MICROPROCESSOR SYSTEM SERVICING

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Prentice/Hall International

Englewood Cliffs, NJ   London   Mexico   New Delhi
Rio de Janeiro   Singapore   Sydney   Tokyo   Toronto

Library of Congress Cataloging-in-Publication Data

Ferguson, J. D. (John D.)
Microprocessor system servicing.

Includes index.
1. Microcomputers—Maintenance and repair.
2. Microcomputers—Maintenance and repair.
I. Macari, L. II. Williams, Peter, 1937–
III. Title.
TK7887.F47 1986 621.391'6'0288 86–21246
ISBN 0–13–581132–5 (pbk.)

British Library Cataloguing in Publication Data

Ferguson, John D.
Microprocessor system servicing.
1. Microprocessors —— Maintenance and repair
I. Title II. Macari, L. III. Williams, P. (Peter), *1937–*
621.391'6 TK7895.M5

ISBN 0–13–581132–5

Prentice-Hall Inc., Englewood Cliffs, *New Jersey*
Prentice-Hall International (UK) Ltd, *London*
Prentice-Hall of Australia Pty Ltd, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana S.A., *Mexico*
Prentice-Hall of India Private Ltd, *New Delhi*
Prentice-Hall of Japan Inc., *Tokyo*
Prentice-Hall of Southeast Asia Pte Ltd, *Singapore*
Editora Prentice-Hall do Brasil Ltda, *Rio de Janeiro*

Printed and bound in Great Britain for
Prentice-Hall International (UK) Ltd,
66 Wood Lane End, Hemel Hempstead, Hertfordshire, HP2 4RG
by A. Wheaton & Co. Ltd, Exeter.

1 2 3 4 5 90 89 88 87 86

ISBN 0-13-581132-5

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To Lyn, to Anita and to Susanne

Preface

Servicing a microprocessor system requires a different base of knowledge from that for conventional electronics servicing. It does not demand a different attitude. The same questioning attitude, the same logical process of elimination holds good. Designers and technicians alike can have confidence that the good habits they have acquired, whether in analog or digital circuits, or in an earlier electromechanical era, will transfer to the microprocessor and its systems.

It would be foolish to deny the problems implicit in this new technology, but with the right attitude they can be kept in perspective. In this book we start from the assumption that the reader has a general knowledge of electronics, including digital techniques, with a logical approach to problems. We do not assume a detailed knowledge of microprocessors but a good appreciation of their principles will be helpful.

It is the purpose of Part I to bring these themes together so that readers with differing backgrounds can appreciate the new techniques presented in the body of the book. The aim is not to teach digital electronics nor to provide yet another 'Micros for Beginners'. Rather, it is to review these topics from a servicing standpoint in order to place the known facts in a new framework. For the practicing electronics engineer much in this first section will be familiar, though the viewpoint may be less so. Readers with a programming background may find these hardware ideas strange at first but without them the route to microprocessor servicing is blocked.

Part II looks at the techniques available for tackling the servicing problem. At each stage from development through production to user maintenance there will be common difficulties to which these techniques can be applied. The kind of information generated by any one method will vary in how helpful it will be to the individual. A designer needs to know why a system is not behaving as expected, while a serviceman working to tight time and cost budgets will give priority to the method that pinpoints a quick cure.

The ideal would be for each user to have a full range of professional equipment. Part III looks at simple designs that can be constructed to cover straightforward tasks and to offer cost-effective training tools. Because each user will have different priorities, the designs are presented in outline form suitable for adaptation by experienced electronics engineers and technicians.

Chapter 1 reviews the characteristics of digital devices and the appropriate fault-finding techniques. Microprocessor systems are considered in Chapter 2, emphasizing those aspects that help the understanding of servicing ideas. In Chapter 3 the characteristics of the interface between microprocessor systems and peripherals is considered from the same standpoint. An introduction to fault finding in Chapter 4 looks at those general points that can be checked without special equipment. Self-testing, discussed in Chapter 5, assumes that the system functions sufficiently to allow it to generate test patterns to probe suspect sections. A logic analyzer (Chapter 6) monitors the sequential bit patterns on the system bus lines to reveal both straightforward component faults and the more subtle effects of timing errors. Once data transmission takes place there are additional sources of faults, and Chapter 7 introduces the characteristics and appropriate testing procedures for serial interfaces. In-circuit emulation is a technique available on development systems as a design tool but Chapter 8 looks at its role in fault finding. Chapter 9 covers signature analysis in which a system is first documented running a pre-defined routine: the bit-pattern at any point results in a unique code, any departure from which siginifies a fault. Automatic test procedures for production lines can have application in fault finding but, as Chapter 10 shows, the actual equipment may bear little resemblance. Part III provides ideas for test equipment based on microcomputers and user-designed test boards. Chapter 11 illustrates this approach with a simple in-circuit emulator based on a standard microcomputer. Signature and logic analyzers can be implemented as low-cost single board devices for training purposes (Chapter 12). The serial interfaces between computers and their peripherals can be tested by using the serial analyzer and character generator of Chapter 13.

J.D.F., L.M., P.W.

Contents

1

Digital Devices and Systems

Microprocessors need other circuits and devices to form a complete system. Logic circuits of different families differ considerably in their behavior, even when performing similar functions. An outline of these differences is given. Test devices are available that can trace a fault to a specific pin on a device, and their advantages and limitations are discussed.

* * *

The best servicing aid to any system is a well-written manual. As in all other topics covered in this book, the reader should exhibit that true spirit of optimism without which servicing tasks can be so difficult – assume that the manual will be helpful until proven otherwise.

For the moment we ignore those unfortunately too frequent occasions when the manual is missing or hastily put together. It should give clear diagrams of the layout, and with luck a number of critical test points. A typical problem it can help avoid is in the measurement of clock frequency. A counter or oscilloscope may present sufficient loading to disturb the frequency of an oscillator if tapped onto a high-impedance port. Any manufacturer-designated test point should be well buffered, avoiding this risk.

The manual may contain a set of test procedures to trace the main categories of faults anticipated by the designers. Only the foolhardy would ignore such help, though in fairness there may be limited fault information available to the designers at the time of writing the manual.

It is important to realize that just because a pcb is part of a microprocessor system, any standard logic circuits behave in *exactly* the same way from a servicing standpoint as in older logic systems. Although the functions may be more complex, the electrical and mechanical faults are the same – track shorts, solder bridges, open-circuit gates. It may be more difficult to track down the area of the board where the fault occurs, but once narrowed down to one or two chips, all the well-known tests can be used. In this section we shall review these tests: there are many books dealing with these techniques more fully.

When would these simpler methods be used, and when the advanced techniques discussed later? If automatic or semi-automatic tests are available, use them. They will have been implemented by professionals having considerably more experience and thinking time than you will have under pressure on an unfamiliar system. If by good fortune the fault is one that advertises itself, that is different. Symptoms visible on a display or output port may suggest a driver chip, and a quick test with a pulser and logic probe may identify the fault quickly. Equally, bad fortune may leave the service engineer without the appropriate analyzer or emulator tools at the critical moment. To fall back on these traditional approaches is then the only choice.

Let us identify some characteristics that can be picked up by suitable probes.

Static	Logic 0
	Logic 1
	'Bad' level (intermediate between 0 and 1)
	Open circuit
	Short circuit
Dynamic	Short duration pulses
	Transients
	Low repetition-rate pulses
	Reverse polarity pulses
	Current flow

Logic levels should be either 0 or 1. As noted above, the precise levels at which these states are guaranteed varies between device families. Taking the usual TTL values, the voltages below 0.8 V are recognized as logic 0 and above 2.4 V as logic 1. Intermediate values imply a circuit fault, and a logic probe should give a separate indication. An open circuit usually leaves the probe in the same state, i.e. there is no distinction between an open-circuit condition and a 'bad' logic level. Similarly a short circuit to either of the supply lines will ensure a level that will be unambiguously interpreted as a true logic level. A voltmeter (or oscilloscope) will distinguish between a TTL logic/output and a short circuit to the supply line.

A single light-emitting diode with suitable driving stage can provide three states to represent the three groups of possibilities:

'off'	Logic 0 (or s/c to common)
'dim'	Open circuit or bad (intermediate between level 0 and 1)
'bright'	Logic 1 (or s/c to positive supply)

Fortunately we are not restricted to static testing. By adding a transient detector and a monostable circuit to the LED driver, an output pulse of fixed duration is obtained on an input transition. If the probe is connected to a point at logic 1 which experiences a narrow negative pulse of as little as 10 ns, the LED is pulsed off for a fraction of a second. A second time delay inhibits its response to repetitive transitions such that a flashing output at ~10 Hz is obtained for pulse rates from this frequency up to many MHz.

Thus with a single indicator LED, single short transients of either 0–1 or 1–0 can be detected as well as a continuous pulse train (Fig. 1.1).

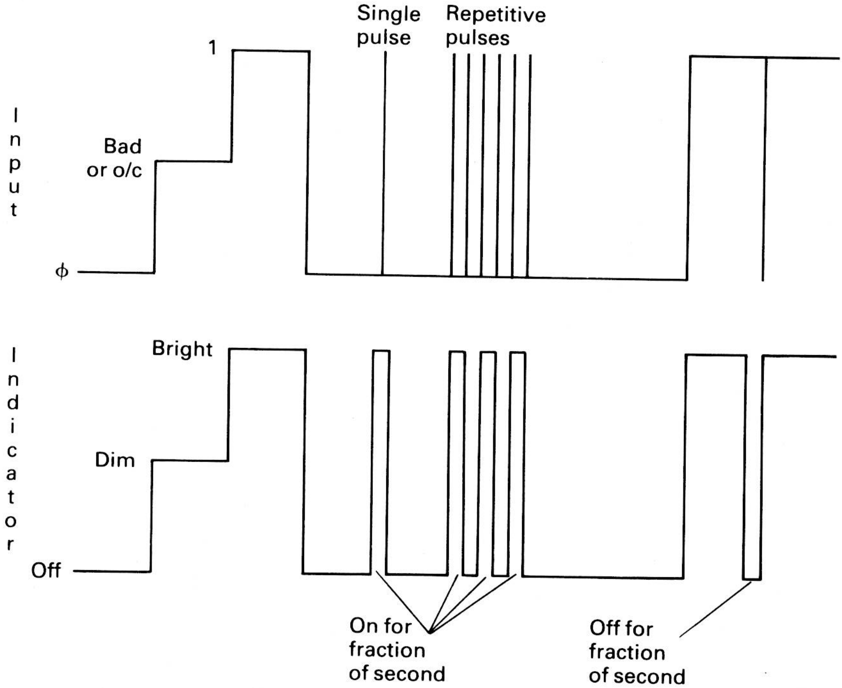

Fig. 1.1 Single indicator monitors static and dynamic logic states

High indicator on, Low indicator off	True logic 1
Low on, High off	True logic 0
Neither on	Bad or open circuit
Both flashing	Low frequency pulse train
Both dim	High frequency pulse train (relative brightness indicates mark/space ratio)

A third LED is added, flashing for a pulse train but off for any static condition. No information is provided on the mark-space ratio of any such pulse train. If separate LEDs are used to indicate logic 0 and 1 levels with appropriate threshold detectors, more information can be provided (Fig. 1.2).

These alternatives can be extended by, for example, having a latched mode in which an LED is held on following the receipt of a single pulse, even of short duration. Each manufacturer adopts different specifications too for the pulse timings. The probes may respond to minimum pulse widths between 10 and 100 ns with output pulse widths between 50 and 300 ms. They may have switched threshold levels to make them compatible with different logic families. Check the manual to make sure you are getting the best possible use out of your probe.

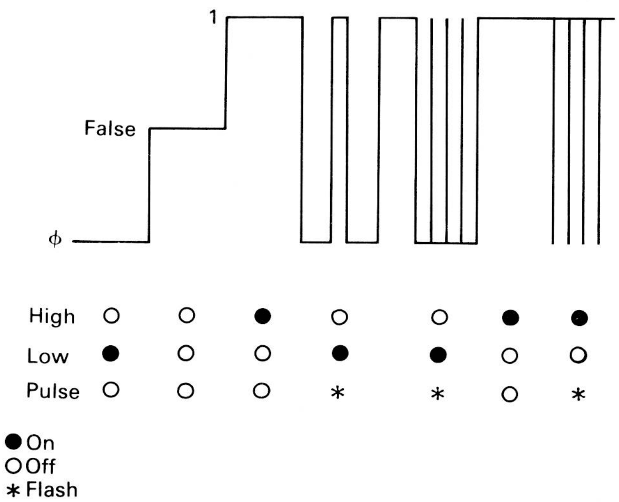

Fig. 1.2 Three LEDs give more information including mark-space ratio

CURRENT PROBE

Some faults cannot be identified by voltage probes no matter how complex the probes become. A short circuit may be distinguishable at a given node, but not the particular device, connected to that node, which is causing it. Similarly, a short circuit between two points might be within an IC or between pairs of tracks serving these points. We need to know where the current flows are being diverted to, without breaking tracks or removing ICs if at all possible. Though in the last resort this often has to be done, it is both time consuming and risky. It is so easy to introduce other faults in the process.

To detect a direct current is difficult though possible: Hall-effect devices are one possibility. It is difficult to achieve sensitivities appropriate to the levels in modern digital systems. Pulsed currents are somewhat easier and the current probe is a powerful tool. By aligning the tip of the probe along the conducting path, the field generated by the pulse is detected and the sensitivity is adjusted to keep an indicator on. The probe is then moved along the expected current paths until the indicator goes off, identifying the start of an unexpected conducting path. Note that it is a noncontact measurement, requiring close proximity to the conductor but not a direct electrical connection.

To see the different capabilities of voltage and current probes, consider Fig. 1.3. A pulse train at A should result in an inverted version at B, with the original recreated at D (ignoring propagation delay). No pulse activity should be present at C and E. A voltage probe at D might show no pulses, the output being at logic 1. This could be a fault in this gate, an output short circuited to the supply externally or that B is held at logic 0. Transfer the voltage probe to B. If a pulse train is present, that confirms a fault in the output gate or a short at D. No pulse train could mean:

1 the input inverter is faulty;
2 a short circuit at B to ground, supply line or other track.

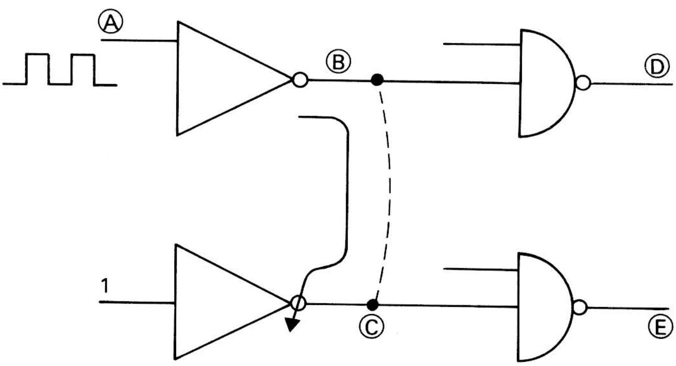

Fig. 1.3 Current probe traces short circuit current

If B is stuck at logic 0 this would check with the logic 1 state of D, suggesting the output gate as 'good'. A current probe at B should show a pulse train if the input inverter is functioning. Adjust the sensitivity so that the indicator is just on. Move the probe towards the output until the indicator goes out. This shows the point on the track at which a short circuit occurs. Inspection of the board should show up a solder bridge or other fault. Failing this, a check of neighboring points such as C might identify where the current is being diverted to, if not directly to ground, pinpointing the physical location of the dotted short circuit.

If a gate is used to drive multiple inputs the design will normally