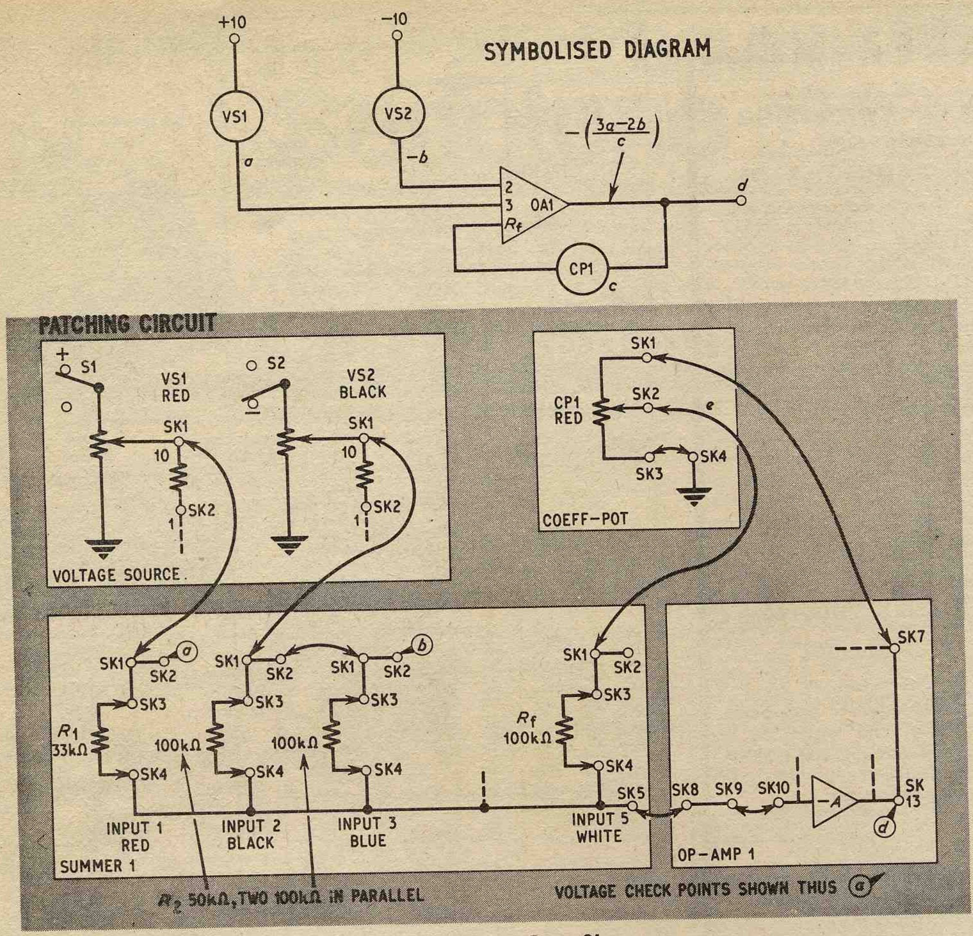

Fig. 4.2 Programme layouts for $\frac{3a - 2b}{c} = d$

output as term $-a$, when the $\frac{R_f}{R_{in}}$ ratio is unity. One way of looking at this operation, which is common to all single operational amplifier configurations, is to assume that a has been multiplied by -1, hence $\frac{R_f}{R_{in}} = -1$. In effect, to multiply by -1 is to move a mathematical term from one side of its equation to the other, so sign change can be used to transpose.

The operational symbol of Fig. 4.1a avoids the bother of inserting resistors and their values when drawing up a programme layout on paper. The figure inside the triangle—in this case "1"—merely indicates that the computing resistor ratio, or alternatively the operational amplifier gain, is unity.

Addition. In Fig. 4.1b, positive terms a and b are added to yield an output $-(a + b)$, which can also be written $-a - b$. If $-(a + b)$ is applied as an input to a second unity gain operational amplifier, to give two sign changes, it will be converted to $a + b$. Note that the figures in the operational symbol triangle show that $\frac{R_f}{R_1} = 1$, and $\frac{R_f}{R_2} = 1$.

Subtraction. The only difference between Fig. 4.2b and Fig. 4.2c is that term b has been made a negative quantity. The operational amplifier output is therefore $-(a - b)$ or $-a + b$.

Multiplication. In Fig. 4.1d, R_f and R_{in} are adjusted so that $\frac{R_f}{R_{in}} = b$. Hence, a is multiplied by factor b to become an output $-ab$. The letter inside the operational symbol triangle shows that the $\frac{R_f}{R_{in}}$ ratio is b.

Fig. 4.1e gives an alternative method of achieving multiplication. A computing potentiometer is connected to the op-amp input to multiply a by a factor b. Therefore, with an input ab, and $\frac{R_f}{R_{in}}$ adjusted to equal c, the result is an output $-abc$.

Division. When a computing potentiometer is wired as in Fig. 4.1f, with R_f connected to its slider, term a will be divided by constant b when $R_f = R_{in}$. Note that R_f is written inside the symbol triangle to show that b is a divisor.

It can sometimes happen that a feedback resistor is inadvertently left plugged into an operational amplifier when it is re-programmed for a division operation, and this will result in the circuit of Fig. 4.1g. Instead of an output $-\frac{a}{b}$ the operational amplifier will yield $-\left(\frac{a}{b+1}\right)$.