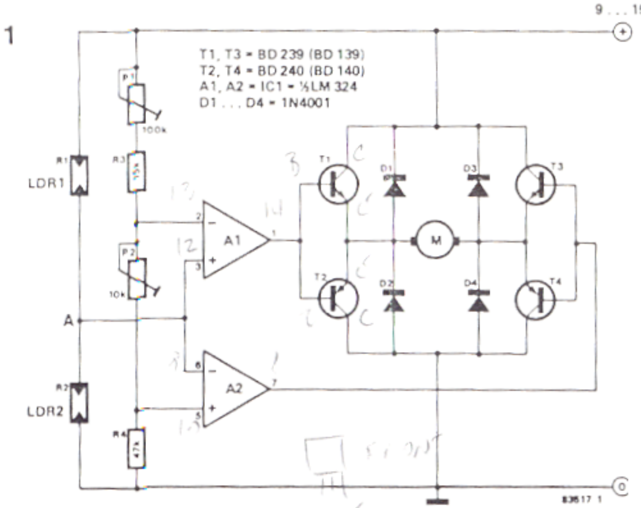
coulombs and V is the voltage in volts. If, therefore, two capacitances have equal charges, their values can be calculated when the voltages across them are known. Two circuits ensure that reference capacitor C_r and the capacitor to be measured, C_x, are charged equally. The circuit for C_r consists of C2, D1, and T1 and that for C_x of C3, D2, and T3. Each time the output of gate N2 rises, the charges of capacitors C2 and C3 are transferred to C_r and C_x by transistors T1 and T3 respectively. When the output of N2 drops, C2 and C3 recharge via diodes D1 and D2. Gate N2 is controlled by astable multivibrator N1 which operates at a frequency of about 2 kHz: C_r and C_x are therefore charged at that frequency.
The voltage across C_r is compared by IC2 with a reference voltage derived from the power supply via R3/R4. When the voltage across C_r exceeds the reference voltage, comparator IC2 inverts which inhibits N2 and causes N3 to light D3. The charges on C_r and C_x are now equal and the meter indicates by how much the voltage across C_x differs from that across C_r. Buffer IC3 presents a very high load impedance to C_x. Pressing reset button S1 causes both C_r and C_x to discharge via T2 and T4 respectively, after which the charging process restarts and the circuit is ready for the next measurement.
The meter is calibrated by using two identical 10 nF capacitors for C_r and C_x. Press the reset button and, when the LED lights, adjust preset P1 to give a meter reading of exactly one tenth of full scale deflection (fsd). That reading corresponds to $1 \times C_r$. If, therefore, C_r = 100 nF and C_x = 470 nF, the meter will read 0.47 of fsd.
To ensure a sufficient number of charging cycles during a measurement, C_r and C_x should not be smaller than 4.7 nF. To measure smaller values, capacitors C2 and C3 will have to be reduced. For instance, to enable a capacitor of 470 pF to be measured, C2 and C3 have to be 10...20 pF. The circuit is reasonably accurate for values of C_x up to 100 μF. Above that value the measurement will be affected by leakage currents. To measure capacitors of up to 100 μF, the values of C2 and C3 should be increased to 1 μF.
Current consumption is minimal so that a 9 V battery is an adequate power supply.

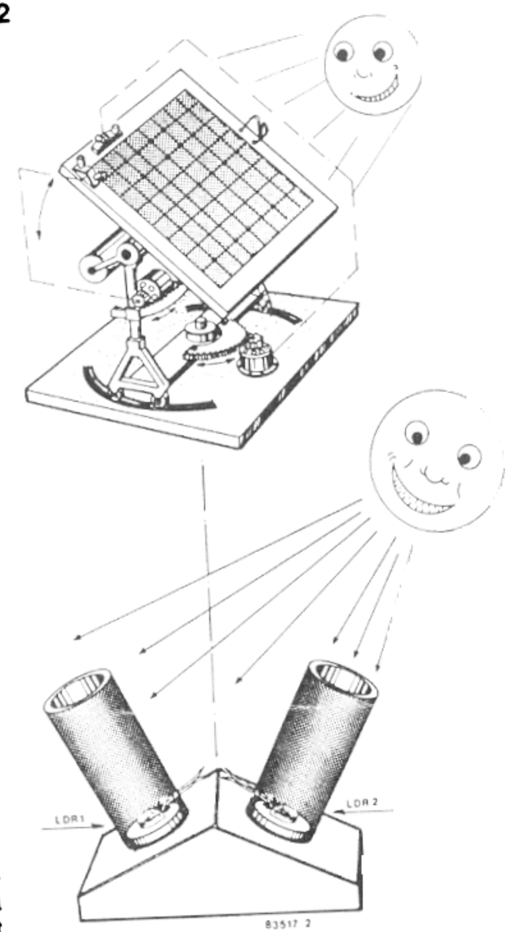
253 solar tracking system

There are some hopes that the sun will become a main source of energy in the 21st century. By then, sources of oil will be almost exhausted and will only play a minor part in the supplying of energy. The present interest in solar energy is therefore not surprising. Some work has already been done with solar cells and solar panels. However, these only operate with optimum performance when positioned exactly at right-angles to the sun. Unfortunately, this situation is not usual in our latitudes unless the solar panels are rotated with respect to the sun. The efficiency of a solar panel system can be improved if the panels track the sun, and remain as long as possible at the most favourable angle of incidence.
The circuitry required is relatively simple. It uses a window comparator which keeps the drive motor idle, as long as the two LDRs (light-dependent resistors) are subjected to the same illumination. Half the operating voltage is then applied to the non-inverting input of A1 and to the inverting input of A2. When the position of the sun changes, the illumination affecting LDRs R1 and R2 is different, if they are at an angle to each other as shown in figure 2. In this case, the input voltage for the window comparator deviates from half the supply voltage, so that the output of the comparator provides information to the motor for clockwise or anticlockwise rotation. Transistors T1...T4 in a bridge circuit cater for reversing of the motor. Diodes D1...D4 serve to suppress voltage peaks which can be produced when the motor is switched. Preset potentiometers P1 and P2 are used for alignment. They are adjusted so that the motor is idle when the LDRs are subjected to the same illumination. If less light reaches R2 than R1, the voltage at point A rises to more than half the supply voltage. The result is that the output of A1 goes high and transistors T1 and T4 conduct. The motor then runs. If the illumination of the LDRs is then changed so that the voltage at point A drops to less than half the supply voltage, output A2 goes high and transistors T3 and T2 conduct. The motor then rotates in the opposite direction. Small geared motors of the type used for models, with a suitable voltage and maximum operating current of 300 mA, are suitable for driving the solar panels. The use of this control circuit makes it possible to control the solar panel in one plane. Of course, to track the sun from sunrise to sundown, two control circuits will be required: one for horizontal and one for vertical tracking.

1



2



254

The usual method of operating an LED (light-emitting diode) from a voltage which is higher than its forward voltage is well known. A limiting resistor is used to limit the LED current to its rated value. Calculating the value of the resistor is simple enough: supply voltage minus LED forward voltage divided by the maximum