FIELD-SERVICE SYSTEM FOR INTELLIGENT MEASURING EQUIPMENT

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Summary

The introduction of microelectronic components posed many, qualitatively new, problems in the instrumentation industry as regards the development, the manufacturing and servicing of devices.

The paper deals with the field-service system, the latter phase of the manufacturing life-cycle of intelligent, microprocessor-controlled instruments. We discuss the technico-economic viewpoints and the necessary aids as well.

The paper describes the field-service system for the instruments based on the MMT Microprocessor Application System and its base, the μSER field-service equipment.

Introduction

Recently, the type-spectrum and the number of microprocessor controlled intelligent instruments have increased rapidly.

The growing use of microelectronic devices and the decreasing costs of components lead to a drastic fall of equipment prices. As the intelligent instruments are widely used the effective and economic field-service becomes more and more vital. This problem is well exposed by the yearly service-cost, which can be up to 10—20% of the equipment price.

The principal problems in the field-service facilities due to microcomputing technology [1]—[3]

The use of microelectronics caused a revolutionary change in the instrumentation industry. With the growth of the users' circle the earlier development, manufacturing and test technology based mainly on the analogous technology, was suddenly confronted with complex requirements of computer manufacturing.

From this point of view, field-service — similarly to development activities — struggles against difficulties caused by lack of specialists skilled in the new technology.

The complexity of the products manufactured by the instrumentation industry is continually increasing.

The main causes of this are as follows:

- The increasing *complexity of the components* is a direct factor causing a higher complexity of the equipment.
- The *complexity of the structure* of instruments is on the up. Information processing in classical metrology was typically implemented by the propagation of electrical signals through a chain of functional operating elements.

  The main feature of this information processing were relatively few cross couplings with a simple control structure. From the point of field service it was of great advantage that fault location of the elements could be directly traced from the functional error diagnosis. In intelligent instruments the main part of the functions performed is concentrated in the microcomputer, so the implementation of the dataflow paths and control sequences is mainly influenced by it and not by the function to be performed. Therefore the problem of how to conclude on the fault from the functional error-symptoms becomes more and more difficult.
- An addition, a complexity heightening factor is that the built-in intelligence typically increases the level of user utilities, requiring the implementation of more *complicated algorithms.*
- Manufacturers — due to the obvious specialization process of manufacturing — integrate into their equipment more and more complete, so called *OEM subunits.*

  For the field-service of these units often a knowledge, tools and methods are necessary, which are not available for equipment manufacturers.

The classical field-service strategy and its problems [1]—[4]

The goal of any field service is to localize the physical defect down to a given level and thereafter by exchanging the faulty unit to produce a suitably operating equipment. The level of local fault localization in electronic instruments is usually the board-, in certain cases the component level.

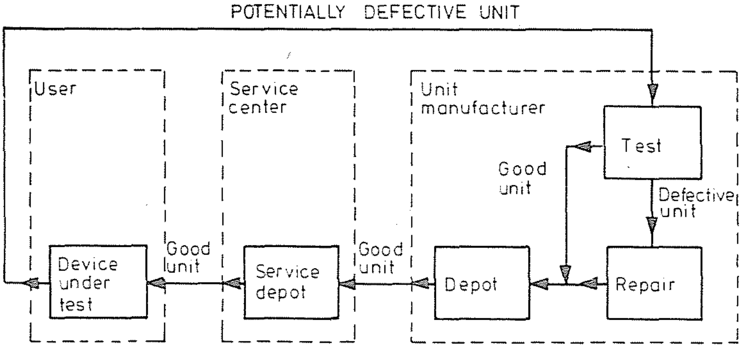

Fig. 1

In the classical board-level field-service two phases are involved:

- First, the fault is *approximatively located*, using a measurement (observation) series based on the unsuitable function symptom.
- The second step is a *"try and error" method to exchange the boards* for positively suitable ones in the previously determined area until the equipment operates correctly.

  The exchanged boards receive an "unsuitable or potentially unsuitable" qualification and are added to the repair cycle (Fig. 1).

The error-locating procedure described above is a rather accidental one and implicates many errors.

It is not sure that the "try and error" board-exchange procedure does find the defective elements, because it does not perform the investigation *in the worst-case environment*. E.g. the fault of a defective unit can be concealed by a newly added suitable unit overfullfilling its specification. In slightly worse conditions the instrument may naturally perform in a faulty way because it still includes the error-source.

The *diagnostic uncertainty* of the functional method is an additional source of error. In many cases it may lead to more exchanges than would be obviously necessary.

Some suitable boards are therefore added to the repair cycle and according to observations, their rate can be up to 20—50%. The cycle-time of the repair pipe-line is usually half a year. The above enumerated factors implicate locking up a too high amount of inventory.

A method for reducing these assets is to increase effectiveness in the repair pipe-line. One of the possibilities is a *decentralized service hierarchy* to be seen in Fig. 2. With its help the mean cycle-time in the repair pipe-line decreases by

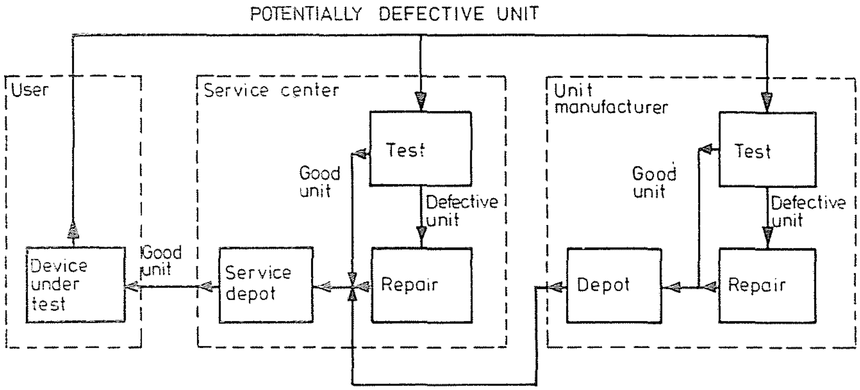

Fig. 2

about half. The principle is to shift part of the test and repair functions from the manufacturer to the better equipped service centers.

The above described modification cannot give a complete solution to the problems caused by the uncertainty of error diagnosis.

The fundamental question in the field-service of intelligent instruments can be formulated as follows:

How could
    a *reliable error-diagnosis*
    in more and more *complex products*
    be performed with a *service-staff*
    more and more *poorly-skilled*, as regards
    the equipment.

To answer this question a new detailed analysis of the viewpoints for the evaluation of the complete service-environment becomes obviously necessary.

Evaluation of the service-environment [2]—[3]

The requirements of an efficient field-service for intelligent instruments are as follows:

— A *test environment* (special test vectors, which differ from normal operation; test-response measurement with minimal information — loss, known references etc.), for an exhaustive test of the device and its parts must be developed.

— *An error-diagnosis tree* describing the algorithm of fault finding must be available.

— The measuring and error-diagnostics *methods and devices* used must be — as far as possible — independent from the individual, tested types of devices and also easily understandable and usable.

— The error-diagnostics process must be *automatized* within reasonably economic limits — to increase the reliability and decrease the time demand (mean time to repair) of the field-service.

— The field-service must get a significantly greater than hitherto support both as regards the tested device and the resources, to realize the described above environment.

The development of this support should become an integral part of the device and technology development. The serviceability must be designed into the instruments. Elaboration of the servicetools becomes important and critical.

— *The construction specifications* form an important group in the requirements for well-serviceable devices. Their purpose is to assure system- and circuit-technological, mechanical etc. conditions for an easy testability with respect to the field-service technology. Such rules are e.g.: to eliminate some poorly testable switching methods, to assure the connection possibility of the service instrument, etc. It is important that to fulfil these requirements necessitates only a very low cost increase (usually no more than 1—2% of the total component-cost), but helps the entire product-testing procedure — including in the course of manufacturing as well as the final test.

— *The self-test built* into the instruments is fundamental from the point of field-testing. The intelligence built into the instruments can be used to test their proper operation and so to increase the reliability of the measurement results. The adequate implementation of the device self-test programs, either built-in or revocable from a background store makes not only a GO/NOGO kind of qualification, possible but also an approximative, functional error diagnosis. It therefore gives a starting point for the field-service procedures.

The additional requirements of field-service resources can be satisfied in the form of *service instruments.* In the following we will draw the attention to the most characteristic features of microcomputer element test devices.

The typical structure of service instruments

Service instruments — based on the chronological order of their appearance and the level of their service can be divided into the following *generations:*

- general purpose instruments,
- general purpose digital test-instruments,
- special test instruments for microprocessor-controlled devices,
- portable automatic test equipment.

The category of *general purpose instruments* includes mainly the classical analysis instruments for analogous and digital signals (oscilloscope, DVM, frequency- and time-meter, logic pulser and probe etc.). They are suitable for a single purpose analysis of single, statical or short period signals.

The importance of this category as service instruments disappeared with the increasing complexity of the devices, but some of their functions (voltage-, current-, resistance-, frequency-, time interval-, logic level-measurement) are built into the modern service instruments supporting component — level fault finding and simple circuit analysis (e.g. power supply test).

General-purpose digital test instruments are tools to measure and analyse complex data flows.

The most characteristic representatives of this category are:

- the logic state analyzer (LSA), enabling the analysis of multibit, parallel timed signalgroups.
- the signature analyzer (SA) and the transition counter (TRC) which measure long signal sequences using the information-compression facility.

These devices are effective for measuring test-responses but the problem of how to generate the testvectors remains practically unsolved. Their use without additional external support implies considerable restrictions in the construction. For measuring the tested device they require certain significant modifications, e.g. exchange of the ROMs to test ROMs, reconfiguration of boards for test operation — such as CPU free-run, etc.

The *special test instruments for microprocessor-controlled devices* integrate all these fundamental tools for field-servicing. Their most important functions (observation of the device under test and emulation of some of its modules) are similar to the functions of the development systems.

Thus there are two fundamental possibilities to connect the service instrument and the device under test:

- In-circuit emulation, where the connection between the service instrument and the device under test is implemented through the integrated-circuit socket of the microprocessor element of the latter,

— Bus emulation, where the connection interface is the bus of the device under test.

The service instruments of this category incorporate a microcomputer. Its most important functions are:

— operator-communication control
— loading the test-programs from the data input peripherals,
— supervising the system under test (running and stop of test programs etc.),
— control of the built-in measuring devices,
— in the case of an algorithmic test the evaluation of the test-responses.

Setup for measuring and fault-finding are done by the operator manually on the basis of information contained in the service-documentation.

The measurements described by the two earlier categories in the instruments belonging to this category, are integrated.

The *portable automatic test equipment* can be considered an important evolution due the following:

— *Setup* and realization of measuring are nearly fully *automatized*, thus the speed and the reliability of error-diagnostics is significantly increased.

— *Fault-localization* is done by the microcomputer belonging to the service-instrument using the stored diagnostics tree so the skill required from the operator and the volume of necessary documentation is decreased.

— The possibility of connecting the service instrument to *data transmission* lines makes a remote diagnosis possible. Using this facility, complicated field-service problems can be solved with only one technician aided by a high performance computer or a highly qualified expert in the service center.

It is to be mentioned, that the additional cost investment (more costly service instrument, higher grade development of the field-service algorithms, etc.) for this level automatization of the field-service process is recoverable only in the case of higher complexity and/or production volume of the devices.

The field-service system of the MMT Microprocessor Application System [8]—[9]

The MMT system was developed by the Department of Measurement and Instrumentation at the Technical University of Budapest.

The typical structure of the equipment based on the MMT-System is shown on the scheme in Fig. 3.

The functions to be found in the majority of the instruments are implemented by the so-called "system element cards", which are general-purpose series production ones. Some specific device problems need the development of special instrument dependent cards. The majority (60%—80%) of the hardware modules are of the system-element type. In the MMT-System the bus is the standardized surface, the system hardware — within the limits of the bus — is independent from the processor-type.

The features of the system element cards from the testing point of view are as follows:

- There is usually a *correspondence between a board and a function*, so the greater part of the error diagnostics problem can be solved on this basis.
- To support the field-service, *self-test modules* with standard interfaces for the functionality test of the system elements can be developed.
- To repair the system element cards, an automatic card tester (developed for the in-manufacturing test [9]) can be efficiently and economically used.

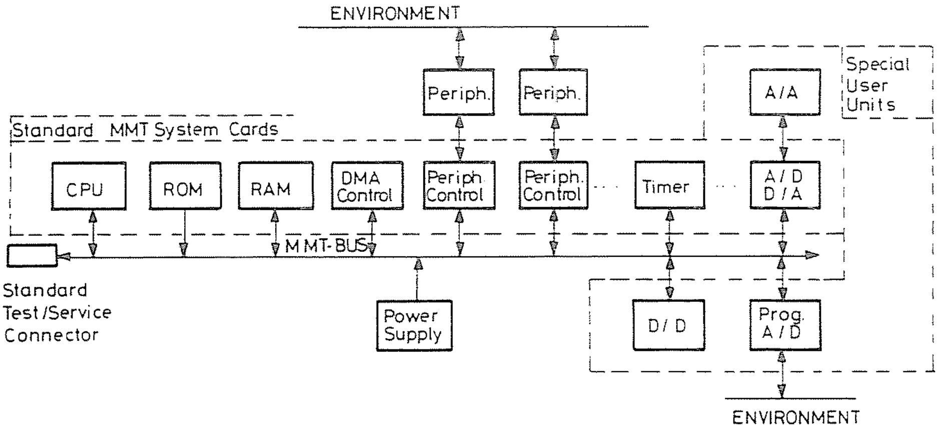

Fig. 3

— The fundamental needs of the service are taken into consideration at the designing level of system element cards and instruments.
For example the CPU, ROM, RAM functions can be inhibited in certain phases of the service, every device contains a built-in standardized service connector, built-in test points are provided in the cards to test the critical functions, etc.

The main features of the special cards are:

— *Compatibility with the construction rules* makes possible an approximate check through the bus.

— The *self-test* functions are *not always* available.

— The *test to be performed on the automatic card tester* is *usually not elaborated* below a critical production volume.

Further factors that influence the evaluation of the service-environment of the MMT System are:

— The hardware architecture of the MMT system-based equipment is usually of a *medium level* (10—20 boards) *complexity*.

— A service-center is competent for relatively diverse from each type, however, always for a low or maximum a medium number of equipment.

— The *functionality* factor MTBF/(MTBF + MTTR) required for the equipment is usually not extremely high.

— The *service-staff* is required to have a general, occasionally even a low skill, only.

As a consequence of the above factors the main features of the evaluated service system are as follows:

— The task of the local field-service is fault localization down to the *board-level* and repair by means of *board-exchange*.

— Error-diagnosis is supported by the *service-instrument*.

— The *complexity* of the instruments and the service-*speed* requirements do not implicate a full automation of fault localization, therefore the service instrument is a *test instrument for microprocessor-controlled equipment* (third generation). The reference values and the diagnostic algorithms are stored in the *service documentation.*

— The *system-element cards* are repaired on basis of the automatic card-tester, usually after a coupling into the manufacturing cycle.
The low volume of inventory in the service-depot is assured by the general purpose feature of the reserve boards.

— The *special cards* are repaired in the service-center. This process is supported fundamentally by the service instrument.

The specification of μSER, — the MMT-system service instrument

The specification of the service-instrument fulfilling the requirements described above is in Table 1 together with those of some similar devices, while its structure is seen in Fig. 4.

The developed service instrument and the device under test are connected by means of bus-emulation. The BS bus-switch unit performs the connection and protects the service instrument from consequences of fatal faults in the device under test.

The service programs for the fundamental functions (bus, RAM, ROM, CPU) are resident in the instrument. The standardized test programs for the system element cards, the specific test programs for the special cards and the service programs additional to the self-test programs included in the device to be tested may be loaded by means of an exchangeable ROM.

The service instrument is also able to test subunits not incorporating a microprocessor (e.g. the special cards), and assure the possibility to use basic electric measurements (voltage, current frequency, time-interval) and digital analysis (signature and logic state analysis).

The set-up of the service configuration is generally the service man's task (e.g. setting up CPU to free-run, removal of undesired peripheral control cards etc.), but some setups (e.g. CPU, memory inhibition and emulation) are realized automatically by the service instrument itself.

For reference-generation and test-response analysis fundamental is the SA method.

During error-diagnosis the signatures registered from a known good device and defined in the documentation are compared by the operator with the values being measured. The facility of observation and emulation gives the

Table 1

Mass services

Type	Fundamental measurement	Digital measurement	Connection interface	Built in test	Reference	Automatic error diagnosis	Peripherials
HP 5005 SA MULTIMETER + HP 5001 μP Exerciser	U, I, R, C	SA	ICE + probe	CPU, BUS, ROM, RAM I/O	HW docu		ROM
Solartron Locator 7201	U, I, R, C	SA, LSA, TRC, T, F	ICE + probe		HW docu On line HW		ROM
Fluke 9000 system Trouble-shooter		SA, LSA	ICE + probe	BUS, ROM, RAM, test-programs	HW docu	Partially	Minicasette, data trans. line
Millenium μ system analyser	SA, LSA,	TRC, T, F	ICE + probe	BUS, ROM, RAM	SW + HW + HW docu	Partially	ROM data trans. line
MMT μSER	U, I	SA, LSA, TRC, T, F	BE + probe	BUS, ROM, RAM, ext. library	HW docu		ROM

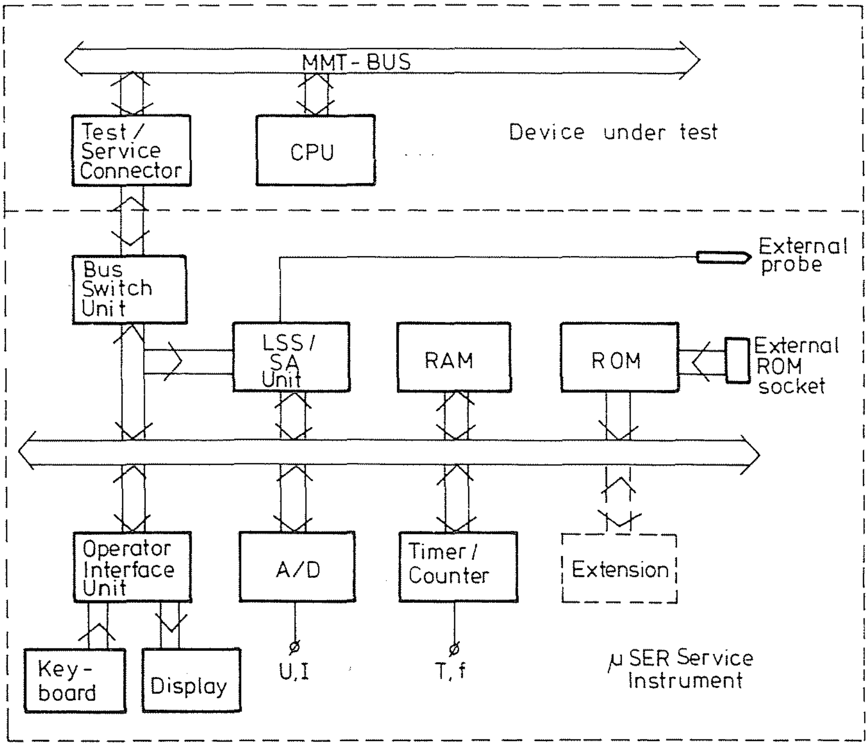

Fig. 4

additional possibility for generating the references and for automatic result evaluation by means of the software — mainly to test the hard core (CPU, ROM, RAM, BUS) of the device to be tested.

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