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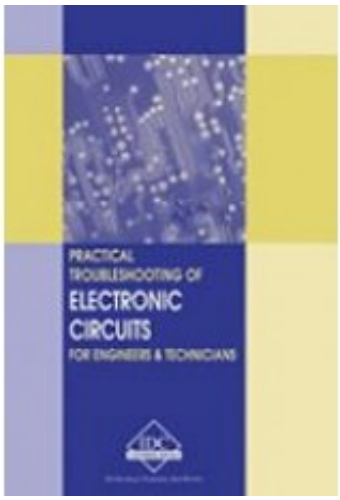
EI-E - Practical Troubleshooting of Electronic Circuits for Engineers and Technicians



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Short Description

This manual will give you a solid understanding in common electronic terminology and symbols, as well as the construction and operation of common electronic components. The general troubleshooting process is explained followed by a brief study of various hand tools and electronic test and measuring instruments. You will learn to implement procedures for the testing of electronic components as well as skills for carrying out simple repair procedures for the correction of faults on printed circuit boards with confidence.

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1 Introduction to Troubleshooting

Electronic equipment can develop a wide variety of problems. The act of troubleshooting arises in order to make the problems disappear so that the equipment works as per the expectation. This introductory chapter provides an overview of troubleshooting processes and various troubleshooting techniques. It also emphasizes how to prepare and read a circuit diagram, as a first step for troubleshooting.

Learning objectives

- Understand how to prepare a circuit diagram
- Study of electronic equipment in brief
- Study the basic concepts of troubleshooting
- Understand the process of troubleshooting
- Study the techniques used in troubleshooting
- Understand how to start troubleshooting
- Know preliminary precautions

1. Troubleshooting Basics

In general, for any application, equipment is designed and manufactured to work trouble free within its specified limits during its useful time. However, sometimes there is a conflict between the expectations of the user and the performance of the instrument. Thus develops the need for troubleshooting and maintenance.

What is Troubleshooting?

Troubleshooting is the process of isolating and correcting a problem in malfunctioning equipment so that it returns to its expected performance level. The process of troubleshooting requires a systematic fault finding approach. Whenever a fault occurs, two things can happen:

- The equipment does not work at all
- The equipment works abnormally

The second type of fault can be further sub-divided into:

- Constant error or malfunctioning (exceeding absolute maximum rating)
- Intermittent errors (external noise pick-up, heat, shock, increase in humidity, etc.)

The basics which can be applied to troubleshooting are given below:

- Look for obvious possibilities. If there are no obvious faults, measure the power supply voltage. If it is not the correct value, don’t go any further until you find out why.
- Use symptoms whenever possible to zero in on the section at fault. If the symptoms do not get you to the trouble region, use a signal tracing or signal injection method. These methods are discussed in an upcoming chapter.
- Once you have zeroed in the on the troubled circuits, locate the defective component. Tough problems like closed loops, distortion, noise and intermittent, require special troubleshooting techniques.
- Make efficient use of the troubleshooting and test equipments. Specialized equipment that you build yourself can also be very useful.
- Digital and microprocessor circuits require special equipment and a few special techniques.
- When looking for faulty components, troubleshooting should involve the following steps:
    - Make a measurement
    - Compare the measured value with what you are supposed to get
    - If the measured values do not match what you are supposed to get, find out why
- When you have located the defective component, replace the component

professionally. For surface mount components, some newer techniques are required.

- You should be well informed with the operation of testing and troubleshooting equipment. The selection of test equipment depends on the amount of service and the type of service. Some of the popular test equipment are:

    - Analog VOM
    - Digital VOM
    - Oscilloscope
    - Logic Probe
    - Logic Pulser
    - Sine-wave generator
    - Regulated DC power supplies
    - Transistor testers

- Finally make sure that your work indicates high quality professional servicing. Experienced technicians often use a type of statistical approach for troubleshooting. For example, if there is some distortion in sound in a speaker, there can be several possible faults for the symptom. From experience the technician knows that a battery will fail more often than a transistor. So the battery would be checked and replaced first.
- It is usually easier to replace a battery than a transistor; ease of replacement is also a factor.

The following table shows a list of component failure in their order of probable occurrence:

Table 1.1

Order of occurrence of component failure

Order of occurrence of failure	Component
1	Mechanical and electromechanical devices such as relays, switches, plugs and sockets.
2	Components that get hot in their normal operation, like power amplifiers and rectifiers.
3	Electrolytic capacitors of small versions and those subjected to high voltage.
4	Active devices like transistors and SCRs.
5	Passive devices like resistors and capacitors.

- As said earlier it is best to measure the power supply voltage first, when beginning troubleshooting. If the power supply voltage is not the correct value, nothing will work well in the circuit.
- A low power supply can cause failure to the circuit, which is not located anywhere near the supply. It is best to measure the power supply voltage while it is delivering current to the system. In battery operated equipment, the system should be energized when the battery voltage is being measured.
- An incorrect power supply voltage can damage a digital system. If a wrong power supply voltage is measured in a digital circuit, shut it down immediately. Then use your bench supply to energize the circuit and look for possible damage caused by the incorrect voltage.
- While measuring the power supply voltage with an analog meter, if you are not sure what value of voltage (or current) you are going to be measuring, then you have to start with the highest scale and work down.

The Troubleshooting Process

The process of troubleshooting comprises the following steps:

- Fault Establishment
- Fault Location
- Fault Correction

Let's address these steps in brief:

Fault Establishment

It is important to establish the presence of a fault in equipment before taking any other action. In some cases a system may be reported faulty, but it could be a case of faulty operation or a system failure may be reported with either very little or misleading information. It is essential that a functional test, checking the system's actual performance against its specification must be made and all fault systems must be noted.

It is also important to check the history of the equipment and repair and servicing work carried out earlier by any other person.

Fault Location

This involves pin-pointing the cause of the fault by studying the literature relevant to servicing, maintenance and repairs. The fault is located first in subsystem and then in a single component in the sub system.

Fault Correction

Fault correction consists in replacing or repairing the faulty component. This is followed by a thorough functional check on the whole system.

Figure 1.1 *Troubleshooting Procedure*

Troubleshooting Aids

Troubleshooting aids help in quickly analyzing a malfunction and taking corrective action. The following points are discussed in this aspect:

Tools

A basic set of tools and test equipment like multimeter and oscilloscopes are necessary. Sometimes specialized equipment are required, such as a high speed scope. The maintenance technician is required to have all this knowledge.

Documents

A complete set of documentation is a must. Most manufacturers supply the following documents with their manuals:

- Schematic document
- Circuit board illustration
- Circuit board location
- Power distribution diagram
- Circuit board interconnection diagram
- Fault tracing flowchart
- Diagnostic software
- List of replaceable parts
- List of special tools for servicing

Data Manuals

A good list of data manuals is essential. There are data books from all major component manufacturers which can be collected.

Thumb Rule in Troubleshooting:

- If the equipment is totally dead, then the problems are generally related to the malfunctioning of the power supply.
- If the equipment starts malfunctioning when it warms up, it can be due to the dryness of electrolytic capacitors. In this case they should be tested.
- The problems which come and go suddenly, intermittent problems are often due to bad connections. The reason for this can be a cold solder joint of internal or external connectors that need to be cleaned.
- Failures because of burnt, melting of the leads of components, cracking of the components and so on are identified by visual inspection and burnt smell.

1. Common Troubleshooting Techniques

The various troubleshooting techniques given below are used in the majority of electronic systems. The type of system being handled will decide which technique should be adopted.

Functional Area Approach

An electronic system comprises several functional parts such as power supplies, amplifier, signal converters, etc. When the system fails to give the expected performance, the problem could be in any of these functional areas. Therefore, it is essential to troubleshoot the system in order to isolate the fault to the failing functional area and then to the failing component. The logical approach of isolating a fault is through a process of elimination of the functional areas that are performing properly. Once a failure is isolated, further analysis of the circuitry within this area is carried out to isolate the malfunction to the faulty component. This functional area approach is also called the Block- Diagram approach to troubleshooting.

Split Half Method

In this technique, as the name suggests, the circuit is split in half and the output is checked at the half-way point in case of an absence of an output. This helps to isolate the failing circuit in the first or second part. When the faulty half is

determined, the ageing circuit is split into half for further isolation of failure. This splitting is continued until the failure is isolated to one function or component.

The Half- split method is extremely useful when the system is made up of a large number of blocks in the series:

Figure 1.2

Split Half Method

Many electronic systems do not involve only series connected blocks. They may have feedback loops or parallel branches in a part of the circuit. Hence use of this method is rather restricted.

Figure 1.3

Divergent Path

Here the output from one block is fed to two or more blocks. In such systems, it is best to start by checking the common feed point. Alternatively if output is normal (at A or B in fig. 1.3), check after the divergence point. Conversely, if one output is abnormal, check before the common point. The most common example is that of the power supply circuit which supplies dc power to various subsystems in equipment.

Convergent Path

In a convergent path two or more input lines feed a circuit block:

Figure 1.4

Convergent Path

In order to check such a scheme, all inputs at or before the point of convergence must be checked one by one. If any of the inputs is incorrect (at C or D in fig. 1.4), then the fault lies in that particular input circuit. If all are found to be correct, the fault lies beyond the convergent point. For example, if C and D are correct and there is no output at E, the fault lies in unit 3. But if input at C is faulty, the fault lies in block 1 or before that.

Feedback Path

The feedback loop usually corrects the output of some block with the input of an earlier block via some network called feedback network. Since the circuit behaves as a closed loop, any fault within the loop will appear as if all the output blocks within the system are at fault:

Figure 1.5

Feedback Path`

Before starting the troubleshooting of a system having feedback loop, the type of the feedback and its use should be well understood. Feedback paths are basically provided for the following functions:

- To modify circuit function ---- Feedback loop is provided to modify the characteristics of the system. For example, automatic gains control system in a radio receiver.
- To sustain circuit function ---- Feedback is totally essential for an output to exist. For example, an Oscillator circuit.

Having identified the type of feedback circuit, one can proceed as follows regarding locating the fault.

For the first type, i.e. modifying feedback, it may be possible to break the feedback loop and convert the system to a straight linear data flow. Each block can then be tested separately without the fault signal to be fed around the loop. In some cases instead of completely breaking the loop, the feedback can be modified at or near the point where it rejoins the main forward path. If the output appears normal, check the feedback path, otherwise, check the forward path.

For the second type, i.e. sustaining type, feedback is disconnected from the output and a suitable test signal is injected to check the performance of various circuit blocks.

Figure 1.6

Fault Location in Switching Path (rsk40)

If a system has switch-able parts and if the circuit function is found faulty in one position of the switch then throw the switch to another position. If the problem persists, check the switch in common circuitry. If the problem disappears with this action, check that the circuitry switched out.

1.3 Gaining Circuit Familiarity

A circuit diagram is a graphical representation of the interconnections of various components constituting the equipment. It is the most important document for the maintenance technician. Usually every assembly in electronic equipment is assigned an assembly number which appears on the circuit board and on the diagram. Commonly used symbols in electronic circuits are shown below in

Figure 1.7.

The maintenance technician should be well versed with the circuit of the system before actually starting troubleshooting. A circuit diagram is the most important document for the technician. Many-a-time the circuit diagram of the system or equipment is not ready or not provided by the manufacturer. In that case, the technician has to prepare the circuit diagram. The circuit diagram makes the fault finding process easy.

Preparing a Circuit Diagram

The technician should be experienced enough to draw a circuit diagram. Usually, it is not recommended for larger systems. A larger system is broken into parts (subsystems) and then circuit diagrams for the smaller, suspected systems is drawn to trace the fault. The following points must be noted when preparing a circuit diagram:

- After identifying what is the type of fault, the very first thing to be done is to understand the functionality of the system. Split the system into a few functional blocks, which will make a functional working diagram.
- The components and their types are identified. The specifications of the components are notes taken from the manual or data book given with the equipment.
- Make a note of the interconnections of various subassemblies like power supply, PCB assembly, front panel, etc.
- The printed circuit board is removed. Usually individual boards can be removed in industrial systems as they are of modular construction for easy maintenance.
- First locate the components on the paper. Understand the PCB pattern. Place the PCB in front of strong light so that the PCB interconnections are clearly visible. If you look at the back of the PCB, then what you see is the mirror image of the connections as seen from the front. Now, make a sketch of the components and PCB pattern.
- Clearly differentiate between input and output. Start with the supply rail, not the common. Now draw the components connected to the supply lead. The ground or common lead will be easy to identify.
- Use your knowledge of the functional aspects of the equipment to draw out the stages. Power transistors will be either with the power supply

circuit or in the output stage. If one stage gets a bit complicated try starting from another stage like input or output stages following the signal path.

- Now redraw the circuit in the conventional manner. After the initial attempt, the technician will be able to identify the nature of the circuit.
- Check if all the components on the card are in the sketch and check the polarities of the components.
- Always draw the sketch with pencil for easy correction.

Reading a Circuit Diagram

A circuit diagram is a graphical representation of interconnections of various components constituting the equipment. It is the most important document for the maintenance technician. Usually every assembly in electronic equipment is assigned an assembly number which appears on the circuit board and on the diagram. Commonly used symbols in electronic circuits are shown below:

Table 1.2

Various Symbols in electronic circuits

Circuit symbols to DIN EN, NEMA ICS/ANSI/IEEE/CSA

(The following comparison of circuit symbols is based upon the following international/national specifications:

-IEC 60617 graphic symbol database (DIN EN 60617-2 to DIN EN 60617-12

-NEMA ICS 19-2002, ANSI Y32.2/IEEE 315/315 A, CSA Z99)

A circuit diagram illustrating some symbols is also shown below:

Figure 1.7

Electronic Circuit Diagram

The Making of an Electronic Circuit

An electronic circuit makes use of both active and passive components. These components are physically interconnected with each other to form any electronic circuit. There are three major techniques to interconnect the components. Let us have a brief overlook of these methods:

- Solder
- Wire-wrap
- Printed Circuit Board

Solder

This method makes use of a solder and a wire to interconnect electronic components. It is a very slow method and is very cumbersome if a large number of devices are to be connected.

Wire-wrap

This technique tightly winds a small gauge wire around a wire-wrap metal post or

terminal. There are special wire-wrap metal post sockets for the ICs that have longer posts for wire-wrapping the wire. Also, special tools are needed for wrapping and un-wrapping the wire.

Printed Circuit Board (PCB)

This technique includes interconnections between points printed in metal on the non-conductive board. The circuit is printed on the board by a series of photographic and chemical procedures. Most of the equipment in practice make use of PCB. They are generally made for completely checked out and working boards, as it is difficult to make wiring changes on the PCB.

A Quick Glance at Electronic Equipment

There can be one or more circuit boards inside of electronic equipment. They are mounted inside a wooden or metallic cabinet with some arrangement of interconnecting the circuit boards. This arrangement is called Edge Connectors.

The purpose of edge connectors is to bring signals and powers to and from the circuit boards without having to connect a wire to the circuit board itself. This arrangement provides easy installation and removal of the circuit board in equipment:

Figure 1.8

Electronic Equipment

Also inside of electronic equipment there is an assembly called card rack for the compact placement of the PCBs. But it is difficult to put a test probe on the circuit board for making any type of measurement or for troubleshooting. To eliminate this problem, special circuit boards called 'extender cards' are inserted into the card rack and the circuit board is extended into the extender card.

An extender card is just a wiring extension to make the circuit board accessible for testing.

Classification of System

In the literature, terms such as component, equipment or system have been used. The following table distinguishes between these terms:

Table 1.3

Classification of System

Serial Number	Nomenclature	Description	Example
1	System	Collection of equipment arranged to perform a function.	Television, Missile.
2	Equipment	Collection of components arranged to operate without the need for other components.	Radio Transmitter, the central part of a missile.
3	Assembly	Collection of components in a prescribed order not all of which have, as yet, been so arranged.	Terminal board with components parts attached.

4	Component	Collection of elements arranged in a prescribed order.	Resistor.
5	Element	A simple object which can not be further sub-divided.	Filament, a relay contact.

1.4 Getting Prepared for Troubleshooting

Where do you start?

A close visual inspection is a good and quick start for troubleshooting. It gives a clue for problems such as burned spots and places where high voltage arc has occurred. A quick look to the circuit also gives an idea of the condition of fuses and circuit breakers.

The troubleshooting technician should collect the history of the system. He/she should know whether the problem had occurred before and what is the frequency of the occurrence of the problem.

On the basis of the knowledge of how the system works, the kind of failure can be detected. This would lead you to select the troubleshooting technique.

If the system is not producing the desired end result, look for what is doing it correctly. You can locate where the problem is not present so that you can then

focus on another location for troubleshooting.

If the system has been having problems immediately after some kind of maintenance or other change, the problems could be linked to those changes.

After all, the choice of techniques and strategies for troubleshooting totally depends upon the technician. The following points would be helpful for effective troubleshooting:

- Familiarity with the equipment
- Analyzing possible causes of trouble
- Developing a general troubleshooting procedure

Preliminary Precautions

- Identify the mains power supply voltage and the maximum voltage that can be applied from the power source. The mains power supply voltage can be either 110 V, 60 Hz or 220 V, 50 Hz. Make sure that a protective ground connection by way of the grounding conductor is or is not provided.
- In order to avoid shock, the power cord must be plugged into a properly wired receptacle before connecting to the equipment's input or output terminal.
- The service manual which is provided along with the equipment should be studied thoroughly before starting troubleshooting. The caution statements, warning statements and other information should be read carefully.
- Always disconnect the power to the equipment before removing the cabinet panels and before cleaning or replacing parts to avoid electric shock hazard.

- The circuit boards should be handled by edges to avoid inaccurate performance because of static charges, dirt, dust etc. Check the conditions of all external cables for splits, cracks, twists and so on

1. Summary

For the process of troubleshooting, preparing the circuit diagram is the initial and basic process performed by the maintenance technician.

The components can be physically interconnected to each other using solder, wire-wrap and printed circuit board methods.

Any electronic system consists of an element, component, assembly and equipment. All these parts together make a complete electronic system.

The troubleshooting process consists of fault establishment, fault location and fault correction.

Functional area approach, Split half method, Divergent path, Convergent path, Feedback path, Switching path are the common troubleshooting techniques. Which technique has to be applied totally depends on the type of system.

To start the process of troubleshooting, first the technician should have a close visual inspection of the system. He should understand the basic functionality of the system. Then he can proceed to analyze the cause of the trouble.