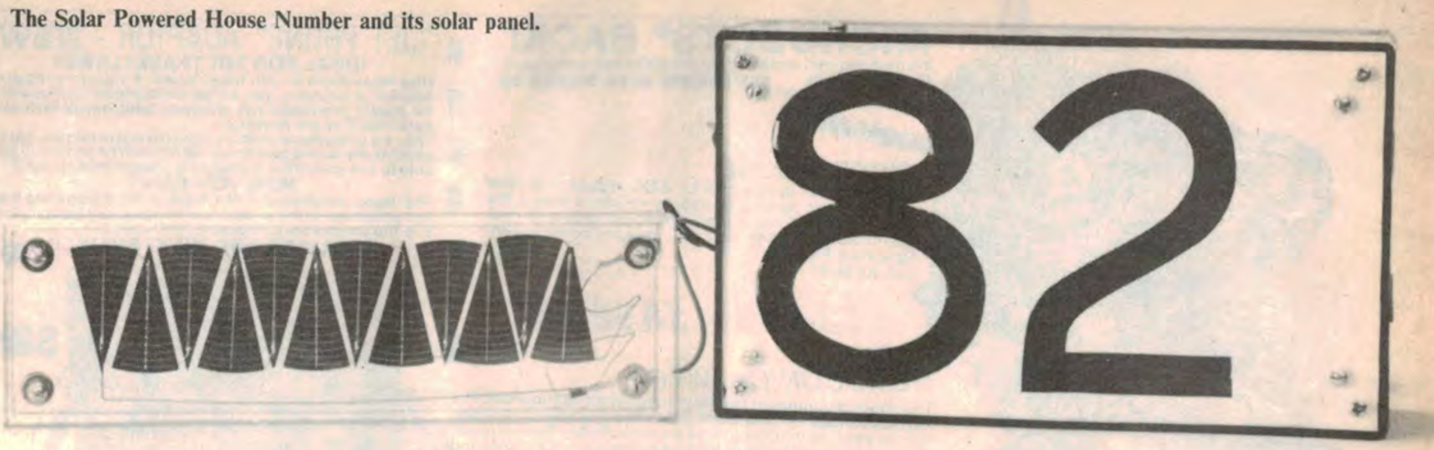
The Solar Powered House Number and its solar panel.



SOLAR POWERED HOUSE NUMBER

by COLIN DAWSON

Searching for a house at night in an unfamiliar street can be a frustrating business. This illuminated house-number switches itself on at dusk and switches off six hours later.

Illuminated house numbers are a great idea but they invariably have one drawback — you have to remember to switch them on at dusk and off again when you retire. They also tend to be expensive. Any system powered directly from the mains must be installed by a licensed electrician although it is possible to use a low-voltage lamp with a step-down transformer.

By contrast, this project is completely automatic in its operation and provides an illuminated house number that is independent of the mains supply. Two rechargeable batteries, topped up during the day by solar cells, provide power for up to 30 high-brightness LEDs. These, in turn, backlight a number mask attached to a tinted plastic backing.

The project operates by using a light dependent resistor (LDR) to monitor the ambient light level. As dusk falls, the LDR resistance increases until, at a certain critical level, the circuit triggers and illuminates the LEDs. A second LDR controls the LED brightness while a timer switches the LEDs off after six hours to minimise battery drain.
An optional "retrigger" switch can be used to reset the timer circuit for a further six hours of operation if required.

A feature of the circuit is that it is very easy to build. Most of the components are mounted on two printed circuit boards (PCBs) and housed in a plastic zippy case that can easily be waterproofed. The solar cells are wired in series and sandwiched between two sheets of perspex to protect them from the weather.

Use of the solar cell array dictated that the circuit be carefully designed to minimise current consumption. Apart from the timer circuit already mentioned, the LEDs are driven in series pairs, a technique that enables two LEDs to be driven with the same current as a single LED. In addition, a multiplexer ensures that no more than three LED pairs (out of a total of 15) are turned on at any given time.

Finally, we have the automatic dimmer circuit which gradually reduces the drive to the LEDs as it gets darker.

Batteries

Initially, we had proposed a simple solar-charged battery circuit consisting of three or four small nickel cadmium (NiCd) cells and a preassembled solar panel costing about $30. Unfortunately, both of these choices proved unsuitable. The solar panel simply lacked capacity and a NiCd battery of suitable capacity turned out to be more expensive than we had anticipated. The alternative was a new sealed lead-acid cell manufactured by Gates Energy Products, USA. These are available in several sizes, with the smallest (illustrated) equivalent in size to the familiar "D" cell. Strictly speaking, this is larger than necessary for this project — two such cells, wired in series, could run the circuit for at least a week without re-charging. Whilst this in itself is desirable, it also meant that the preassembled solar cell package lacked sufficient capacity to take full advantage of the batteries.

Another impressive specification of the Gates cells is their low internal resistance and consequent high discharge capability. The application manual lists the D cell as providing a maximum power transfer of 130W at 130 amperes! Whilst this is of no particular advantage in the Solar Powered Street Number, there are no doubt many situations where it could be used to advantage.

Solar cell array

Having settled on the batteries, the next task was to devise a suitable solar cell array. Preliminary tests had already indicated that the preassembled array lacked sufficient capacity and, in any case, was not really waterproof. Eventually, we decided that a more suitable unit could be built "from the ground up".

What we wanted was an array completely sealed against the weather and capable of supplying at least 20mA at 5V in indifferent sunlight. Most of the cells we tested had a useful output in bright sunlight towards the middle of the day. It's outside of these circumstances that the cell's performance is critical.

We eventually chose cells rated at

The two LDRs are on the right.

78mA and 0.45V. These are 30° circular segment types, available from Jaycar (Cat Zm9004). Twelve are required in all, giving a nominal voltage of 5.4V when connected in series.

This may seem excessive for a battery voltage of 4.2V, but remember this is only the strong sunlight rating. It will be somewhat less during the early morning and late afternoon.

The actually charging rate will vary from about 20mA up to a maximum of 50mA in reasonably bright sunlight, with an average somewhere around the 30mA region. Assuming that this average rate is available for six hours, a daily charge of 180mAh would be accumulated.

In calculating the necessary solar panel capacity, we have assumed that the circuit will operate for six hours per night, althought this can easily be altered. The circuit draws only about 80μA during the standby mode, increasing to a maximum of 60mA just after sunset (LEDs at maximum brightness), and then reducing to about 8mA in total darkness due to the action of the dimmer circuit.

The total amount of power consumed during the six hours of operation thus depends upon the length and brightness of the twilight period. Generally, 110mAh will be the greatest demand.

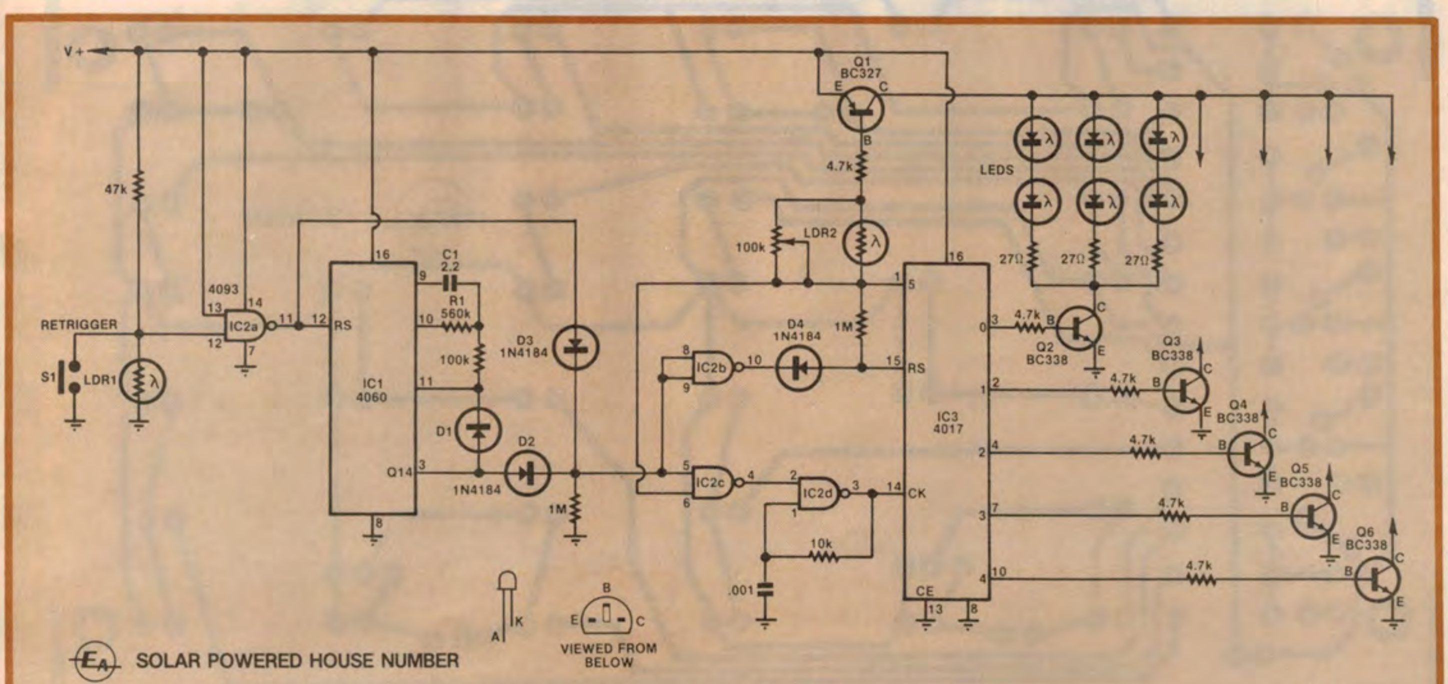
With charging losses generally accepted as 10% of the total charge, a typical daily demand on the solar cells would be thus about 120mAh. The difference between this figure and the actual capacity of the solar cells (180mAh) is important for two reasons: first, and primarily, it ensures that the batteries will eventually be restored to full charge when the sun does shine after several overcast days. Second, the number of days on which a full charge can be acquired is greatly increased because less than six hours of sunlight is needed for this charge.

Circuit operation

The circuit can be divided into five sections: a light detector/switch (LDR1 and IC2a); a timer (IC1); a multiplexer (IC3); a LED driver stage (Q2 to Q6); and a dimmer control circuit (LDR2 and Q1). Let's see how it all works.

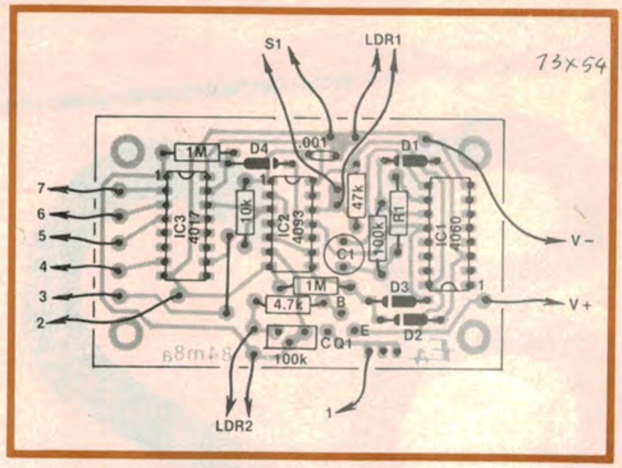
LDR1 is the circuit enable "switch". Together with a fixed 47kΩ resistor it forms a voltage divider, the output of which varies according to the amount of light falling on the LDR. This voltage controls IC2a. At sunset, the LDR resistance (and hence the voltage divider output) increases until, at a certain critical level, IC2a toggles and its output switches from high to low.

The output of IC2a (pin 11) is connected to the reset (pin 12) of IC1, a 4060 14-stage binary counter. As soon as the high to low transition occurs, the



SOLAR POWERED HOUSE NUMBER

The Gates sealed lead-acid cells. They are "D" size, 2.5AH, at 2V.



Control board layout from the component side.

SOLAR POWERED HOUSE NUMBER

reset of IC1 is released and it begins to count.

Clock pulses are provided by IC1's internal oscillator, the frequency of which is set by external components R1 and C1. With R1 = 560kΩ and C = 2.2μF, the clock operates at only one cycle per 1.3s. Since the 4060 divides by 2^{14}, or 16,384, it takes about six hours for its Q14 output to go high (the other outputs are not connected).

By altering the value of either R1 or C1, the six-hour time period can be varied as required. The optional retrigger switch allows the timer to be manually reset for a further six hours of operation at any point in its cycle. Diode D1 stops the clock at the end of the six-hour period by pulling pin 11 of IC1 high.

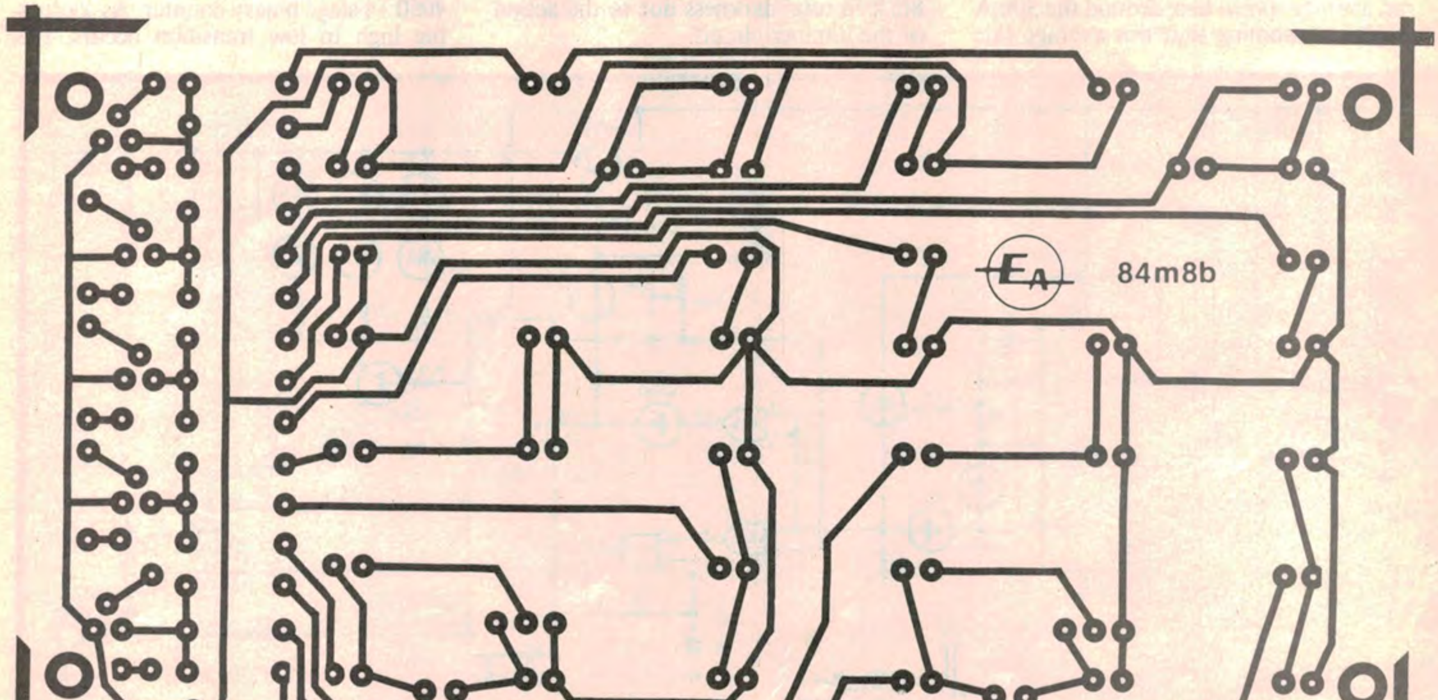
If it were not for D1, IC1 would simply commence a second six-hour period at the expiry of the first. This is due to the fact that it will still be dark after the first six hours which means that the reset of IC1 (pin 12) will still be low.

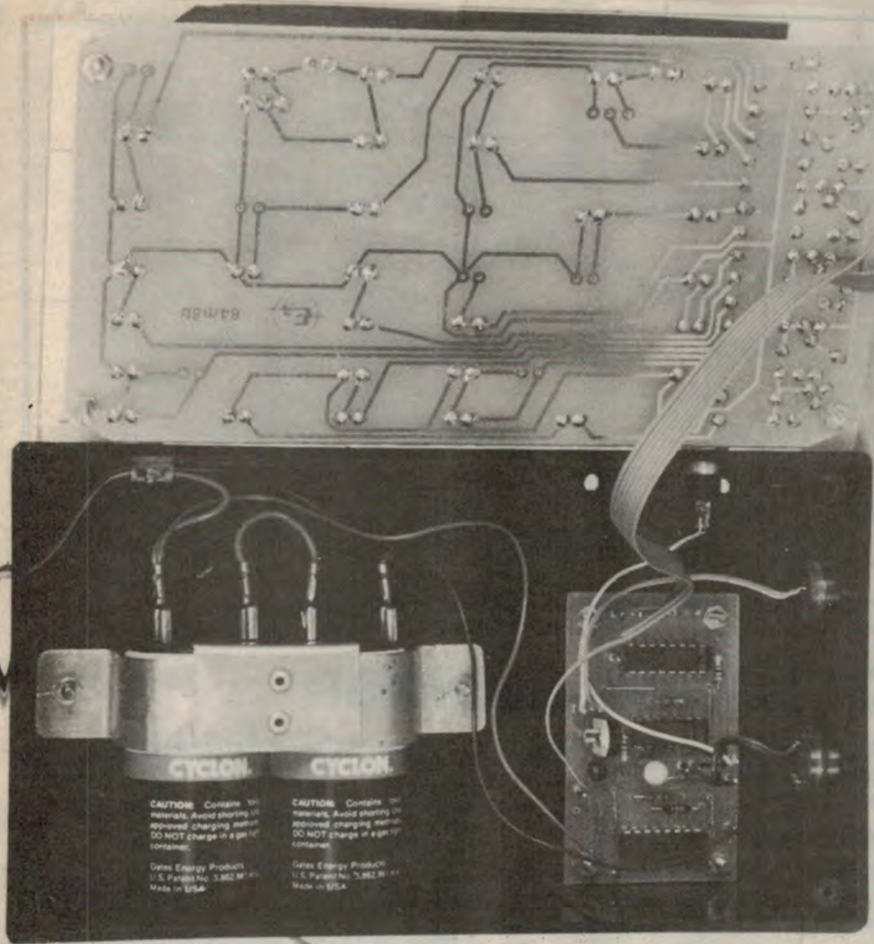
The output of IC2a is not only connected to the reset of IC1, but also to diode D3. Another diode (D2) is connected to Q14 (pin 3) of IC1, while the cathodes of both diodes connect to a common control point. The polarities of D2 and D3 are such that whenever either of their inputs (anodes) is high, the control point is also high. At other times, the control point is held low by a 1MΩ pull-down resistor.

In order for the multiplexing and LED driving circuitry to be enabled, the control point must be low. It follows, therefore, that in the period between IC2a being triggered (sunset) and IC1 completing its count (Q14 high), the display is operating.

IC3, a 4017 decade counter, is used to multiplex the display. Because this circuit only calls for a five-way multiplexer, output 5 (pin 1) is connected to reset (pin 15) via a resistor. IC3 resets almost immediately when pin 1 goes high so, effectively, one of IC3's five output lines (0 to 4) is high at any given time, while ever it is operating.

Notice that the number five output (pin 1) is connected to the reset (pin 15)





Interior view showing control board (right), battery (left), and display board (top).

via a 1MΩ resistor and that the reset is also connected to the anode of diode D4. This means that normal resetting can only occur when D4 is reverse biased. At other times, the reset pin will be held low and IC3 prevented form resetting.

To appreciate the significance of this, it is necessary to consider the circumstances whereby this diode will be forward biased.

The cathode of D4 is connected to the output (pin 10) of IC2b, whose inputs are connected back to the D3/D4 junction. Recall that when this control point is high, the multiplexing circuitry is disabled. As IC2c is connected as an inverter, a logic high at the control point is translated into a low on the cathode of D4. The diode is thus forward biased, inhibiting the reset function of IC3.

Clock pulses for IC3 are supplied by IC2d, a simple Schmitt oscillator with a nominal output frequency of 110Hz. This is enabled by a logic high from IC2c which has one of its inputs connected to the D2/D3 control point and the other to the number 5 output (pin 1) of IC3.

Thus, the clock will be inhibited when both inputs to IC2c are high, ie, when the D2/D3 junction is high (multiplex inhibit) and the number 5 count has been reached.

TABLE 1

NUMERAL	HIGH EFFICIENCY LEDS	DUMMY LEDS	L1	L2	L3	L4
1	3, 6, 8, 11, 14, 16, 19	13	●			
2	2, 4, 6 11, 13, 15, 17, 18, 19,	1, 10			●	
3	2, 4, 6, 8, 10, 14, 15, 16, 18	1. 11, 17		●		
4	2, 3, 5, 6, 7, 8, 9, 11, 12, 13, 14, 16, 19	1, 2*, 15	●			
5	1, 2, 3, 4, 7, 9, 10, 14, 15, 16, 18	2*, 6, 17		●		●
6	2, 5, 7, 9, 10, 12, 14, 15, 16, 18	1, 2*		●		●
7	1, 2, 3, 6, 8, 11, 14, 16, 19	2*, 4, 10	●			
8	2, 4, 6, 7 8, 10, 12, 14, 15, 16, 18	1, 2*, 3 9, 11		●		●
9	2, 3, 4, 6, 7, 8, 10, 11, 14, 16, 19	1, 2*, 9	●			
0	2, 4, 7, 6, 8, 9, 11, 14, 15 16, 18	1, 2* 3, 10		●		

**Install at second digit position.*

Normally, a number 5 count will reset the multiplexer. However, at the completion of the six hours, Q14 (pin 3) of IC1 goes high and prevents IC3 from resetting. At the same time, the multiplexer clock is stopped (due to the multiplex inhibit and number 5 count), and so the 4017 ceases counting. The number 5 output (pin 1) thus remains high while all other outputs remain low. This keeps all display drivers turned off.

The display drivers (Q2-Q6) are driven by the 0-4 outputs of IC3 via 4.7kΩ base current-limiting resistors. Up to three LED chains can be driven by each transistor, each chain consisting of two LEDs wired in series with a 27Ω current limiting resistor. The chains are connected between the collectors of their

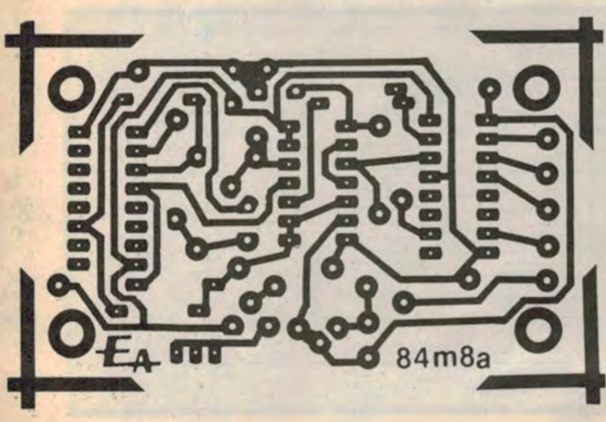
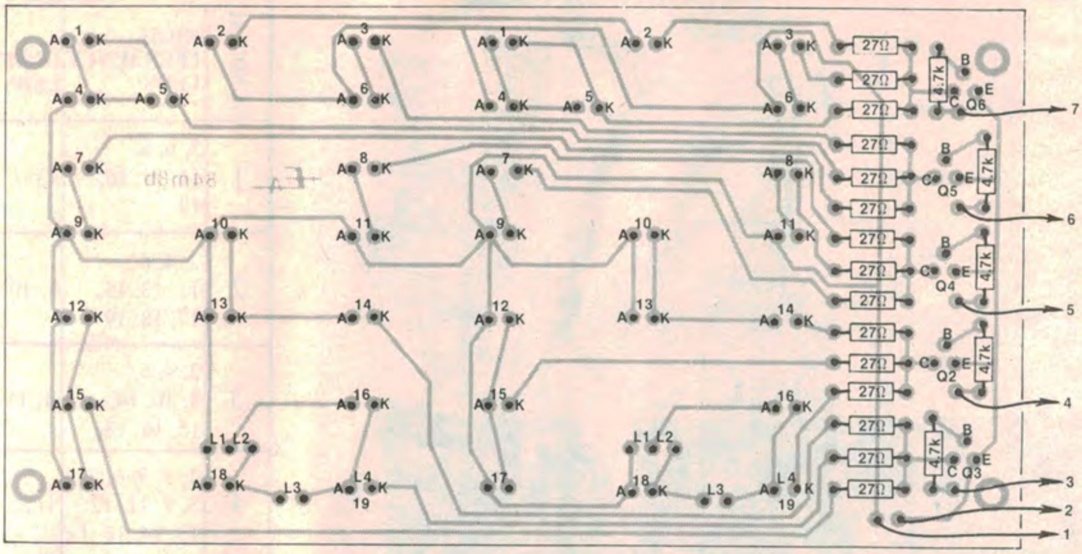


TABLE: OPTIMUM INCLINATION FOR SOLAR ARRAYS

Darwin	17°
Cairns, Broome	22°
Rockhampton, Alice Springs	28°
Brisbane, Geraldton, Broken Hill, Perth	37°
Sydney	39°
Canberra, Adelaide	40°
Melbourne	43°
Hobart	48°



Component layout for the display board from the component side, superimposed on the wiring pattern.

SOLAR POWERED HOUSE NUMBER

respective display driver transistors and the collector of Q1 which forms part of the dimmer circuit.

The dimmer circuit consists of PNP transistor Q1, LDR2, VR1, and Q1's associated 4.7kΩ base resistor. Q1 has its emitter connected to the positive supply rail and its collector to all of the LED anodes. The LDR simply provides base current for the transistor. During twilight, more base current is provided for the transistor so that the LEDs operate at maximum brightness. As the level of ambient light falls, less base current is provided for Q1 and the LEDs dim.

VR1 is adjusted after installation to provide a suitable minimum level of brightness, according to the installation.

Note that the drive current for Q1 is not derived from the negative supply rail as this would result in a wasteful base current flowing during the day when the LEDs are not operating. Instead, the base current is derived from output 5 (pin 1) of IC3. When the multiplexer operation is inhibited, output 5 remains high and thus no current flows to the base of Q3.

Construction

Construction can be divided into four main areas — the solar panel, display, control electronics and preparation of the box to house the project. Because the solar panel will have to be sealed after assembly and then left to dry, it should be attended to first. You should have the following parts handy before beginning: two pieces of perspex or Lexan (about 195 x 60mm), 12 solar cells, 300mm of enamelled copper wire, four machine screws and nuts, eight washers, four solder lugs and a 1N4001 diode.

Actually, it is unlikely that the perspex will be supplied as 195 x 60mm pieces. We obtained a 300 x 300mm sheet from Radio House (760 George St, Sydney. Phone 212 3810) and cut it to size. This meant that there was more than enough left over to use for the display.

Having trimmed the two pieces of perspex to size, clamp them together and drill a hole in each corner to accept the machine screws. This done, drill two smaller holes at one end of one sheet to provide access for the output wires.

The solar cells should now be connected in series using small lengths of the tinned copper wire. Two longer lengths (about 200mm and 40mm) are used for the output connections.

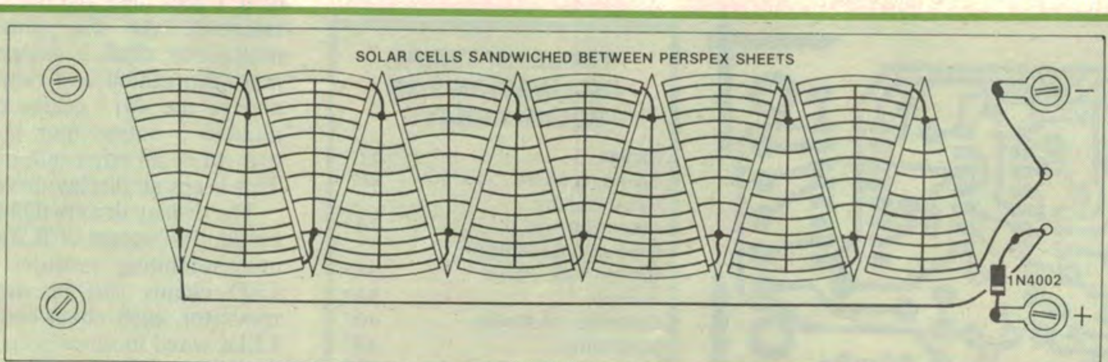
Note that the cells are extremely brittle and will crack if mishandled. They can also be damaged by excessive soldering time, so treat them gently.

Once the cells are all interconnected, smear a dab of silicone rubber compound on the back of each and lay them out on the lower perspex sheet as shown in the diagram. Feed the output wires through

We estimate that the current cost of parts for this project is approximately

$75-80

This includes sales tax.



Physical layout and cell interconnections for the solar panels.

their respective holes in the lower perspex sheet and connect the positive lead to the anode of the 1N4001 diode. This done, terminate the cathode and negative leads with solder lugs.

Construction of the array can now be completed by running a fillet of silicone rubber compound around the edge of one of the perspex sheets, and then fastening the two sheets together using machine screws and nuts. Note that spaces should be inserted between the two sheets to prevent them from crushing the cells. Two small washers stacked together at each screw location should do the trick.

We also used solder lugs to terminate the external leads and these should be added during the final assembly. Don't forget to seal the holes for the output wires from the cells.

The circuit itself is built on two printed circuit boards (PCBs): a control board coded 84m8a and measuring 73 x 44mm; and a display board coded 84m8b and measuring 180 x 95mm.

Begin by assembling the control board according to the parts overlay diagram. Note that the ICs are CMOS devices so be sure to solder their supply pins (7 and 14, 8 and 16) first to enable the internal static protection diodes. We used PC stakes to terminate the external wiring connections (nine in all).

The display board (84m8b) has been designed to accommodate various LED combinations to form any one or two digit number. If you require a three-digit number, then you will have to wire the display using matrix board or Veroboard.

low efficiency types. In use, they are simply blocked from view by the number mask on the display panel.

Do not omit the dummy LEDs. They are necessary because all LEDs must be connected in series pairs to avoid variations in brightness.

All that remains now is to mount the various parts into the plastic zippy case. First, cut a piece of perspex to replace the original aluminium lid and attach to it a cardboard number mask representing your street number. The display board can then be mounted behind the number mask using 25mm screws as stand-offs.

If you like, you can use a coloured filter behind the mask to improve its daytime visibility.

The control PCB is mounted on the base of the case, at one end, and secured using machine screws and nuts. As shown in the photograph, the two LDRs are mounted on the end of the case, adjacent to the PCB, and secured using epoxy adhesive. We also mounted the optional retrigger switch adjacent to the LDRs.

The battery holder can be manufactured from a piece of scrap aluminium. Make sure that it is reasonably substantial and that the batteries are firmly secured. Should the battery terminals happen to contact the holder or some other mounting hardware, there will certainly be a spectacular display — at least for a few seconds.

To test the Solar Powered House Number, temporarily alter the values of R1 and C1 so that a much shorter time

PARTS LIST

- 1 PCB, code 84m8a, 73 x 44mm
- 1 PCB, code 84m8b, 180 x 95mm
- 1 perspex sheet, 300 x 300mm (see text)
- 2 2V/2.5Ah sealed lead-acid batteries, D-size, Gates Cyclon or equivalent
- 1 plastic zippy case, UB2, 60 x 113 x 196mm
- 4 spade connectors (to suit batteries)
- 4 solder lugs
- 1 SPST momentary contact pushbutton switch (optional, see text)
- 1 sheet of red tinted plastic, 200 x 110mm

Semiconductors

- 5 BC338 NPN transistors
- 1 BC327 PNP transistor
- 4 IN4148 diodes
- 1 1N4001 diodes
- 1 4060 14-stage binary counter
- 1 4017 decade counter
- 1 4093 quad NAND Schmitt trigger
- 12 solar cells, 0.45V/78mA (see text)

Capacitors

- 1 2.2μF bipolar electrolytic
- 1 .01μF metallised polyester (see text)
- 1 .001μF metallised polyester

Resistors (¼W, 5% unless noted)

2 x 1MΩ, 1 x 560kΩ, 1 x 100kΩ, 1 x 56kΩ (see text), 1 x 47kΩ, 1 x 10kΩ, 6 x 4.7kΩ, 15 x 27Ω, 1 x 100kΩ 5mm vertical trimpot, 2 x ORP12 light dependent resistors

Miscellaneous

Machine screws and nuts, tinned copper wire (300mm x 0.5mm), silicone rubber sealant, rainbow cable, scrap aluminium, high-efficiency and low-efficiency LEDs (number to suit)

INSTALLATION

The solar cell array should be mounted on the roof of your house and tilted towards true north to ensure maximum solar illumination. Make sure that you choose a spot that will not be shaded by trees or other objects at any time during the day. If the solar cells are shaded, their output will be drastically reduced and the panel may not recharge the batteries.

Note that the optimum angle of inclination of the cells varies according to the latitude of your town or city. This needn't be too accurate, as a few degrees either way won't make all that much difference. Table 2 lists the optimum angle of inclination for various Australian towns and cities.

Perhaps the best way of mounting the solar cells panel is to attach it to the top of the TV antenna mast. The leads can then be run down the mast, adjacent to the antenna lead-in, and routed to the control unit.

Because the number required will vary, the LED locations are represented by numbers on the parts overlay diagram. To select a certain number, all you have to do is install LEDs and wire links at the locations indicated by Table 1.

For example, to make up the number "5", install high efficiency LEDs at locations 1, 2, 3, 4, 7, 9, 10, 14, 15, 16 and 18; dummy LEDs at 2, 6 and 17; and links at L2 and L19.

The dummy LEDs, by the way, are

period results. Substituting 56kΩ and .01μF will give a period of about 10s.

Once power is connected, cover the LDRs or turn the room light off. the circuit should now trigger for the duration of the time interval, provided that darkness continues. Turning the lights on during this time should cancel the cycle immediately.

While the circuit is operating, try altering the level of light falling on LDR 2. This should alter the brightness of the display. Calibration of this control, however, can only be carried out properly with the unit in situ.

Allow the circuit to go through one cycle, then press the retrigger switch. This should cause another cycle to commence. Resetting should occur after LDR 1 is exposed to light, irrespective of whether the switch is fitted or not.

Provided that the circuit appears to be working properly, restore R1 and C1 to their normal values. The solar panel can now be connected, but make certain the diode on the panel is installed with correct polarity. If the Gates cells are heavily discharged, it may be advantageous to leave them charging for a few days before connected to the rest of the circuit. Otherwise, the circuit is ready for permanent installation.