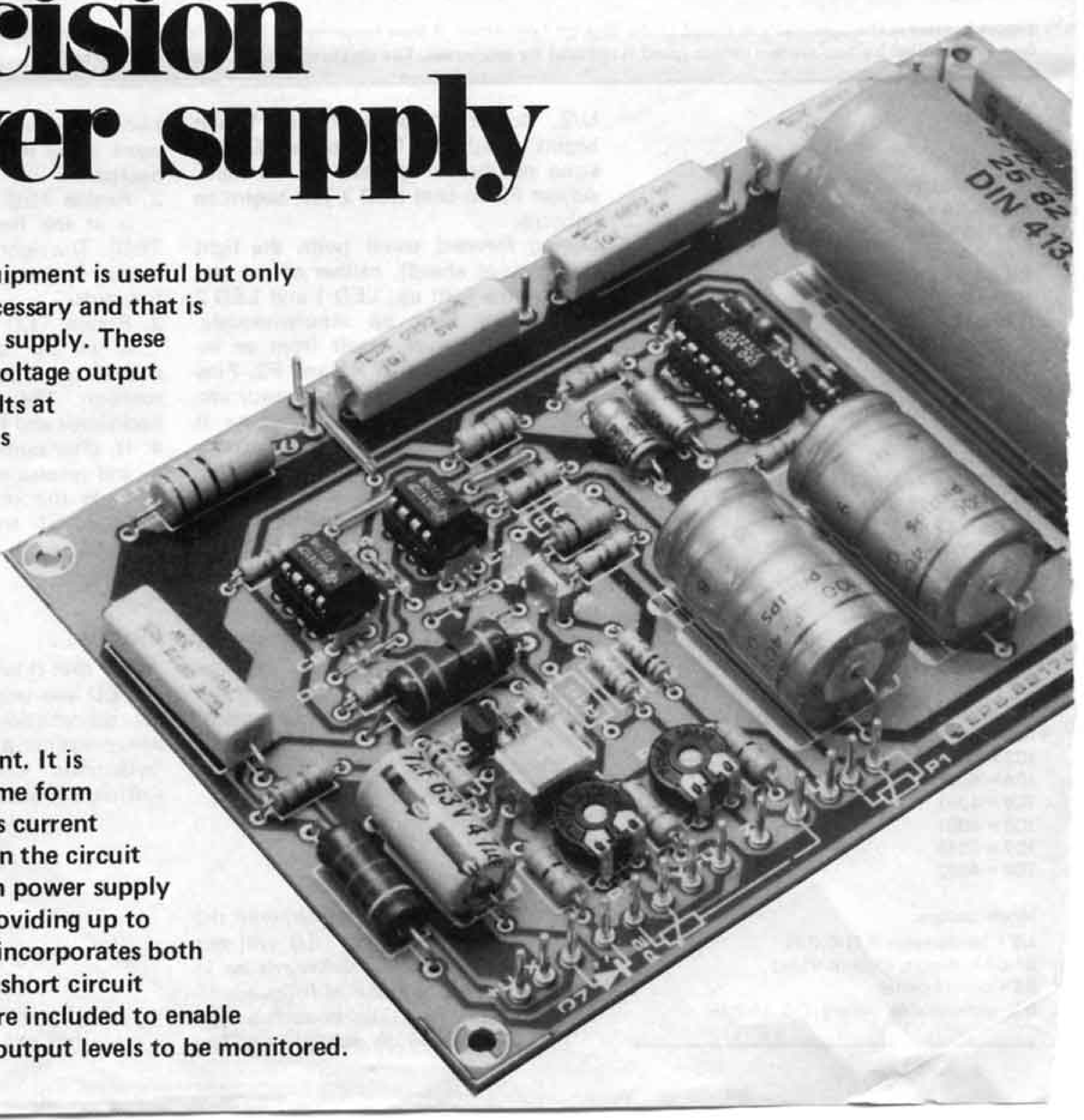
precision power supply

Good control with high power

Any item of test equipment is useful but only one is absolutely necessary and that is some form of power supply. These normally provide a voltage output of up to 25 or 30 volts at about 1 amp which is fine for most purposes. However, this current level can be rather limiting when testing computers, audio amplifiers and other high power equipment. It is essential too that some form of protection such as current limiting is included in the circuit design. The precision power supply here is capable of providing up to 3 amps at 35 V and incorporates both current limiting and short circuit protection. Meters are included to enable current and voltage output levels to be monitored.



If any circuit is to be accurately and safely tested a good power supply must be used. It is not sufficient for it to be just a stabilised supply, it must also include some form of protection against faults arising in the circuit under test. This usually takes the form of current limiting and output short circuit protection.

In order for it to fulfil its function correctly, a power supply should have the following facilities.

- The ability to deliver fairly high current levels at voltages of 24 V or more.
- It must be completely stable at all output conditions.
- The output must have some form of short circuit protection.
- Current limiting control up to the maximum current output.
- An output voltage control that is fully variable from 0 to maximum.
- Accurate indication of both current and voltage output levels.
- Sense inputs to allow compensation for voltage drops when long supply cables are necessary.

Although the last two points are not strictly necessary, their inclusion makes the power supply more versatile and easier to use.

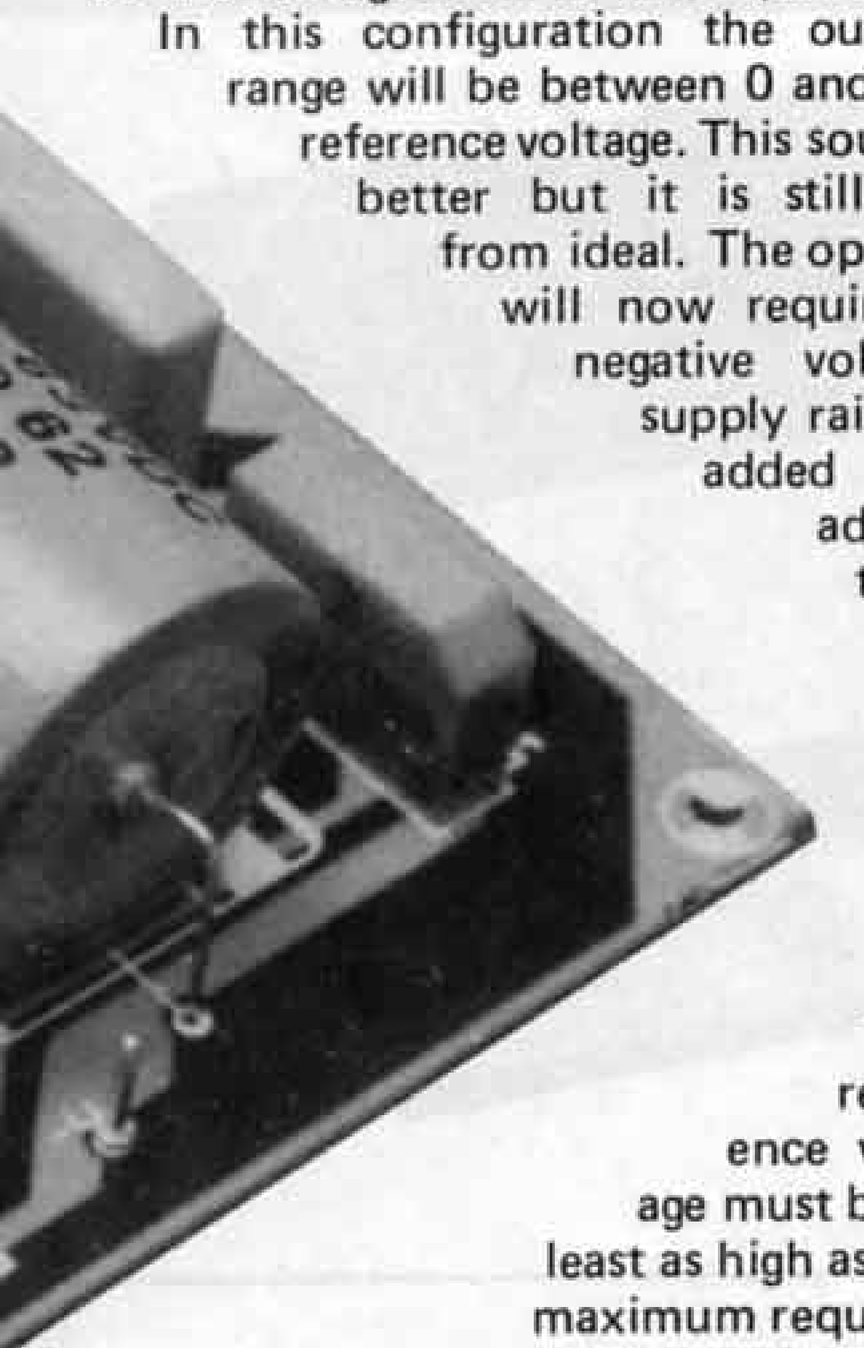
The precision power supply here follows the standards set by commercial equipment and includes all of the above features. It has a variable output voltage range of 0 to 35 V and continuously variable current limiting up to 3 amps. The performance is on a par with fairly expensive commercial power supplies but approaches the stabilisation problems with a rather novel circuit design.

The principles

The vast majority of power supplies use either 'series' or 'pass' regulation. This means that the stabilising power transistors are connected (effectively) in series or in parallel to the load. In common with most designs the circuit here utilises series pass regulation. The originality in the circuit design is the method used for stabilisation.

The block diagram in figure 1a illustrates the principle of a conventional series regulator. The active element of the ciruit 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

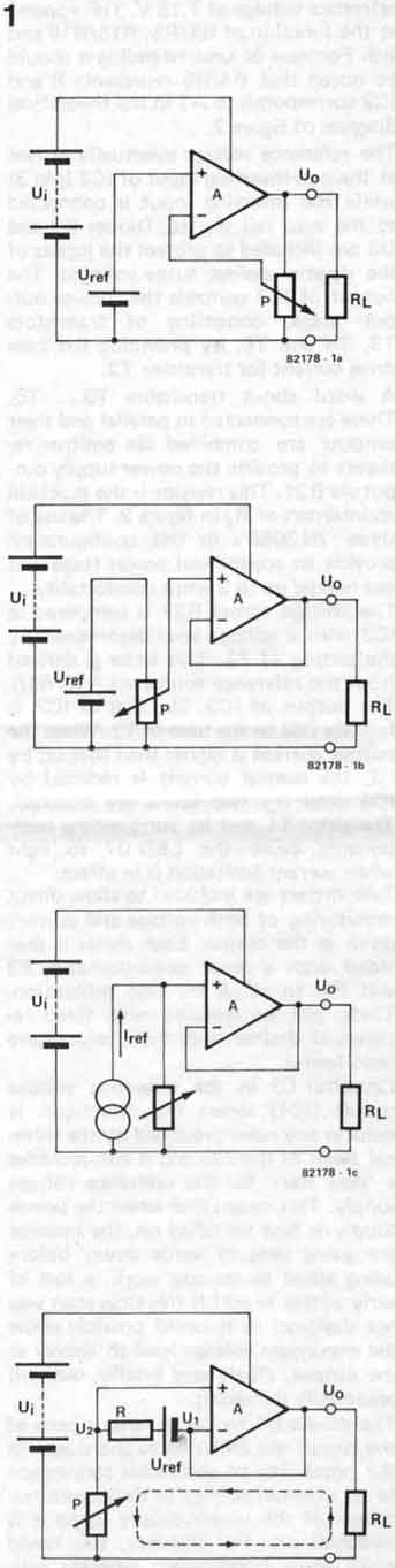


Figure 1. The drawings here, in conjunction with the text, illustrate the advantages of why the use of a constant current reference source is preferable to a reference voltage.

around this IC were chosen to provide a reference voltage of 7.15 V. This appears at the junction of R1/R5, R15/R16 and R9. For ease of understanding it should be noted that R4/R5 represents R and IC2 corresponds to A1 in the theoretical diagram of figure 2.

The reference voltage eventually arrives at the non-inverting input of IC2 (pin 3) while the inverting input is connected to the zero rail via R8. Diodes D2 and D3 are included to protect the inputs of the opamp against surge voltages. The output of IC2 controls the power output stage, consisting of transistors T3, T4 and T5, by providing the base drive current for transistor T2.

A word about transistors T3 . . . T5. These are connected in parallel and their outputs are combined via emitter resistors to provide the power supply output via R21. This resistor is the practical counterpart of R_S in figure 2. The use of three 2N 3055's in this configuration provide an economical power stage that can handle up to 3 amps comfortably.

The voltage across R21 is compared in IC3 with a voltage level determined by the setting of P2. This latter is derived from the reference source via R15/R16. The output of IC3, like that of IC2, is fed (via D5) to the base of T2. When the output current is higher than that set by P2, the output current is reduced by IC3 until the two levels are matched. Transistor T1 and its surrounding components cause the LED D7 to light when current limitation is in effect.

Two meters are included to allow direct monitoring of both voltage and current levels at the output. Each meter is provided with a series potentiometer, P3 and P4, to allow for fine calibration. These can be replaced with fixed resistors if desired once their values have been found.

Capacitor C3 in the reference voltage circuit (IC1) serves two functions. It reduces any noise produced by the internal zener of the 723 and it also provides a 'slow start' for the reference voltage supply. This means that when the power supply is first switched on, the opamps are giving time to 'settle down' before being asked to do any work, a sort of early coffee break! If this slow start was not designed in it could possibly allow the maximum voltage level to appear at the output, albeit very briefly, but still potentially damaging.

The diodes D1 to D8 in various parts of the circuit are included to guard against the possibility of accidental connection of an external voltage to the output terminals of the power supply when it is switched off. For instance, this could quite easily occur when working with a circuit that has a built in battery back-up.

Components R7 and C6 increase the reaction time of the circuit when changing output voltage levels while capacitors C7 and C8 eliminate the possibility of oscillation in the opamps. For stable operation of the circuit a minimum

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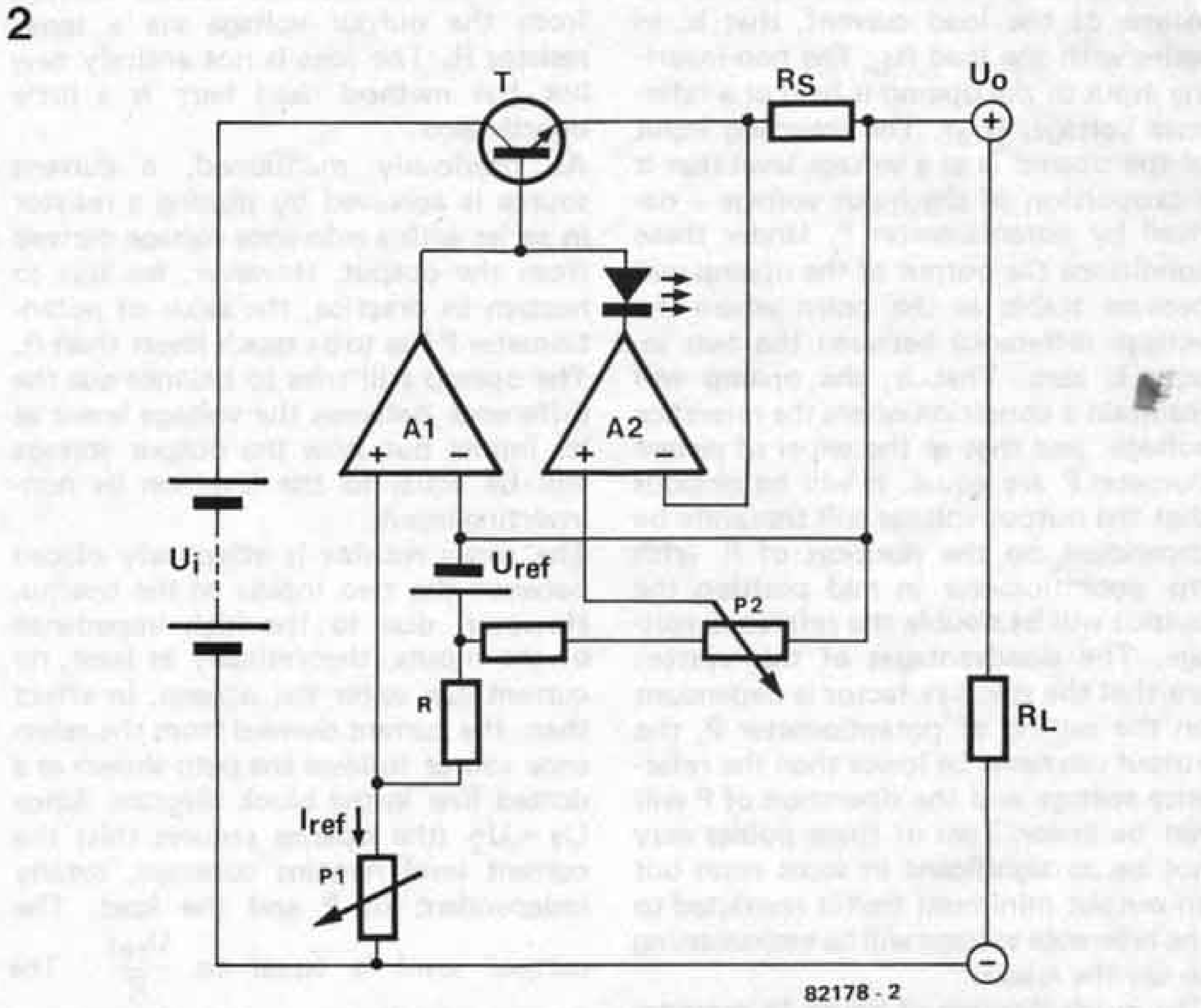

Figure 2. The basic block diagram of the precision power supply. Opamp A1 provides the voltage regulation while A2 takes care of the current limiting.

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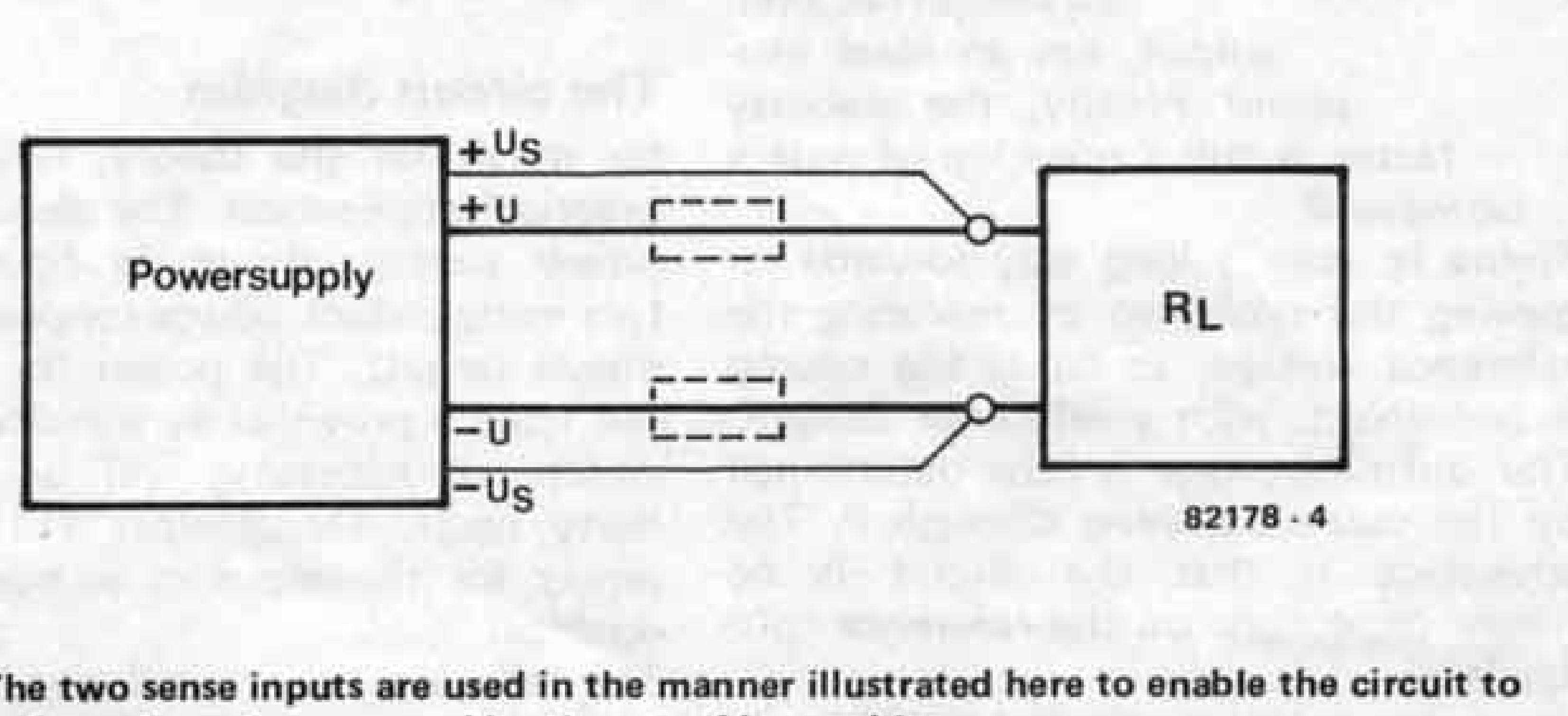

Figure 4. The two sense inputs are used in the manner illustrated here to enable the circuit to compensate for voltage drops caused by the use of long cables.