EXPERIMENTAL WORKSHOP

M. J. HUGHES M.A.

LEARNING BY PRACTICAL PROJECT STEPS

PART 2—THE BISTABLE

WE are going to look at a very fundamental switching circuit this month that is based on the principles we developed in the last part. It is called the *bistable switch*—the reason for this name should become clearer as its story progresses. If you look at the basic circuit in Fig. 9a you will notice a marked similarity to the experiments we did last month; two transistors are cross connected—the base current for each being drawn from the collector circuit of the other. Notice, however, that both base resistors (R2 and R3) are permanently connected in and we are not using switches this time!

Basic assumptions

For those who like to sweat over puzzles try this one before reading on. Assuming that the circuit is completely wired up and power is supplied use your knowledge regarding base current and driving voltages to work out whether Tr1 and Tr2 are conducting or not conducting!

Unless you have made an assumption you should be completely stuck because the system does not seem to make sense. In stages you could have said that when power is not applied both transistors must be non-conducting hence at the instant you apply power both points A and B will be at +9V. This set of circumstances, however, provides base current for the opposite transistor and the effect of this is to make each transistor go into conduction and *both* the respective voltages will fall cutting off the base current; the result of this would be to make both collectors rise back to +9V and we are again at the start point of a vicious circle! To arrive at a sensible result we must make a practical assumption—that there is bound to be a slight difference in the current gains of the two transistors used and the one that has the higher value will go more rapidly into conduction when power is applied. Let us assume Tr1 has a nominally higher current gain than Tr2.

When power is applied Tr1 will draw base current from point B through R3 and the voltage at A will fall rapidly—cutting off the supply of base current to Tr2. The latter therefore will *not* go into conduction and the voltage at B will stay at +9V while that at A will fall to nearly zero. Try this with your experimental circuit making and breaking the power line and you should find that it is always the same transistor that goes into conduction—in your case, of course, it might be Tr2.

Anyway we shall carry on with our assumption that after switch on point A is at zero volts and we have—after all—a stable state. Let's assume

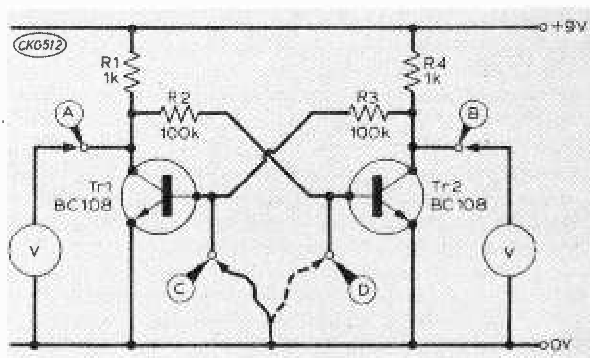


Fig. 9a: A conventional bistable circuit.

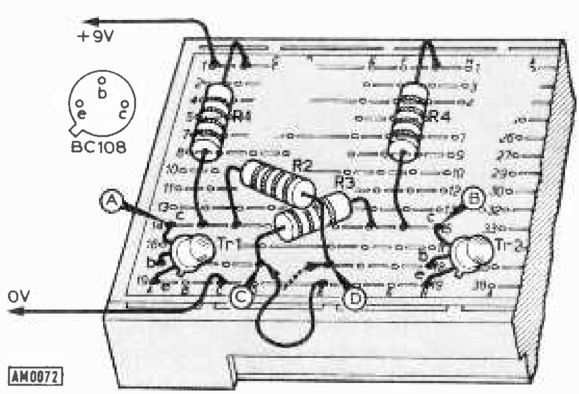


Fig. 9b: T-Dec layout for Fig. 9a.

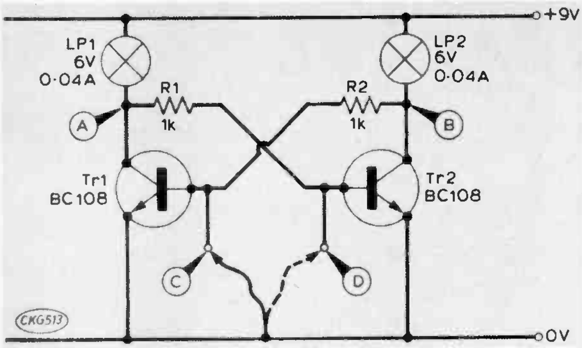


Fig. 10a: A bistable with components modified to drive lamps direct.

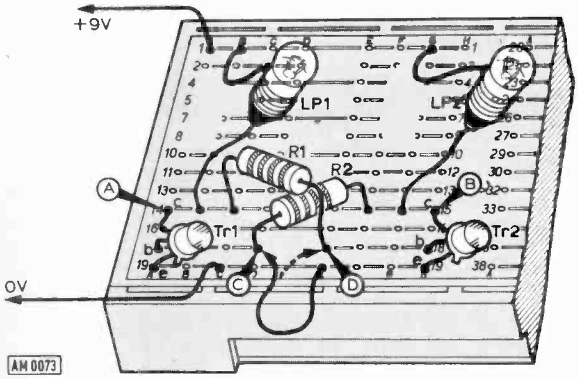
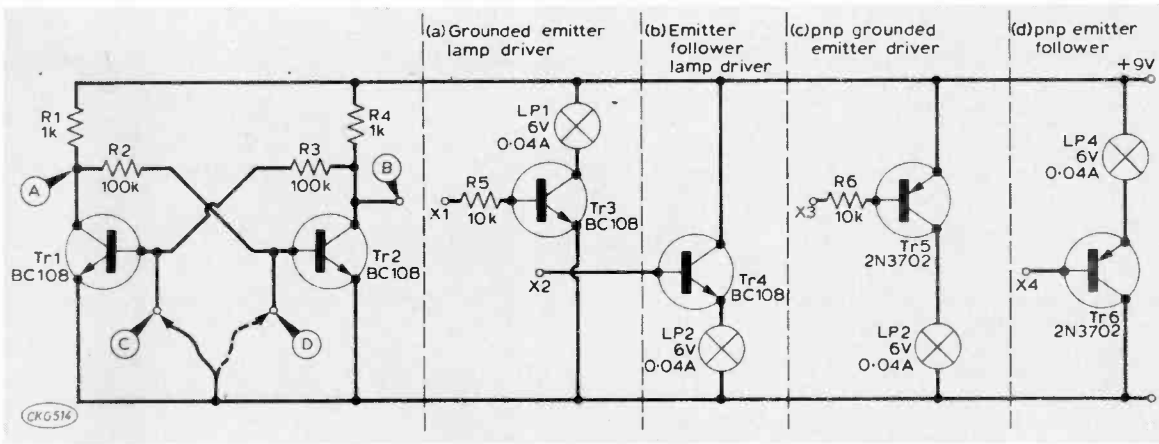


Fig. 10b: T-Dec layout for Fig. 10a.

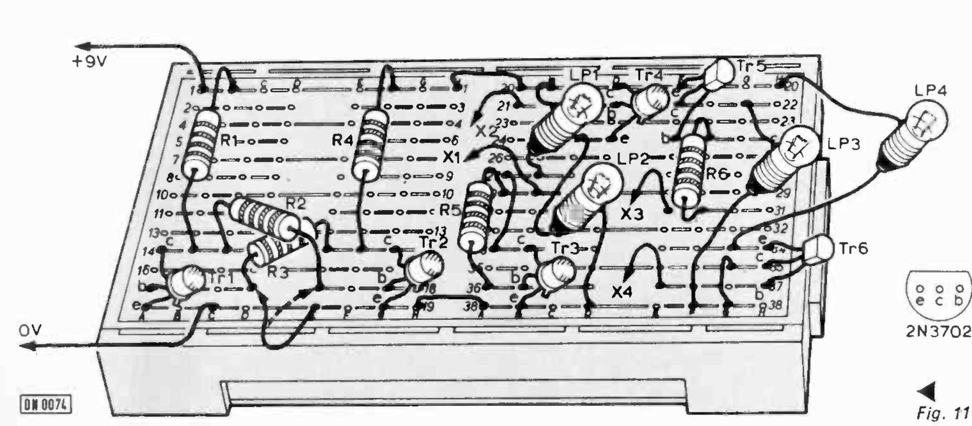
that we really wanted point B to go to zero volts. For this to happen we must, somehow, make base current flow into Tr2. To do this we must make the voltage at A rise to +9V by momentarily removing Tr1's supply of base current—conveniently done by shorting point C to ground. Do just that and watch the voltage at B as you make the short. Sure enough, it falls to zero while you make the short, but notice that when you have removed the shorting link from C point B stays at zero volts—not only that, but A is now at +9V and the system is again stable. You can make the circuit revert to its original state by momentarily shorting point D to ground. The circuit has two possible stable states (hence its name) and we can make it go into either of them by externally tampering with the base current supplies.

Alternative loads

The rules of current gain apply in this circuit without undue complication and taking into account the normal current limitations of transistors you can use collector loads other than pure resistors. Fig. 10a is an identical circuit in which lamps are used; the cross coupling resistors have to be of lower values to ensure that enough base current flows to control the larger load. Alternatively connect the flying lead to points C and D and you will see that you can make LP1 go on—and stay on—when point D is quickly shorted to ground and similarly with LP2 and point C.



▲ *Fig. 11a: Alternative ways of driving low voltage lamps from a bistable. Low voltage relays (requiring less than 100mA) can be substituted for the lamps provided protection diodes are inserted (see part 1, last month).*



◄ *Fig. 11b: T-Dec layout for Fig. 11a.*

If you wish to you can use the voltage swings at the collectors of the bistable transistors to drive other circuits. A selection of lamp drivers are shown in Fig. 11a. Any of the single transistor driver stages (with inputs marked X1, 2, 3 and 4) can be connected to either points A or B. (We shall assume they are connected to B.) Take driver (a) which is a simple grounded emitter inverter stage. When point B is +9V Tr3 can draw base current through R5 and the lamp will light. Notice that we have to put a 10kΩ resistor in to prevent the base emitter circuit of Tr3 pulling the voltage at B down to +600mV; if that were to happen the action of the bistable would be interferred with.

Circuit (b) is a simple form of emitter follower and in this case we can do away with the 10kΩ resistor. The reason for this is that when point B goes "high" we immediately pass base current into Tr4 and it starts to conduct, but when this happens the voltage at its emitter rises as current flows through the lamp. The voltage rises to a value 600mV less than the voltage at B; the difference in voltage is due to the standard base emitter forward voltage drop associated with silicon transistors. If, say, point B went to +9V we would end up with approximately 8·4V across the bulb. The only drawback of this circuit—although it does not bother us in this application—is that we will always lose 600mV of driving voltage across the bulb and it will not glow quite so brightly.

In both these two drivers the lamp went on when point B went to +9V. The remaining two drivers use pnp transistors in grounded emitter and emitter follower configurations and because they are sensitive to opposite polarity signals the lamp goes *off* when point B goes high. In circuits it is often useful to make use of opposite polarity transistors to get this type of inversion. It is not very impressive in this application because if we had wanted any inversion we could have used point A as the driving source.

Dividing

An interesting development of the bistable circuit is the *divider* shown in Fig. 12a. The basic circuit of Fig. 9a is still there and you can ignore Tr3 because it is only a lamp driver. We have added a couple of diodes and capacitors and a few more resistors. The object of the circuit is to make Tr1 and Tr2 take up their alternative stable states each time we make a single short circuit path to ground (we shall be shorting point G to ground as a signal).

Let's assume that point A is at +9V (B will be zero and so will C, and D will be at approximately +600mV). The voltage at A effectively reverse biases D1, and D2 is just on the edge of conduction through R6 to point B—which is just slightly more

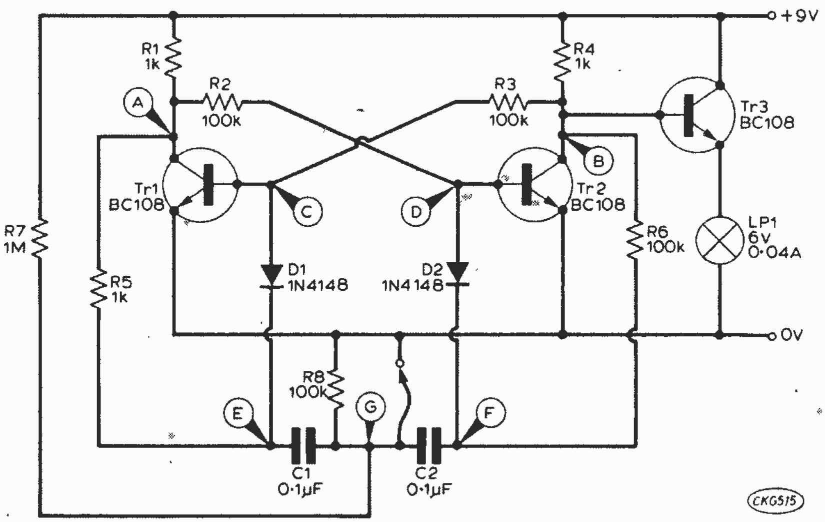


Fig. 12a: A bistable with built in gating so that it switches in alternate directions each time point G is connected to ground. This is sometimes called a divider.

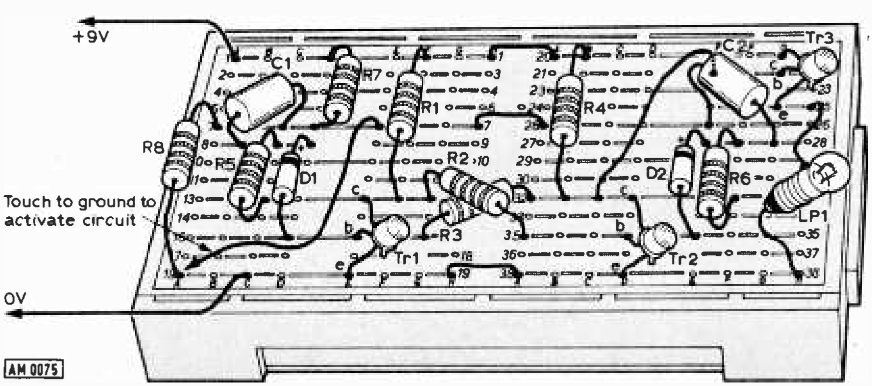


Fig. 12b: T-Dec layout for Fig. 12a.

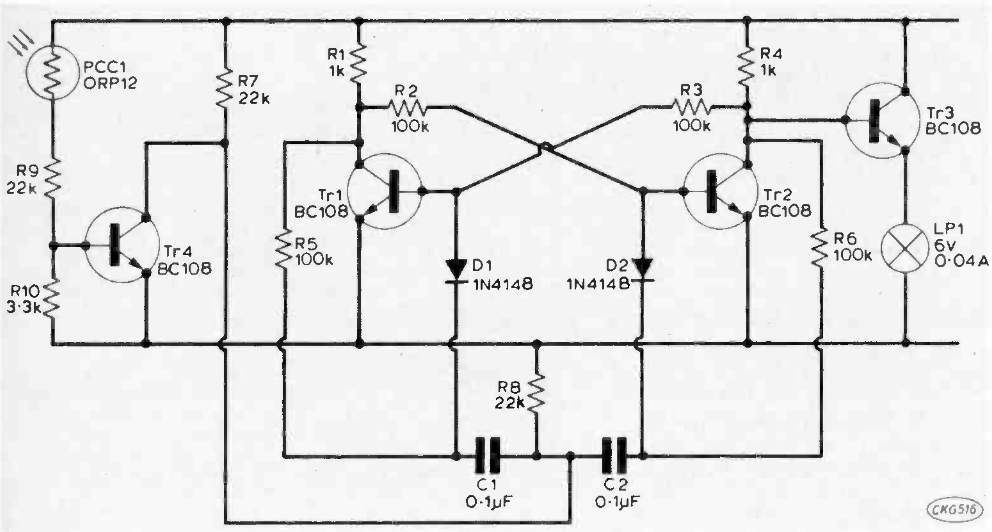


Fig. 13a: With the addition of a few more components, the divider can be made to "toggle" whenever bright light falls on the photo-conductive cell.

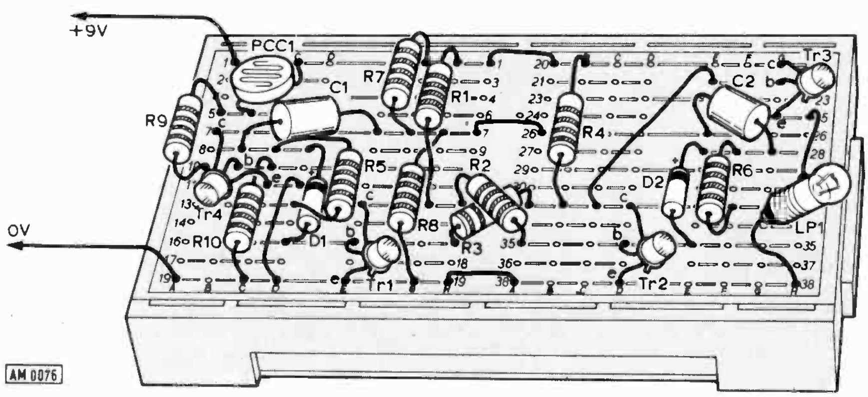


Fig. 13b: T-Dec layout for Fig. 13a

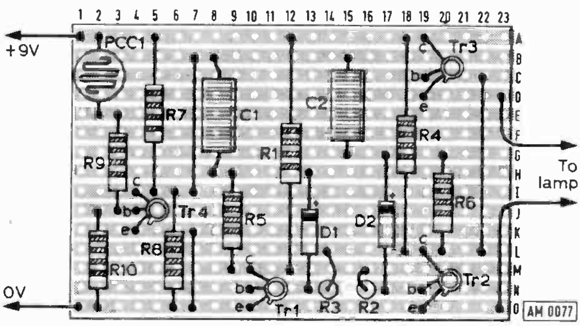


Fig. 13c: Veroboard layout for Fig. 13a.

negative than D. The potential at G (without the shorting link made) will be just under 1V because of the potential divide action of R7 and R8.

By repeated dabbing of the shorting link to ground you can make the lamp go on and off alternatively. There is something that you have to note, however. The circuit is very sensitive and you must make very good clean makes and breaks of the shorting operation; it is very easy to accidently give a double "pulse" when you think you have, in fact, only made one. R7 has deliberately been made a high value to allow time for the voltage at G to recover and this helps to eliminate what appears to be erratic action. Nevertheless the time constant of 1MΩ with the 0·1μF capacitors is still quite short so do not be too surprised if sometimes the lamp appears not to respond. What actually happens is that the lamp switches on and back to off so quickly you do not see it happen! Try reducing R7 to 100kΩ and R8 to 10kΩ and you will deliberately aggravate the problem. In a circuit of this nature it is wiser to use some form of non-mechanical switch to do the triggering so that we lose the "bounce' problem.

When you short point G to ground there will be a change in voltage at point E by about 0·8V in a negative direction but because D1 is reverse biased there will be little effect on the base circuit of Tr1. On the other hand the similar drop developed at point F will put D2 into sufficient conduction to momentarily drop the voltage at D and hence remove the base current from Tr2. The voltage at B will rise and bistable action will take place and the voltage at A will fall as the circuit takes up its other stable state. The set of circumstances is now reversed and if the shortening link is removed to allow the two capacitors to regain their original equilibrium the operation can be repeated to make the circuit flip back to its first stable state.

—continued on page 645

—continued from page 644

Fig. 13a shows a very crude electronic form of trigger for the divider. A sudden transition of from near darkness to full room light on PCC1 will make Tr4 go suddenly into conduction and the voltage at the junction of C1 and C2 will fall rapidly to zero—stimulating the divider. Switch off the room light and switch it on again and the circuit reverts. The reason for doing this experiment is to show that it needs two complete operations of switching the room light on and off to make the lamp in the circuit go on and off once. We are effectively dividing the number of operations by a factor of two—the reason why the circuit gets its name. While doing this experiment it is worth noting that slow signals do not have any effect on the divider; slowly covering and uncovering PCC1 will not be an effective trigger—you need the very fast action of switching a light on and off to get reliable results. The reason for this is that C1 and C2 are not able to pass slow waveform signals. You need a wide range of lighting levels to make this circuit switch rapidly but there are a range of switching circuits called 'triggers" which speed up the action of slow stimuli. We shall be looking at this effect next month.

TO BE CONTINUED

DO YOU HAVE A STANDARD SIZE "COMPACT CASSETTE" TAPE RECORDER?

If so, why not send us a "taped" letter for the letters page?

WE WILL AWARD

TWO FREE CASSETTE TAPES

FOR EACH "TAPED" LETTER PUBLISHED IN "PRACTICAL WIRELESS"

and return your original cassette* as well.

Please note that we cannot accept nor deal with cassettes which contain queries or any other message than a letter of comment or discussion for "Dear Sir." Although we will return cassettes to readers, we cannot be held responsible for any cassettes that are lost or damaged in transit. If you wish to have your cassette returned*, please write your full name and address on it in block capitals and enclose a 4p stamp. "Tapedletters" on **cassettes only** can be sent to:

"Dear Sir," Practical Wireless, Fleetway House, Farringdon Street, London EC4A 4AD.

We can still accept handwritten letters, too!

*We can only send cassettes to U.K. addresses.

Dear Sir, letters

Mum writes in

I am writing as a 'Mum' of one of your enthusiastic readers. Do you by any chance know the ages of some of your younger readers?

My son Edward is 6½ years old and has taken *Practical Wireless* for over a year now. It is used for bedtime stories together with Aesop's Fables (I insist on that!)

Thus one outcome of the enthusiasm of one small boy is that his mother now knows the difference between a diode and a triode, step-up transformers and step-down transformers.

I must confess I find the whole subject of wireless very difficult and show no enthusiasm myself but if you could see a certain little boy's eyes light up when "*P.W.*" as it is affectionately called arrives, it persuades me once more to plough through details of digital multimeters and who is selling what component at the cheaper price!

Through your magazine, Edward bought a pocket multimeter from an advertiser, so we are all having our resistance tested!—**Mrs. Pat Russell** (Herts.).

Darkroom thermometer

Some time ago, you published an article by R. A. Bottomley on the construction of a darkroom thermometer. I have built this unit with great success but I found it was necessary to increase R3 to obtain balance at the mid-point on the scale. I arranged for 24° and 29° by duplicating R3, VR1 and R4. R3 then became 1·5 + 2·2k and 1·5 + 3·3k. A changeover switch completed the revised arrangement, the two temperatures being respectively for developing colour film and colour prints. The meter I used was a Japanese Henelec 0-100uA.—**C. G. Dahl** (Surrey).