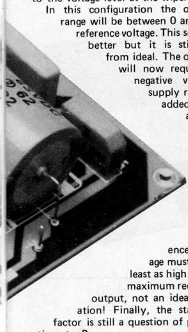
cuit is opamp A and its output is the source of the load current, that is, in series with the load R_L. The non-inverting input of the opamp is held at a reference voltage, U_{ref}. The inverting input of the opamp is at a voltage level that is a proportion of the input voltage — derived by potentiometer P. Under these conditions the output of the opamp will become stable at the point where the voltage difference between the two inputs is zero. That is, the opamp will maintain a condition where the reference voltage and that at the wiper of potentiometer P are equal. It will be obvious that the output voltage will therefore be dependant on the position of P. With the potentiometer in mid position the output will be double the reference voltage. The disadvantages of this system are that the stability factor is dependant on the setting of potentiometer P, the output can never be lower than the reference voltage and the operation of P will not be linear. Two of these points may not be so significant in some cases but an output minimum that is restricted to the reference voltage will be embarrassing to say the least!

The block diagram of figure 1b provides another solution. In this case, the opamp is used as a unity gain amplifier and P becomes a voltage divider connected across the reference voltage. The output of the opamp will now be proportional to the voltage level at the wiper of P. In this configuration the output range will be between 0 and the reference voltage. This sounds better but it is still far from ideal. The opamp will now require a negative voltage supply rail, an added disadvantage.



The reference voltage must be at least as high as the maximum required output, not an ideal situation! Finally, the stability factor is still a question of potentiometer P.

Figure 1c goes a long way towards removing the problems by replacing the reference voltage, as far as the opamp is concerned, with a reference current. The output voltage is now determined by the current passing through P. The advantage is that the circuit is no longer dependant on the reference voltage level.

We now arrive at figure 1d which, in principle, is very similar to 1c. The reference current in this case is derived from the output voltage via a series resistor R. The idea is not entirely new but the method used here is a little unorthodox.

As previously mentioned, a current source is achieved by placing a resistor in series with a reference voltage derived from the output. However, for this to happen in practice, the value of potentiometer P has to be much lower than R. The opamp still tries to balance out the difference between the voltage levels at its inputs but now the output voltage will be equal to the level on its non-inverting input.

The series resistor is effectively placed between the two inputs of the opamp. However, due to the high impedance of the inputs, theoretically at least, no current can enter the opamp. In effect then, the current derived from the reference source follows the path shown as a dotted line in the block diagram. Since $U_1 = U_2$ (the opamp ensures this) the current level remains constant, totally independant of P and the load. The current level is equal to $\frac{U_{ref}}{R}$. The opamp will balance out the voltage across P and, in doing so, the reference current is compensated for any change in load. The result of all this is that the circuit conforms to what we are looking for, a constant reference current (even at 0 V) using a reference voltage source and a resistor.

The precision power supply

The major difference between the block diagram of the precision power supply in figure 2 and that of figure 1d is the fact that two opamps and a series pass power transistor are included. The current source (U_{ref} and R) and the potentiometer P1 are very similar.

The second opamp A2 is responsible for output current limitating. The voltage across the emitter resistor R_s of transistor T is proportional to the output load current. A proportion of the reference voltage is derived by the setting of P2 and this is compared to the voltage across R_s by opamp A2. When the voltage across R_s becomes higher than that set by P2, the opamp reduces the base drive current to T until the difference is reduced to zero. The LED at the output of A2 functions as a current limiter.

The circuit diagram

So much for the theory, now for its practical application. The circuit of the power supply, shown in figure 3, has two independant power supplies (if that makes sense!). The power for the output stage is provided by transformer Tr2 which, of necessity, will be rather a hefty beast. Transformer Tr1 provides power for the reference source and the opamps.

The reference source is derived with the aid of the inevitable 723 (the worlds longest living chip?). The components

1

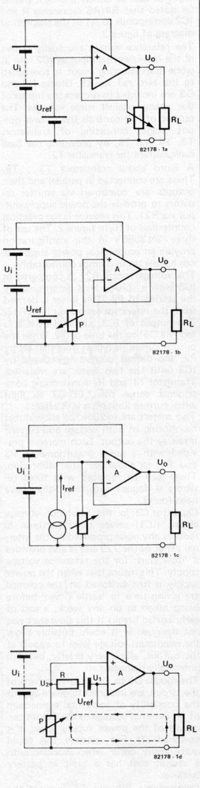


Figure 1. The drawings here, in conjunction with the text, illustrate the advantages of why the use of a constant current reference source is preferable to a reference voltage.