COMBINED OPERATIONS

The configurations of Fig. 4.1 have many similarities, which lead naturally to the combination of several operations. In fact, it is possible to perform, say, ten additions or subtractions, three multiplications, and one division operation all at once using a single operational amplifier with several inputs and coefficient potentiometers.

PROBLEM EXAMPLE 1.
SOLVING A SIMPLE EQUATION

UNIT "A" can solve a linear algebraic equation consisting of more than ten unlike terms, but a simple example with only four terms will serve as an adequate practical introduction to programming.

Take $$\frac{3a - 2b}{c} = d \qquad \text{(Eq. 4.1)}$$

the letters a, b, and c are regarded as known quantities, and d is the unknown, but the equation can be transposed to solve for any unknown.

Eq. 4.1 is implemented on the computer as shown in the Fig. 4.2 patching circuit. Two voltages corresponding to a and $-b$ are taken from the voltage source to summer S1, where a is multiplied by $\frac{R_f}{R_1} = 3$, and $-b$ is multiplied by $\frac{R_f}{R_2} = 2$.

The machine equation for the problem is,

$$\frac{\frac{R_f}{R_1}a - \frac{R_f}{R_2}b}{c} = d \qquad \text{(Eq. 4.2)}$$

and if R_f is made 100 kilohm the equation will take the form of

$$\frac{\frac{100}{33}a - \frac{100}{50}b}{c} = d \qquad \text{(Eq. 4.3)}$$

Computing resistor values could equally well be $R_f = 10$ kilohm, $R_1 = 3{\cdot}3$ kilohm, and $R_2 = 5$ kilohm, to yield the same multiplication ratios. Since a 50 kilohm resistor is not included in the short list of Table 4.1, two 100 kilohm resistors are patched together in parallel in the patching circuit Fig. 4.2.

Routine. To set up Eq. 4.1 on UNIT "A", first of all ensure that the voltage source switch S6 is off. Insert computing resistors into the positions shown in Fig. 4.2 patching circuit, and connect the computing elements together with patching leads. Set VS1 and VS2 dials to zero, and CP1 to "10", corresponding to a divisor of 1. Wire a voltmeter to OA1/SK13 and zero-set the operational amplifier by means of VR15. Next connect a voltmeter to S1/I1/SK2, and switch on S6. Set VS1 dial for a trial value of $a = 2$V. Transfer the voltmeter from S1/I1/SK2 to S1/I3/SK2, and set VS2 dial for a trial value of $b = -2$V.

UNIT "A" will now be computing

$$\frac{(3 \times 2) - (2 \times 2)}{1} = 2 \qquad \text{(Eq. 4.4)}$$

with $a = 2$, $b = -2$, $c = 1$, and therefore $d = 2$. When a voltmeter is linked to OA1/SK13 it will be discovered that the output voltage d is actually -2V, due to the operational amplifier sign change. Remedy by reversing the readout meter leads. If the output voltage is not exactly -2V, recheck voltages for a and $-b$. To check the exact setting of CP1 dial for any value of c, temporarily remove the patching lead from CP1/SK1. Patch CP1/SK1 to a precise $+10$V from a spare voltage source output, and connect a voltmeter to S1/I5/SK2. The voltmeter will then indicate the potentiometer coefficient while taking into account the loading effect of R_f (see Fig. 4.3). A voltmeter reading of 4·75V is equivalent to a coefficient of 0·475. CP1 can now be patched back into the problem set-up. With a 100 kilohm resistor for R_f, CP1 will be dividing by numbers equal to or less than unity. If R_f is changed to 10 kilohm, the range covered by CP1 will become 0–10. Therefore, increasing c by a factor of 10 can be seen quite clearly to be the same as decreasing computing resistor ratios by a factor of 10.

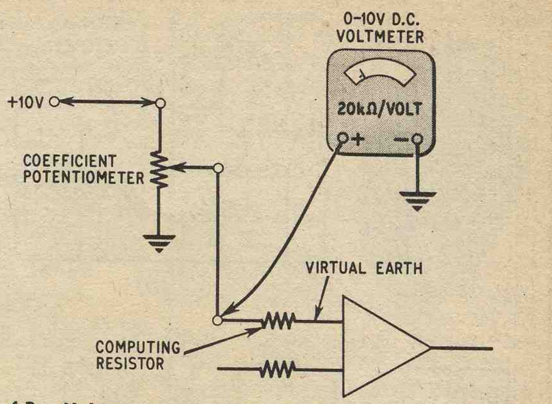

Fig. 4.3. Voltmeter method of determining coefficient potentiometer settings

With UNIT "A" now programmed for Eq. 4.1, it is possible to investigate fully the problem for all reasonable values of a, b, c, and d, and for any unknown without the need for transposing terms or altering the problem set-up. For example, to find a when b, c, and d are known, set b and c and adjust a for an operational amplifier output equal to d. Always monitor an input voltage with a voltmeter when it is being adjusted.

To see how serious computing errors can occur at extreme limits, set VS1 and VS2 so that terms $3a$ and $-2b$ are virtually equal, and $d \simeq 0$. Also, set CP1 to near zero and observe that d will pass beyond the 10V operational amplifier maximum output swing.

PROBLEM EXAMPLE 2.
ANALYSIS OF VOLTAGE DIVIDER CIRCUIT

The voltage divider of Fig. 4.4a is often encountered in electronic circuits. At first sight, a network consisting of only two resistors might be considered far too simple to merit investigation by means of a computer,