'Transistor match-maker'

A transistor tester for finding matched pairs.

'Oh no, not another transistor tester!" may well be several readers' initial reaction. Don't worry, this article is designed to save you and your eyes hours of strain and boredom. The device is capable of picking matched transistor pairs from a whole pile of 'possibles', and all within seconds. Two transistors will be 'matched' if their base/emitter voltage and their current amplification are the same. The degree of accuracy may range from 'roughly the same' to 'identical' (1%) and can be adjusted, as required. It really is an indispensable aid when suitable matched transistors are needed for differential amplifiers, or temperature sensors.

Finding matching transistors is a highly unpopular and tedious occupation. Nevertheless, it is one of those jobs that just have to be done from time to time, as such transistor pairs are often used in differential amplifiers and in particular, of course, when they act as temperature sensors. Usually, it means improvising a test circuit, getting hold of a universal meter and spending the entire evening testing a whole pile of transistors while jotting down the results. Better make sure there's nothing on the box that night!
Elektor has now come up with a short-cut in the form of a transistor tester. It makes life a lot easier, as it actually compares two transistors. LEDs light to indicate whether their U_{BE} and H_{FE} correspond or not. The circuit does all the work — you just plug in transistors and watch the LEDs. There are three LEDs altogether: one to indicate that sample no. 1 is 'better' than no. 2, one to indicate the opposite and another to show the pair is a perfect match.

Operation

All this may seem rather complicated, but in actual fact the tester is based on a fairly straightforward principle. Figure 1 shows a simplified version of the circuit to make matters clear. A triangular wave-shape is applied to the transistors under test (TUTs). Any differences between their collector voltages are detected with the aid of two comparators and will be indicated by the LEDs. That, in a nutshell, is the theory.
Now to put it into practice. As shown in figure 1, the two TUTs are driven by exactly the same control voltage, but their collector resistors are marginally different. $R2_a$ and $R2_b$ together are slightly greater in value than R1, whereas $R2_a$ alone is a little smaller than R1. And that is the whole trick of the tester circuit.
Let us suppose the two TUTs are identical as far as their U_{BE} and H_{FE} are concerned. The rising slope of the input voltage will then switch them both 'on' at the same time and the voltage at their collectors will drop. If we were to freeze the action at any point, we would see that TUT2's collector voltage is a tiny bit lower than that of TUT1, due to its total collector resistance being slightly greater. Since, on the other hand, $R2_a$ is a little smaller in value than R1, the voltage at the $R2_a/R2_b$ junction will be slightly higher than that at the collector of TUT1.
As a result of this, the '+' input of comparator 1 will be positive with respect to its '—' input. This means that the output of K1 will be high and LED

1

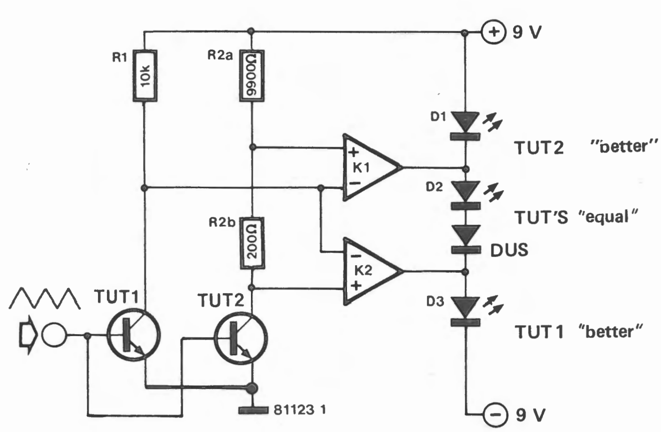


Figure 1. The simplified circuit diagram of the transistor tester. Comparators check the two transistors for differences in voltage and the result is indicated by the LEDs.

2

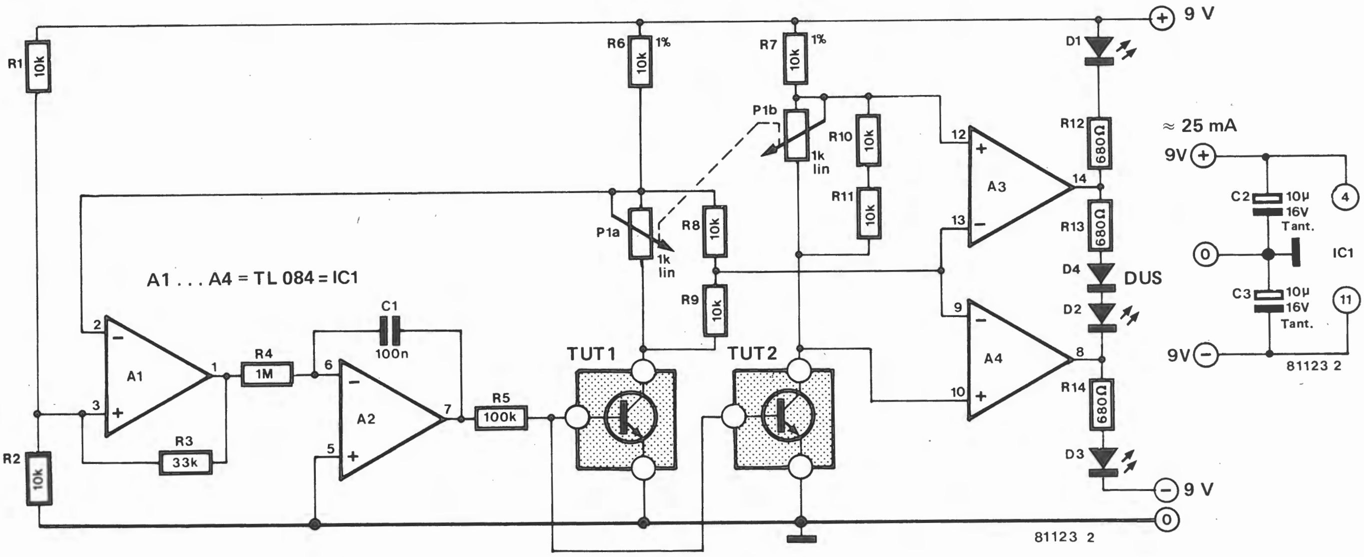


Figure 2. The final version of the circuit diagram. It is built around a set of four opamps. Two (A1 and A2) constitute the triangular wave generator and the other two act as comparators.

D1 will not light. At the same time, the '+' input of K2 is negative with respect to its '—' input and so its output will be low and LED D3 will not light either. In this situation, where K1's output is high and K2's is low, D2 will light up as an indication that the two transistors are in fact identical.

Now let us see what happens when TUT1 has a lower U_{BE} and/or a higher H_{FE} than TUT2. During the positive edge of the triangular signal, the voltage at the collector of TUT1 will drop sooner and/or faster than that of TUT2. Comparator K1 will react to this in the same manner as before, in that the '+' input will again be positive with respect to the '—' input and its output will therefore be high. Since TUT1's low collector voltage is also connected to the '—' input of K2, that particular '—' input will now be lower than the '+' input connected to TUT2's collector. This will cause the output of K2 to rise. Since the two comparator outputs are high, D1 will not light; D2, like D1, will be connected between two high levels and thus unable to light either, and now there is nothing to stop D3 from lighting. D3's LED will therefore indicate that TUT1 is the 'better man' of the two transistors.

If TUT2 turns out to be 'better', this will of course cause its collector voltage to drop at a faster rate. As a result, both the voltage at the collector itself and that at the $R2_a/R2_b$ junction will be lower than the collector voltage of TUT1. This means that the '+' inputs of the comparators will both become low

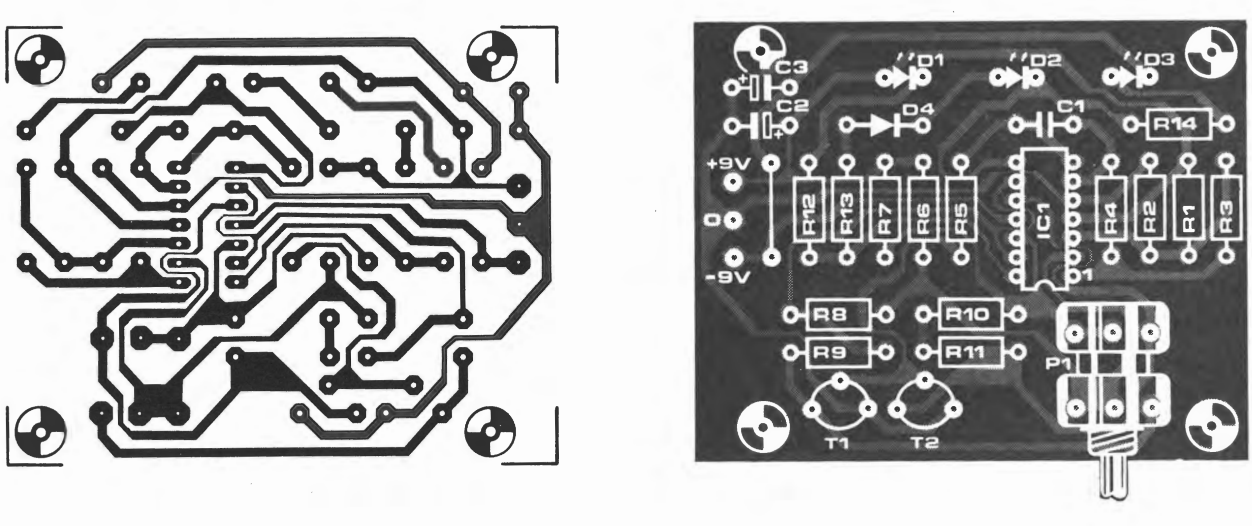
Parts List

Resistors:
R1,R2,R8 . . . R11 = 10 k
R3 = 33 k
R4 = 1 M
R5 = 100 k
R6,R7 = 10 k 1%
R12,R13,R14 = 680 Ω
P1 = 1 k tandem potentiometers, linear

Capacitors:
C1 = 100 n
C2,C3 = 10 µ/16 V

Semiconductors:
IC1 = A1 . . . A4 = TL 084
D1 . . . D3 = LED
D4 = DUS

3



The component overlay and track pattern of the tester printed circuit board. Reliable sockets should be used for the two TUTs.

with respect to the '—' input, so that the two outputs will be low. This prevents D2 and D3 from lighting and this time it is D1 that lights to indicate that TUT2 is the 'better' choice.

The circuit diagram and the printed circuit board

Figure 2 shows the complete circuit diagram of the tester. All it consists of is a single IC, type TL 084, which contains four FET opamps. Schmitt trigger A1 and the integrator built up around A2 combine to form a simple triangular wave generator. This provides the transistors under test with an input voltage. The other two opamps (A3 and A4) act as comparators and it is their outputs which control the LED indications, D1 . . . D3.

A closer look at the conglomeration of resistors in the collector leads of the two TUTs will explain why we used a simplified version of the circuit to clarify the principle. The final circuit looks much more complicated, as a tandem pot (P1) has been added to preset the range within which the transistors may be considered to be identical. If P1 is turned left as far as it will go and the middle LED (D3) lights, the two TUTs will be identical within about 1%. The 'matched pair' criterion is relaxed to about 10% tolerance when the pot is turned fully clockwise.

The maximum possible accuracy is limited by the tolerance in R6 and R7, by the offset voltage of the TL 084 and by the tracking accuracy of P1a and P1b. In addition, the transistors under test will react to changes in their temperature, which is something to watch out for. If, for example, a transistor is held in the hand and then inserted in the tester, the results of the test will be affected, and so it is better to wait until it cools off again before jumping to conclusions.

The tester requires a symmetrical power supply. The level of the supply voltage is not critical and the circuit will not only work well at the indicated + and —9 V, but also at + and —7 V or even at + and —12 V. The circuit can easily be powered from two 9 V batteries, as its current consumption is only 25 mA and, in any case, the tester is hardly likely to be switched on for hours on end. Being battery fed, the circuit can be constructed into a neat, compact device and is therefore easy to work with.

Figure 3 shows the tester's printed circuit board. It is difficult to see how anything could go wrong (touch wood!), considering the small amount of components required. All that it needs are a single IC, two transistor sockets for the TUT's, a few resistors and three LEDs. Make sure resistors R6 and R7 are 1% types.