TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 18
Number 2
June 2024
DOI: 10.12716/1001.18.02.05

Diagnostics and Troubleshooting of Ships Digital Electronics Systems

S. Mikhailov, A. Veretennik & I. Kulyeshov
National University "Odessa Maritime Academy", Odessa, Ukraine

ABSTRACT: Algorithms and procedures of digital information systems testing, adjustment and sustainable.

1 INTRODUCTION

Today, digital and computer technology is present and participates in the work of virtually any service on board a modern transport vessel. At the very top (in the ship's control center) - on the navigation bridge - the work of the navigator is almost completely provided by digital electronic equipment. For this, special professionally oriented integrated bridge systems [1] are organized, combining the main radio-electronic means of navigation.

Suffice it to mention the ECDIS electronic cards [2, 3]. In the energy center of the ship - in the engine room - computer equipment has completely changed the organization of watchkeeping for ship mechanics [4] and electricians. There is electronic equipment that is relevant to absolutely all crew members, regardless of their professional orientation, for example, an emergency beacon, radar or radar transponder beacon (Automatic Radar Plotting Aid - ARPA) [5, 6].

For the operation, maintenance and keep of all this electronic equipment in good working condition directly on board the ship, the International Maritime Organization (IMO) by its convention for the training, watchkeeping and certification of seafarers -"STCW"- provides for a special position of an officer in staff: ship radio electronics 1-st or 2-nd class [7].

However, this vacancy actually exists only on a limited type of sea vessels, such as large passenger liners. On other transport ships, in order not to spend money on trifles to call onshore specialists, the crew members on board try to take on the functions of maintaining the operability, maintenance, restoration and current repair of digital electronic and computer equipment.

The methodology of diagnostics and troubleshooting of digital electronic equipment proposed in the article is intended to help them in this task. This is a specific working tool for an electronic engineer (even for a non-professional).

The recommendations are based on many years of practical experience of the authors in the work on diagnostics and adjustment of digital electronic equipment [8].

2 MAIN

Modern information control computer and electronic systems are certainly more complex than systems of previous generations. And often the complexity of software and circuitry solutions leads to the fact that engineers operating such systems consider all the problems associated with their debugging to be the same difficult. As a result, simple solutions of various set-up problems become unnoticed.

Therefore, a methodology (basic engineering algorithm) of troubleshooting and setting up digital devices at the system level is proposed, and its steps are called "Ten rules for debugging". The Ten Rules is a practical, systematic tool for solving some of the most common problems associated with the development and operation of information control computer electronic systems.

These principles apply to troubleshooting of wide variety of circuit board types, such as digital or analog circuitry, power supply and mixed hybrid integral circuits.

The use of these principles when debugging a failed system will simplify the problem of solving process and ensure the operability and commissioning of the system as soon as possible. Knowledge of these methods is important on all stages of professional height of specialist on information technologies: from the primary educating to the subsequent in-plant training and perfection [9].

3 RESEARCH RESULTS

The effectiveness of these ten commandments can be demonstrated by the example of solving the problems of certain digital system debugging (Figure 1). Here we take a “typical” digital system as a model [10]. The presented digital printed circuit board is a part of a larger system that includes other functional units, such as power supply, digital interface, data conversion interface (analog-to-digital and digital-to-analog converters), and an interface section generating in digital form the signals that come from external equipment. In this case, we assume that the board being debugged is the "brain" that controls the rest of the components of the electronic system as a whole.

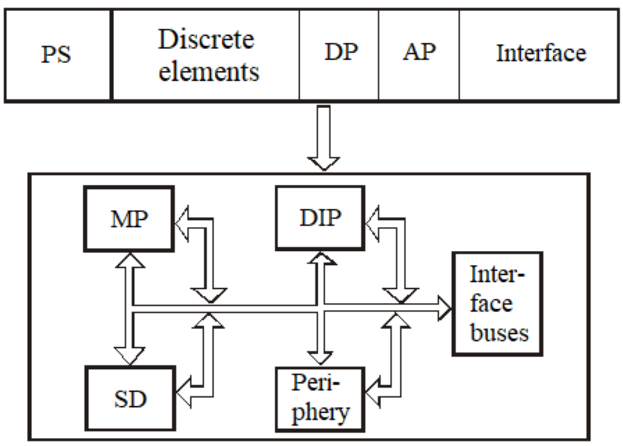

Figure 1 Objects of analysis of the digital part of the system: PS - power supply; DP - digital part of the system; AP - analog part of the system; MP - microprocessor; SD - storage device; DIP - digital interface part of the system

The main components of the board are the following: microprocessor, local memory (both operational, on static storage devices with random access (RAM), and non-volatile, on reprogrammable read-only memory (EPROM)), an intelligent peripheral device (requiring minimal participation from the main processor to implement its own functions), a parallel bus interface, and an application-specific integrated circuit (IC) such as a gate array or programmable logic array (PLA), depending on circuit complexity and speed requirements. In addition to integrated circuits, additional sources of possible malfunctions can be discrete elements on the board - resistors, capacitors and connectors.

The aforesaid digital card is used to control other cards in the system, interacting with them via parallel bus interface. In this example, an intelligent peripheral is a serial data bus port through which an electronic system can communicate with other similar systems that form an entire computer network. A microprocessor located on the board controls the transmission of all internal and external messages and determines the information that must be requested from other boards or systems on the network.

In addition, the processor performs local computing functions.

What should be the first step in the process of debugging such device? To turn on the power and hope for the best? Not like that in any case!

3.1 *Rule I: Conduct a visual inspection of the board.*

The inspection consists of several steps:
1. match the layout drawings of the board with the real product; make sure all parts are installed correctly;
2. check that none of the components was damaged during installation, review all the IC and discrete component pins, the quality of the IC panel, and the quality of the rations;
3. match the real board with the scheme and with the list of elements to make sure that the devices provided for the scheme are installed. If a discrepancy is found, you should refer to the passport data or reference book to make sure that the replacement is acceptable;
4. check the values and tolerances of all capacitors and resistors.

3.2 *Rule II: check the elements connections.*

Several important checks:
1. make sure that there is no short circuit between power and ground. Many boards have several supply voltages (for example, 5V, 12V, etc.) and they can have several independent common "ground" buses (for example, the "ground" of the digital part of the system and the analog part can be different and have a difference in potentials). There must be no short circuit between all "grounds" and power circuits;
2. check the wiring diagram of the board for compliance with the wiring diagram. The circuit should be called for continuity from the final output on the connector to the output of each component (and not to some intermediate control point!);

3. check the correct wiring of the sync signal circuits from the connector to each component where this sync signal is used;
4. check the circuits from the final contact of the connector to the corresponding contacts of the panel for installing the microcircuit.

3.3 *Rule III: check the basic parameters of the system.*

After fulfilling the first two commandments, you should control all the main parameters of the system level:
1. check the amplitude and noise level of the power supply, set the voltage rating according to the circuit requirements. If the noise (ripple) of the supply voltage is large, you should try to reduce it by switching on decoupling and smoothing filter capacitors or by other means;
2. configure the current limiter circuit - power supply protection to make it work at a certain level of current consumption (thanks to this, one can hope that the components will not burn out in case of unexpected problems);
3. check the frequency and duty cycle of the system clock if it is generated outside the board.

3.4 *Rule IV: check the problem node for compliance with the circuit diagram.*

To fulfill this commandment, you should undertake the following steps:
1. supply power to the board. Monitor the current consumed. Turn off the power and check the first three commandments in case it is too huge;
2. run the board tests. These tests or verification procedures allow you to determine quickly whether the board matches its electrical circuit (i.e., whether all components are functioning, whether all traces and through-holes for double-sided and multilayer boards are intact, and whether all signals from the connector pins are correctly applied);
3. if the test fails, then the problem must be carefully documented. Record the number of the test failed and all the signs of such failure. First of all, make sure you are supplying the correct input signals. Eliminate your own operator errors. Then check for correct installation.

Let's suppose, for example, that a test should verify the functioning of four discrete instruments. It provides for the supply of setting signals to discrete devices No. 1, No. 2, No. 3 and No. 4 and reading results 01, 02, 03 and 04 on the indicator. You run the test and send signals to the first instrument. You see 02 instead of 01 on the display. Record your results and continue. When you apply the reference signal to the second discrete device, you notice that 01 is indicated on the display. Record the results again and continue. By giving signals to the third and fourth device, you see the correct display readings - 03 and 04, respectively. The question arises: "For what reason does the first discrete device look like the second, and vice versa?"

First of all, make sure that you are making the correct input signals. Operator errors should be eliminated as soon as possible. Then check for correct installation. The circuit from the controlled discrete device to the indicator may be routed incorrectly (for example, two signals are mixed up). Maybe discrete device number 2 is associated with the least significant bit of the indicator, or vice versa? If we are talking about a wired breadboard, then the error can be eliminated immediately. If you are working with a printed circuit board, you can either clear the error first, or skip the entire test to check the rest of the board. However, you must clearly fix each problem so that you know exactly under what circumstances it occurred and what are the evidences.

Let's give one more example of the scheme implementation. You have just received a volumetric wiring board for setup. After visually inspecting the board, checking the integrity of the connections and setting the basic system parameters, you turn on the power - and suddenly you smell smoke. What is burning? More importantly, what is the reason? Turn off the power, repeat the first commandment and visually check the board. If you can not notice anything, try to check several circuits. This will allow you to understand which conductor or element has burned out. The fulfilled checking may indicate that the line from the connector power pins to the board is broken. If so, you should check whether too small conductor size was mistakenly chosen for the power wiring.

3.5 *Rule V: "separate and powerer!"*

Debugging complex systems usually require to solve complex problems, but many of them are easily solved by breaking them down into several simple ones, i.e. usually they use the method with the name "divide and rule".

To fulfill this commandment, follow the next steps
1. identify the problem correctly;
2. isolate the suspicious part of the microcircuit from the rest of the parts.

Isolation makes it possible to observe and control the input reference signals and check the output signals. This approach allows you to resolve such problems as conflicts (race) on the common bus, problems with the load of In / Out circuits, and others.

Example 1. Conflict situation on the bus [3].

It occurs when several users simultaneously try to seize the right to control the bus. To solve this problem, you should:

Disconnect all devices from the system bus, except for those suspected of creating conflict situation, in this situation such devices as transceivers and buffers shall be removed from the board. You should not expect that isolation will be ensured by using IC selection circuits (at the CS input) or at the output enabling input for tri-steady state logic. These control circuits can lead to malfunction and allow access to the system bus when not provided. After securing the isolation, check the reading and writing operations for the devices suspected, with a time-lapse analysis of the signals driving these operations.

Example 2. Problems of loading input/output (I/O) circuits. They arise when a particular output circuit is unable to handle the system's load. There are usually two reasons for this:

1. insufficient levels of logic signals that are out of tolerance;
2. excessive durations of the leading and trailing edges of the pulses.

Isolation provides the opportunity to observe unloaded output signals. If they are normal, then their distortion is associated with excessive loading.

Example 3: Specialized integrated circuit receives invalid data from a memory device (no bus conflict occurs).

In this case, various memory access control signals (eg write enable, IC select, output enable, etc.) should be isolated; analysis by comparing signals without load and with load for the levels of logical zero and one, surges / dips and the steepness of the leading and trailing edges of logical pulses shall be provided.

The point «divide and rule» leads you to focusing on debugging small sections of the system. This prevents the temptation to believe that the chips and other semiconductor elements located on the board are inoperative and need to be replaced. Such force methods such as replacing board or system components are highly ineffective and often fail to identify real system problems.

3.6 *Rule VI: Understand how board elements should work*

Many debugging problems arise because the computer engineer simply does not understand how the electronic components used in the system are supposed to work. This is not only about the clean functioning of the devices, but also about the electrical characteristics for direct and alternating current. Various problems can manifest themselves at the system level, even if all the devices on board are functioning. These can be problems with the performance of the board as a whole, the correctness of the input information, the integrity of the data and the required time sequence for the arrival of information - and all of them can be both permanent and episodic, intermittent. Moreover, problems can occur in the device as a whole, even if individual components of the board are functioning normally.

The procedure includes the following sequence of actions:

1. it is necessary to take into account the electrical characteristics of the DC circuits;
2. identify unused inputs that are not connected anywhere ("floating" and "hanging in the air" inputs). The way to eliminate such malfunctions is to fix the logic levels by installing load resistors on such inputs;
3. it is necessary to take into account the type of output circuit when checking the output signals. There are three options (Figure 2): U-out - max (logic level "1"), U-out - min (logic level "0") and "third state" - high impedance.

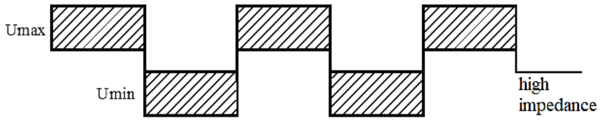

Figure 2. Possible levels of output signals of digital ICs

It is necessary to find out the type of logical signals in the device - "positive" or "negative" logic, the values of the logical levels "1" and "0" for it, as well as the permissible values of fluctuations of these values.

Many system problems are the result of not taking into account the electrical characteristics of the DC input circuits, or unused inputs not connected anywhere (so called "floating" or "suspended in air" inputs). The output circuit must create the required voltage levels of logical zero and one for all inputs connected to it. You should double check the voltage requirements for all ICs in the problematic or isolated specialized section of the board.

Floating inputs are board inputs that do not receive voltage or current setting signals from one or another output. These inputs can cause functional and parametric problems in the system, such as increased current consumption, increased noise, and unexpected or unwanted generation of logic control signals as a result of unwanted or unexpected malfunctions. During debugging, check that all inputs receive either dynamic or constant static reference signals. Only inputs with leakage or load resistors can be left without such signals.

When checking the output signals, the type of output circuit must be considered. Active output circuits create voltage for inputs: high - for the logic level "1" or low - for the logic level "0". Three-state outputs create voltages for the inputs: high or low, or a third, high-impedance, state. Open-drain or open-collector outputs create only voltage for the input - a high level. In the absence of an active signal at such an output, a high-impedance state.

In order for an open collector/drain tri-state output circuit to properly drive the input, it requires a drain or load resistor. In the absence of such a resistor, the output circuitry, when it goes into a high impedance state, essentially causes the input "to float". Check all inputs to the circuit to determine if a drain or load resistor is required here. You also should remembered that the resistance of the resistor and the current capabilities of the output buffer affect the duration of the rising and falling (leading and trailing) edges of the output signal.

4. analyze the logical formulas describing the functioning of the elements in the board;
5. check the configuration of the devices.

Since most of the elements are programmable (RAM, ROM, MP, PLM, BMK, MS, DC), incorrect setting of their configuration creates problems for the operation of the device as a whole.

It is necessary not only to take into consideration the input and output characteristics of all microcircuits in the system, but also to understand the functioning of semiconductor devices such as PML (programmable matrix logic) and specialized ICs. When debugging the system, you should re-analyze the logical formulas describing the functionality of these microcircuits. It often happens that an error in a logical formula will require many hours of setup work to correct it. For example, a PML programmed to implement bus arbiter functions may from time to time grant bus access to more than one DMA device. The reason of such a problem can only be identified by a careful analysis of the logical formulas of the PML using the “divide and rule” methodology.

3.7 *Rule VII: Understand how software is supposed to work.*

To fulfill this commandment, use the following guidelines:
1. interactions between hardware and software often cause many system-level failures and problems. The key to effectively debugging such systems is understanding of how software affects the hardware;
2. check that the configuration software to be working correctly;
3. analyze the interaction of hardware and software. The hardware operability check is usually performed by writing (issuing) data to a device with the following reading for this device;
4. the best way to debug for complicated systems, complicated software and hardware systems, is to simplify the software. This approach is conceptually similar to the method of isolating individual device nodes.

Let's start with the main question: "How does software affect hardware?" In this example of a tunable system (Figure 1), a programmable microprocessor controls the configuration and operation of the ASIC and intelligent peripheral device. When debugging the system, verify that the configuration software is working correctly. Then you need to analyze the interaction of hardware and software. If at the hardware level incorrect transfer of information to system devices takes place, then problems usually arise. A simple hardware check is usually done by writing (outputting) data to a device and then reading it for that device.

This method of debugging by performing stepwise read / write operations allows you to identify effectively certain hardware limitations of the system. Failure to read correctly the data written to the device will confirm the presence of problems such as access to odd/even addresses or word length.

Problems of access to odd/even addresses arise when the microprocessor and software provide for recording only by odd or only by even words (for example, 1, 3, 5, etc.), and system devices require both odd and even addresses. Word length problems arise when the software and circuitry of the system requires different word lengths. All such problems, if identified in a timely manner, can be easily resolved.

3.8 *Rule VIII: Understand how test facilities are supposed to work.*

This commandment refers to the setup process, when the last enters the stage of testing the board or the complete system. Here you have to deal with problems related to test equipment and test software:
1. determine the necessity of this test;
2. interpret correctly the research results, identify incorrect testing methods;
3. analyze the problem and classify it, referring to the category of functional or parametric. When it comes to parametric problems, the measuring instruments used, such as test loads and measuring instruments, should be evaluated. Analysis of functional problems consists in comparing test modes with real modes of system operation.

At this stage of testing, it is determined whether the test operations correspond to the real capabilities of the system. Many functional problems arise when test programs do not test all modes and means of the system or board that correspond to the real operating conditions. These problems can usually be solved when the system or board performs certain operations and the methods used to control these operations are analyzed.

3.9 *Rule IX: Don't "get hung up" - take breaks.*

For this commandment, it is necessary to follow the present recommendations:
1. when you work on complex problems, you are forced to concentrate completely on it and, unfortunately, you focus on one problem area. The break allows you to open your eyes and see other possible causes of the malfunction;
2. taking a break will help you get out of stress.

A timely break can often be very useful. If you are "obsessed", you can just have a cup of coffee, take a "stretch" or get a good night's sleep.

Why take breaks? First, when you are working on difficult problems, you have to concentrate your full attention on them. Unfortunately, it may turn out that you are only focusing on one problem area. A break in operation allows you to see other possible causes of the observed abnormalities. Taking a break is a way to remove blinders and solve a problem.

Second, if you have been trying to solve a particular serious problem for a long time, you may find yourself too much stressed. Do not panic. Take a break, check the fulfillment of commandments from I to VIII. By repeating this systematic procedure for debugging your board, you may find important "points" that you simply did not notice before.

3.10 *Rule X: Try to look at the problem from a new perspective.*

You have fulfilled the commandments from I to IX, but you could not find the cause of the disfunction and understand any systemic problems. What to do next? Invite someone from your colleagues who can help you to look at the problems from a new perspective - someone who is not familiar enough with your board and its construction, but can ask a number of fundamental questions, i.e. have a fresh view on the problem.

The important thing to remember in this rule is that Commandment X is about taking a fresh look at your task, and not about asking too much help. You can just get confused if you have too many helpers and advisors. Be selective inviting colleagues to participate in the setup process. Ask for help from those experts, whose analytical mind, experience and opinion you value. Then your request for help will be beneficial and will not influence your credibility.

4 CONCLUSIONS

Algorithms and procedures of digital information systems testing, adjustment and sustainable, integral and complex estimation of refuse of the digital informative system, both «from within» her and «outside», gives an opportunity to define reasons of refuse and find the ways of renewal of the system [11]. The described methodology of search of disrepairs in the digital systems is a quite good working instrument for these aims.

REFERENCES

[1] Andy Norris. Integrated bridge systems. Vol.1 & Vol.2. - Nautical Institute, 2013.

[2] E.Caroletti. Usingt the ECDIS route corridor function. – Seaways, January 2022. - p. 10-14.

[3] ECDIS: The future of navigation. – Navigator, N 5, February, 2014. – p. 2-11.

[4] A. Veretennik, I. Kulyeshov & S. Mikhailov. Navigation's Safety Improving by Efficiently Analysis of the Ship's Power Plant Energy Flows Interconnection. - The International Journal on Marine Navigation and Safety of Sea Transportation. - Volume 16, Number 1, March 2022. – p. 40-42. DOI: 10.12716/1001.16.01.03

[5] RADAR: Eyes in the dark. – Navigator, N 6, June, 2014. – p. 2-11.

[6] Y.Chhabra. Speed input into an ARPA. – Seaways, December 2021. - p. 8-9.

[7] S.Singh, J.Carson-Jackson, V.Rambarath-Parasram, M.Lind, W.Lehmacher, R.Watson, S.Haraldson, O.Eriksson. Are we on track?. – Seaways, January 2022. - p. 21-23.

[8] S. Mikhailov, "ITU Excellence Center For Digital Broadcasting in Odessa", Xth International Conference TCSET'2010 "Modern problems of radio engineering, telecommunications and computer science", February 23-27, 2010 Lviv-Slavske, Ukraine, p. 159.

[9] Steven Jones. Keeping clear of a new threat. // Seaways: The International Journal of The Nautical Institute/ September, 2014. - London - UK.: Stephens&George, Merthyr Tydfil, 2011. - p.10.

[10] Zhilenkov A. Investigation performance of marine equipment with specialized information technology [Text] / A. Zhilenkov, S. Chernyi // Energy Procedia. - 2015. - Vol. 100. - P. 1247-1252.

[11] Wake Philip. Guarding against failure. // Seaways: The International Journal of The Nautical Institute/ September, 2014. - London - UK.: Stephens&George, Merthyr Tydfil, 2011. - p. 3.