Semiconductor Tests with an Ohmmeter

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Your ohmmeter can double as a diode and transistor tester.

A SIMPLE LOW-POWERED OHMMETER OR A MULTI-range testmeter switched to an "ohms" range can be used to reveal quite a few useful things about semiconductor diodes and transistors. Indeed, it is often possible for a suitable ohmmeter to provide almost as much information as an inexpensive transistor tester about semiconductor junctions and whether a transistor is working or not.

Before commencing, however, a few words of caution about the type of meter to be used for these tests are needed, for it is not difficult to ruin a perfectly good diode or transistor by the use of an unsuitable meter or by thoughtless testing.

Ohmmeters are of various types, these including the instrument designed specifically to measure resistance over several ranges, the multirange meter and ohmmeter facilities, the "ohms" ranges

of a valve voltmeter, and the Megger type of tester which applies a high voltage to its resistance measuring circuit.*

To test a semiconductor junction, current must be passed through it from the ohmmeter. This current is usually supplied either by an internal battery (or batteries) or by a mains power unit in the case of a valve voltmeter switched to "ohms". The Megger type of tester may differ in that either a small hand- or motor-operated electromagnetic generator, or semiconductor generator, may be employed to provide the test current. The Megger type of tester should *not* be used for the tests described in this article.

Current flows through the test circuit and indicating movement because the e.m.f. of the ohmmeter power source is applied across the test terminals. A semiconductor junction under test is, therefore, subjected to the voltage of the instrument's power supply and the current available from the instrument, which is usually that required to provide full-scale deflection on the meter movement. An elementary ohmmeter circuit of this kind is shown in Fig. 1.

Important Points

This simple series type of ohmmeter is ideal for transistor tests, but in some instruments the circuit is modified over the various "ohms" ranges. A shunt resistance may be applied across the meter movement and the internal battery may be tapped up, or the mode of testing may differ from the series arrangement to the shunt arrangement, where the test circuit forms a shunt across the meter movement terminals. There are numerous arrangements, which cannot be dealt with here, but what we must discover before using the ohmmeter are (i) the voltage across the ohmmeter terminals on the range most suitable for semiconductor junction testing, (ii) the short-circuit current available at the instrument's terminals and (iii) the polarity of the voltage at the terminals.

This latter is important, for the positive or red test lead or terminal on a multirange testmeter is *not* always connected to the instrument's supply or battery positive when the instrument is switched to measure resistance.

* "Megger" is the trade name of Evershed and Vignoles, Ltd.

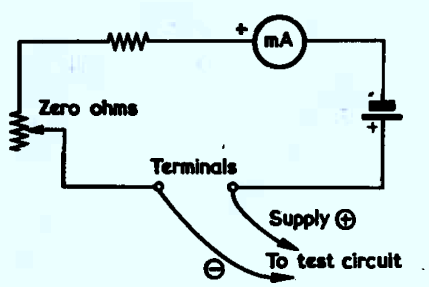

Fig. 1. Elementary "ohmmeter" circuit. Note that in the case of a multirange testmeter the red or positive terminal or socket may not always correspond with the positive of the internal battery

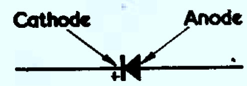

Fig. 2. The diode symbol

The voltage across the test terminals can usually be considered as being equal to the voltage of the internal battery. One could, of course, connect a voltmeter across the test terminals, but this would not read the true, open-circuit voltage. However, in the absence of a circuit of the instrument the voltmeter test is, in any case, necessary, in order to establish the polarity of the test leads. The short-circuit current can be determined by connecting a current meter across the ohmmeter test terminals.

Safe Power

Generally, an ohmmeter range that produces no more than 1.5 volts at 1mA can be considered to be perfectly safe to test any diode or transistor, no matter which way round the latter is connected to the instrument. Large power transistors are, of course, capable of handling powers far in excess of those corresponding to 1.5 volts at 1mA.

However, the emitter-base junction of even power transistors may not be able to stand the test power produced by instruments designed for "low ohms" measurements and by shunt type ohmmeters. So, ensure that both the voltage and current available at the ohmmeter terminals are low enough to be safe for testing semiconductor junctions. If in doubt, use no voltage higher than 1.5, and no current greater than 1mA.

Now let us see how the tests are made. From the d.c. aspect, a transistor can be considered as two semiconductor junctions, the emitter-base junction and the collector-base junction. A semiconductor diode features a very similar sort of junction, of course, but this works by itself, while the transistor effect is produced by the action of the two junctions with a common base.

We may start with the diode. The symbol for this is given in Fig. 2, the two electrodes being called "anode" and "cathode", to correspond with the electrodes of a valve diode. The cathode end of the semiconductor diode is usually coloured red or

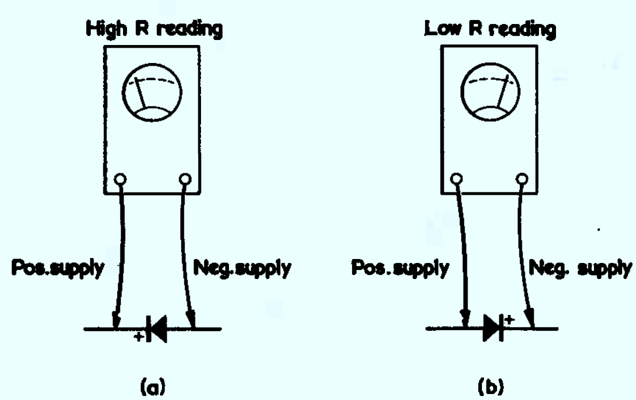

Fig. 3. Diode tests. Reverse resistance is checked at (a) *and forward resistance at* (*b*)

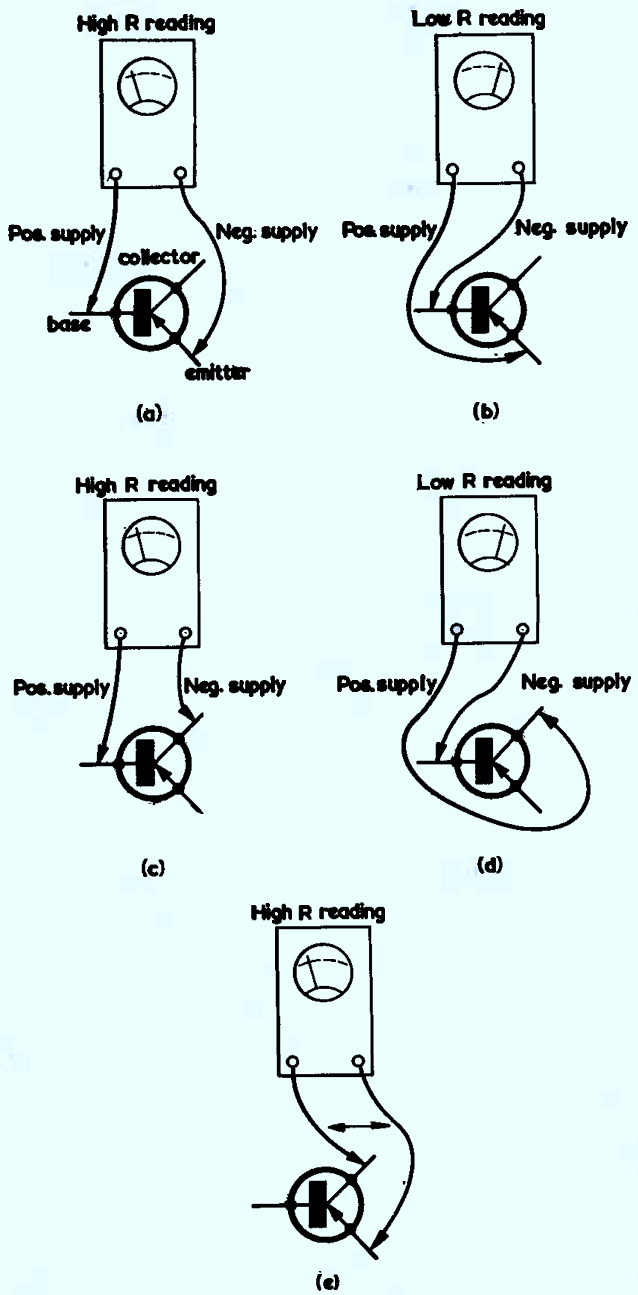

Fig. 4. Junction measurements with a p.n.p. transistor

marked with a plus sign while the anode end may be coloured black or marked minus.

The arrow on the symbol in Fig. 2 points in the direction of conventional current flow when the diode is biased for forward conduction. This means a current flow from positive to negative. Thus, forward current will flow through the diode when the anode is connected to positive and the cathode to negative. Under this condition, the diode offers very little resistance to the current. When the polarity is reversed, the diode becomes reverse-biased. Normally, only a very small current flows under this condition and the diode exhibits a very high resistance.

Diode Tests

The ohmmeter with an internal battery is ideal for performing forward and reverse conduction tests and translating the current flow into values of resistance, as shown in Fig. 3. At (a) the ohmmeter biases the diode for reverse conduction and a very high resistance reading is given, while at (b) the polarity is reversed and forward current flows as is revealed by the low resistance reading.

It should be noted that, in Fig. 3 and the subsequent diagrams, the meter leads are designated "Pos Supply" and "Neg Supply". These indicate the polarity of the voltage appearing at the test leads due to the instrument's internal battery or other supply source. As was mentioned above, this polarity may be determined by a voltmeter connected to the test leads, and it may not necessarily correspond to any polarity markings provided on the instrument itself.

Exactly what the reverse and forward resistances of the diode of Fig. 3 are likely to be cannot be told, as they will depend on the nature of the diode under test and on the supply voltage across it. The main aspect of the test, however, is not so much to determine the actual values of the resistance, but to establish the *ratio* of the reverse to the forward resistance. Most diodes tested on a meter producing 1.5 volts across its test leads give forward resistance readings in the range of hundreds of ohms (a slightly higher voltage may reduce this to tens of ohms). Reverse resistance values, on the other hand, are up in the megohm ranges for good diodes of all types. Ratios in excess of 5,000 : 1 are commonplace with ordinary diodes tested at normal temperatures.

The reverse conduction reading will drop considerably should the test diode be checked in a hot environment, such as near a soldering iron. Germanium diodes are more subject to temperature influence than their silicon counterparts, and power silicon diodes may give a lower forward resistance than small germanium devices.

Any diode with a "conduction ratio" greater than 1,000 : 1 can be taken as good. Usually, the ratio will be much greater than this. Diodes with smaller ratios may also probably be in order, but they should be treated with suspicion. A faulty diode will usually exhibit a very low or high resistance in both directions, giving unity or a very small ratio.

Transistor Tests

Now we come to transistors. These can be tested as two separate diodes, as shown in Fig. 4. The base of any transistor is common to both emitter and collector, and with p.n.p. types the emitter and collector can be considered as the anodes of the diodes, the base being the common cathode.

Thus, with the positive supply connected to the base and the negative supply to the emitter the reverse resistance of the emitter-base junction can be tested (a). The forward resistance of the same junction is obtained by reversing the test leads (b). Likewise, the reverse and forward resistances of the collector-base junction can be found, as shown in (c) and (d).

Whether or not the junctions are intact and

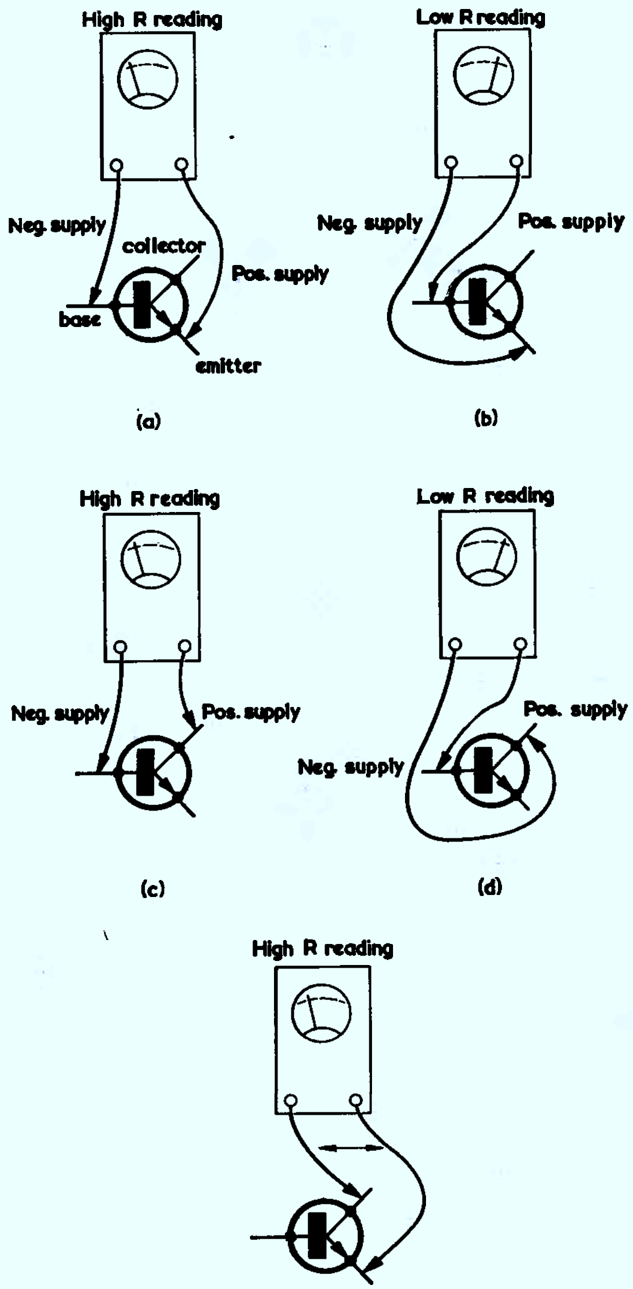

Fig. 5. Junction measurements with an n.p.n. transistor

working correctly is again determined by the *ratio* of reverse to forward conduction resistances. Some transistor junctions will exhibit extremely high ratios, while others will have relatively lower ratios, sometimes below those associated with semiconductor diodes.

Power transistors generally have the lowest forward resistance and silicon transistors the highest reverse resistances. With many transistors the "conduction ratio" is approximately the same at both junctions, but in a few instances the forward resistance of the emitter-base junction is less than that of the collector-base junction.

Ratios for germanium transistor junctions range upwards from about 1,000 : 1, and they are even higher with silicon types. Sometimes it is virtually impossible to get a useful reverse reading from a silicon transistor on a "safe" ohmmeter range. Nevertheless, there is never any doubt as to whether a junction is working or not from the tests described.

With n.p.n. transistors, the supply polarity has to be reversed to secure the readings in Fig. 4, as shown in Fig. 5.

Test (e) in both Figs. 4 and 5 will show a high resistance whichever way round the meter is connected. This is because the two junctions between emitter and collector are effectively connected in opposition, so that one exhibits reverse resistance when the meter is connected one way, and the other exhibits reverse resistance when the meter leads are changed round.

Leakage Currents

When the supply negative test lead is connected to the collector and the positive test lead to the emitter of a p.n.p. transistor (or the positive to collector and negative to emitter in the case of an n.p.n.

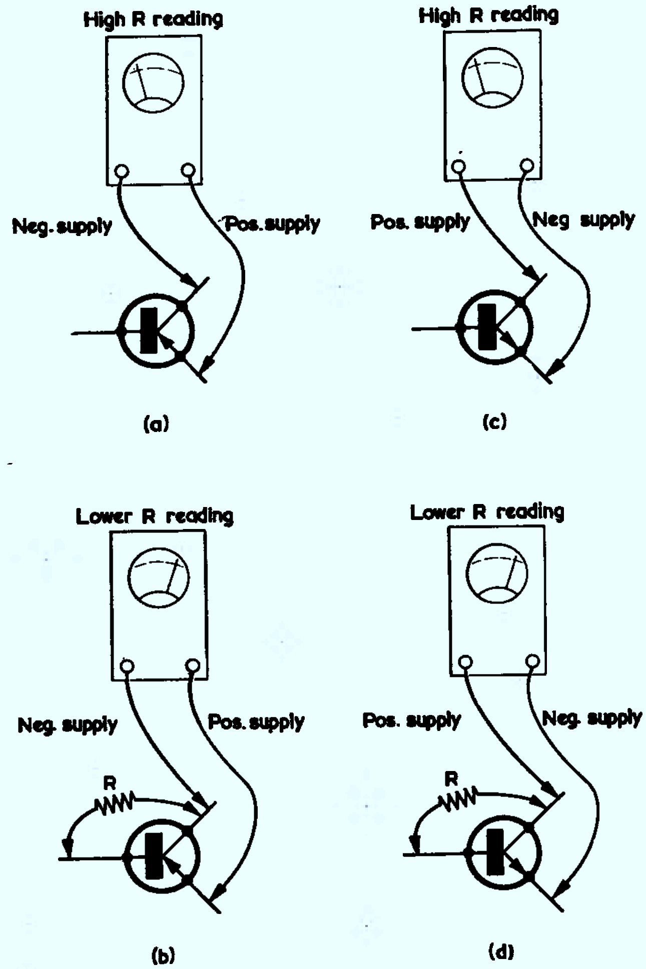

Fig. 6. Showing how the "transistor effect" can be checked for (a) a p.n.p. transistor, and (b) an n.p.n. transistor

transistor), the meter reads collector leakage current with the base open-circuit (i.e., I_{ceo} or I'_{co}). This reading is very much influenced by the temperature of the transistors, and even the heat from a finger holding a transistor while it is being tested can cause it to fall (the resistance measured being reduced). This applies especially to germanium types.

This test is best made, therefore, with the transistor suspended by its lead-out wires and away from any heat source. It is possible to match transistors on this reading and, generally speaking, the lower the resistance, the higher the d.c. h_{fe} (current gain).

Emitter leakage current checks with the collector open-circuit (i.e., I_{eo} or I_{ebo}) and collector leakage current checks with the emitter open-circuit (i.e., I_{co} or I_{cbo}) are given by tests (*a*) and (*c*) respectively in Figs. 4 and 5.

A fair idea of whether or not the two junctions of a transistor are working together to give the "transistor effect" can be gleaned by initially connecting the ohmmeter across the collector and emitter leads with supply negative to the collector in the case of an p.n.p. transistor and supply positive to the collector in the case of an n.p.n. transistor. These connections are shown in Fig. 6 (*a*) and (*c*). Under this condition, as we have already seen, a good transistor will exhibit a high resistance (provided its temperature is at normal ambient level).

We can next use a resistor, R, of about 4.7kΩ to introduce a little forward current in the emitter-base junction, and thus produce the transistor effect. The connection of R is shown at (*h*) and (*d*) in Fig. 6. A transistor which is "good" will give a somewhat lower resistance reading when the resistor R is connected. The ratio between the previous high resistance reading and the lower resistance reading with the resistor connected offers a measure of the h_{fe} of the transistor. This test, in conjunction with the I_{ceo} test described earlier, provides a remarkably good indication of the condition of any transistor, and quite accurate assessments are feasible when one gets used to how a particular testmeter or ohmmeter behaves when connected to semiconductor junctions.