ANALOGUE COMPUTER

PEAC

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THE detailed explanation concerning the operation of UNIT "A" is continued in this month's article, with further practical examples.

We resume by considering the use of the operational amplifier as an integrator.

An operational amplifier will be handling time as well as voltage when acting as an integrator, so some means must be found of inserting intervals of time onto the computer. One method is to employ external oscillators to provide known functions of time in terms of frequency. An input to an integrator might consist of a steady d.c. voltage which is switched on for a time t (step function or square wave), or alternatively, a sinusoidal voltage of frequency f and period $1/f$.

If a graph is drawn of the resulting integrator output function, and this is the form that answers to problems involving change or motion will usually take, the X axis of the graph will be calibrated in intervals of time, with voltage on the Y axis. It follows that an oscilloscope, which also uses time on the X axis and voltage on the Y axis, can provide a convenient form of output display, especially when an integrator is operating at high speed.

The operational amplifier is converted to an integrator when a capacitor C_f is inserted, in place of a resistor, in the feedback path; see Fig. 5.1. When an input voltage $-E_{in}$ is applied to the integrator by means of a simple switch S for a time t, the output E_o will take the form of an increasing ramp voltage proportional to t with slope

$$-E_{in} \frac{1}{R_{in}C_f}$$

Note that the operational amplifier will continue to invert an input voltage even when used as an integrator.

THE INTEGRATOR IN EQUATION SOLVING

The electronic analogue computer does provide a powerful technique for obtaining rapid solutions to problems involving calculus, which cannot be equalled either by numerical methods or by a digital computer.

If differentiation and integration are regarded as straightforward mathematical operations, it will be found that the terms of, say, a second order differential equation can be manipulated on the computer in much the same way as the terms of a "steady state" algebraic equation.

For example, when an equation term y is differentiated against time its derivative dy/dt is obtained, and a second differentiation yields the second derivative d^2y/dt^2. The reverse process is where integration of the second derivative d^2y/dt^2 produces the first derivative dy/dt, and another integration gives y as the result.

Fig. 5.2 shows how a simple integrator can handle equation terms. Combined operations are made possible by cascading integrators, while using coefficient potentiometers and computing component ratios for summation, multiplication, and division (Fig. 4.1).

The process of differentiation, although feasible if care is taken, is generally avoided on analogue computers because it gives rise to unstable operational amplifier configurations, but this imposes only a slight limitation since integration can be employed—in the majority of cases—in place of differentiation.

INTEGRATOR ACCURACY

The transfer accuracy of an operational amplifier, when it is used as an integrator, will be theoretically limited by its finite value of open-loop gain. However,