FAULT FINDING PART 1

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A vital new series on the rudiments of faults diagnosis

PROBABLY every experimenter or constructor has experienced the frustration of finding that the circuit he has just built fails to work correctly at switch on, or after a short time in use. Assuming that the circuit has been designed and built correctly, the failure is generally caused by some component fault.

For the newcomer to electronics this can be very discouraging and the causes of failures can seem baffling. However, there are some basic rules to follow in diagnosing faults, and one learns more about electronics in the process.

The skill of rapid fault diagnosis is also very important in Test and Service Departments of the electronic industry, and anyone wishing to enter the profession usually has to complete a suitable course of study at a technical college. For example, the City and Guilds 272 and 222, or one of the new T.E.C. courses. In the final year an examination in fault diagnosis has to be passed.

BASIC REQUIREMENTS

What then are the basic requirements for fault diagnosis? A short list would include the following:

(a) An understanding of the way in which components work and how they fail.

(b) A good understanding of how the circuit or instrument operates.

(c) Skill in recognising fault symptoms.

(d) A systematic common sense approach to the problem.

When, for example, a faulty instrument is returned to a service department the engineer's first job is to define the fault. To do this he has to check the functional performance of the instrument and then list the symptoms associated with the fault. For a complex instrument he then has to narrow down the search for the faulty component by dividing the unit into functional blocks: power supply, oscillator, amplifier, etc. The various methods used for this are dealt with next month.

Let's first of all consider how to diagnose faults in a single electronic circuit such as the simple oscillator shown in Fig. 1.1. Like most oscillators it is made up of an amplifier, a tuned circuit, and a positive feedback loop. R1 and R2 provide forward bias for the transistor amplifier, L1, C1 and C2 determine the operating frequency and a portion of the output is fed back to the emitter in order to maintain the oscillations. All the components are vital for correct operation and should any one of them fail the circuit would stop producing oscillations.

HOW AND WHY DO COMPONENTS FAIL?

Just like everything else an electronic component has a finite operating life. Stresses are acting continuously on all components. These stresses are of two kinds, operating and environmental. The operating conditions of current, voltage, and power are determined by the design and naturally the life can be extended by operating the component well within its maximum rating. Environmental stresses are those caused by the surrounding conditions.

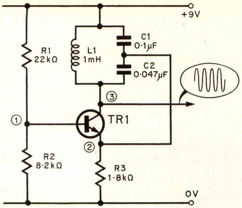

Fig. 1.1. Sinewave oscillator

High humidity, extremes of temperature and mechanical shock and vibration being three that will, if excessive, rapidly reduce the life of a component.

Take for example a resistor. It is subjected to continuous cycles of heating and cooling; this causes it to expand and contract and very slowly its chemical properties change. It becomes brittle and one day it will suddenly fail open circuit. Of course, not all failures are sudden and complete; a component may gradually drift out of specification causing a gradual loss of circuit performance.

Another common cause of component failure is where high voltage pulses or "spikes", generated from switched reactive loads, are transmitted along the mains lines and appear on internal power supply leads. These "spikes" can easily lead to the breakdown of semiconductors.

Table 1 shows the most likely type of failure for different types of components which would appear as follows:

Table 1

Component	Common type of fault
Resistors	high in value or open circuit
Variable resistors (pots)	open circuit or intermittent contact resulting from mechanical wear
Capacitors	short or open circuit
Wound components (inductors and transformers)	open circuit or shorted turns or short circuit coil to frame
Semiconductor devices, diodes, transistors, thyristors, etc.	open or short circuit at any junction

DIAGNOSING FAULTS IN THE CIRCUIT

One component failure usually gives a unique set of symptoms. These being changes in the output signals and changes in d.c. bias levels. Returning to the oscillator, let us imagine that L1 becomes open circuit. A possible fault since the coil is made of relatively thin wire. The signal output would be zero and the d.c. bias voltages, measured with a standard (20kΩ/volt) multimeter at the three test points with respect to zero volts will be:

Test Point	1	2	3
Voltage	1·2V	0·6V	0·7

(meter readings with L1 open circuit)

Whereas the expected readings should be:

Test Point	1	2	3
Voltage	2·4V	1·8V	+9V

(normal readings)

How can we use the first set of voltages to guide us to the faulty component? When L1 is open circuit an equivalent circuit of the fault conditions is as shown in Fig. 1.2. There is no d.c. path for collector current, so the base emitter junction acts as a forward biased diode passing base current only. The voltage at TP2 will be low because current through R3 has fallen. Given the values and the equivalent circuit for the fault you can readily calculate that the voltage on the emitter will be approximately 0·7V and the voltage on TP1 will be about 0·6V above that at 1·25V.

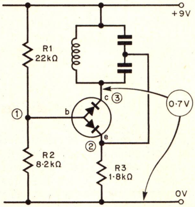

Fig. 1.2. Fault conditions for L1 open circuit

Most readers might assume that TP3 would read zero volts but when a meter is connected from the collector to the 0V rail, the base collector junction acts as a forward biased diode and so a small voltage is indicated.

When you have a set of symptoms for a particular fault try and fit the effects of the component you suspect with these results. Take for example a fault with the following symptoms:

TP	1	2	3
Voltage	0·7V	0·7V	9V

(Fault readings)

Note that the voltage on TP1 is the same as that of TP2 and this indicates a possible short circuit between those points. This would mean a short circuit between the base and emitter of the transistor. If this happens all transistor action ceases, since no emitter current is going to flow across the base into the collector, and the collector voltage should rise. This then is the correct fault, since it fits the symptoms.

Now try your hand at diagnosing the following oscillator fault conditions. The answers are given at the end of the article (Answer (1)). The symptom is no oscillations.

TP	1	2	3
Fault A	0V	0V	+9V
Fault B	2·5V	0V	+9V
Fault C	1·2V	0·6V	+9V
Fault D	2·5V	2V	+9V

FAULTS IN A MORE DIFFICULT CIRCUIT

Many circuits contain d.c. negative feedback loops which tend to complicate diagnosis since a change in bias level at one point usually effects all voltages. A simple series regulator is a good example of this. The circuit shown in Fig. 1.3 is designed to give a relative stable output of 10 volts at 200mA from an unstabilised 15 volt supply. A larger output current can be obtained by mounting TR1 on a heat sink. Remember, if you build the circuit for fault diagnosis, the circuit is not short circuit proof.

Most readers will have a good understanding of the operation but it's worth going over it briefly. TR1, the so called series control transistor, acts like an emitter follower so that an output voltage is provided across the potential divider R3, VR1 and R4.

A portion of the output voltage selected by VR1 appears on the base of TR2, the error amplifier, and this voltage is compared with the reference voltage from the Zener diode. Since the Zener has a fairly constant voltage across it any change in output voltage causes more or less current to flow through TR2. The output of TR2 is used to control the base of the series element TR1. Thus, if the output voltage falls, caused by an increase in load, TR2 conducts less, its collector voltage rises and TR1 is turned on more to correct the original fall in output.

When the circuit is working correctly and supply a 200mA load current the voltages at the test points are:

Test Point	1	2	3	4
Voltage	10·7V	6·05V	5·2V	19V

normal readings

Let us start by imagining a fault caused by an open circuit Zener diode. We should expect an unstabilised output with higher ripple, and this in fact would happen. Since the emitter voltage of TR2 rises towards the unstabilised input (+15V) the output must also rise because TR2 is cut off. However, the output voltage will not rise much above +12V because the load current requires that TR1 be supplied with base current resulting in a volt drop across R2. If the load is disconnected the output voltage will increase.

The fault conditions are:

Test Point	1	2	3	4
Voltage	13V	12·3V	15·2V	12·3V

D1 open circuit.

Naturally other faults will cause the output voltage to rise and for stabilisation to be lost. For example R3, VR1 or TR2 base emitter open circuit would do this. The particular symptom that points to D1 open circuit is of course

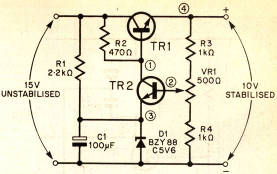

Fig. 1.3. Representative series regulator

that TP3 has risen to +15·3V. What then would be the symptons for R3 open circuit? (See Answer (2) at end of article.)

Electrolytic capacitor C1 is included to reduce the amount of ripple on the reference voltage. Consider the effect of this becoming short circuit. The emitter of TR2 becomes zero volts, and this causes TR2 to conduct hard. TP2 falls to about 0·7V setting up a voltage of about 1·3V at the output (TP4). This means that TP3 must be at about 2V, that is 0·7V greater than TP4. The output voltage must be about twice V_{be} of TR2 because of the potential divider R3, VR1 and R4.

Voltages for C1 short circuit:

Test Point	1	2	3	4
Voltage	2V	0·7V	0V	1·3V

Finally, try and diagnose faults from these symptoms. Voltages measured with 200mA load. (Answer below)

Test Point	1	2	3	4
Fault A	0V	0V	5·2V	0V
Fault B	14·8V	0V	5·2V	0V
Fault C	7V	5·9V	5·3V	6·2V
Fault D	1·5V	0·67V	5·2V	1·5V
Fault E	13V	7V	5·2V	12·3V

ANSWERS

(1) **Fault A** R1 open circuit.
Fault B Base-emitter open circuit.
Fault C Collector open circuit.
Fault D R3 open circuit.

(2)

TP	1	2	3	4
Voltage	13V	12·3V	5·2V	0V

(3) **Fault A** R2 open circuit.
Fault B Base/emitter open circuit.
Fault C R4 open circuit.
Fault D TR1 b/e short circuit.
Fault E TR2 b/e open circuit.

Next Month: Fault finding on systems