality of the technique, which is applicable to linear, time variant and non-linear systems with continuous or discrete signals. After discussing the choice of state variable for network modelling he showed how the stability of a network (linear or non-linear) can be checked using the Liapunov method and that because state equations are first-order differential equations, straightforward solutions were available. For non-linear networks he suggested several methods including standard Runge–Kutta methods.

Mr C. Den Brinker (Texas Instruments) showed how a more efficient solution of a particular circuit problem can be obtained using numerical methods. In his analysis of the emitter-coupled amplifier, he used the theoretical transfer function of the transistor to obtain the proportional change k in the emitter current resulting from the differential input voltage. This gave a partially normalized equation which could be used to evaluate a transfer relationship independent of bias current. The effect of emitter feedback was included by expressing the emitter resistor in terms of the slope resistance of the transistor input characteristic. This gave a simple relationship between the differential input voltage and k. He then used the result to analyse signal distortion in terms of k and the feedback factor M. The solutions to this equation for varying values of k and M were derived by computer and the results analysed.

Dr W. J. Cullyer (Signals Research and Development Establishment) demonstrated the power of CAD in the design of the layout and interconnexion pattern of thin-film microcircuits. If the integrated circuit is very complicated this is a very complex task and if carried out manually may take several weeks. An added advantage lies in the ability of the computer to store the information and regenerate it several times more quickly and efficiently than a draughtsman.

Most existing computer programs stand on their own. Where a problem requires not only analysis programs, but also optimization programs, layout, interconnexion and calculation of reliability and so on, a computer language designed for the specific technology is particularly valuable. Rather than the more conventional high level languages designed by, and for, the mathematician, engineers require a tool more particularly suited to their needs. Languages such as this already exist and one developed at Racal Research Ltd was described by Mr Meadows. A considerable expansion of the existing facilities can be expected in the very near future.