SOFTWARE REQUIREMENTS

FOR AUTOMATING A

RADIO TELEPHONE SYSTEM

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any Technikon or University for a degree.

Signature: ______________________ Date: ______________

The study leader, Professor P, J, S, Bruwer has accepted this final version of the thesis.

Signature: ______________________ Date: ______________

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SYNOPSIS

Sentech is the common carrier signal distributor in South Africa for Television and Radio programs. This radio telephone system is used by the company as a communications link for voice and data between remote transmitter sites and the Transmitter Control Centre. The system was installed in 1986 and consists of a mixture of fixed bases and mobile units.

The location of these transmitting sites is mainly on top of mountains in remote, sparsely populated areas. The use of cellular telephones for communication is impossible, as 80% of the sites fall outside the coverage area of the cells. Telkom infrastructure in these areas is most of the time not available or consists of shared farm lines. Only in the big metropolitan centres can data lines be considered at the main sites. It is not cost effective to consider it for the small sites.

When the new system was installed, it replaced a single repeater system that relayed VHF radio signals from as far as 200 Km. The new system was a major improvement over the old system. Within a year it became apparent that it did not fulfil in all the needs of the company. A telephone-patch and two-tone cell call was added to increase the functionality. Data transfer and call-out systems were added to implement the new telemetry system to the sites.

When the old handhelds became unreliable and the new units only use DTMF signalling, it became apparent that the system had to be upgraded. The following options were considered:

- Replacing the existing system at a cost of 4 million Rand
- Replacing the existing processor card at a cost of R100, 000.00
- Using Telkom lines to all the sites. (Lines cannot be installed at about 60% of the sites)

- Using cellular telephones at all the sites. (Signals are not available at 80% of the sites. At the sites that fall inside cellular network the cell-phones are unusable at 95% of these sites)

The option to develop and replace the microprocessor card was chosen, as the most cost effective. At the same time the system will be enhanced and streamlined.

The following process was followed to implement the new microprocessor system:

- Modify the existing interface cards so that most of the alignments in the audio paths could be eliminated.
- Design and develop the new processor card, replacing the old one and eliminating hardware problems.
- Build two systems interface controllers as test rigs for testing hardware and software.
- Develop the software modules to perform hardware testing and diagnostics, signal generation for system alignments, system configuration for setting operating parameters of the system and programming software to load the operating software.
- Develop a windows based software package that will communicate with the control software modules on the card. Design an integrated help system that includes diagrams and hardware test points of the microprocessor card.
- Reverse engineer the existing software and then develop the new operating software that will control the system.
- Prepare the systems interface controller to accept the new processor card and replace them at all sites.
- Test the software to eliminate bugs and then upgrade it to enhance the operation of the phone-patch.

A total of 35 sites have been installed and the results indicate that the system is now performing well with the new processor card. The set-up and alignment time have been reduced from 16 hours to half an hour for the system interface controller alignment.

The conclusion is that with the new software and ultimately a new processor a system can be cost effectively given a new lease on life.

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CHAPTER 1

1 THE PROBLEM STATEMENT

1.1 INTRODUCTION

Sentech is the common carrier signal distributor in South Africa for Television and Radio programs. The radio telephone system is used by Sentech in the Western Cape area for voice and data communications between transmitter sites and the Transmitter Control Centre. The system was installed in 1986 and consists of a mixture of fixed bases and mobile units. The transmitters and receivers used in the system are off the shelf units from General Electric USA. The controller used to control the system was developed in South Africa and uses non-standard control signalling. The intent of this research is to upgrade the existing controller to full automation, making the controlling signals standard and more user-friendly. The connection of external equipment and the general maintenance of the system will also be addressed. The control of radiotelephone systems has internationally been standardised to a large extent. It is not known if these control codes can be implemented on the current system and used to automate it.

The problems with the existing radio telephone system started from the day that it was installed in the Cape Town, Vredendal and George regions. Because the radio telephone system was developed for Sentech in the Western Cape, there are only three systems in the country. The company that developed it is no longer in existence, thus making it difficult to implement changes. With the expansion of Sentech and the deregulation of broadcasting in South Africa, the load on the system has progressively increased. A telephone patch was added to increase the functionality but due to the codes used, could not be implemented in full. The transfer of telemetry data and a call-out system were also added and increased the problems already experienced.

The benefit of this study is to broaden the in-house knowledge on automated control of radiotelephone systems, increase the productivity in managing the maintenance centres and to increase the data throughput of the telemetry system. The hypotheses to be tested is, ***"can the system be upgraded and if so can a fully automated system be implemented based on the broad principles used in cellular car telephones"***. The concept of transferring data on the same carrier using inter system communication will also be tested.

1.2 RADIO TELEPHONE SYSTEM DEFECTS

The following section describes the system problems and defects that were gathered. The methods used were general discussions with staff and management, questionnaires and problems mentioned in the weekly meetings held at the Transmitter Control Centres. Out of these methods the following problems were formulated.

1.2.1 MANAGEMENT PROBLEMS

The following statements, as expressed by management, is an indication of the problems they experience with the system.

- The current radio telephone system does not fulfil in the requirements for managing the maintenance centres at Cape Town, George and Vredendal on a daily basis. The current control codes used by the system are limited and non-standard.
- The system does not allow easy expansion or interfacing to external equipment.
- Not all the functions of the stand-alone telephone patch are available.
- Voice priorities over telemetry data transfers are not fully operational throughout the whole system.
- The call-out system does not call the new radiotelephone handheld.

1.2.2 SOFTWARE PROBLEMS

The following statements are an indication of the software problems that are experienced with the system.

- The two versions of software that is used in the system sometimes causes confusion - one for high sites and one for spur sites.
- If there is a change in the software the Erasable Programmable Read Only Memory (EPROM) on site must be changed, taking care that the correct type for the site is installed.
- The routing tables that controls the limited auto route set-up of the system form part of the compiled software and cannot be changed without recompiling and installing EPROM's on all the sites.
- Due to the assignment and use of Dual Tone Multi Frequency (DTMF) signalling control codes on the radiotelephone (RT) system, the codes 7,8,9 and 0 cannot be used for addressing. Only a limited number of addresses can be assigned, using only digits 1-6 and no address can be repeated in any of the three systems.
- The "*" has been assigned to shut the accessed sites down after a conversation has been terminated. The phone patch uses the "*" as the attention code, thus every time you want to issue a command to the phone patch, you shut the system down.
- The cell call system uses two tone signalling to call a mobile or handheld. The new handheld use DTMF signalling and cannot be contacted. The call-out system uses the RT cell call to contact the person on standby and the old unreliable handheld must still be used to monitor the call.
- There is no automated communication between the sic boxes, thus full automation is not possible with the current system.
- When the radiotelephone system is accessed, a node controller inhibit line is set. This is used to stop telemetry data transfer. The VHF channel inhibit is activated every time the receiver receives audio, thus when data is sent on the VHF, the receiving site stops its node controller to receive the data.
- When the system has been accessed, one person can keep the system busy for an indefinite time. All data transfers and other communications are then blocked.
- Any person can issue the termination command from any site and so cut a conversation midway. All the users try to get their call through immediately by using this method to gain access.

- By setting the address at the system's interface controller to above 80 hex, the built in tests are activated. These tests are used to align the system. To get back into the normal operating mode the site address must be set again.

1.2.3 HARDWARE DEFECTS

The following statements are an indication of the hardware problems that are experienced with the system.

- The audio level alignment of the system is very critical as there is input and output adjustments on each board. The result is that there is more than one adjustment per signal path. The receiver output is a transformer and the effect is that any change to the load will cause a change in level. This is so critical that two identical boards, in the same system, are not interchangeable. Alignment of the system can take up to two man-days per site.
- The Central Processor Unit (CPU) used in the system is an 8085 processor from Intel Corporation. Support for the chip has been withdrawn since 1985.
- Two-tone signalling was added later by modifying the keyboard and DTMF generation. The keyboards are now starting to fail and no replacements are available.
- When the display stops working, the system stops in a loop, waiting for the display to respond. The system will only start to operate once the display has been replaced.
- The old handheld units use two-tone signalling for cell calls and the system was programmed accordingly. The handheld units were replaced with new 12.5 kHz channel spacing units, to comply with the new international regulations. The new unit's uses DTMF signalling that makes them not fully compatible with the current system.
- The call-out system does not handshake with the RT system, with the result that a call will be sent regardless if the RT is in use.

1.3 OBJECTIVES OF THE UPGRADE

The project can be broken up into five phases, each with its own objectives. These are upgrading of existing hardware, control codes of the system, interfacing of the telephone patch, interfacing of the telemetry data transfer and automatic routing capabilities.

1.3.1 PHASE 1: UPGRADING OF EXISTING HARDWARE

To improve the functionality of the current system, the hardware has to be upgraded and modified. The objective of phase one is to improve the hardware. Only the micro controller will be redesigned. All other hardware changes will mainly consist of component value changes.

- **Alignment Procedures**

The current alignment of the system takes about two man-days per unit. The objective of this step is to determine the current alignment procedures used and ways and means to simplify and streamline them. It is assumed that some of the new alignment procedures can be implemented in the current system.

- **UHF Mixers**

The mixers are used to link the UHF radiotelephone links with one another. The objective of this step is to modify the existing UHF channel audio mixers to eliminate some or all of the alignment procedures on the board.

- **UHF and VHF Controllers**

The two controllers are used to interface the on site controls and handset to the radio telephone system. The objective of this step is to modify the UHF and VHF radiotelephone controllers to eliminate some or all of the alignment procedures on the board.

- **Micro Controller**

The objective of this step is to redesign the micro controller board and incorporate the existing modifications in the system. Also to expand and improve the hardware capabilities of the micro controller board. The existing micro controller used in the system is based on the obsolete 8085 processor from Intel Corporation and will be replaced by the more modern 8032 from the same company.

- **Power Supply**

The objective of this step is to evaluate and possibly redesign the current power supply regulator, to cater for the increased power consumption of the new system.

1.3.2 PHASE 2: CONTROL CODES OF THE SYSTEM

The objectives of phase two are to improve the overall control of the system. The first phase software has to interface with the existing system as it is currently in daily use and cannot be taken out of commission for any length of time. Once all hardware modifications have been completed, the second phase software can be implemented.

- **Reverse Engineering of the current system in use**

Analyse the current system software to provide a better understanding of its operation, providing flow diagrams of all procedures. Compile a list of the existing functions, codes and shortcomings.

- **Research on existing control code trends**

Gather information on control codes and standards from industry. Research the implementation of new codes on the radiotelephone system and what effect it will have on the operational procedures of the maintenance centres.

- **Implement a radiotelephone unit**

Implement an experimental radio telephone unit that includes the functionality of the new system that can communicate with the old system. Analyse the operational procedures of the new unit.

1.3.3 PHASE 3: INTERFACE OF THE TELEPHONE PATCH

The objective of phase three is to review the operation of the telephone patch and how it can be enhanced by software solutions. Analyse the current hardware interface and handshaking to the radio telephone system to improve overall operation.

1.3.4 PHASE 4: INTERFACE TELEMETRY DATA TRANSFER

The telemetry data is transferred on the radio telephone system by the Transmit Net network node controller. The objective of phase four is to research and develop the procedures needed to handshake with the Transmit Net controller, allowing proper utilisation of the current channel capacity. Also to streamline and improve the call-out system used by the telemetry.

1.3.5 PHASE 5: AUTOMATIC ROUTING CAPABILITIES

The objective of phase five is to implement automatic routing capabilities. The second phase software will be implemented in this phase.

- **Experimental radiotelephone system**

Implement an experimental radio telephone system as a test rig for testing the new codes and procedures to be used in phase 2 software. Finalise the software to be installed on the current system

- **Automatic routing**

Research the procedures and protocols needed for automatic routing and re-routing and what effect it will have on overall system performance. Develop the controlling software and test it on the experimental system. Finalise hardware design and modifications to be implemented on the new system.

- **Upgrade of the existing radiotelephone units**

Complete production of the hardware units and modify all radio telephone units in the region to the new system with phase one software.

- **Automatic routing software**

Install automatic routing software in Cape Town area and do field studies on the operational success. Finalise the software and install it in the whole region.

1.4 IMPLEMENTATION STEPS OF THE UPGRADE

To be able to implement the upgrade, the following steps were followed in the research and development of the new system.

- Create a block diagram of the current system interface controller to fully understand the hardware functions of the system.
- Using the source code of the old processor draw a complete set of flow diagrams to fully understand the software operations of the system.
- Gather and define the list of problems with the system and then compile a specification list.
- Build two systems interface controllers as test rigs to be used in the development of the hardware and software.
- Research, design and implement the modifications on the system to reduce the alignment procedures and implement them as a preparation to the new microprocessor board.

- Research, design and develop the new interface controller and manufacture two prototype units to be used in the test rigs.
- Develop the diagnostics software and controlling software to test the new boards.
- Refine the micro controller and manufacture the pre-production boards for final testing.
- Start with the development of the operational software and refine the diagnostics software by adding the system test and set-up modules.
- Manufacture 40 units of the processor board to be implemented in the region.
- Compile 30 modification kits and instruction manuals to implement the modifications to eliminate the alignment procedures in the Western Cape Region. Co-ordinate the implementation of the modifications.
- Complete the first phase software and implement a new processor board in the Cape Town region for field trials.
- Refine the software and compile the 30 installation kits to install the new processor boards. Co-ordinate the installations and give training courses for staff at Cape Town, Vredendal and George.
- Continue with software refinement, maintenance and functionality upgrades.

1.5 STRUCTURE OF THE THESIS

- The background to the upgrade is given in chapter one and as well as the problems experienced with the radio telephones system.
- The description of the operation of the system modules and the functions that they perform.
- The description of the functions of the new micro controller board and the hardware modifications to eliminate the alignment procedures in the systems interface controller.
- The description of the test results on the audio paths that were obtained during the research into the alignment elimination process.
- The description and structure of the diagnostics and operational software.
- The four appendices give the following information:
- Appendix A. Micro controller circuit descriptions and diagrams.
- Appendix B. The flow diagrams for the operational and diagnostics software.

- Appendix C. Source code of the operational and diagnostics software.
- Appendix D. Installation disk for the controlling software.

CHAPTER 2

2 LITERATURE REVIEW

The review is in two parts. The first section will deal with the radios and the second section, where most of the research will be carried out, the controlling software.

2.1 RADIO TELEPHONE SYSTEM

The first step in implementing a system is to decide what the operational frequencies and mode of operation of the radiotelephone (RT) system will be. The following four options are available [9]. If a single frequency is used, the system is said to be a simplex system. Two modes of operation are possible: single direction simplex and two-direction simplex. In both modes communication is in one direction at a time. Dual frequency half-duplex where one frequency is used in one direction and the other in the opposite direction, but transmission is in one direction at a time. This mode is most commonly used for mobile vehicle radio systems. Dual frequency full duplex where both transmit and receive communications occur simultaneously. The current Sentech system is already in existence using two modes of operation: dual frequency half duplex to mobile units and dual frequency full duplex to fixed sites. The system uses a mixture of very high frequency (VHF) and ultra high frequency (UHF) frequencies. Channel spacing is the distance in hertz (Hz) that two carriers is from each other. This spacing is currently set to 12.5 kHz for VHF and 25 kHz for UHF. The original design of the system was for 25 kHz spacing as used internationally at the time [9]. The VHF spacing was later changed to 12.5 kHz as instructed by the then telecommunications regulator to set more channels free for other users.

2.1.1 COMMUNICATION LINKS AND TALK-THROUGH

Two possibilities exist that will connect the control centre with the remote site housing the base station. These are landlines normally provided by a line telephone system, or by radio links where poor infrastructure exists. The link path between the control centre and base station is normally fixed "line of site". The more demanding characteristics of UHF or microwave frequencies can thus be accommodated.

In dual frequency, simplex operation mobile units can communicate with the control centre but cannot communicate between each other. The requirement is thus for the base station to re-transmit the received audio signal, so that the other mobile units can receive it. This operation is known as talk-through. Inter mobile communication is one of the advantages and the other is that in the event of a link failure, some sort of communication still exists. Controlling the talk-through conditions has to be strict to avoid unwanted triggering at the base station.

2.1.2 SIGNALLING METHODS

"Selective-Calling" has been associated with more complex systems. This provides the capability to identify a particular mobile or group of mobiles. This facility is vital in cellular radiotelephone systems. The following techniques are generally employed based on two types of signalling, "out of band" below 300 Hz and "in band" between 300 and 3500 Hz [20]. The out of band signalling is also known as Sub-audible tone signalling. This system employs a continuous tone below 300 Hz to enable the selected receiver. The system is known as either Continuous Tone Coded Sub-audible Squelch (CTCSS) [20] or Continuous Tone Controlled Signalling System (CTCSS) [15]. This system is restricted in the number of separate codes available for signalling and is frequently used with other signalling schemes as an additional safeguard preventing the reception of unwanted transmissions.

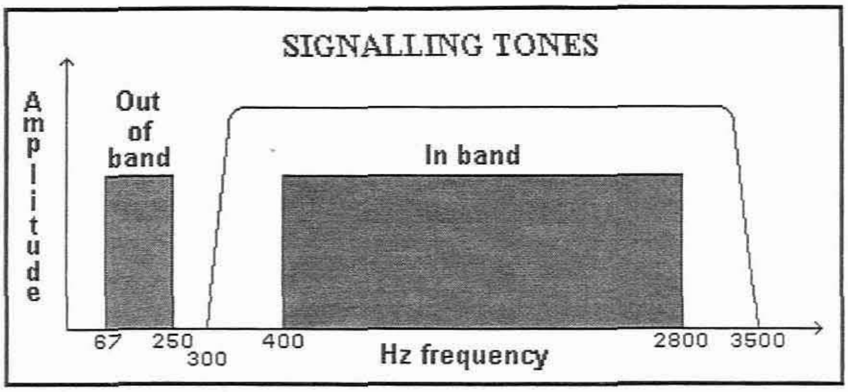

Figure 1: Radiotelephone frequency spectrum allocation [20]

Single tone burst signalling is the simplest in band signalling method and uses a single tone burst to address the receiver. As each receiver uses a frequency in the audio band, a very limited number of receivers can be addressed. Allowing for tone separation the scheme can accommodate up to 40 separate receivers [20]. An improvement on this scheme is the sequential single tone system. This scheme uses a sequence of tones consisting of two [14] to five tones [20]. The sequence of two tones give a theoretical limit of 1600 receivers but practically a limit of 100 receivers can be reliably controlled [14]. Using a sequence of 5 tones to address the receiver, a theoretical limit of 100,000 receivers is reached. At present the commonest examples are Comité Consultatif International Radio Communication (CCIR), Zentralverband der Electrotechnischen Industrie (ZVEI) Germany and Electronic Engineering Association (EEA) United Kingdom [15][20].

Sequential dual tone systems use signalling tones known as Dual Tone Multi-frequency (DTMF) tones. This standard originated on the public telephone systems and the extended DTMF tones use the digits 0 to 9, *, #, and A to D. These digits are represented by two-tone frequencies transmitted simultaneously. To call a station, the tone pairs are sent sequentially and can also be used on the public telephone network. To avoid false triggering by voice, also known as "falsing", frequencies for each tone pair were chosen carefully to represent a digit [20].

Digital selective calling can be used on both digital and analogue systems. Digital techniques provide more addresses, higher transmission rates and error detection and correction protocols. At present a system known as digital selective calling (DSC) is being implemented in the Global Maritime Distress and Safety System to be completed by 1999 [20].

Additional features become available when sequential tone systems are implemented. It is often desirable to communicate with several mobiles simultaneously, known as group calling [15]. A group tone or digit is transmitted in the place of some of the address codes enabling calling of 10, 100 or 1000 units. Secondly it is often convenient to have confirmation that a mobile has received the message. This is achieved by making the mobile respond with its own code after receiving its own address. This process is frequently referred to as "vehicle identification".

2.1.3 RADIOTELEPHONE SERVICES

If a system is capable of accessing a local line network, it is a small step to extend the operation to the national telephone system. Total automatic connection between the radiotelephone and line telephone systems are now commonplace, but was not available when this project was started. The more common way was to provide an operator to do the dialling and connecting. Implementing the system puts new constraints on the codes and signalling techniques as, historically, radio telephones and line telephones developed their own codes of practice, engineering philosophies and standards.

2.1.4 AREA COVERAGE TECHNIQUES

Most radiotelephone systems are required to operate over larger areas than can be covered by a single base station. To solve this problem, some kind of area coverage technique must be implemented. Multiple transmitters are used to cover a given area and generally simultaneous operation is better than sequential operation. A technique known as "quasi-synchronous operation" (also known as Simulcast) [15] is used for simultaneous operation. It was assumed that due to the capture effect inherent in frequency modulated

(FM) receivers, the mobile would only respond to the strongest signal. Periods of equal signal strength would be infrequent giving no reception. In practice, it was found that unless both phase and amplitude of the modulating signals were carefully matched, good performance could not be obtained. The matching was more easily achieved using radio links rather than landlines. Using radio links led to the phrase "backbone" where the links between the base stations formed the backbone of the system with the base stations connected to it.

The alternative is to sequentially turn the transmitters on at the base stations. However the operator does not know where the mobile is and a mobile location scheme or "voting" system must be incorporated. This involves the sequential calling of the mobile from all the base stations. On receipt of it's call code it automatically answers. All the base stations that receive the signal will then decide between them on the optimum station, i.e. the receivers "vote" as to the best station to use. When the mobile transmits first, the "voting" will automatically select the optimum station. At UHF the range can be extended by "on frequency" repeaters, but are not generally favoured due to the difficulty in implementing them.

2.2 NETWORKING PROTOCOLS

As the Sentech radio telephone system is already in existence and limited control over the system is available, the following sections of the literature that will be dealt with is mainly on how to design protocols and types of protocols.

2.2.1 PROTOCOL LAYERS

Generally protocols are implemented in layers and each layer will then provide a specific service for the layer above and use the services provided by the lower layers. The scheme is used in all protocols and is known as the protocol stack. All protocols are made up of five distinct parts and is known as the five elements of a protocol [8] and is:

(i) The service to be provided by the protocol.

(ii) The assumptions about the environment in which the protocol is executed.

(iii) The vocabulary of messages used to implement the protocol.

(iv) The encoding (format) of each message in the vocabulary.

(v) The procedure rules guarding the consistency of message exchanges.

The five elements form the basis for any kind of information transfer. between two stations.

2.2.2 PROTOCOL DESIGN

The next step is the design of a protocol. The International Standards Organisation has a model known as the Open Systems Interconnection (OSI) model and proposes a 7-layer stack. This has been accepted internationally as a standard and nearly all protocols implement it. The principles of the layers are as follow [18]:

(i) A layer should be created where a different level of abstraction is needed.

(ii) Each layer should perform a well-defined function.

(iii) The function of each layer should be chosen with an eye towards defining internationally standardised protocols.

(iv) The layer boundaries should be chosen to minimise the information flow across the interfaces.

(v) The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity, and small enough that the architecture does not become unwieldy.

The design issues for the layers [18], states that each layer must have a mechanism for connection establishment, some form of addressing to specify the destination and a mechanism to terminate the connection. The rules for data transfer must be laid down and what type of error detection and correction control will be implemented. Some sort of feedback is needed to stop a fast sending transmitter swamping a slow receiver and breaking up long messages into smaller units. The ten rules [18] for designing a protocol is:

(i) Make sure that the problem is well defined. All design criteria, requirements and constraints, should be enumerated before a design is started.

(ii) Define the service to be performed at every level of abstraction before deciding which structures should be used to realise these services (what comes before how)

(iii) Design external functionality before internal functionality. First consider the solution as a black box and decide how it should interact with its environment. Then decide how the black box can be organised internally. It likely consists of smaller black boxes that can be refined in a similar fashion.

(iv) Keep it simple. Fancy protocols are "buggier" than simple ones, harder to implement, harder to verify, and often less efficient. There are few truly complex problems in protocol design. Problems that appear complex are often just simple problems huddled together. Our job as designers is to identify the simpler problems, separate them, and then solve them individually.

(v) Do not connect what is independent. Separate orthogonal concerns.

(vi) Do not introduce what is immaterial. Do not restrict what is irrelevant. A good design is "open-ended," i.e., easily extendible. A good design solves a class of problems rather than a single instance.

(vii) Before implementing a design, build a high-level prototype and verify that the design criteria are met.

(viii) Implement the design, measure its performance, and if necessary, optimise it.

(ix) Check that the final optimised implementation is equivalent to the high-level design that was verified.

(x) Don't skip Rules (i) to (vii)

The most frequently violated rule is Rule (x). When a protocol is designed it must be kept in mind that they can fail under certain conditions. The ways that they can fail are [8]:

(i) Deadlocks - States in which no further protocol execution is possible, for instance because all protocol processes are waiting for conditions that can never be fulfilled.

(ii) Livelocks - Execution sequences that can be repeated indefinitely. Often without ever making effective progress.

(iii) Improper terminations - the completion of a protocol execution without satisfying the proper termination conditions.

These points form a good framework to use in implementing a control system between the RT units as they can be seen as a "network" of controllers. When the research was started no automated communication was possible between any of the controllers. With the upgrading of the microprocessor, serial communications capabilities were added to the hardware. Thus to be able to implement a fully automated system, proper structured communications has to be designed and implemented between the controllers.

2.2.3 FLOW CONTROL SYSTEMS

In order to show the flow of control in a protocol, some form of flow-charting must be used. Using a picture will highlight any flow control problems faster than trying to describe them. The protocol flowchart symbols deviate from the normal flowchart types and the six different types given in figure 2 are:

(i) Statement - assignments.

(ii) Boolean tests - expressions.

(iii) Wait conditions - receives.

(iv) Internal events - timeouts.

(v) Message inputs

(vi) Message outputs

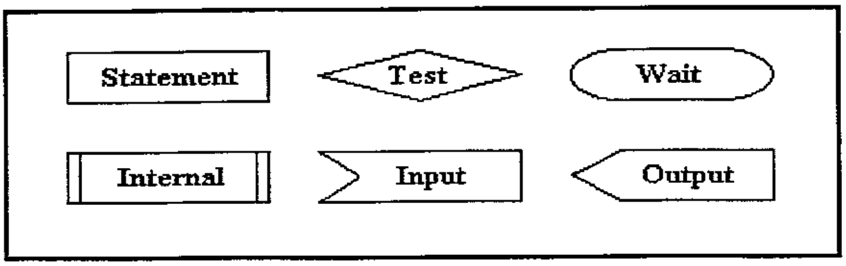

Figure 2: Flow chart symbols for a protocol [8]

To transfer messages between two points, a protocol must have a method to control the flow from one point to the next. This includes the acknowledgement of the received messages or the rejection when errors are detected. It is also used to control the rate that a transmitter can send messages to the receiver. The most widely used is the sliding window protocol, where a certain number of message acknowledgements can be outstanding. Another method is the "Ping Pong" method where a message is sent and the next one will only be sent once an acknowledgement is received. The last type is the X-on/X-off protocol, where the transmitter is controlled by the receiver, by means of an on or off message. This protocol is currently used mainly between computers and serial peripherals and not on networks itself. [5][8][18]

2.2.4 TYPES OF ERRORS

No protocol will ever operate without encountering errors while transferring messages between transmitter and receiver. The loss and re-ordering of messages and time outs are the most common errors that occur. The rate control of a protocol is set so that there is a minimum of timeouts and re-transmissions, as this will decrease the data throughput. When implementing sliding windows, the maximum window size can be reached when there is a slow receiver. By using the negative and positive acknowledgements, dynamic flow control can be implemented that will adjust the window size to the acknowledgement rate. A way of increasing the rate is to block acknowledge messages. This involves the sending of a range of messages and acknowledging only the range that was received error free. [8][18]

2.2.5 DATA FORMAT

In order for a message to be sent from one point to the next, the format of the data must be specified. The type of channel used is serial and the two types of encoding to represent the data are asynchronous or synchronous. The data is transferred over the channel, using one of three types of modulation - amplitude, frequency or phase, as normal transmission lines do not transfer raw digital data easily. When transferring the data, transmission errors will occur. These errors are introduced by the channel and include the following types of errors. Insertion and deletion where bits are inserted or removed from the data stream. Duplication or re-ordering is when complete messages are duplicated or re-ordered. Normally when messages can follow more than one path to the destination and distortion when noise is encountered on the channel itself. In order to check that the data was received correctly, an error detection scheme can be implemented. This will ensure that the messages are received "error free".

The types of error detecting codes are:

(i) Block codes - all code words have the same length

(ii) Convolution codes 2 depends on the data message and a given number of previously encoded messages

(iii) Linear codes - every linear combination of valid code words, produces another valid code word (modulo-2 sum)

(iv) Cyclic codes - every cyclic shift of a valid code word, produces a valid code word.

(v) Systematic code - each code word includes the data bits from the original message unaltered. [8][15][18]

2.3 LITERATURE REVIEW CONCLUSION

In the previous sections it can be seen that when implementing a radio telephone system, a great deal of different facets have to be taken into account. Installing even a basic system, planning it is of crucial importance. Expanding it into a system similar to the one used currently by Sentech, increases the problem tenfold. Once the basic hardware is installed and operational, controlling the system is of utmost importance. These systems must be available 24 hours a day and is normally used in areas where there is no other means of communication. The sites they service are in remote areas, on top of mountains. Accesses to the sites are by hiking trails or two track 4x4 roads that are travelled in all adverse weather conditions. Having a system with basic controls is useful up to a point, but using a proper automated control system can enhance the functionality of the system. The control system will only operate successfully, if the basic design is based on sound networking principals. Experience with the current radiotelephone system and Sentech telemetry system, showed that when a protocol evolves without proper design, a constant fixing of symptoms and not root problems will occur. This work addresses these problems by sound research principals and designing the control system properly.

CHAPTER 3

3 RADIO TELEPHONE SYSTEM OPERATION

3.1 INTRODUCTION

During the early 1980's the old radio telephone system was replaced with the one used currently. The old system consisted of a repeater site at Table Mountain, which relayed the signal from as far as Villiersdorp site. The current system was installed based on imported radio equipment and a controlling system developed locally.

3.2 SYSTEM CONFIGURATION

The Cape Town radiotelephone system will be used to explain the general layout of the sites and operation. The terminology that is used was given to the sites by the original supplier and has been used ever since. The sites that have UHF and VHF sets are called high sites and form the backbone of the system. The rest of the sites only have VHF sets and are called spur sites. The mobile units consist of handheld sets and sets installed into the fleet vehicles.

3.2.1 SYSTEM LAYOUT

The system is configured so that there is a permanent li.e backbone on UHF, between the high sites. The VHF radios at the high sites are used to communicate to mobile units and spur sites. The VHF radios can be linked to the backbone to extend the range. This operation is called VHF linking or VLINK. The VHF sets can also be made into a repeater, for communication between two mobile units via the high site. All sets use different frequencies for transmit and receive, enabling full duplex communication. The VLINK is not a permanent link, making it possible to accommodate more than one call at a time, without interfering with each other. The spur sites are fixed sites that communicate to the nearest high site, via the VHF radio. If a mobile wishes to communicate to the spur site, it's transmit and receive frequencies are swapped. With a mobile unit communicating to a spur site and the spur site turned into a repeater, the coverage area of the system is vastly increased. The layout of the Cape Town system is shown in figure 3 and the different meanings of the codes of the sites are given in table 1.

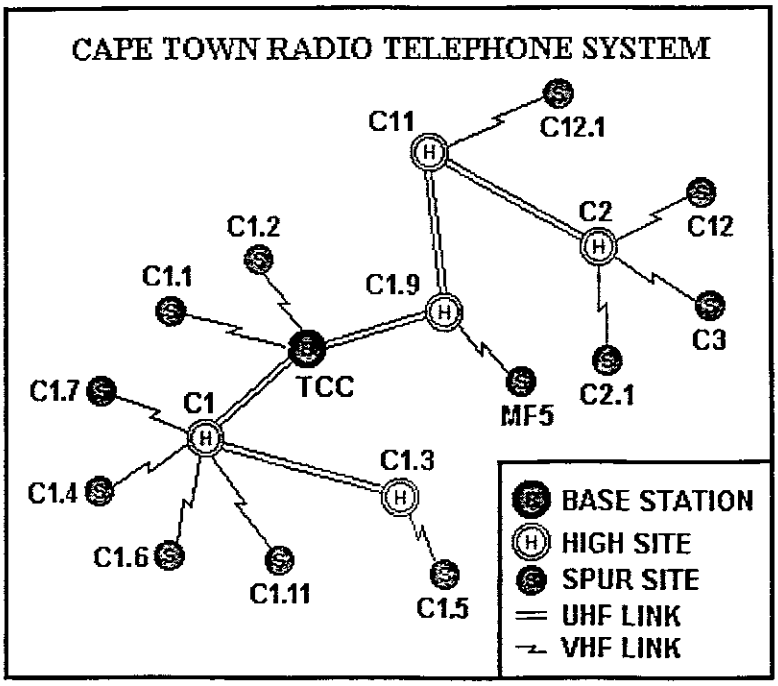

Figure 3: System layout

SITE	DESCRIPTION
TCC	Cape Town Transmitter Control Centre, Milnerton
C1	Constantiaberg
C1.1	Table Mountain
C1.2	Ritz Protea Hotel, Sea Point
C1.3	Paarl
C1.4	Simonstown
C1.5	Franschhoek
C1.6	Stellenbosch
C1.7	Houtbay
C1.9	Tygerberg
C1.11	Fishhoek
C1.15	Grabouw
C2	Villiersdorp
C2.1	Hermanus
C3	Napier
C11	Piketberg
C12	Matjiesfontein
C12.1	Ceres
MF5	Klipheuwel

Table 1: Cape Town area site names

3.2.2 HARDWARE LAYOUT

The hardware layout for all the high and spur sites is identical. The configuration of the site determines what printed circuit boards will be installed. Figure 4 gives the layout of the hardware and the following sections describe the basic operation of the boards.

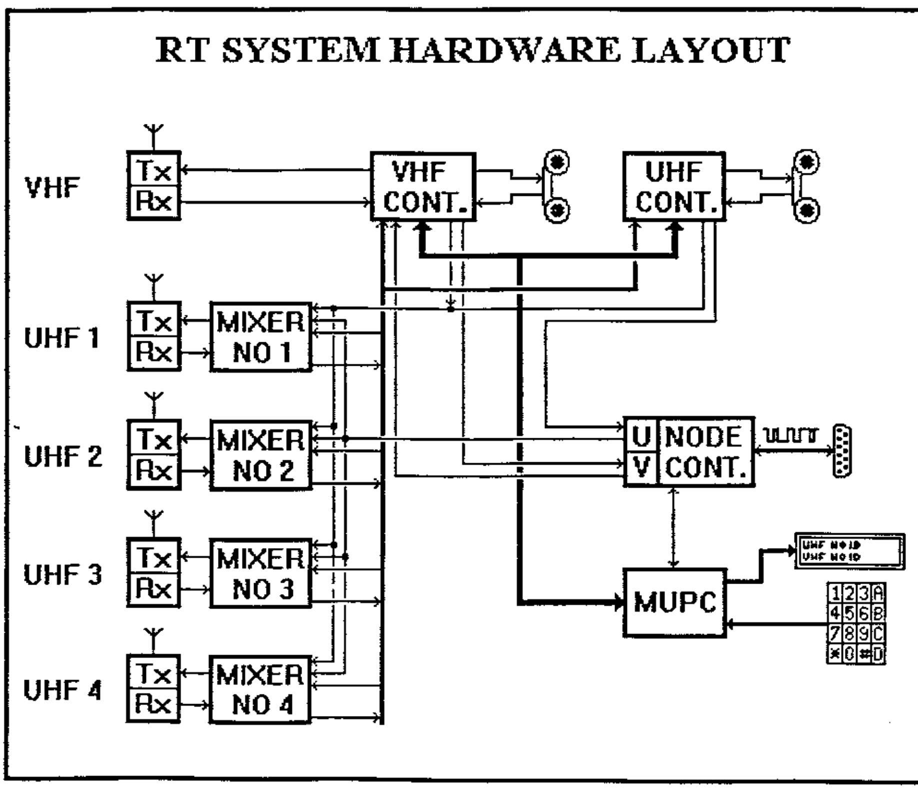

Figure 4: General hardware layout for a generic site

- ### MUPC Micro controller

The MUPC board that contains the microprocessor and software, controls the system. The keyboard and display is connected directly to the board, for local system command inputs and display of system status. The decoded DTMF signals on the UHF and VHF radios are interpreted by the board and the system status displayed. The board generates all tones and control signals. This board was completely redesigned and 40 were manufactured to replace the old processor boards. The name MUPC was retained for the new board, to minimise confusion and was released as version 1.1.

- ### VHF Controller

The controller is the interface between the VHF radio and the internal audio paths to the handset, UHF radio's and Node controller. The VHF repeater and VHF to UHF VLINKing are done on the board. The VHF press to talk from the handset, node controller and MUPC is combined and sent to the VHF radio. The VHF DTMF tones are decoded on the board and the MUPC interrupted when a valid tone is decoded. The board is part of the original system and the upgrade work done on it, consisted of the elimination of the variable resistors by replacement of fixed resistors.

- ### UHF Controller

The controller is the interface between the UHF radios and the internal audio paths to the handset, VHF radio and Node controller. The UHF DTMF tones and the key busy signal are decoded on board and the MUPC interrupted, when a valid code is decoded. The board is part of the original system and the upgrade work done on it, consisted of the elimination of the variable resistors by replacement of fixed resistors.

- ### UHF Mixers

The UHF mixers combine the audio signals from the UHF radio's, VHF controller, UHF handset, key busy signal generator, DTMF generator and Node controller. This combined signal drives the UHF transmitter and the received signal from the receiver is buffered on the board. There can be a maximum of four UHF radios on a site and the number of UHF links to the site determines the number of mixers installed. The board is part of the original system and the upgrade work done on it, consisted of the elimination of the variable resistors by replacement of fixed resistors.

- ### Node controller

The Node controller implements a computer network on the radiotelephone system and is based on a subset of the X.25 packet switching network protocols. It functions completely separate to the control of the radio telephone system, using only the radio carriers. The node controller is used to transfer telemetry data from the sites to the Transmitter Control Centre. These boards were developed as a separate project by the author of this paper.

3.2.3 SOFTWARE CONFIGURATION

There are three software modules that were used to control the radio telephone system. These modules are programmed into an erasable read only memory (EPROM) that is on the MUPC board. Changes to the software can only be implemented by reprogramming of the EPROM. Module one is the high site software that controls all operational functions of the site. Module two is the spur site software that controls the operational functions of the site. Module three is the diagnostic module that is used to align the radio telephone system. A copy of it is programmed into the EPROM of the high and spur sites and is activated by setting up a null address and resetting the MUPC.

3.3 OPERATIONAL PROCEDURES

The following section describes the basic operational procedures that are currently used to access and control the operation of the radio telephone system.

3.3.1 ACCESS OF SITE

To access or 'ID' a site, the two digit site code of that site must be keyed and these codes must be in DTMF format for it to be recognised. If the site is accessed and has recognised the codes, a beep-baap tone is generated tc indicate that the operation was successful. If a spur site is accessed transmit and receive frequencies is swapped in the handheld.

3.3.2 AUTOMATIC ROUTING

The system has routing lookup tables that are programmed into the EPROM and are used to implement a semi-automatic routing protocol. If a high site is used to originate the call and a remote spur site is accessed, the high site will automatically vlink the audio path. If a spur site is used to access a remote high site, the local high site must first be accessed before the remote high site can be accessed.

3.3.3 REMOTE CONTROL

The system has limited remote control capabilities that can be used to control external equipment on site. Switching the MUPC into remote control mode, activates the output control. To do this, access the site and ring the buzzer for longer than 5 seconds. A baap-beep tone is generated and then by sending DTMF codes 1 to 6, the lines will go high as long as the tone is there.

3.3.4 ACCESS OF TELEPHONE PATCH

The telephone patch is an external unit that was added to the system at a later stage. The codes that is used to control it, conflict with the radio telephone system codes. The result is that only a limited number of functions can be used. The '*' code is used to get the phone patch attention and is also used by the radio telephone system as the shutdown code. When keying the codes for the phone patch, the duration of each code must be very short, to allow the phone patch to recognise it and the radiotelephone to ignore them.

3.4 TELEMETRY DATA TRANSFER

The separate Transmit Net telemetry data transfer system uses only the audio paths to transfer the data over the radiotelephone network. A network node controller is plugged into the System Interface Controller of the radiotelephone and all data transfer and routing is processed in it. The node controller implements a computer network on the radio telephone system and is based on a subset of the X.25 protocols with minor deviations at the lower levels.

3.4.1 LAYOUT OF NETWORK

The layout of Transmit Net is based on high sites and spur sites. The system is configured so that there is a maximum of 15 high sites, each with 15 spur sites communicating to them. The routing is calculated at each node using the source, destination and local addresses. For this reason the high site address must end with a one. See figure 5 below for the layout of the system.

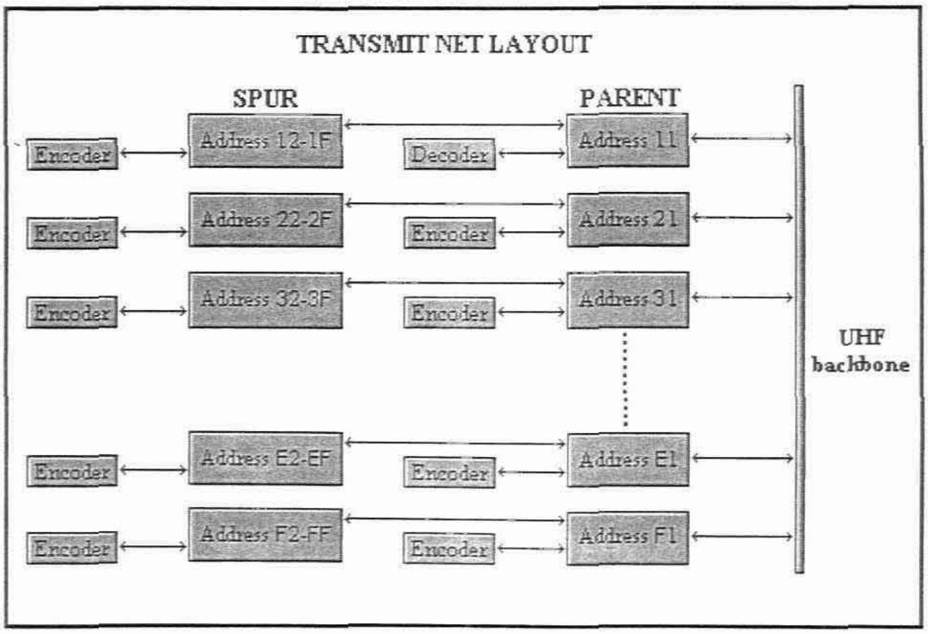

Figure 5: Encoder / Decoder network layout

3.4.2 LAYERS OF NETWORK

The data transfer system is based on a subset of the X.25 protocol implementing layers 1 to 3 of the protocol stack. The telemetry encoder and decoder protocol do not conform to any standard protocols, thus a module in the node controller converts the packet into a X.25 packet and from X.25 to the telemetry packet format. The data link layer uses a SDLC synchronous protocol on the UHF backbone and asynchronous protocol on the VHF radios. Due to the amount of interference on the VHF radiotelephones the asynchronous protocol was found to be more reliable than the synchronous protocol. See figure 6 for the protocol layer mapping.

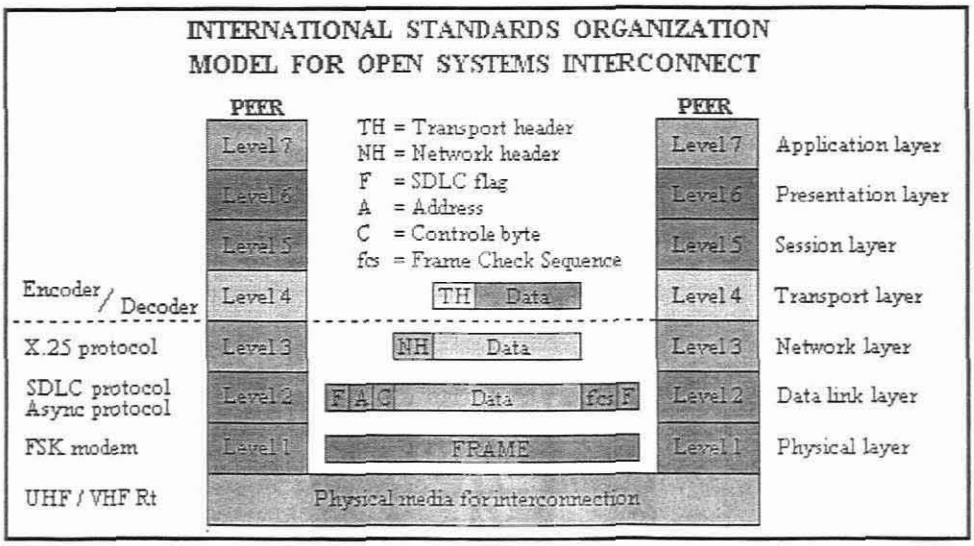

Figure 6: Schematic showing the mapping of the network layers

3.4.3 INTERACTION OF THE RADIOTELEPHONE AND NETWORK

The radiotelephone system and the telemetry data transfer system are two independent systems using the same carrier. The original specifications of the radiotelephone specify that speech has priority over data. The UHF and VHF inhibit lines implement this and will stop any data transfer as soon as the radiotelephone is used for speech.

CHAPTER 4

4 RADIO TELEPHONE SYSTEM UPGRADE

4.1 HARDWARE UPGRADE

This section gives the description of the changes to the hardware that was implemented in the radio telephone system. These changes include the upgrading of the hardware and the changing of the alignment procedures.

4.1.1 MUPC MICRO CONTROLLER UPGRADE

The original controller board was named MUPC. The name MUPC stands for Microprocessor Unit Process Controller and has been retained to minimise the impact on the staff that have to use and repair the system. The new micro controller that is used in the radio telephone system was developed to replace the old board, that became obsolete. Modifications that were added to the system before the upgrade were incorporated into the new board. The micro controller plugs into the existing slot and the pin-out functions are logically the same as the old board.

Functions of new card:

The following section describes the different functions of the board. Figure 7 gives a layout of the sections of the board.

- **Central Processor Unit**

The CPU is the heart of the system and it consists of the CPU, control logic and memory. Configuration switches switch in an EPROM that contains the diagnostics software or a flash prom for the operational software. When in diagnostics mode, the flash prom is mapped to the ram area, enabling the card to load the operational software. The operational parameters can be programmed into the card by the controlling software, or from the keyboard, depending on the diagnostics mode selected. All operational parameters are stored into a serial EEPROM on board. The processor enhances the system as follows: program memory from 16 to 32 kilobytes, data memory from 2 to 8 kilobytes.

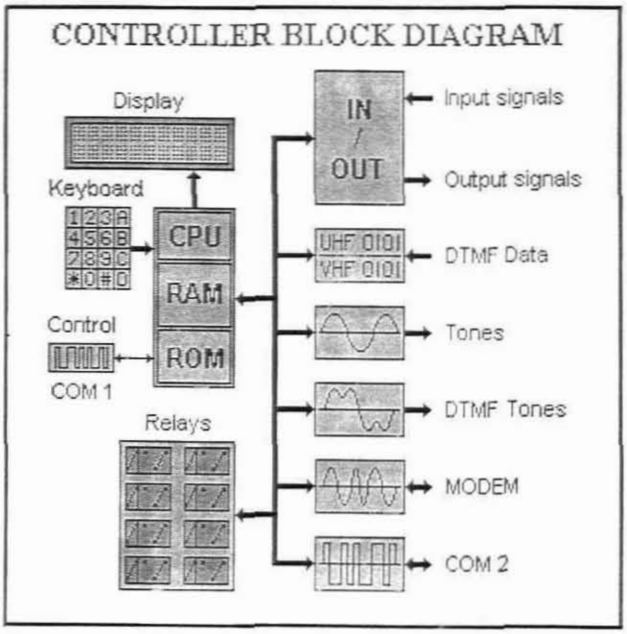

Figure 7: MUPC controller functional block diagram

- ## Keyboard and Display

By adding a keyboard controller, the software scanning of the old, unobtainable keyboard has been eliminated. This provided the electronics to interface commercially available keyboards, which can directly plug into the micro controlle. board, to be used. The benefit of this is that the system keyboard is now more dependent on a specific model of a manufacturer. The display problems were solved in the software driver.

- ## Relays

The relays on the board provide output control signals and replace the TTL output control signals of the old board. This eliminated the need to add buffering electronics to the systems interface controller, so that the control lines could be used. The output control capacity was increased from 6 to 8 output lines.

- **Input / Output lines**

No change or enhancement was needed to the input and output lines that control the rest of the unit. Extra input lines were provided for handshaking, so that more external equipment could be added to the systems interface controller.

- **Tone & DTMF generation**

Alert tone generation for UHF and VHF is now combined into one unit. The external DTMF generator board was removed and the circuitry added to the CPU card. The output levels can now be adjusted on the CPU card without removing it from the rack and the signals are combined and routed to the UHF and VHF channels, as needed. The old keyboard modification on the back plane of the systems interface controller could now be removed.

- **Serial communications**

Three serial ports have been added to the micro controller board. The first port is the control port and is used to monitor the system or control the card when in diagnostics mode. The control software to upload the operational software, to the card, also uses the port. A two-channel serial communications controller forms the second and third ports. Channel A is connected to the modem that is used to send commands between the radio telephone units on the backbone. Channel B is connected to a RS232 driver and is used to communicate to external equipment. These two ports are not used in the first phase software during the modification period of the systems interface controller units.

- **Conclusions**

The upgrading of the micro controller enabled a number of the hardware and software problems to be solved clearly. The replacement controller is able to plug directly into the existing slot of the systems interface controller, as these units will not be replaced. The software emulates all the functions and operations of the old card, as the system have to stay alive while the upgrade process is in operation. Appendix A gives a detailed description of the micro controller board that was implemented.

4.1.2 SYSTEMS INTERFACE CONTROLLER MODIFICATIONS

- **VHF controller modifications**

The VHF controller is the interface board between the VHF radio and the rest of the system. The board is part of the original system and was not redesigned. The upgrade of the board consisted of component changes, to eliminate the adjustment points on the board.

The board combines all the functions needed to interface the audio and digital signals to and from the VHF radio and the micro controller board. Figure 8 shows the block diagram of the board and the points where the adjustments were eliminated.

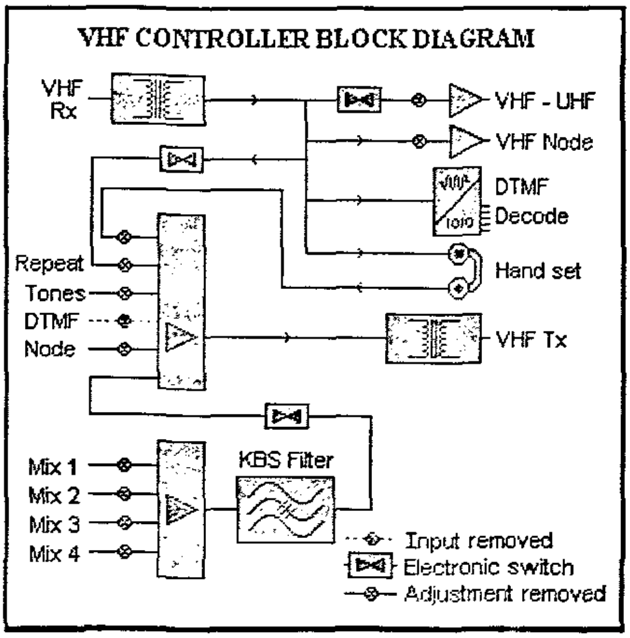

Figure 8: VHF controller block diagram showing the adjustment elimination points

The changes to the board eliminated eleven adjustment points in the systems interface controller.

- **UHF controller modifications**

The UHF controller is the interface board between the UHF mixers and the rest of the system. The board is part of the original system and was not redesigned. The upgrade of the board consisted of component changes, to eliminate the adjustment points on the board.

The board combines all the functions needed to interface the audio and digital signals to and from the UHF mixers and the micro controller board. Figure 9 shows the block diagram of the board and the points where the adjustments were eliminated. The adjustment for the capture range of the phase locked loop, that detects the key busy signal, was retained.

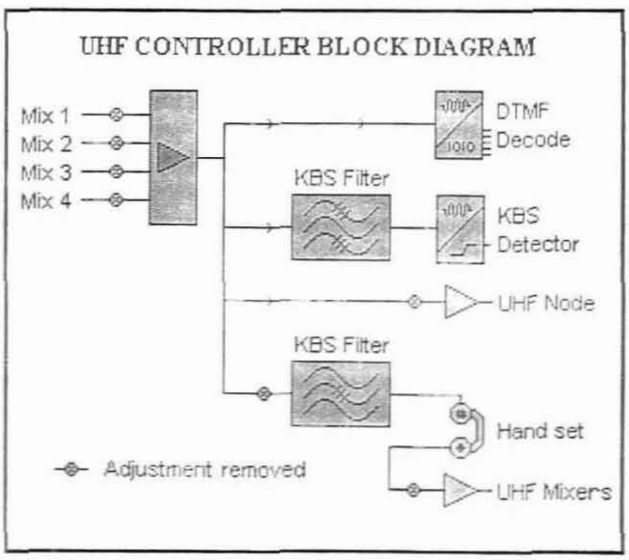

Figure 9: UHF controller block diagram showing the adjustment elimination points

The changes to the board eliminated seven adjustment points in the systems interface controller.

CHAPTER 5

5 AUDIO TEST RESULTS OF THE RESEARCH

The following chapter gives the details and results that were obtained during the adjustment eliminating process.

- ### UHF Node controller test results

The UHF node controller transmit audio level were set to give an output of –11 dBm at the output of the systems interface controller. Two values of input impedance were tested and the results are given below. Table 2 gives the results of the output level changes obtained with the input impedance set to 14K and the node controller output level set to +/- 250 mV P-P.

Table 3 gives the results of the output level changes, with the input impedance set to 18K and the node controller output level set to +/- 300 mV P-P. The output level of the modem had to be readjusted, when boards were removed or inserted, but not when they were interchanged and is due to the node controller's high impedance output.

Mixer no	Mix 1	Mix 2	Mix 3	Mix 4
Input capacitor value	470n	470n	470n	470n
Mix 1 output set to -11 dB	-11.0	-11.2	-11.2	-11.2
Mix 2 output set to -11 dB	-10.9	-11.0	-11.1	-11.1
Mix 3 output set to -11 dB	-10.8	-11.0	-11.0	-11.0
Mix 4 output set to -11 dB	-10.8	-11.0	-11.0	-11.0
Mix 1 output set to -11 dB	-11.0	-11.2	-11.3	XXX
Mix 2 output set to -11 dB	-10.8	-11.0	-11.1	XXX
Mix 3 output set to -11 dB	-10.8	-11.0	-11.0	XXX
Mix 1 output set to -11 dB	-11.0	-11.2	XXX	XXX
Mix 2 output set to -11 dB	-10.8	-11.0	XXX	XXX

Table 2: Mixer impedance set to 14K for the UHF Node controller

Mixer no	Mix 1	Mix 2	Mix 3	Mix 4
Input capacitor value	470n	470n	470n	470n
Mix 1 output set to -11 dB	-11.0	-11.1	-11.1	-11.1
Mix 2 output set to -11 dB	-11.0	-11.0	-11.1	-11.1
Mix 3 output set to -11 dB	-10.9	-11.0	-11.0	-11.0
Mix 4 output set to -11 dB	-10.9	-11.0	-11.0	-11.0
Mix 1 output set to -11 dB	-11.0	-11.1	-11.1	XXX
Mix 2 output set to -11 dB	-11.0	-11.0	-11.1	XXX
Mix 3 output set to -11 dB	-10.9	-11.0	-11.0	XXX
Mix 1 output set to -11 dB	-11.0	-11.1	XXX	XXX
Mix 2 output set to -11 dB	-10.9	-11.0	XXX	XXX

Table 3: Mixer impedance set to 18K for the UHF Node controller

Removing, inserting or exchanging any board or position does not alter the output level more than +/- 0.05 dB. The test results show that the input impedance set to 18K gives the best results.

- ## KBS Tone generator test results

The key busy signal (KBS) audio level were set to give an output of –11 dBm at the output of the systems interface controller. Two values of input impedance were tested and the results are given below. Table 4 gives the KBS output level changes, with the input impedance set to 10K and different capacitor values used in the test.

Mixer no	Mix 1	Mix 2	Mix 3	Mix 4
Input capacitor value	470n	22n	15n	22n
Mix 1 output set to -11 dB	-11.0	-11.6	-11.8	-11.3

Table 4: Mixer impedance set to 10K and different capacitor values for the KBS tone

The input impedance values were changed to 18K and all the input capacitors set to the same value. Table 5 gives the KBS output level changes with the new values.

Mixer no	Mix 1	Mix 2	Mix 3	Mix 4
Input capacitor value	470n	470n	470n	470n
Mix 1 output set to -11 dB	-11.0	-11.1	-11.1	-11.1
Mix 2 output set to -11 dB	-11.0	-11.0	-11.1	-11.1
Mix 3 output set to -11 dB	-10.9	-11.0	-11.0	-11.0
Mix 4 output set to -11 dB	-10.9	-11.0	-11.0	-11.0
Mix 1 output set to -11 dB	-11.0	-11.1	-11.1	XXX
Mix 2 output set to -11 dB	-10.9	-11.0	-11.1	XXX
Mix 3 output set to -11 dB	-10.9	-11.0	-11.0	XXX
Mix 1 output set to -11 dB	-11.0	-11.1	XXX	XXX
Mix 2 output set to -11 dB	-10.9	-11.0	XXX	XXX

Table 5: Mixer impedance set to 18K for the KBS tone

Removing, inserting or exchanging any board or position, does not alter the output level more than +/- 0.05 dB. The test results show that the input impedance set to 18K gives the best results.

- **UHF DTMF generator results**

The following test results are for the phase 1 hardware modifications on the mixer DTMF input line. This input will be removed completely with the installation of the new microprocessor board, as DTMF generation is now incorporated onto the board. Two output levels were tested, as it became apparent during the previous tests, that the changes are working. Table 6 gives the test results and a comparison of the different output levels with the input impedance set to 18K on the new input to the mixer card.

Mixer no	Mix 1	Mix 2	Mix 3	Mix 4
Input capacitor value	470n	470n	470n	470n
Mix 1 set -5 dB DTMF	-5.0	-5.1	-5.0	-5.1
Mix 2 set -11 dB KBS	-11.0	-10.9	-10.9	-11.0

Table 6: DTMF tone level comparison on the mixer card

Removing, inserting or exchanging any board or position does not alter the output level more than +/- 0.05 dB. The test results show that changing the output test level did not have any effect on the output levels.

- **UHF to UHF talk-through**

The changes in level measured between the UHF sets are given in table 7. Cards cannot be interchanged as a result of the output level, changing up to 0.5 dB per card removed or inserted. Levels increased with 0.1 dB when the extender card was removed. With the results obtained in the previous sections, a receiver buffer was added to the mixer card, to provide a low impedance driver. This modification eliminated the large changes observed when removing, inserting or exchanging any board as the output level does not change more than +/- 0.05 dB.

Channel No	Mix 1	Mix 2	Mix 3	Mix 4
Mix 1 - RV 13	15.09	14.80	14.89	14.78
Mix 2 - RV 12	15.15	14.87	14.99	14.86
Mix 3 - RV 11	15.13	14.84	14.97	14.84

Table 7: UHF to UHF level comparison

- **Conclusions**

The elimination of the level adjustments by changing component values were successful. The output and input levels are now set to –6dBm. The alignment time required were drastically reduced and the time between maintenance checks increased, making the system cheaper to maintain.

CHAPTER 6

6 DIAGNOSTICS SOFTWARE

The diagnostics software is used to repair, test, align and configure the radio telephone system. The following four sections describe the four modules in the software. By setting dip switch one to the on position, the diagnostic software is now mapped to the code area of the CPU and the Flash prom to the RAM area. See appendix B pages 5 to 8 for the detailed flow diagrams and appendix C for the diagnostics software source code. Appendix D contains the installation disk for the controlling software.

6.1 COMPUTER MODE

The default module is the computer mode and the card is controlled via a RS232 interface. The Windows based controlling software is used to issue commands to the card and receive responses from it. All the tests and configurations can be done in this mode. A full description of the faultfinding procedures, testing points and equipment needed, is available in the controlling software help files. Figure 11 gives the flow diagrams for the computer mode.

6.1.1 FILE OPTIONS

This section of the software is used to control and program the flash prom on the MUPC board. The software data file must be in the Intel Hex format for the MUPC to be able to program the flash prom.

- **Open File**

The screen is used to open the software data file and set-up the controlling software to load it into the MUPC.

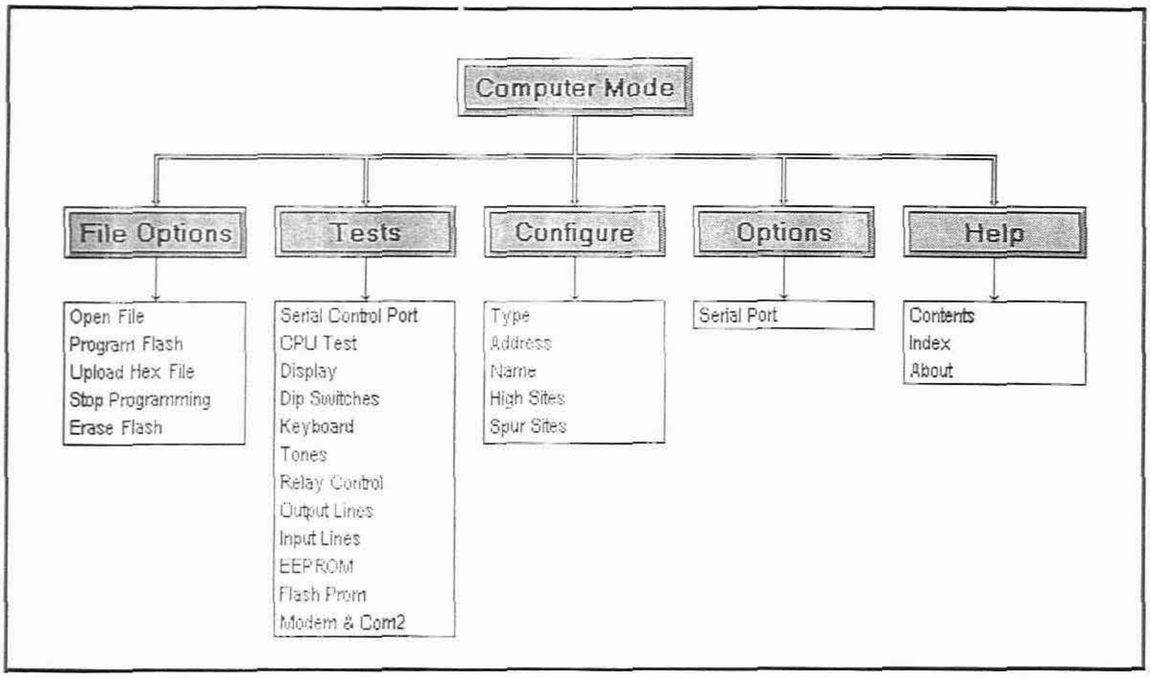

Figure 11: Flow diagram of computer mode diagnostics

- **Program Flash**

The option sets the MUPC into programming mode. Dipswitch 2 on the MUPC is the programming voltage enable switch and is checked before the MUPC goes into programming mode. If switched off the status is reported back to the controlling software.

- **Upload Hex File**

This option starts the uploading process and loads the hex file one line at a time. The flash prom is programmed with the line before the next one is loaded.

- **Stop Programming**

This option is used to abort the flash programming.

- **Erase Flash**

The option is used to erase the flash prom before it is programmed with the new software

6.1.2 SYSTEM TEST PROCEDURES

The following sections represent the screens in the test option of the controlling software.

- **Serial Control Port**

The serial control port or communications port 1 is the port used by the diagnostics software to communicate to the PC. This test is used to check the serial path between the MUPC and the PC running the controlling software.

- **CPU Test**

The CPU test is used to check that the basic processor circuitry is working correctly. The RAM, EPROM, CPU and control circuitry are tested with this test. Once the first two tests have been successfully completed, the rest of the circuitry can be tested.

- **Display**

The display test checks the operation of the display and controlling circuitry. The display is used to report the test selections that were issued to the MUPC card by the controlling software.

- **Dip Switches**

The eight switches on the board are used to select the different diagnostics and set-up options that are available. The test checks the operation of the switches and circuitry.

- **Keyboard**

The screen is used for the keyboard circuitry and operation. This option is also used to check the connections to the keyboard as it displays the key that was pressed. Thus by pressing a key and checking the displayed character the X & Y matrix lines of the keyboard can be correctly connected.

- **Tones**

The screen is used to switch the signalling tones of the system on and off. The DTMF and tone generator circuitry is tested and the audio paths to the UHF and VHF radios.

- **Relay Control**

There are eight relays on board that can be used as general output control signals. The control and driver circuitry for the relays are tested with this screen.

- **Output Lines**

The output lines of the card are used for controlling and signalling of the other cards in the system interface controller. This screen is used to toggle these lines high and low.

- **Input Lines**

The input lines of the card is used to sense actions performed by the other cards in the system interface controller This screen is used to display the status of the lines.

- **EEPROM**

The Electrically Erasable Programmable Read Only Memory is used to store the system parameters. These parameters are used for the normal operation of the system. This screen is used to read, examine and verify the contents of the memory.

- **Flash Prom**

The Flash prom is used to store the operational software of the system. The screen is the same screen as that for the EEPROM and performs the same basic functions for examining the memory areas. The screen can only display 128 characters at a time. To view other areas of the Flash memory, the base address from where the data is read must be changed.

- **Modem & Com 2**

The last screen of the tests is the screen that checks the operation of the onboard modem and the auxiliary communications port com2. The modem is used to communicate between two systems on the UHF backbone. The test is used to check the operation and adjust the levels of the modem. The auxiliary communications port is not currently in use but is available for future expansion of the system functionality.

6.1.3 SYSTEM CONFIGURATION

The system configuration screens are used to set the operational parameters of the system.

- **Type**

The screen selects the operating mode of the system. There are three options available. High for high site operation, Spur for spur site operation and Base for base site operation. Only the High and Spur options are implemented at the current version of software.

- **Address**

The screen is used to set the site address of the system. Each unit must have a unique address to allow for the accessing of the units.

- **Repeater**

The screen is used to enable or disable the repeater mode when the type was selected as a spur. This option is used to prevent system lock-up when a spur site can receive more than one high site.

- **Name**

The screen is used to enter the name of the site. A total of 16 bytes are available for the name.

- **High Sites**

The screen is used to enter the list of other high sites connected to the system. The list is needed for automatic routing from VHF to UHF during the set-up phase of a call. A total of eight sites can be entered.

- **Spur Sites**

The screen is used to enter the list of spur sites working to the high site. The list is needed for automatic routing from UHF to VHF during the set-up phase of a call. A total of eight sites can be entered.

6.2 CONFIGURE MODE

The configuration mode via the screen and keyboard is selected by switching dipswitch 3 on. This option is used to configure the system without the aid of the Windows based controlling software. The same options are available as with the diagnostics software. Pressing the '*' on the keyboard will bring up a help screen and pressing the '#' will return to the main screen. The following options are available in this mode of operation: RT Type, RT Address, RT Repeater, RT Name, High site list and Spur site list. Figure 12 gives the flow diagrams for the keyboard configure mode.

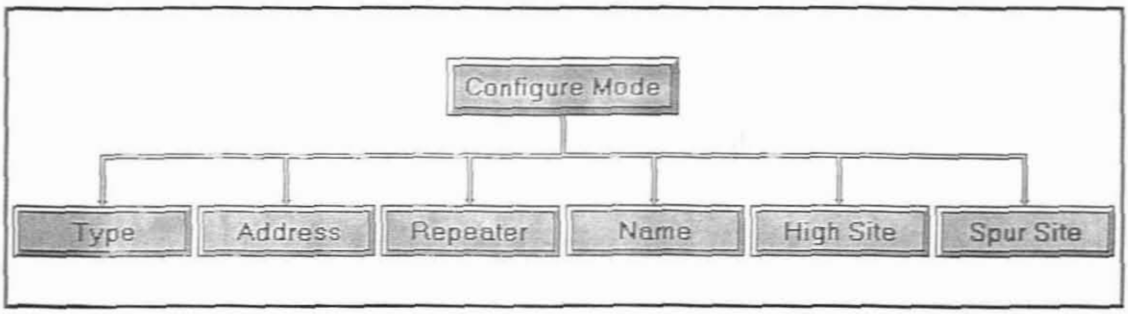

Figure 12: Flow diagram of keyboard configure mode

6.3 TEST MODE

Switching dipswitch 4 to the on position activates the test mode option. These tests are used to do the adjustment of the on site generated signal levels of the radio telephone system. All adjustments of signals not generated by the site radiotelephone, were eliminated in the upgrade. After the master deviation for speech was set the following rule for all other signals was formulated for maximum reliability of the system operation. ***"DTMF EQUALS SPEACH DEVIATION AND ALL OTHER SIGNALS MUST BE SET AT HALF OF SPEACH DEVIATION"***. This holds true for VHF at 2 kHz deviation and UHF at 3 kHz deviation. Figure 13 gives the flow diagrams for the keyboard test mode.

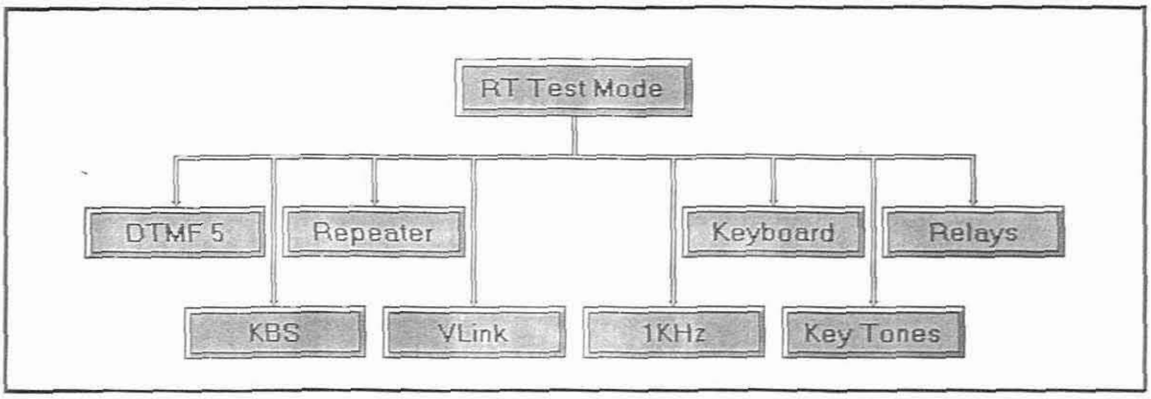

Figure 13: Flow diagrams for keyboard test alignment mode

- ## DTMF generation

The option generates the DTMF code 5 signal for the alignment of the VHF and UHF levels.

- ## KBS generation

The option generates the 2.8 kHz tone for the key busy signal on the UHF backbone.

- ## Repeater mode

This option switches the VHF section into repeater mode.

- **Vlink mode**

This option switches the VHF section into Vlink mode, connecting the VHF radio to the UHF radio.

- **1K on VHF**

This option generates a 1 kHz tone on the VHF radio to align the signal tones.

- **Keyboard mode**

The test enables the keyboard section. If the UHF radio is selected, pressing any key will generate the DTMF tones and key busy signal is sent. If the VHF radio is selected the transmitter will be activated and the DTMF sent.

6.4 BASIC RT MODE

The option enables the user to use the system as a basic radiotelephone. The software allows the following basic operations on the system.

- Access UHF and VHF sections.
- Vlink between the UHF and VHF radios.
- Switch the VHF radio into repeater mode.
- Ring the buzzer on site.
- Terminate the access on site.

This section was included in the diagnostics software to allow the operator to gain some control over the system, in the event that the operational software failed to load properly.

CHAPTER 7

7 OPERATIONAL SOFTWARE

The operational software is loaded into the flash prom by the diagnostics software. It controls the normal operations of the system and is briefly lined out in the following sections. See appendix B page 4 for the detailed flow diagram and appendix C for the software source code. The functions of the operational software are as follow:

- Provide access to the site.
- Provide fully automated routing and call set-up between any two units.
- Provide cell-call functionality at the site.
- Provide seamless integration between the telephone interface and the radiotelephone.
- Allow ordinary handshaking between the radiotelephone and the telemetry data transfers implementing speech priority over data.
- Generate the telemetry call-out sequence.
- Control the operation of the UHF and VHF radios.
- Control the output control relays.

7.1 ACCESS OF SITES

A two-digit code is issued to access the sites. This code must be the same as the ID code of the site and if correct the site will respond with a beep-baap acknowledge tone, indicating that the operation was successful. The system is shutdown by sending the '*' DTMF code.

7.2 AUTOMATIC ROUTING

Automatic routing is a function of the high sites only. The remote high site checks if the spur site is in the entered list. If entered, it sets up the routing to the remote spur site. The spur site ID's first digit must be the same as the high site's first digit for the routing to work. When a high site receives the first digit on the backbone, it Vlinks the VHF set and also sends it out to the spur sites. When the second digit is a spur site ID, the high site permanently enables the Vlink, the spur site is accessed and the route is set up. To automatically route via a high site to another high site, the local high site must first be accessed. The second high site ID is then entered and the route is then set-up.

7.3 REMOTE CONTROL

Remote control on the sites is an added functionality that is used to control external equipment on the site. Accessing the site and then ringing the buzzer for longer than 5 seconds activates the remote control mode. By then sending DTMF codes 1 to 8 the corresponding relay is activated on the MUPC board while the code is present.

7.4 CELL-CALL OF HANDHELDS

All the new handhelds that are on the market today use DTMF signalling to access the sets. The old system used two-tone signalling that is not compatible with current trends and technology. The new software implements DTMF signalling to access the units by sending the desired DTMF data string out.

CHAPTER 8

8 CONCLUSION OF RESEARCH RESULTS

The result of the research shows that with minimal cost a system could be upgraded, giving it a new lease on life. An amount of +/- R 100 000.00 was spent on the upgrading against the replacement cost of R 4 000 000.00, and resulted in a capital expenditure of only 2.5% of the replacement cost.

The hardware changes that were done increased the functionality and reliability of the system. When upgrading a system it is important to check and correct the impedances of the system. This will result in stabilising the audio levels, resulting in the elimination of level adjustments. By decreasing the maintenance time from 8 hours to 30 minutes on the systems interface controller, a labour cost saving of 84% was achieved.

When designing a complicated system, diagnostics to repair the system must form part of the overall design. Too often diagnostics are thought of afterwards, with the result that limited or no diagnostics are incorporated into the system. It is very important that designers of radiotelephone systems must think of where these units are installed. Normally in a small building or container on top of a mountain. The MUPC is a complicated board to faultfind and repair. With the help of the onboard diagnostics software and Windows based controlling software, combined with the help files as a guide, the problem of repairing the board was solved.

As the functionality and operating environment of the system change, it will become necessary to upgrade the controlling software. When designing a system of any reasonable size that uses software to control it, the option of a hex loader program, programming an EEPROM against replacing an EPROM, must be considered. It is easier and more cost-effective to e-mail the new software to the users, than sending them the software in an EPROM. The option to load the operating software was selected for this system, as this method is in line with the new trends in designing of equipment.

The research and upgrading of the system were a very useful and successful exercise that saved money and manpower. The upgrading was successfully implemented in Cape Town, Vredendal and George areas and is successfully working as a system from October 1999.

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APPENDIX DESCRIPTIONS

The following section gives a short description on the contents of the appendixes.

Appendix A - The Microprocessor Board

This appendix contains the full description and circuit diagrams of the MUPC microprocessor board.

Appendix B - Software flowcharts

This appendix contains all the detailed flow diagrams of the radio telephone system. Both the operational software and the diagnostics software flow diagrams are contained in this appendix. As these diagrams were generated in a DOS based program, the flowcharts cannot be supplied on disc and thus are included in this appendix.

Appendix C - Software source code

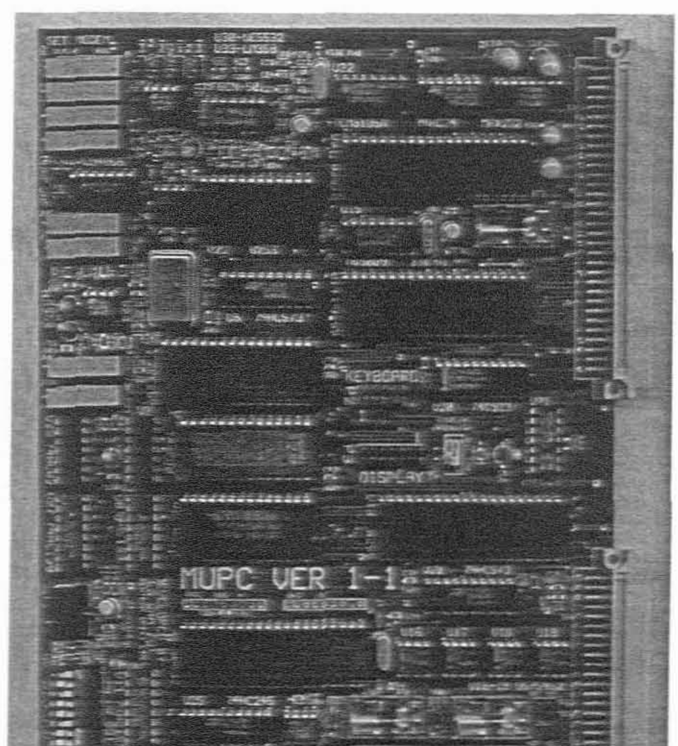
This appendix is a 1.44-MB stiffy that contains all the source code of the operational and diagnostics software. The code is written in Pascal and the System51 compiler was used to generate the machine code. The source code can be viewed wi'h Windows notepad. The total amount of code is in excess of 10 thousand lines.

Appendix D - Control software

The appendix is a 1.44-MB stiffy that contains the control software installation and this software was written in Visual Basic version 3. To install the software Widows 3.1 or better operating system must be installed on the computer. Insert the disc into the 'A' drive and then run Setup.

APPENDIX A

MUPC CONTROLLER



Developed by

Louis S. van Zyl (Reg.Eng.Tech.)

CONTENTS

FIGURES

TABLES

1. BOARD DESCRIPTION.

The MUPC is based on the Intel 8032 Micro controller. The board has place for 8K RAM and one block each of 32K Flash EEPROM and 32K EPROM. Serial communication is via a RS232 port to external equipment and communication between boards is via a SCC connected to a FSK modem. System configuration is stored in a 128 byte serial EEPROM. Programmable Peripheral Interface Adapters connect external signals to and from the board, control the display operation and DTMF generation. The keyboard scanner controls the keyboard functions and the three-channel timer generates the tones needed by the system. Eight relays provide output control lines to external equipment. The switches on the board are used for control and set-up. A watchdog timer checks overall system functions and resets the CPU if needed.

2. CIRCUIT DESCRIPTION.

The following is a description of the circuit operation of the different sections that make up the micro controller of the radio telephone system.

2.1 MICRO CONTROLLER.

U1 is the 8032 Micro controller. The 8032 contains 256 bytes of on-chip RAM, three 16 bit counter / timers, one asynchronous serial port, 6 interrupts with 2 interrupt levels and 32 I/O lines in 4 ports. The 8032 has a 16-bit address bus and 8-bit data bus. The least significant address bits A0-A7 and the data bits D0-D7 are multiplexed together onto port 0. Address lines A8 - A15 are implemented onto port 2. Three control lines, RD, WR, and PSEN partition the address space as 64K bytes each of program and data memory. The RD, WR, T0, T1, INT0, INT1, RxD and TxD are multiplexed onto port 3. Port 1 is a general I/O port and is used for internal system controls.

2.2 MEMORY.

The memory of the board consists of four distinct sections that operate independent of each other. The RAM memory of the board consists of one 6264 8K RAM chip U2 starting at location 8000H to 9FFFH. Reading is done with the RD line and writing with the WR line. One 28F256 32K flash EEPROM U3 contains the operating software that controls the normal system operations. Addressing starts at program memory location 0000H to 7FFFH and reading is done with the PSEN line. One 27C256 32K EPROM U4 contains all the firmware that is used when aligning the system and re-programming the operational software. Addressing starts at program memory location 0000H to 7FFFH and reading is done with the PSEN line when operating software is selected. When the firmware is selected U4 is enabled and U3 is re-mapped onto the RAM area so that it can be programmed. Having separate memory areas for data (RD line) and program area

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(PSEN line), the address space for data and software can be overlapped. The last memory area is a 128 byte EEPROM that is serially controlled by P1.0 to P1.2 of the CPU and is used to store system configuration information.

2.3 CONTROL LOGIC.

U6 is a 74HC573 octal latch and latches the low order address A0 to A7. The ALE signal from the Micro controller is used to latch the low order address into U6. U8A is a 74HC139 and is a 2 to 4 line decoder. Address line A15 is connected to the A input. The program select line is connected to the G input. This is used to enable U4 when the firmware is needed. U8B & U9C decodes the memory into 8K blocks above 32K. U27A decodes block C000H into four 2K blocks and U27B decodes block E000H into four 2K blocks.

U11 i.e. a 74LS153 dual 4 multiplexed inputs. It multiplexes the memory select line, RAM read and write lines and the EPROM read line to U3. This is controlled by SW1A to select between normal operation and service operation. In normal operation, U3 is mapped to the program area with U4 disabled. In the service operation, U3 is mapped to the data area and U4 to the program area.

U25 is a 74HC245 that buffers the remaining switches SW1 C to H. These switches are used to set system options that can be selected by the user.

2.4 WATCHDOG TIMER.

The U7 is a MAX690 dedicated watchdog timer and monitors activity on the P1.5 line. If there is no activity for longer than 1.6 seconds then U7 will restart the processor. SW2 is a push to make switch that will allow the user to manually restart the system.

2.5 PRIMARY & SECONDARY RS232 CHANNEL.

U12 is the primary RS232 channel (COM1) and is connected to the serial port on U1 with P1.6 and P1.7 controlling the RTS and CTS lines of the channel. U34 is the secondary RS232 channel (COM2) connected to the B channel of the SCC U31. Both U12 and U34 are MAX232's and are dual RS232 Transmitter / Receivers. The MAX232 has three sections, a dual transmitter, a dual receiver and a +5V to +/- 10V dual charge pump voltage converter.

The power supply section contains two charge pumps. The first uses external capacitor C4 (C30) to double the +5V input to +10V, with an output impedance of approximately 200E. The second charge pump uses external capacitor C5 (C31) to invert the +10V to -10V, with an overall output impedance of 450E. The +10V can be measured at pin 2 and the -10V at pin 6.

Each of the two transmitters is a CMOS inverter powered by the +/- 10V internally generated supplies. The input has a logic threshold of 1.3V. The open circuit output voltage swing is from (+V - 0.6V) to -V. The outputs are short circuit protected and can be short circuited to ground indefinitely.

The two receivers fully conform to RS232 specifications. Their input impedance is between 3K and 7K and can withstand up to +/- 30V inputs with or without power applied. The TTL / CMOS output of the receiver will be low whenever the RS232 input is greater than 2.4V and high when the input is floating or driven between +0.8V and -30V.

2.6 MODEM CHANNEL.

Serial communication between UHF sites is done in U31. This is a Serial Communications Controller (SCC) and has two independent full duplex Transmitters and Receivers. Channel A is used for UHF and channel B for the secondary RS232 channel.

The register set for each channel includes ten control (write) registers, Two synchronous character (write) registers and four status (read) registers. In addition, each baud rate generator has two (read/write) registers for holding the time constant that determines the baud rate. The interrupt logic is a write register for the interrupt vector accessible through either channel. A write only Master Interrupt Control register and three read registers: one containing the vector with status information (Channel B only), one containing the vector without status (Channel A only) and one containing the Interrupt Pending bits (Channel A only).

Transmit Data A (TXDA) is the data serial output and is fed to the modem U32. Receive Data A (RXDA) is the serial input for data from the modem to the SCC. Request To Send (RTSA) is used to enable the modem for normal operation. In channel B this signal forms part of the normal RS232 channel signals. Clear To Send signals the SCC that the channel is ready for transmission. Carrier Detect from the modem is activated as soon as carrier is being received. The signal is used to enable the receiver in the SCC.

U32 forms the modem channel and is based on the TCM3105 voice band modem. The transmitter is a programmable frequency synthesizer, which provides two output frequencies representing the "Marks" and "Spaces" of the digital signal present on the TxD input. The receive section is responsible for the de-modulation of the analogue signal. The section contains a group delay equalizer and automatic gain control. The carrier detect level is adjusted by RV5 and the receiver bias distortion is adjusted by RV6. The modem is connected to channel A of the SCC U31. The RTSA signal from U31 control the operation of the modem switching it on or off. U33A is the output buffer and the level is set by RV7, the signal is the fed to the UHF channel audio mixer U23A. U33B is the input buffer and the input level is set by RV8.

2.7 KEYBOARD CONTROL.

U20 is a MM74C923 20 key encoder. The key-encoder scans the keyboard and fully encodes the keyboard connected to it. C8 forms the scan oscillator and C9 de-bounces the key closures. The data available is "or'd" with the UHF and VHF DTMF signals by a 3 input NOR gate U21A to provide an interrupt signal to the CPU. U21B and C decodes the chip select and read signals to enable the data in U20. The keyboard is connected to P3 via a ribbon cable. See figure 11.1 for the pin-out connections of the keyboard connector.

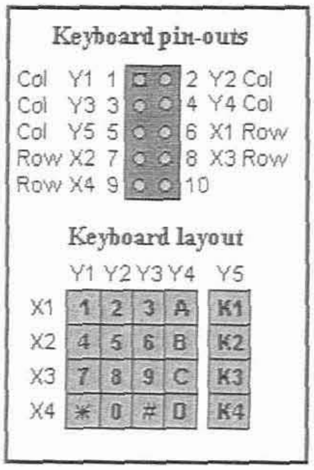


Figure 1: Keyboard connector pin-outs and scan lines.

2.8 DISPLAY CONTROL.

The display is connected to JP10 and RV1 sets the intensity of the display. The display data lines are connected to PPI U13 port A and the display control lines to port C lines 0,1 & 2.

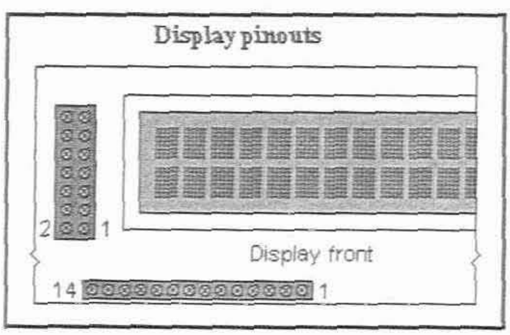


Figure 2: Display connector pin-outs for single or double line headers.

2.9 Relays & Buzzer Control.

The output control relay latch U28 is a 74HC573 and latches the relay control signals. U16 to U19 are DS75452 dual relay drivers that buffer the signal and drives the 8 output control relays RL1 to RL8. The buzzer control signal is provided by U13 port B6. This signal is buffered by Q4 to control RL9 that rings the buzzer and provides the remote signal.

2.10 DTMF Generation.

The Dual-Tone Multi-Frequency (DTMF) generator is a MV5089 U15. The generator tones are controlled by the CPU via a 8255 PPI U14 port A. The output of the port is connected to the row and column inputs of U15. The generator output level can be set by VR2 for the UHF channel and RV3 for the VHF channel at the front of the board.

2.11 Tone Generation and Timers.

The KBS signal and tones are generated in a programmable interval timer 8253 U22. Control of the timer is via the CPU that sets up two timers T0 and T1. The timers are set up in a 16 bit 50% duty cycle automatic reload mode. The clock frequency is derived from a 1.8432 MHz crystal oscillator X3. This signal is applied to the clock inputs of all three timers. The gate inputs of T0 and T1 is connected to U13 port C3 and is used to switch the timers on and off.

U24 is an MF6 6th order switched capacitor butter worth low pass filter. The output of timer 1 is set to 50 times tone frequency and is the clock input to the filter. This signal is buffered by R7, R8 and Q2 before it is applied to the filter. The cut-off frequency is set by the input clock to 4 kHz. Timer 0 output is set to the KBS frequency of 2.8 kHz or the tones. This is level shifted to 6V by C19, R9 and R10. The square wave is then filtered by U24 to produce the tones. The output of the filter is connected to the spare buffer on the chip and the output is fed to the UHF and VHF mixers. Timer 2 is set as an external timer to trigger the CPU internal timer 0. The two timers together forms a general timer to be used by the system for operational timing.

2.12 UHF Audio Mixing and Selection.

U23A is the UHF audio mixer that mixes the DTMF tones, modem tones and KBS tones. These tones can be monitored on TP1. U29A is a CD4066 analogue switch that connects the tones to the output buffer U30A. When the tones are switched off U29C provides an earth signal to the output buffers input. The control of the UHF channel tone selection is done by U1 port 1.3.

2.13 VHF Audio Mixing and Selection.

U23B is the VHF audio mixer that mixes the DTMF tones and function tones. These tones can be monitored on TP2. U29B is a CD4066 analogue switch that connects the tones to the output buffer U30B. When the tones are switched off U29D provides an earth signal to the output buffers input. The control of the VHF channel tone selection is done by U1 port 1.4.

2.14 Input Signals.

U14 is an 8255 PPI and port B & C provides all the input signals from the other boards in the SIC box. The UHF DTMF data is connected to port B 0 to 3 and the VHF DTMF data to port B 4 to 7. Port C contains general input signals. See 11.5 for more details on the input signals. UHF and VHF DTMF data available signals are connected to U13 port C 5 & 6.

2.15 Output Signals.

U13 is an 8255 PPI and port B lines 0 to 5 is the general output signals. See 11.5 for more details on the output signals. Port B.7 signal is buffered by Q5 that drives LED2 and is the general alarm LED.

3. BOARD SET-UP.

The following procedures are used to set up the board for normal operation. Switch SW1.1 to on and press the Reset button. The board is now in computer controlled configuration and set-up mode. To select configuration from the keyboard switch SW1.1 and SW1.3 to on and to enable the test mode switch SW1.1 and SW1.4 to on. The "*" on the keyboard displays a help screen. If a ">" or "<" is also displayed then there is more than on help screen. Use the "*" to cycle between the screens. The "#" exits the help screens, but tests can be activated from within the help screens.

3.1 Display Intensity.

To adjust the display intensity, adjust RV1 next to the display connector until the characters on the display can be read normally.

3.2 DTMF LEVEL.

Select test mode as in section 3. To activate the DTMF generator press "1". This will switch on the generator generating DTMF code "5". Adjust RV2 for 3 kHz deviation on any UHF channel. Adjust RV3 for 2 kHz deviation on the VHF channel. The "UHF/VHF" switch will select between the UHF or VHF channel. Press "#" to stop the test.

3.3 KBS LEVEL.

Select test mode as in section 3. To activate the KBS generation press "2". This will switch the KBS signal on. Adjust RV9 for 1.5 kHz deviation on any UHF channel. Press "#" to stop the test.

3.4 VHF TONE LEVEL.

Select test mode as in section 3. To activate the VHF tone generation press "5". This will switch the 1KHz signal on. Adjust RV10 for 1 kHz deviation on the VHF channel. Press "#" to stop the test.

3.5 MODEM LEVELS.

Select test mode as in section 3. To activate the modem tone generation press "6". This will switch the modem signal on. Adjust RV7 for 1.5 kHz deviation on any UHF channel. Press "#" to stop the test.

For the receive signal inject a 1700 Hz tone at 1.5 kHz deviation into one of the UHF receivers. Monitor on TP3 and adjust RV8 to –6 dBm. Reduce the input signal to 0.5 kHz deviation. Set the carrier detect level by monitoring TP5 and adjust RV5 for the signal to switch from low to high. On any UHF connector remove the cable to the UHF RT and insert a loop plug. Now press "7" to activate a 50% duty cycle signal. Monitor on TP4 and adjust RV6 for minimum distortion of the TTL signal. Remove the plug and restore the UHF cable. Press "#" to stop the test.

4. EDGE CONNECTOR PIN OUTS.

The following pin-outs are available on the edge connector.

TOP CONNECTOR		
Row A		Row C
0 V	01	0 V
+12 V	02	+12 V
	03	
	04	
UHF modem tones input	05	UHF modem tones input
Com 2 Tx data	06	Com 2 Rx data
Com 2 Request To Send	07	Com 2 Clear To Send
UHF tones output	08	UHF tones output
Buzzer signal	09	Buzzer signal.
COM 2 Data Terminal Ready	10	Carrier Detect Com 2
	11	
Remote Buzzer common	12	Remote buzzer common
Remote buzzer normal closed	13	Remote buzzer normal closed
Remote buzzer normal open	14	Remote buzzer normal open
+12 V	15	+12 V
	16	
0 V	17	0 V
+5 V	18	+5 V
	19	UHF / VHF select
UHF node controller busy input	20	VHF node controller busy input
UHF DTMF data 2	21	UHF DTMF data 3
UHF DTMF data 0	22	UHF DTMF data 1
VHF DTMF data 2	23	VHF DTMF data 3
VHF DTMF data 0	24	VHF DTMF data 1
UHF DTMF data available	25	VHF DTMF data available
KBS detected input	26	UHF HMT PTT input
Phone patch busy input	27	VHF RUS input
VHF HMT PTT input	28	Mains fail input
Repeater enable output	29	VHF PTT output
VLink enable	30	Phone patch inhibit
VHF telemetry modem inhibit	31	UHF telemetry modem inhibit
0 V	32	VHF tones output

Table 1: Top edge connector pin-outs on the micro controller board.

BOTTOM CONNECTOR		
Row a		Row c
0 V	33	0 V
+6 V	34	+6 V
+5 V	35	+5 V
	36	
	37	
	38	
	39	
	40	
	41	
	42	
	43	
Relay 1 common	44	Relay 1 common
Relay 1 normal close	45	Relay 1 normal open
Relay 2 common	46	Relay 2 common
Relay 2 normal close	47	Relay 2 normal open
Relay 3 common	48	Relay 3 common
Relay 3 normal close	49	Relay 3 normal open
Relay 4 common	50	Relay 4 common
Relay 4 normal close	51	Relay 4 normal open
Relay 1 output	52	Relay 2 output
Relay 3 output	53	Relay 4 output
Relay 5 output	54	Relay 6 output
Relay 7 output	55	Relay 8 output
Relay 5 common	56	Relay 5 common
Relay 5 normal close	57	Relay 5 normal open
Relay 6 common	58	Relay 6 common
Relay 6 normal close	59	Relay 6 normal open
Relay 7 common	60	Relay 7 common
Relay 7 normal close	61	Relay 7 normal open
Relay 8 common	62	Relay 8 common
Relay 8 normal close	63	Relay 8 normal open
0 V	64	0 V

Table 2: Bottom edge connector pin-outs on the micro controller board.

5. PROGRAMMING SPECIFICATIONS.

The memory map of the board is as follows.

5.1 Normal Operation. (Sw1.1 Off)

In normal operation, the flash prom is mapped to the first 32 kilobytes of code area and the data area is not used. The random access memory used in the system is mapped between 32 kilobytes and 40 kilobytes.

Address	Size	Data memory	Program memory
0000H - 1FFFH	8K	Not used	External EEPROM U3
2000H - 3FFFH	8K	Not used	External EEPROM U3
4000H - 5FFFH	8K	Not used	External EEPROM U3
6000H - 7FFFH	8K	Not used	External EEPROM U3
8000H - 9FFFH	8K	External RAM U2.	

Table 3: Code and data areas during normal operation of the board.

5.2 Set-Up Operation. (Sw1.1 On)

In set-up operation, the flash prom is mapped to the first 32 kilobytes of data area and the Diagnostics EEPROM to the code area. The random access memory used in the system is mapped between 32 kilobytes and 40 kilobytes.

Address	Size	Data memory	Program memory
0000H - 1FFFH	8K	External EEPROM U3	External EPROM U4
2000H - 3FFFH	8K	External EEPROM U3	External EPROM U4
4000H - 5FFFH	8K	External EEPROM U3	External EPROM U4
6000H - 7FFFH	8K	External EEPROM U3	External EPROM U4
8000H - 9FFFH	8K	External RAM U2.	

Table 4: Code and data areas during set-up operation of the board.

5.3 Peripheral Addresses.

All the peripherals are mapped in the data memory area above 32 kilobytes. See section 2.3 for a description on the address decoding for the peripherals.

Address	Size	Data memory
C000H - C7FFH	2K	74573 U28 Relay latch.
C800H – CFFFH	2K	74245 U25 dip switches
D000H - D7FFH	2K	74C923 U20 Keyboard
D800H – DFFFH	2K	8253 U22 programmable interval timer.
D800H		Timer counter 0
D801H		Timer counter 1
D802H		Timer counter 2
D803H		Counter mode control register.
E000H - E7FFH	2K	74HC00 U9 Enable relays.
E800H – EFFFH	8K	8255 U14 programmable peripheral interface.
E000H		Port A
E001H		Port B
E002H		Port C
E003H		Control register.
F000H - F7FFH	2K	8255 U13 programmable peripheral interface.
F000H		Port A
F001H		Port B
F002H		Port C
F003H		Control register.
F800H – FFFFH	2K	82530 U31 SCC
F800H		Channel B status read and parameter write.
F801H		Channel B data read and write.
F802H		Channel A status read and parameter write.
F803H		Channel A data read and write.

Table 5: Address map for the interface peripherals.

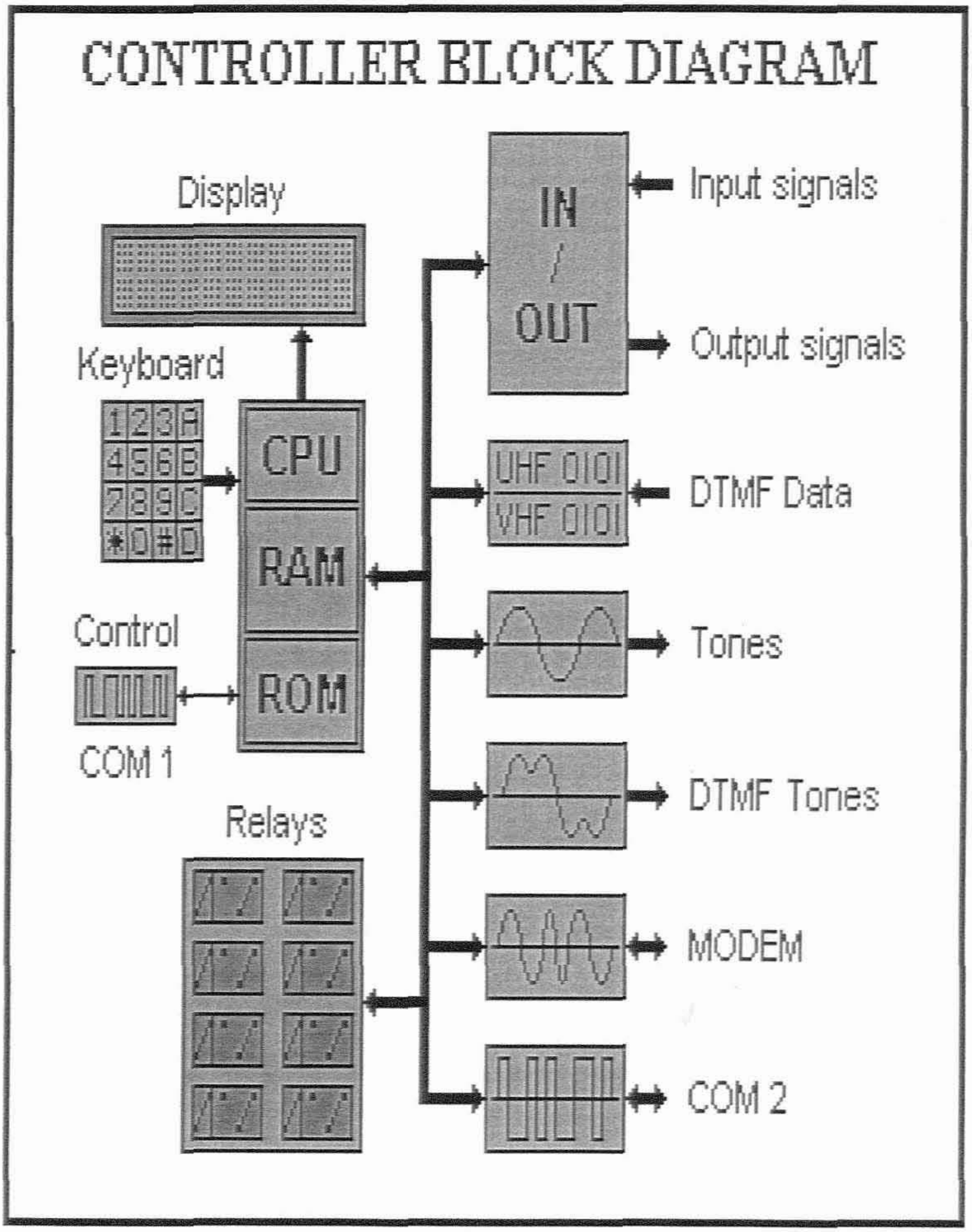
6. BOARD SPECIFICATIONS.

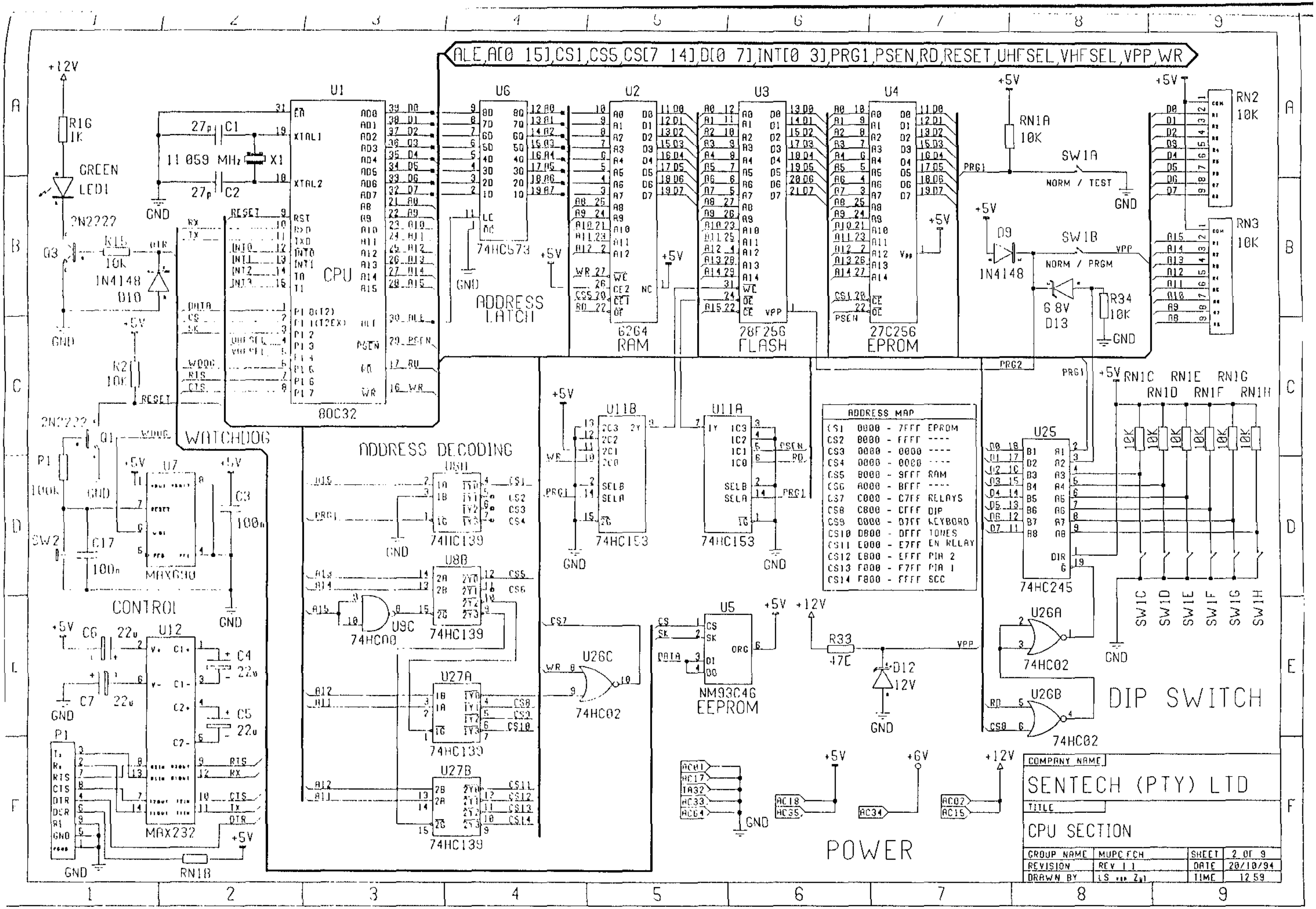
Power Requirements :	+12	Volt	@	430.0	mili Amps
	+6	Volt	@	10.0	mili Amps
	+5	Volt	@	450.0	mili Amps
	0	Volt			
Board size :		235 mm x 160 mm			

7. DRAWINGS

Block diagram	Sheet	1	of	9
Circuit diagram	Sheet	2 to 5	of	9
Component layout	Sheet	6	of	9
Component list	Sheet	7 to 9	of	9

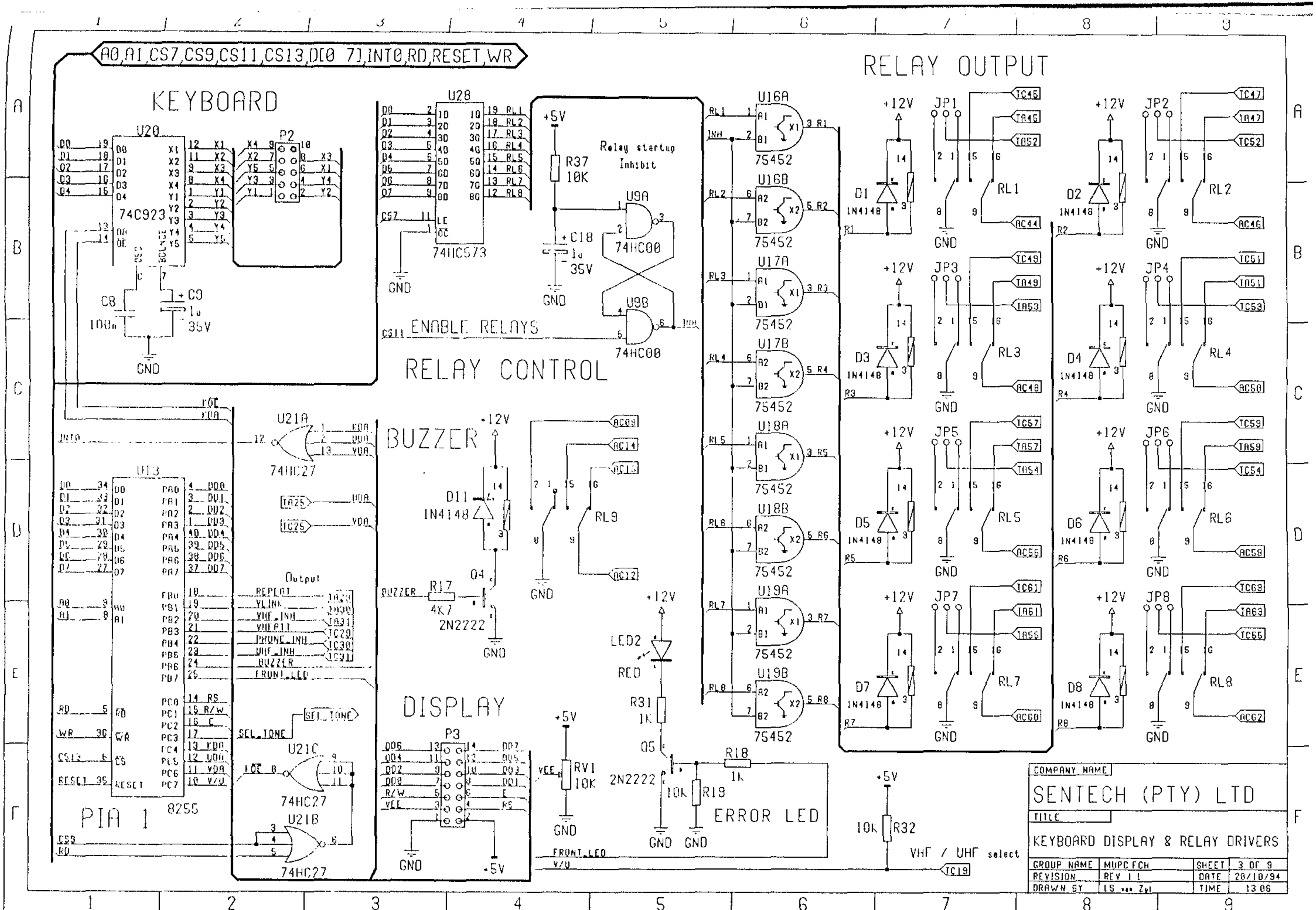
MICRO CONTROLLER BLOCK DIAGRAM



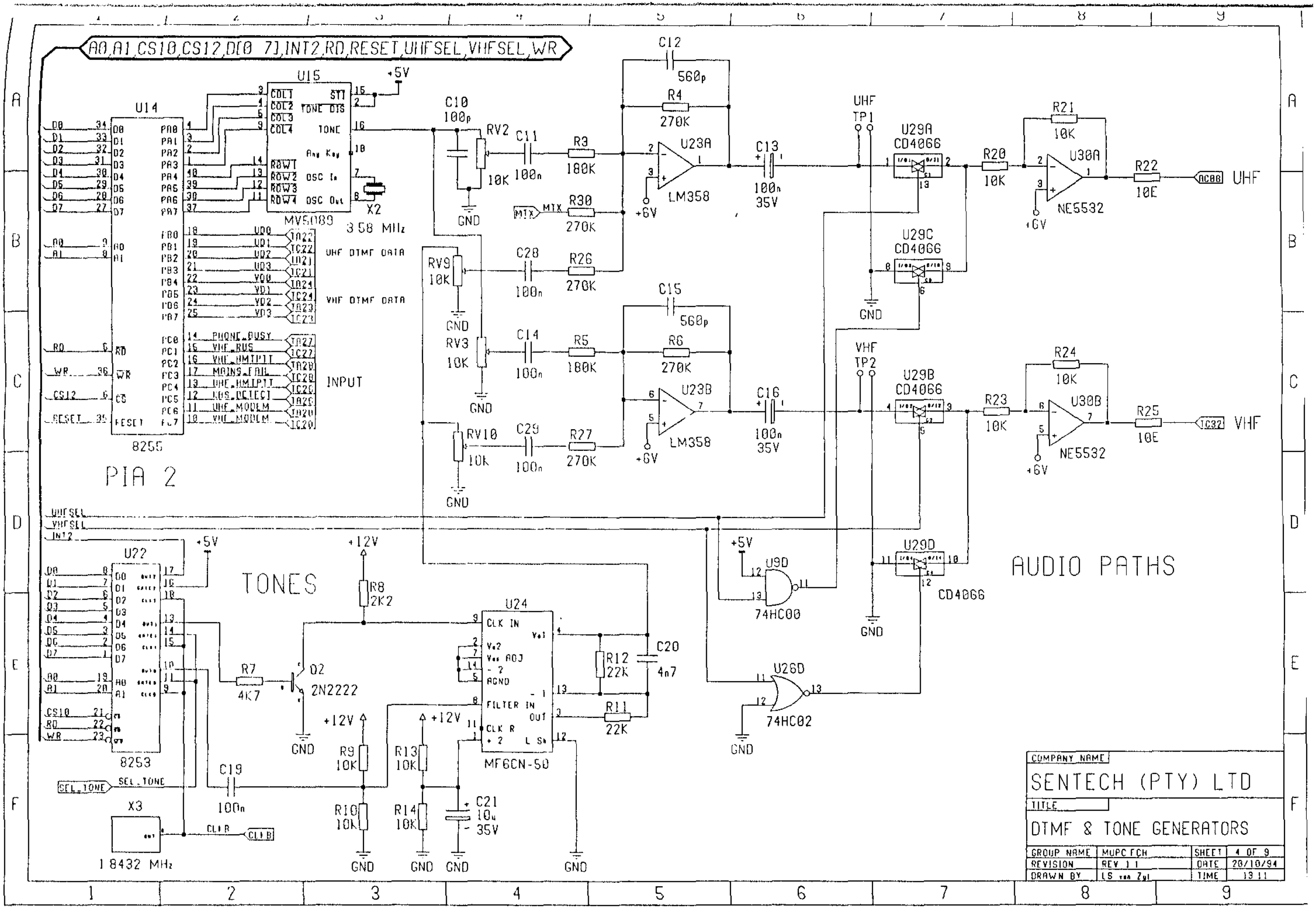


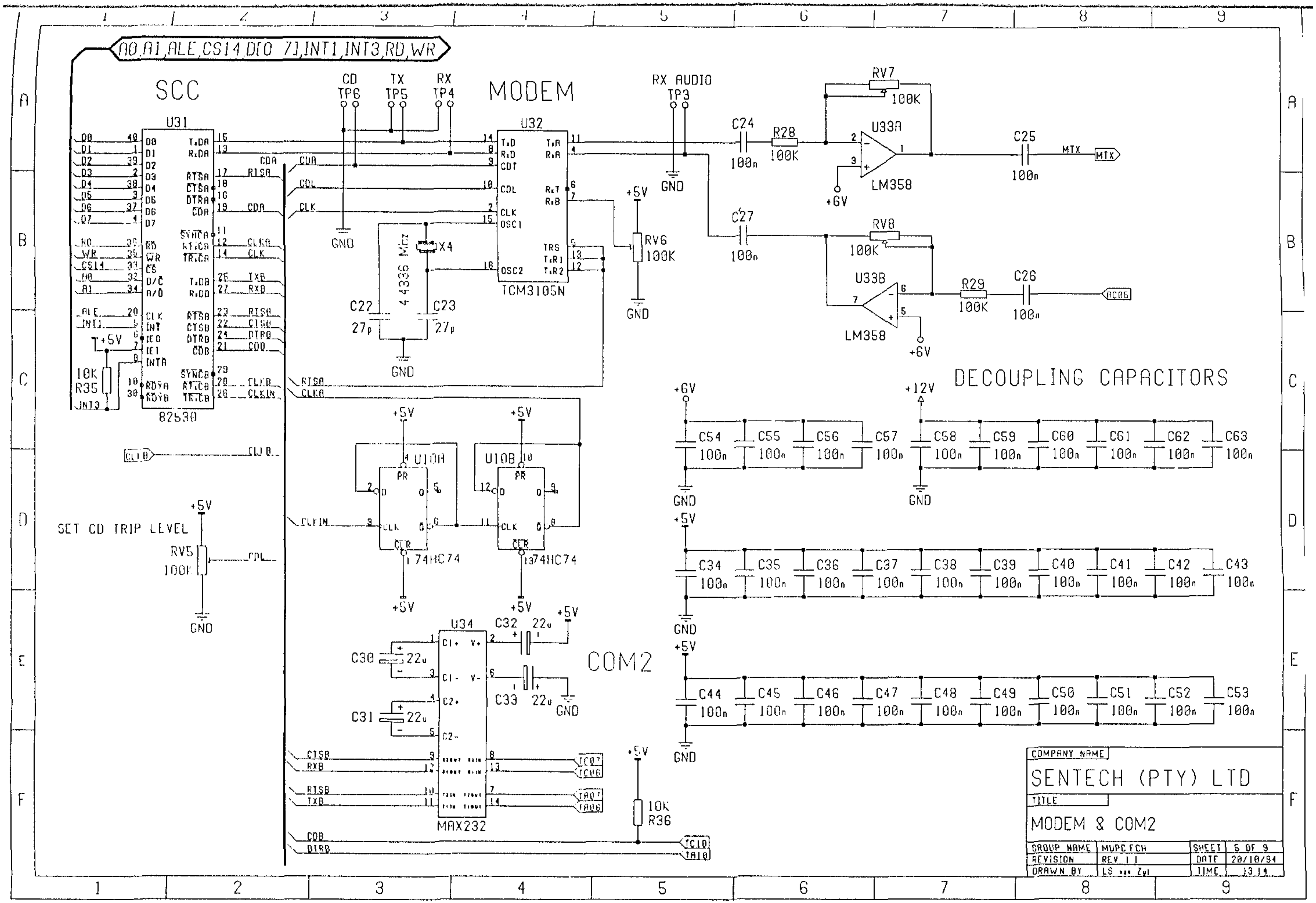
ADDRESS MAP

CS1	0000	-	7FFF	EPROM
CS2	8000	-	FFFF	----
CS3	0000	-	0000	----
CS4	0000	-	0000	----
CS5	8000	-	9FFF	RAM
CS6	A000	-	BFFF	----
CS7	C000	-	C7FF	RELAYS
CS8	C800	-	CFFF	DIP
CS9	D000	-	D7FF	KEYBORD
CS10	D800	-	DFFF	TONES
CS11	E000	-	E7FF	EN RELAY
CS12	E800	-	EFFF	PIA 2
CS13	F000	-	F7FF	PIA 1
CS14	F800	-	FFFF	SCC

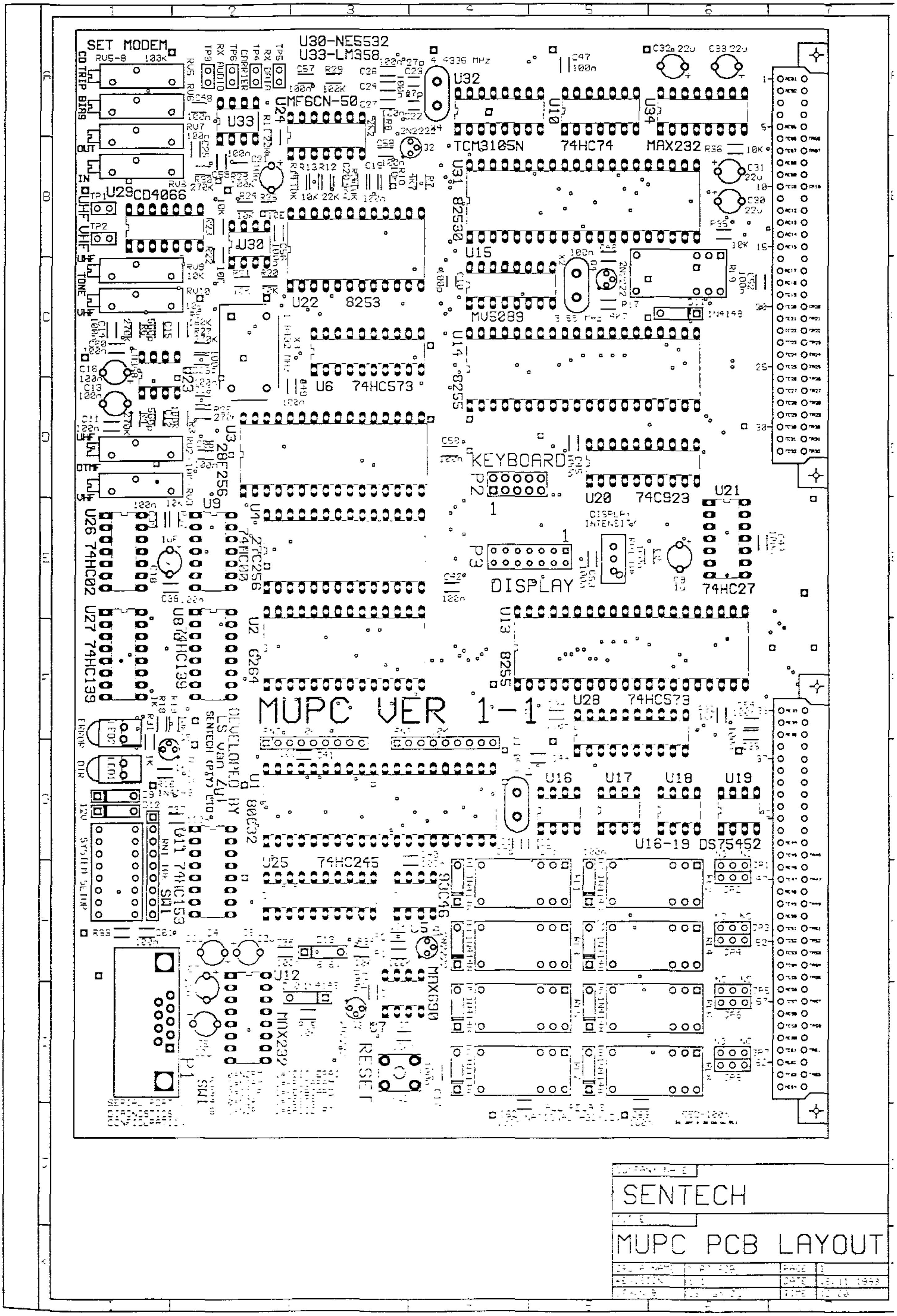


A0,A1,CS7,CS9,CS11,CS13,D[0 7],INT0,RD,RESET,WR
KEYBOARD
U20
74C923
P2
C8
100n
C9
1u
35V
GND
U28
74HC573
CS7
GND
+5V
R37
10K
C18
1u
35V
Relay startup Inhibit
U9A
U9B
74HC00
INH
CS11
ENABLE RELAYS
RELAY CONTROL
RELAY OUTPUT
U16A
U16B
U17A
U17B
U18A
U18B
U19A
U19B
75452
+12V
JP1
JP2
JP3
JP4
JP5
JP6
JP7
JP8
D1
D2
D3
D4
D5
D6
D7
D8
1N4148
RL1
RL2
RL3
RL4
RL5
RL6
RL7
RL8
BUZZER
D11
1N4148
RL9
Q4
BUZZER
R17
4K7
2N2222
U21A
74HC27
INT0
U13
8255
PIA 1
Output
REPLAT
VLINK
VHF_INH
VHFPTT
PHONE_INH
UHF_INH
BUZZER
FRONT_LED
SEL_TONE
U21C
U21B
74HC27
CS9
RD
DISPLAY
P3
VEE
RV1
10K
+5V
LED2
RED
R31
1K
Q5
2N2222
R18
1K
10K
R19
ERROR LED
R32
10K
VHF / UHF select
FRONT_LED
V/U
COMPANY NAME
SENTECH (PTY) LTD
TITLE
KEYBOARD DISPLAY & RELAY DRIVERS
GROUP NAME MUPC FCH
REVISION REV 1 1
DRAWN BY LS van Zyl
SHEET 3 OF 9
DATE 20/10/94
TIME 13 06


A0,A1,CS10,CS12,D[0 7],INT2,RD,RESET,UHFSEL,VHFSEL,WR
U14
8255
PIA 2
UHF DTMF DATA
VHF DTMF DATA
INPUT
PHONE_BUSY
VHF_BUS
VHF_HMIPTT
MAINS_FAIL
UHF_HMIPTT
BUS_DETECT
UHF_MODEM
VHF_MODEM
U15
MV5089
X2
3 58 MHz
+5V
C10
100p
RV2
10K
C11
100n
R3
180K
C12
560p
R4
270K
U23A
LM358
+6V
MIX
R30
270K
RV9
10K
C28
100n
R26
270K
RV3
10K
C14
100n
R5
180K
C15
560p
R6
270K
U23B
LM358
RV10
10K
C29
100n
R27
270K
C13
100n
35V
C16
100n
35V
UHF
TP1
VHF
TP2
U29A
CD4066
U29C
CD4066
U29B
CD4066
U29D
CD4066
R20
10K
R21
10K
U30A
NE5532
R22
10E
UHF
R23
10K
R24
10K
U30B
NE5532
R25
10E
VHF
GND
UHFSEL
VHFSEL
INT2
U9D
74HC00
U26D
74HC02
AUDIO PATHS
U22
8253
TONES
+12V
R8
2K2
R7
4K7
Q2
2N2222
U24
MF6CN-50
CLK IN
FILTER IN
CLK R
R12
22K
R11
22K
C20
4n7
C19
100n
R9
10K
R10
10K
R13
10K
R14
10K
C21
10u
35V
SEL_TONE
X3
1 8432 MHz
CLIB
COMPANY NAME
SENTECH (PTY) LTD
TITLE
DTMF & TONE GENERATORS
GROUP NAME
MUPC FCH
REVISION
REV 1 1
DRAWN BY
LS van Zyl
SHEET
4 OF 9
DATE
20/10/94
TIME
13 11



A0,A1,ALE,CS14,D[0..7],INT1,INT3,RD,WR
SCC
U31
82530
MODEM
U32
TCM3105N
CD TP6
TX TP5
RX TP4
RX AUDIO TP3
X4
4.4336 MHz
C22 27p
C23 27p
RV6 100K
RV7 100K
RV8 100K
C24 100n
C25 100n
C26 100n
C27 100n
R28 100K
R29 100K
U33A
U33B
LM358
+6V
MTX
ACD5
R35 10K
CLK B
SET CD TRIP LEVEL
RV5 100K
U10A
U10B
74HC74
U34
MAX232
C30 22u
C31 22u
C32 22u
C33 22u
COM2
TC07
TC06
TA07
TA06
TC10
TA10
R36 10K
DECOUPLING CAPACITORS
+12V
+5V
GND
C54 100n
C55 100n
C56 100n
C57 100n
C58 100n
C59 100n
C60 100n
C61 100n
C62 100n
C63 100n
C34 100n
C35 100n
C36 100n
C37 100n
C38 100n
C39 100n
C40 100n
C41 100n
C42 100n
C43 100n
C44 100n
C45 100n
C46 100n
C47 100n
C48 100n
C49 100n
C50 100n
C51 100n
C52 100n
C53 100n
COMPANY NAME
SENTECH (PTY) LTD
TITLE
MODEM & COM2
GROUP NAME MUPC FCH
REVISION REV 1.1
DRAWN BY LS van Zyl
SHEET 5 OF 9
DATE 20/10/94
TIME 13:14


SET MODEM
U30-NE5532
U33-LM358
MF6CN-50
U33
U24
U32
U10
U34
TCM3105N
74HC74
MAX232
U29 CD4066
U31 82530
U30
U15
MV5089
U22 8253
U6 74HC573
U14 8255
U23
U3 28F256
KEYBOARD
P2
U20 74C923
U21
U9 27C256
U26 74HC02
P3
DISPLAY
74HC27
U27 74HC139
U8 74HC139
U2 6264
U13 8255
MUPC VER 1-1
DEVELOPED BY
LS van Zyl
SENTECH (PTY) LTD
U28 74HC573
U1 80C32
U16
U17
U18
U19
U16-19 DS75452
U25 74HC245
U11 74HC153
SW1
93C46
U5
MAX690
U12
MAX232
P1
RESET
SENTECH
MUPC PCB LAYOUT

MUPC Micro Controller
Component list

Number	Value		Description
C1 - C2	27p	Ceramic	0805 SMD
C3	100n	Ceramic	1206 SMD
C4 - C7	22u	Tantalum	25V
C8	100n	Ceramic	1206 SMD
C9	1u	Tantalum	25V
C10	100p	Ceramic	0805 SMD
C11	100n	Ceramic	1206 SMD
C12	560p	Ceramic	1206 SMD
C13	100n	Tantalum	25V
C14	100n	Ceramic	1206 SMD
C15	560p	Ceramic	1206 SMD
C16	100n	Tantalum	25V
C17	100n	Ceramic	1206 SMD
C18	1u	Tantalum	25V
C19	100n	Ceramic	1206 SMD
C20	4n7	Ceramic	0805 SMD
C21	10u	Tantalum	25V
C22 - C23	27p	Ceramic	0805 SMD
C24 - C29	100n	Ceramic	1206 SMD
C30 - C33	22u	Tantalum	25V
C34 - C63	100n	Ceramic	1206 SMD
D1 - D11	1N4148	Diode	Signal
D12	12V	Diode	500mW Zener
D13	6.8V	Diode	500mW Zener
LED1	LED	GREEN	PCB mounted
LED2	LED	RED	PCB mounted
Q1 - Q5	2N2222	Transistor	NPN
R1	100K	Resistor	2% - 0.3W - 1206 - SMD
R2	10K	Resistor	2% - 0.3W - 1206 - SMD
R3	180K	Resistor	2% - 0.3W - 1206 - SMD
R4	270K	Resistor	2% - 0.3W - 1206 - SMD
R5	180K	Resistor	2% - 0.3W - 1206 - SMD
R6	270K	Resistor	2% - 0.3W - 1206 - SMD
R7	4K7	Resistor	2% - 0.3W - 1206 - SMD
R8	2K2	Resistor	2% - 0.3W - 1206 - SMD
R9	10K	Resistor	2% - 0.3W - 1206 - SMD
R10	10K	Resistor	2% - 0.3W - 1206 - SMD
R11 - R12	22K	Resistor	2% - 0.3W - 1206 - SMD
R13 - R15	10K	Resistor	2% - 0.3W - 1206 - SMD
R16	1K	Resistor	2% - 0.3W - 1206 - SMD

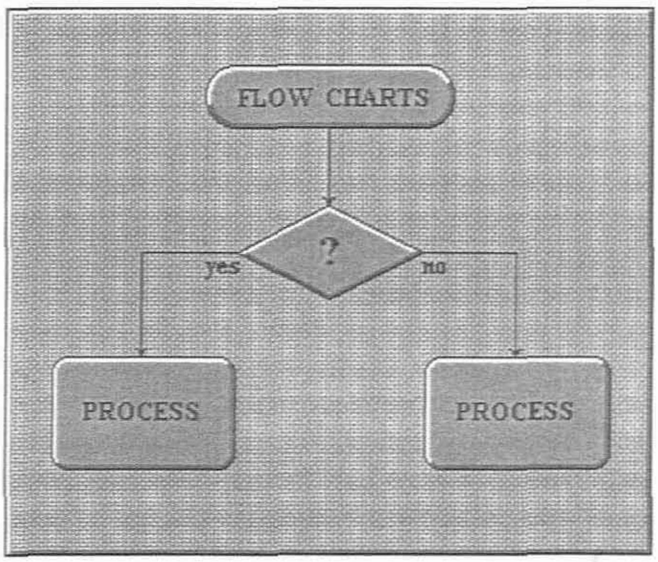
Number	Value		Description
R17	4K7	Resistor	2% - 0.3W - 1206 - SMD
R18	1K	Resistor	2% - 0.3W - 1206 - SMD
R19 - R21	10K	Resistor	2% - 0.3W - 1206 - SMD
R22	10E	Resistor	2% - 0.3W - 1206 - SMD
R23 - R24	10K	Resistor	2% - 0.3W - 1206 - SMD
R25	10E	Resistor	2% - 0.3W - 1206 - SMD
R26 - R27	270K	Resistor	2% - 0.3W - 1206 - SMD
R28 - R29	100K	Resistor	2% - 0.3W - 1206 - SMD
R30	270K	Resistor	2% - 0.3W - 1206 - SMD
R31	1K	Resistor	2% - 0.3W - 1206 - SMD
R32	10K	Resistor	2% - 0.3W - 1206 - SMD
R33	47E	Resistor	2% - 0.3W - 1206 - SMD
R34 - R37	10K	Resistor	2% - 0.3W - 1206 - SMD
RN1 - RN3	10K	Resistor	Resistor Network 8 x 1
RV1	10K	Trim-pot	Multi-Turn Model 67W
RV2 - RV3	10K	Trim-pot	Multi-Turn Model 89P
RV5 - RV8	100K	Trim-pot	Multi-Turn Model 89P
RV9 - RV10	10K	Trim-pot	Multi-Turn Model 89P
RL1 - RL9		Relays	National HB2-12V
SW1	DS-08	Switch	PCB 8 position slide switch
SW2		Switch	PCB miniature push to make
U1	80C32	CPU	
U2	6264	RAM	8K x 8 bits
U3	28F256	FLASH	32K x 8 bits
U4	27C256	EPROM	32K x 8 bits
U5	NM93C46	EEPROM	128 bits
U6	74HC573		Octal latch
U7	MAX690		Watchdog timer
U8	74HC139		Dual 2 - 4 De-multiplexer
U9	74HC00		Quad 2 Input NAND gate
U10	74HC74		Dual D flip-flop
U11	74HC153		Dual 1 - 4 multiplexer
U12	MAX232	Coms	Dual RS232 .ransmitter / receiver
U13 - U14	8255	PPI	Interface Adapter
U15	MV5089		DTMF generator
U16 - U19	75452		Dual Relay driver
U20	74C923		Keyboard encoder
U21	74HC27		Triple 3 Input NOR gate
U22	8253	Timer	3 Channel Counter
U23	LM358		Dual operational amplifier
U24	MF6CN-50	Filter	Switched capacitor filter
U25	74HC245		Octal buffer and line driver
U26	74HC02		Quad 2 Input NOR gate
U27	74HC139		Dual 2 - 4 De-multiplexer

Number	Value		Description
U28	74HC573		Octal latch
U29	CD4066		Quad Bilateral Switch
U30	NE5532		Dual operational amplifier
U31	82530		Serial Communications Controller
U32	TCM3105N		Voice band modem
U33	LM358		Dual operational amplifier
U34	MAX232	Coms	Dual RS232 transmitter / receiver
X1	11.059 MHz	Crystal	CPU clock
X2	3.58 MHz	Crystal	DTMF generator clock
X3	1.8432 MHz	Crystal	Tone generator
X4	4.4336 MHz	Crystal	Voice band modem
P1	DB9	D-Type	9 pin D-Type DPL9/90
P2	HD10	2532/10	10 pin header connector
P3	HD14	2532/14	14 pin header connector
P4-P5	DIN41612	A64-S1-111	PCB angled male connector
TP1 - TP6			Test pins
JP1 - JP8			Jumpers
3x	40 pin		Tulip IC socket
1x	32 pin		Tulip IC socket
2x	28 pin		Tulip IC socket
1x	24 pin		Tulip IC socket
4x	20 pin		Tulip IC socket
7x	16 pin		Tulip IC socket
6x	14 pin		Tulip IC socket
6x	8 pin		Tulip IC socket

APPENDIX B

RADIO TELEPHONE SYSTEM

FLOW DIAGRAMS



Developed by

Louis S. van Zyl (Reg.Eng.Tech)

CONTENTS

1. INTRODUCTION.

This appendix contains all the flow chart diagrams for the software that are used in the radio telephone system. The modules are defined into functional entities, that is, similar procedures are grouped together. The source code of the system is written in Pascal using a native compiler that generates the code for the micro-controller and can be found on the diskette marked "APPENDIX B. SYSTEM FILES".

2. DIAGRAM NUMBERING.

The flow chart diagram file names are used in the numbering and cross reference between the source code and the flow charting sheets. The following table gives the reference between the source code file name and the flowchart file name.

No	Source Code	Flow Chart
1	MUPCSOFT.PAS	INIT-##x.FCD
2	RT_MAIN.PAS	MAIN-##x.FCD
3	MUPCDIAG.PAS	DIAG-##x.FCD
4	RTTESTS.PAS	TEST-##x.FCD
5	RTCONFIG.PAS	CONF ##x.FCD
6	RTALIGN.PAS	ALGN-##x.FCD
7	RTDISPLY.PAS	DISP-##x.FCD
8	RTFLASH.PAS	FLSH-##x.FCD
9	RTEEPROM.PAS	PROM-##x.FCD
10	RTSERIAL.PAS	COMS-##x.FCD
11	RTUTIL.PAS	UTIL-##x.FCD
12	RT_INTR.PAS	INTR-##x.FCD
13	RTDRIVER.ASM	----------

Table 1 : Radio Telephone system file cross reference.

All the flowchart names are inserted into the source code at the position where the chart starts in the following format:

{=== Flow chart file : XXXX-##x.FCD ===}

If a flow chart is over multiple sheets, the x can be from A to Z.

The Headings on the flow chart sheets is in the following format:

Title	Title of the flow chart sheet.
File	Name of the flow chart sheet.
Date	Date last modified.
Module	Source code module applicable to flow chart.
Section	Section in source code module.

A cross link is created between the flow charts and the source code to make it easier to follow the program flow of the system.

3. FLOW DIAGRAMS.

The first section gives the overall flow diagrams of the system software that is currently implemented in the radio telephone system.

File Names	Description	Page
MAST-01A.FCD	Operational software.	4
MAST-02A.FCD	Diagnostics software.	5
MAST-02B.FCD	Basic radio telephone module.	6
MAST-02C.FCD	Keyboard alignment and configuration modules.	7
MAST-02D.FCD	Computer controled diagnostics module.	8

The following thirteen sections gives the software modules and the flow charting sheets of the complete system software.

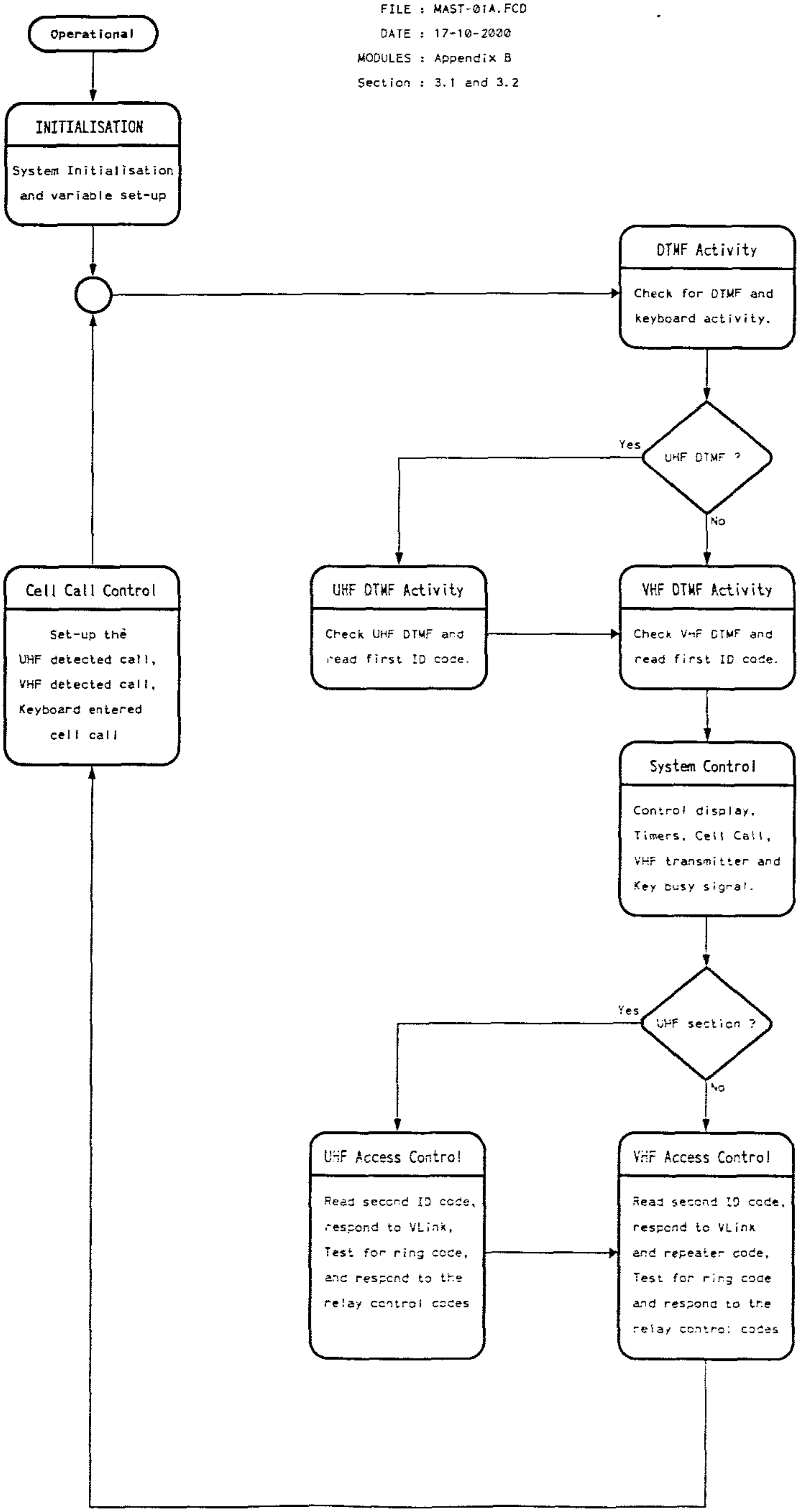
MUPC CARD : OPERATIONAL SOFTWARE

FILE : MAST-01A.FCD

DATE : 17-10-2000

MODULES : Appendix B

Section : 3.1 and 3.2



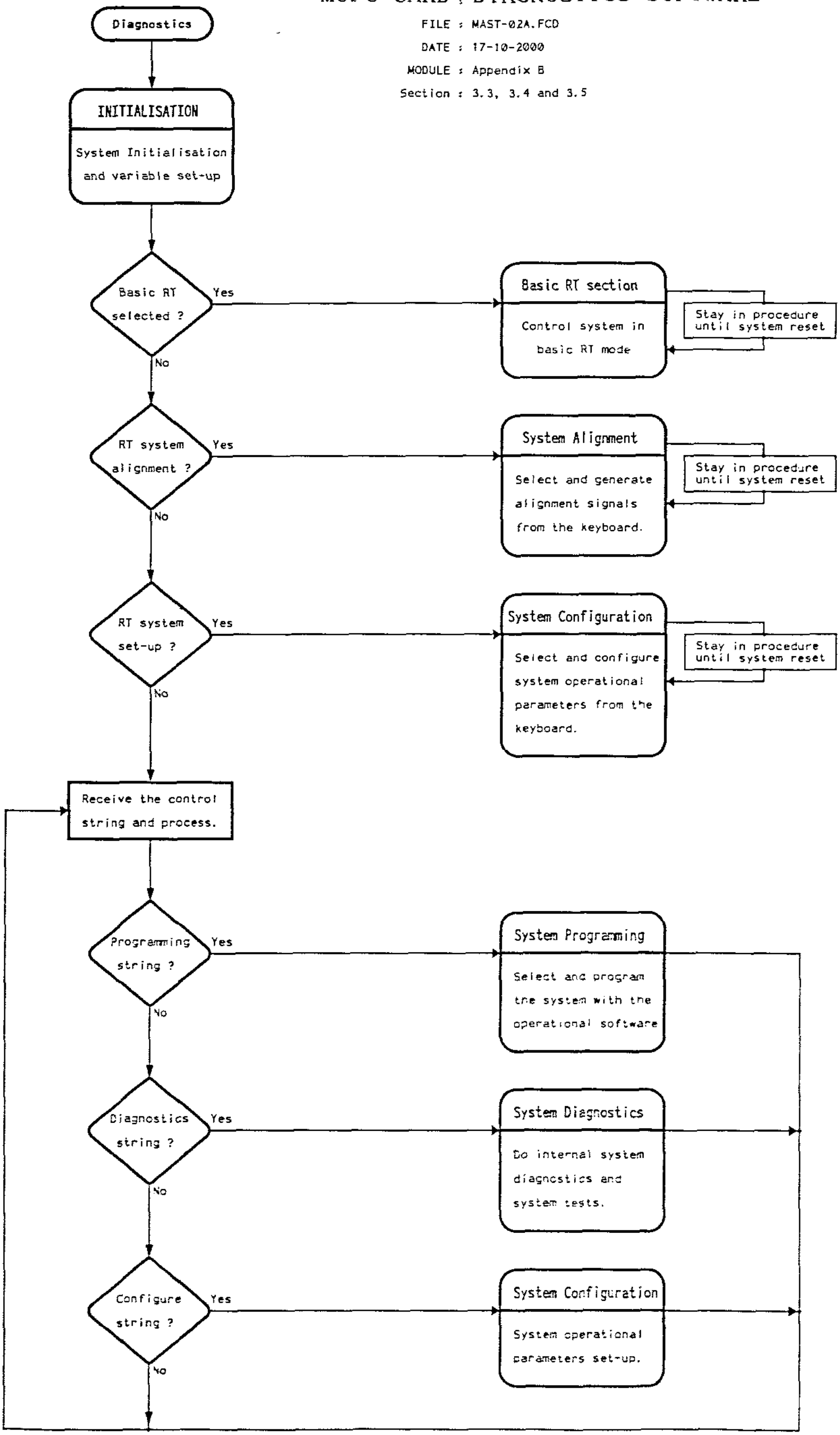
MUPC CARD DIAGNOSTICS SOFTWARE

FILE : MAST-02A.FCD

DATE : 17-10-2000

MODULE : Appendix B

Section : 3.3, 3.4 and 3.5



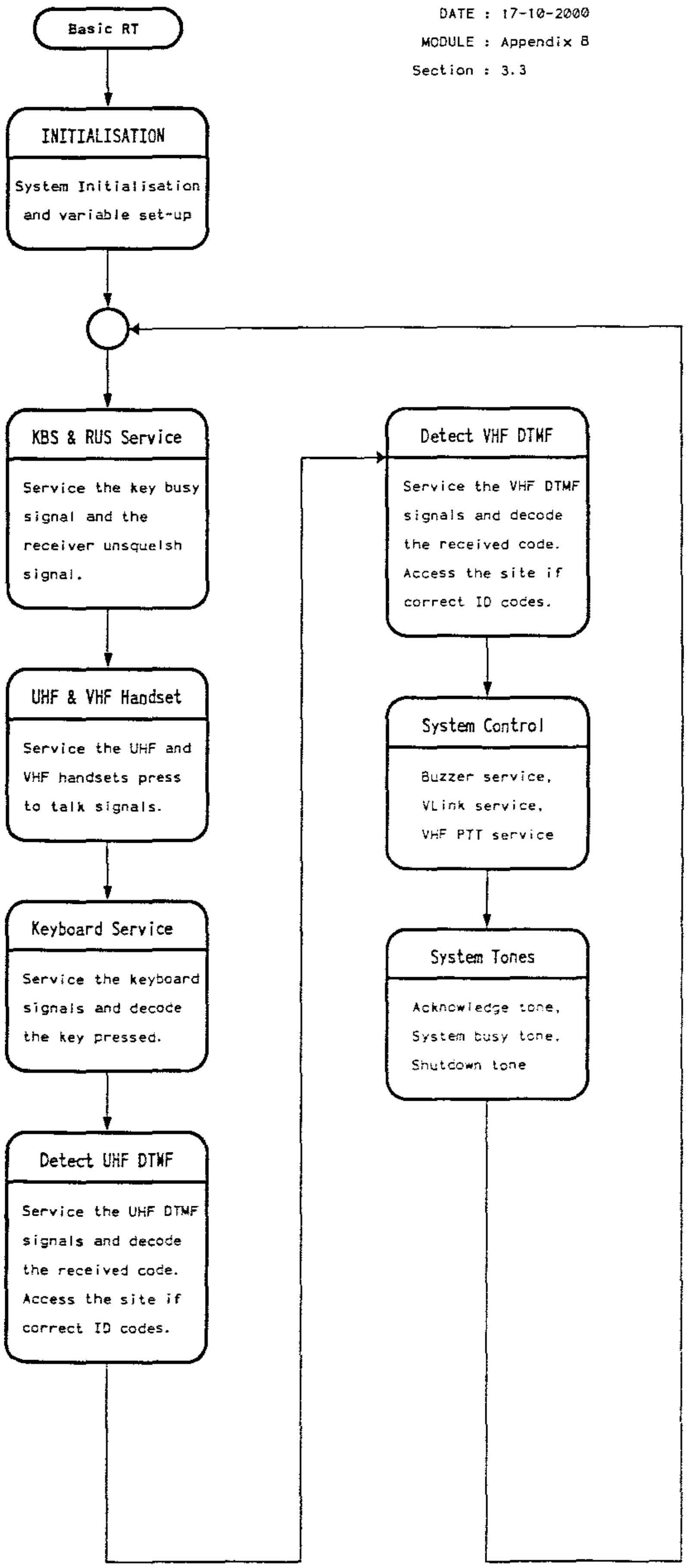
MUPC CARD . BASIC RT SYSTEM

FILE : MAST-02B.FCD

DATE : 17-10-2000

MODULE : Appendix B

Section : 3.3



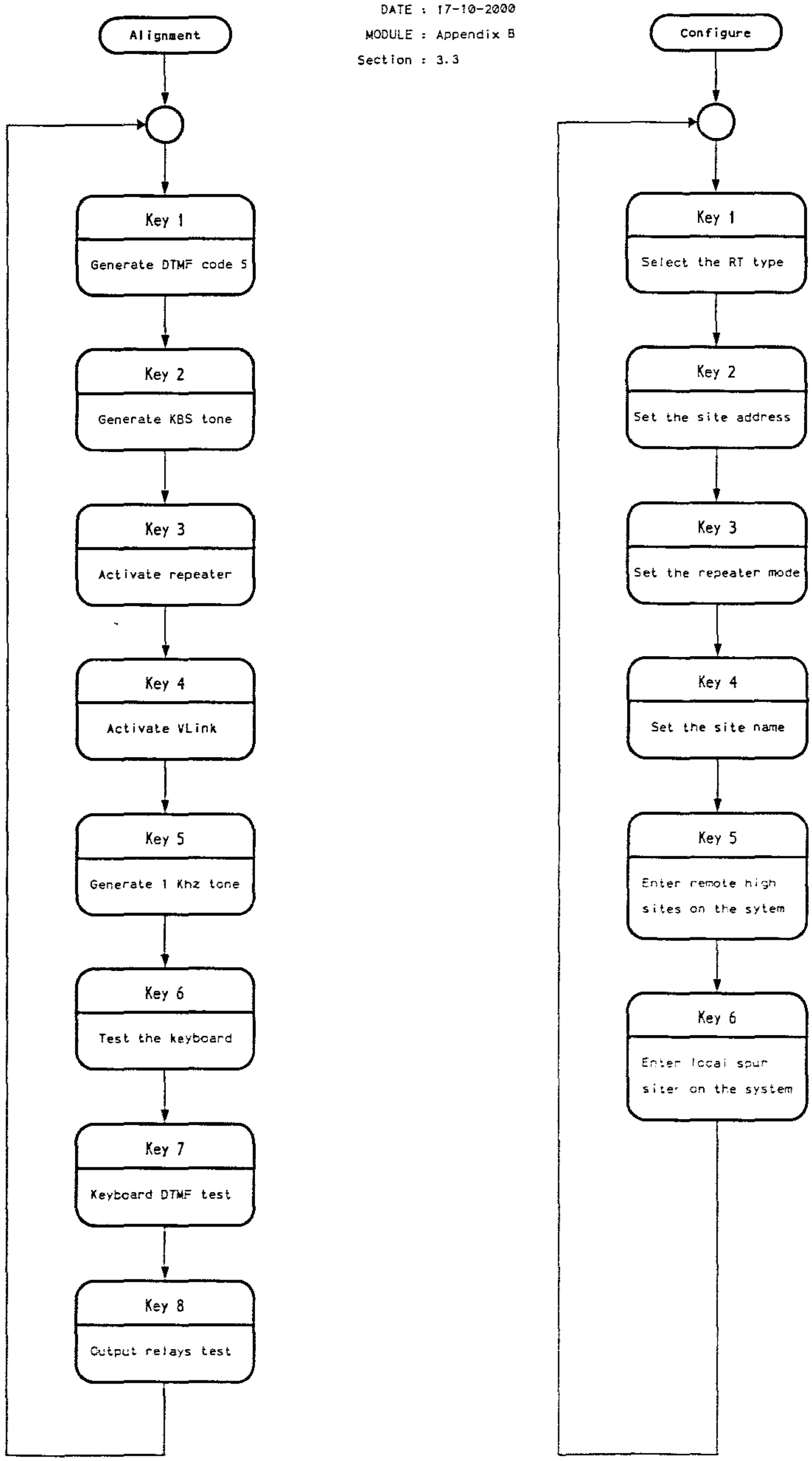
MUPC CARD : ALIGNMENT & CONFIGURATION

FILE : MAST-02C.FCD

DATE : 17-10-2000

MODULE : Appendix B

Section : 3.3



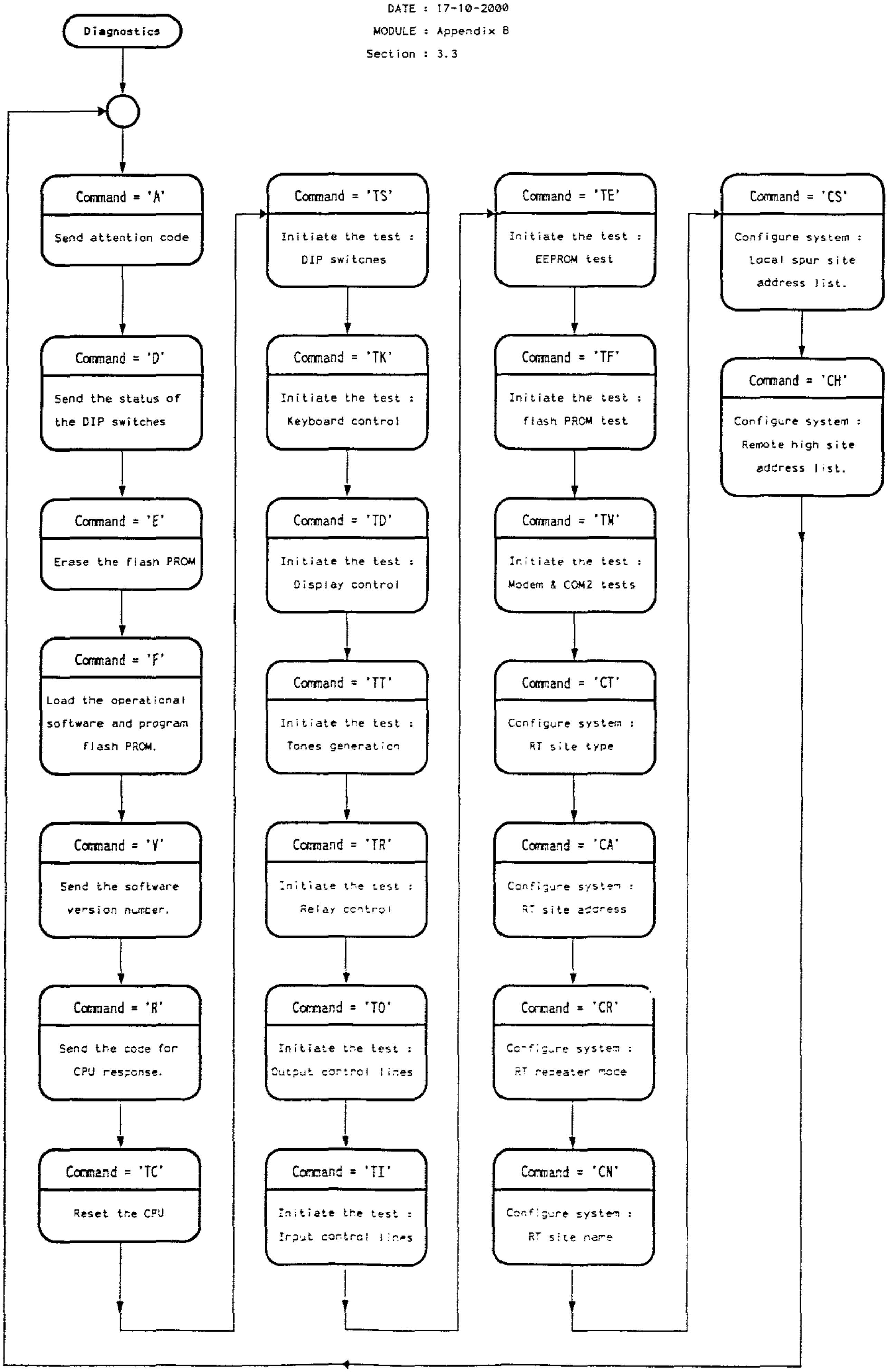
MUPC CARD : DIAGNOSTICS

FILE : MAST-02D.FCD

DATE : 17-10-2000

MODULE : Appendix B

Section : 3.3



3.1 SYSTEM MODULE.

The system module is the main start-up and initialisation module of the operating software.

File Names	Description	Page
MUPCSOFT.PAS	Pascal source file in appendix C.	---
INTR-10A.FCD	External Interrupt 0.	10
INTR-11A.FCD	Timer 0 Interrupt.	11
INTR-12A.FCD	Timer 1 Interrupt.	12
INIT-10A.FCD	Main loop.	14
INIT-11A.FCD	Delay procedure and hex function.	16
INIT-12A.FCD	Initialisation of system.	17

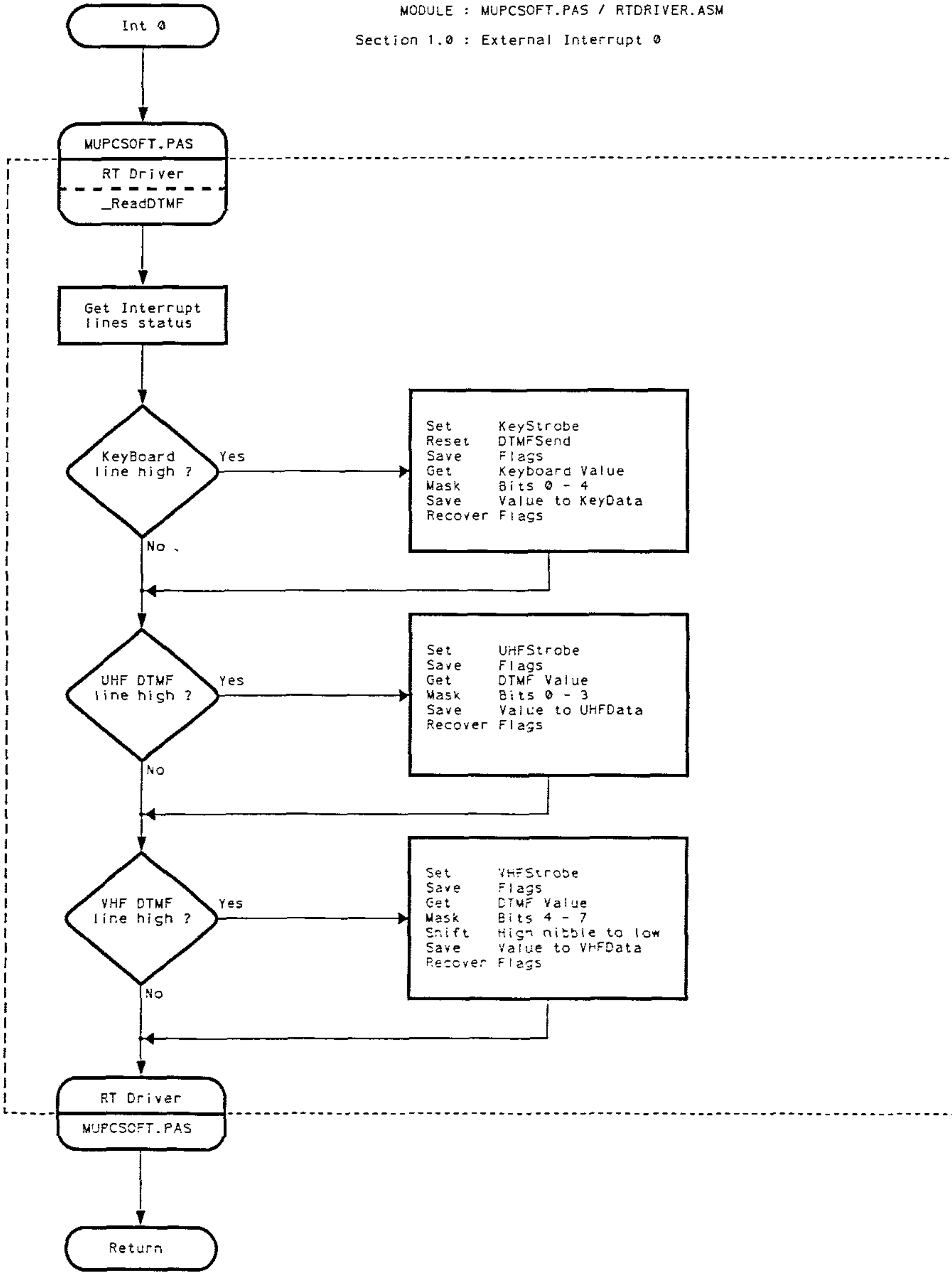
MUPC CARD : INTERRUPT ROUTINE

FILE : INTR-10A.FCD

DATE : 10-10-1996

MODULE : MUPCSOFT.PAS / RTDRIVER.ASM

Section 1.0 : External Interrupt 0



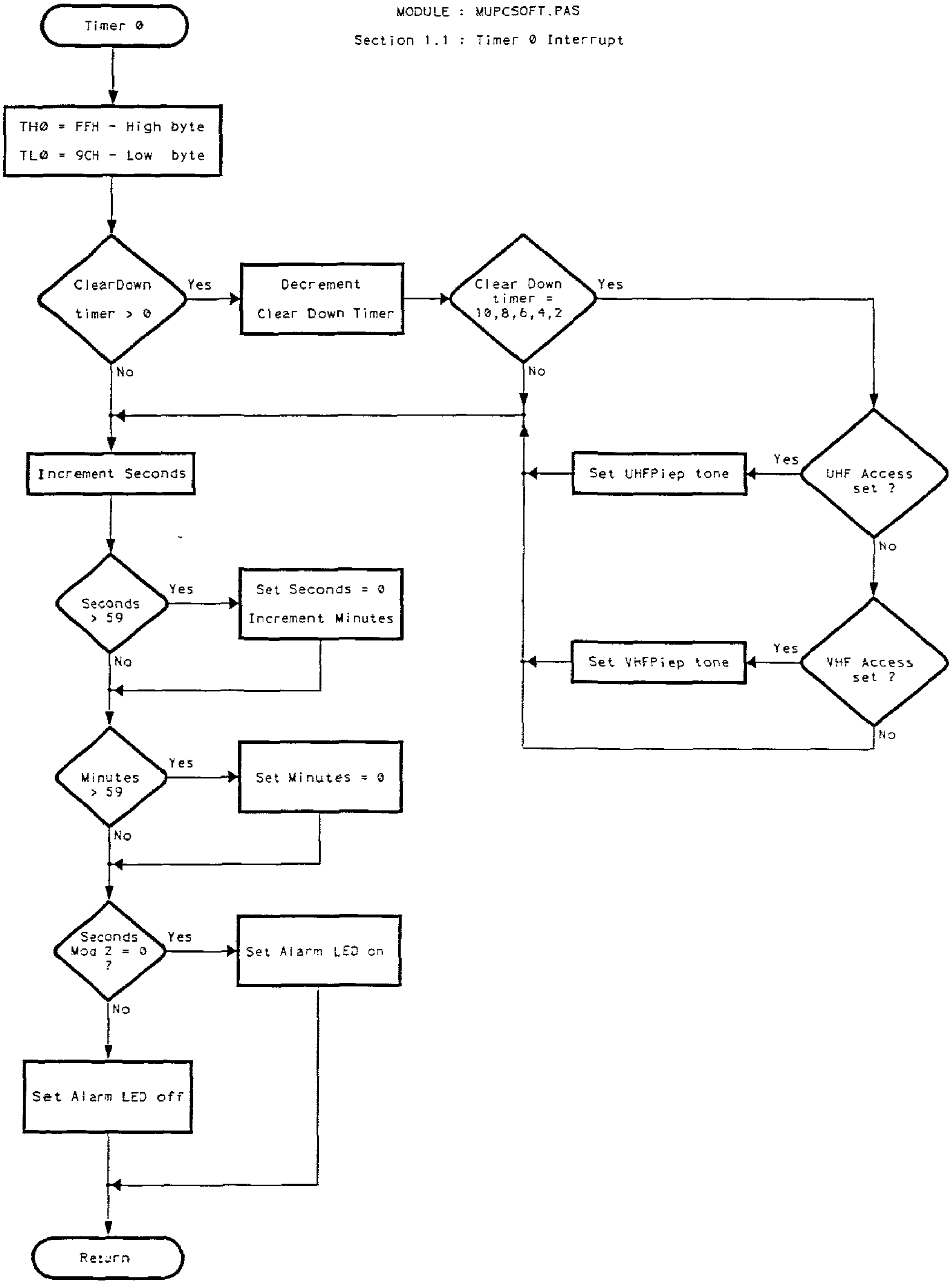
MUPC CARD : INTERRUPT ROUTINE

FILE : INTR-11A.FCD

DATE : 11-10-1996

MODULE : MUPCSOFT.PAS

Section 1.1 : Timer 0 Interrupt



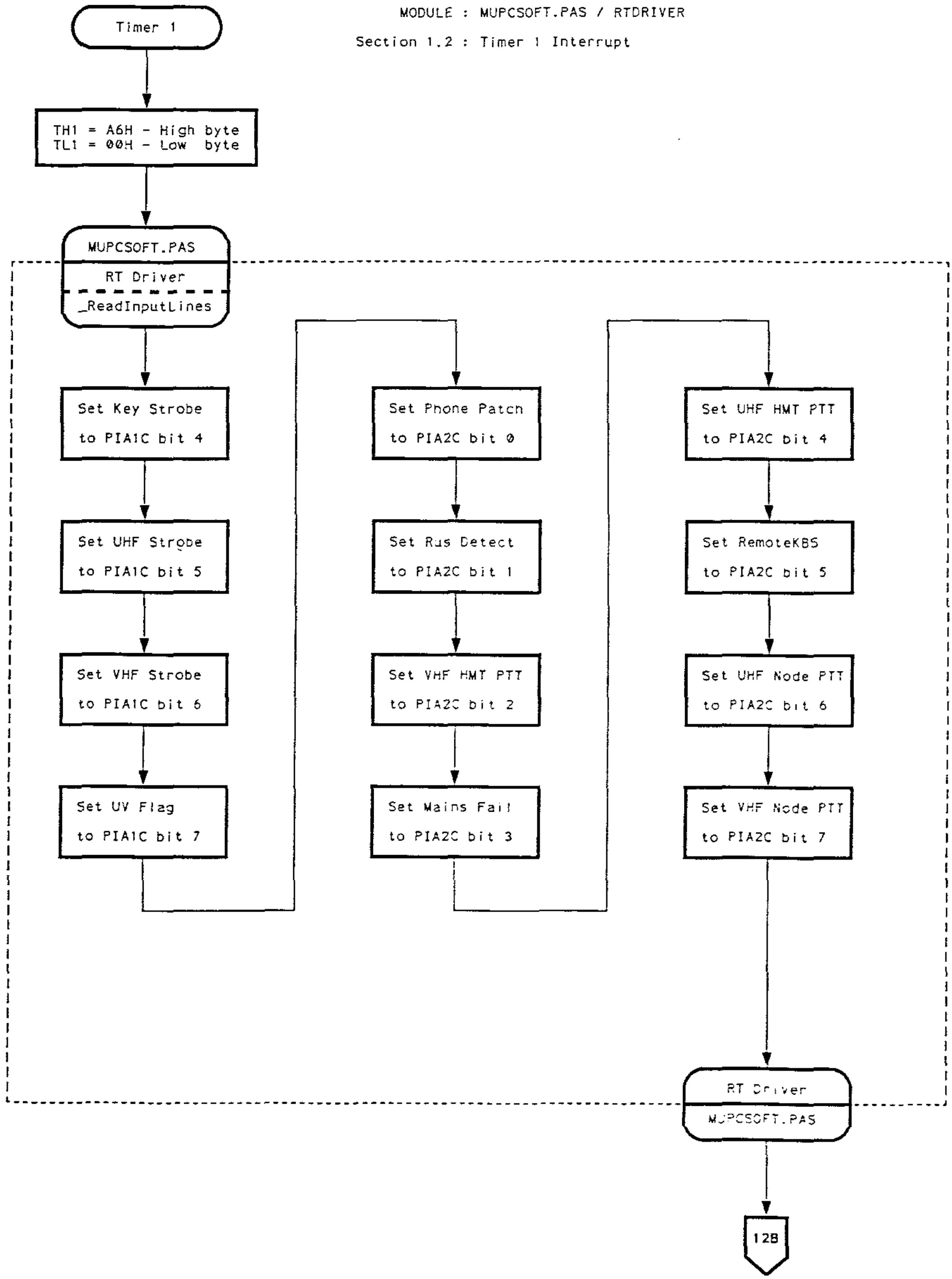
MUPC CARD : INTERRUPT ROUTINE

FILE : INTR-12A.FCD

DATE : 11-10-1996

MODULE : MUPCSOFT.PAS / RTDRIVER

Section 1.2 : Timer 1 Interrupt



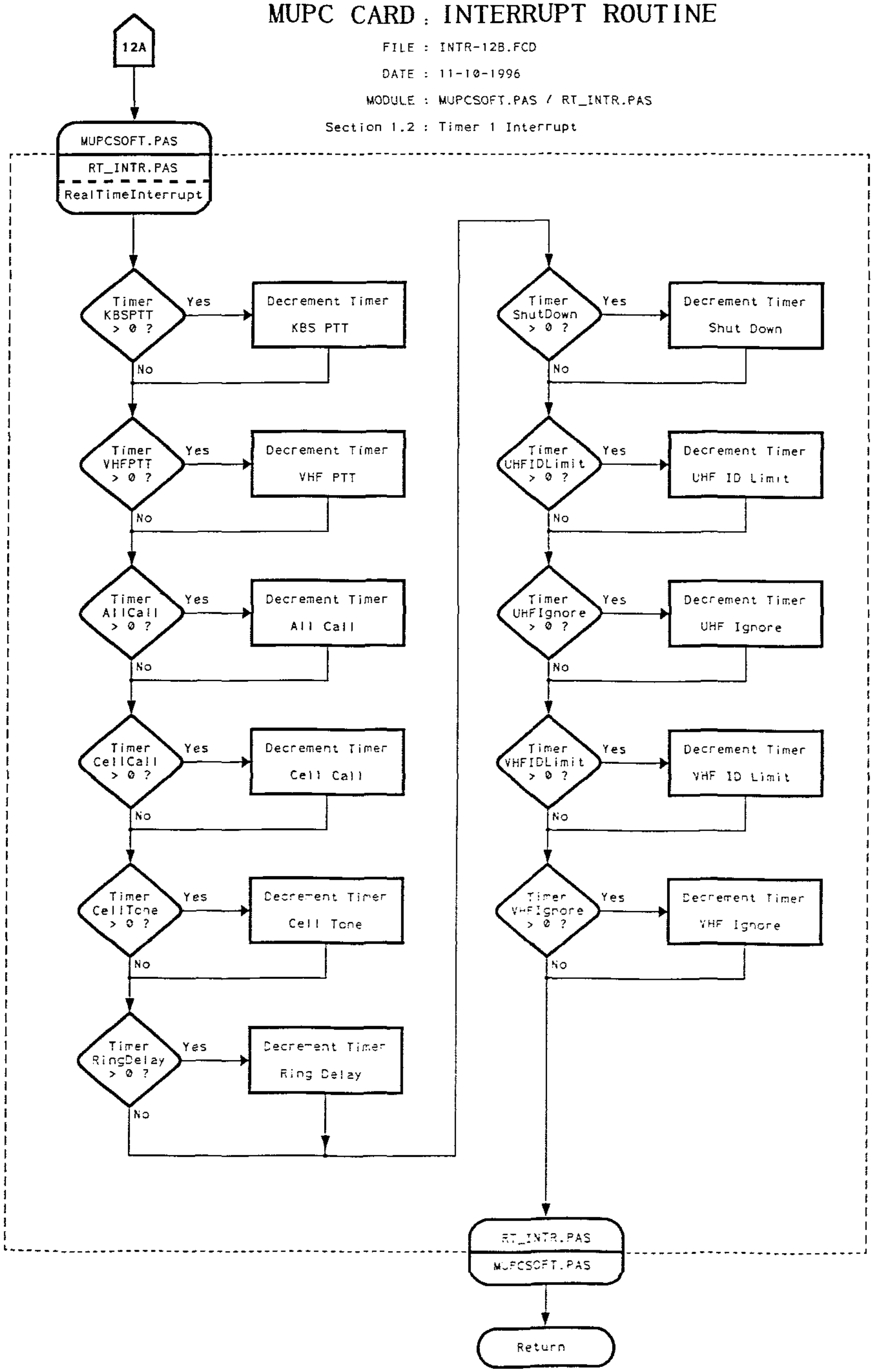
MUPC CARD : INTERRUPT ROUTINE

FILE : INTR-12B.FCD

DATE : 11-10-1996

MODULE : MUPCSOFT.PAS / RT_INTR.PAS

Section 1.2 : Timer 1 Interrupt



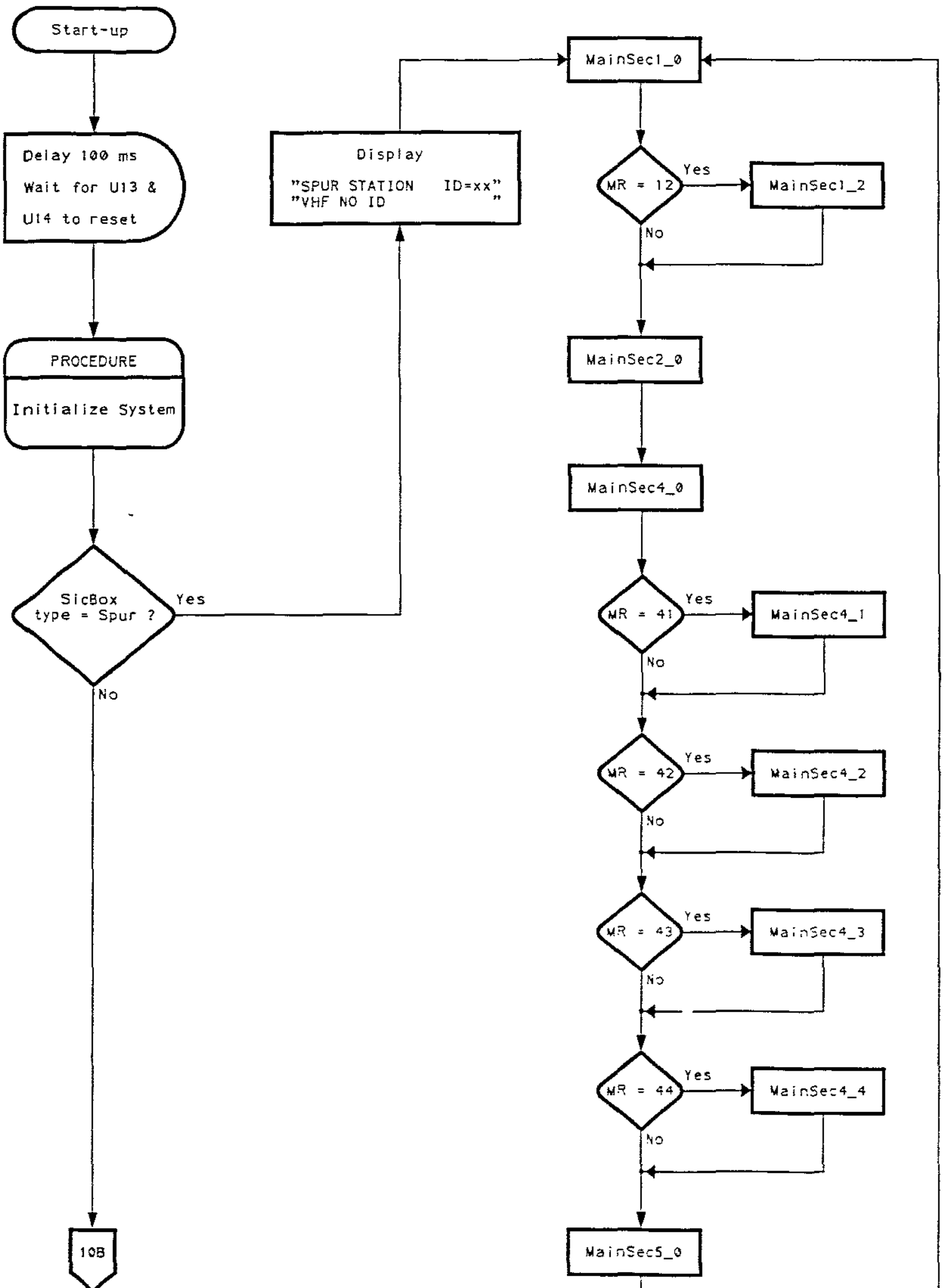
MUPC CARD : INITIALISATION

FILE : INIT-10A.FCD

DATE : 25-10-1996

MODULE : MUPCSOFT.PAS

Section 1.0 : Main Loop



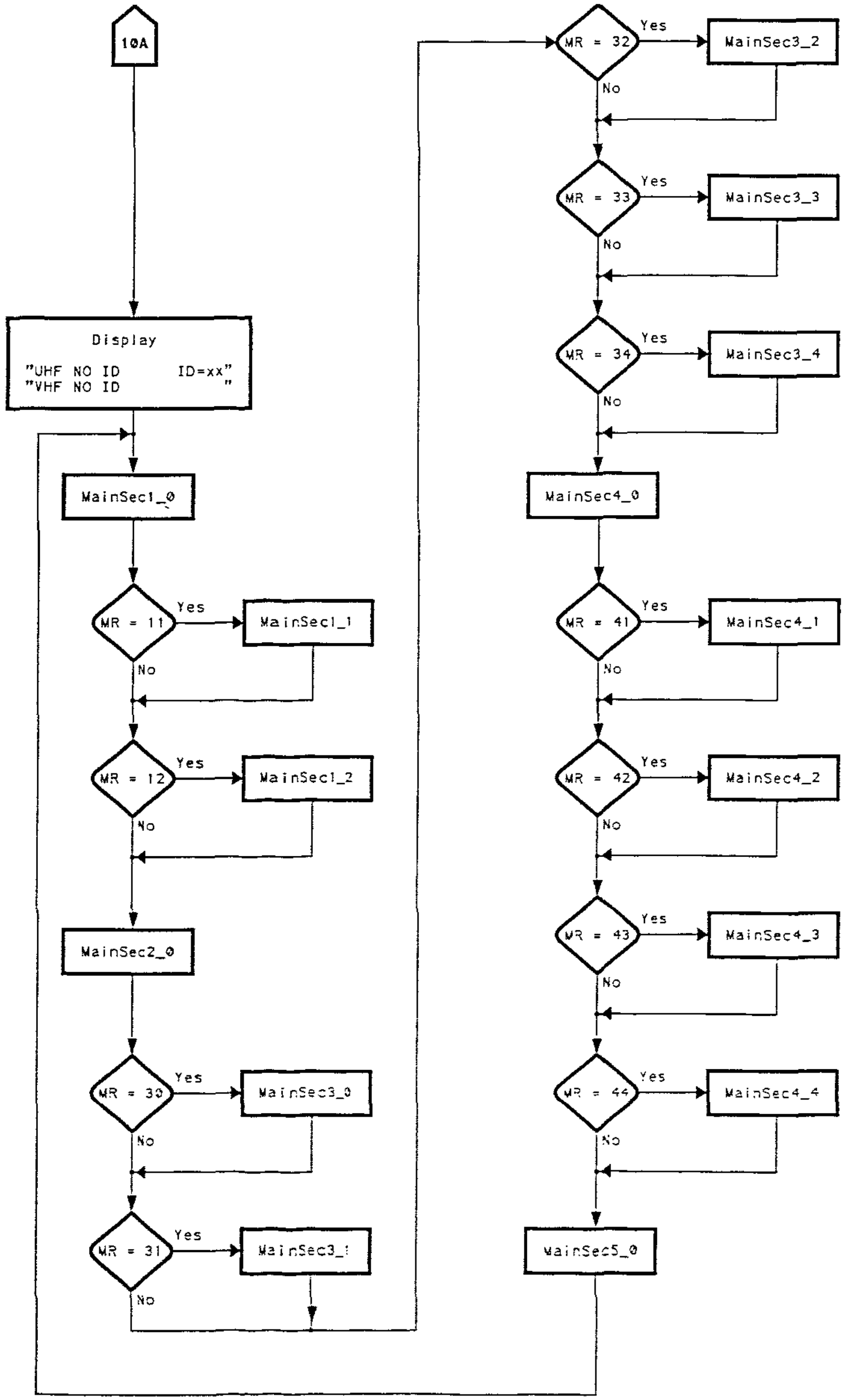
MUPC CARD : INITIALISATION

FILE : INIT-10B.FCD

DATE : 25-10-1996

MODULE : MUPCSOFT.PAS

Section 1.0 : Main Loop



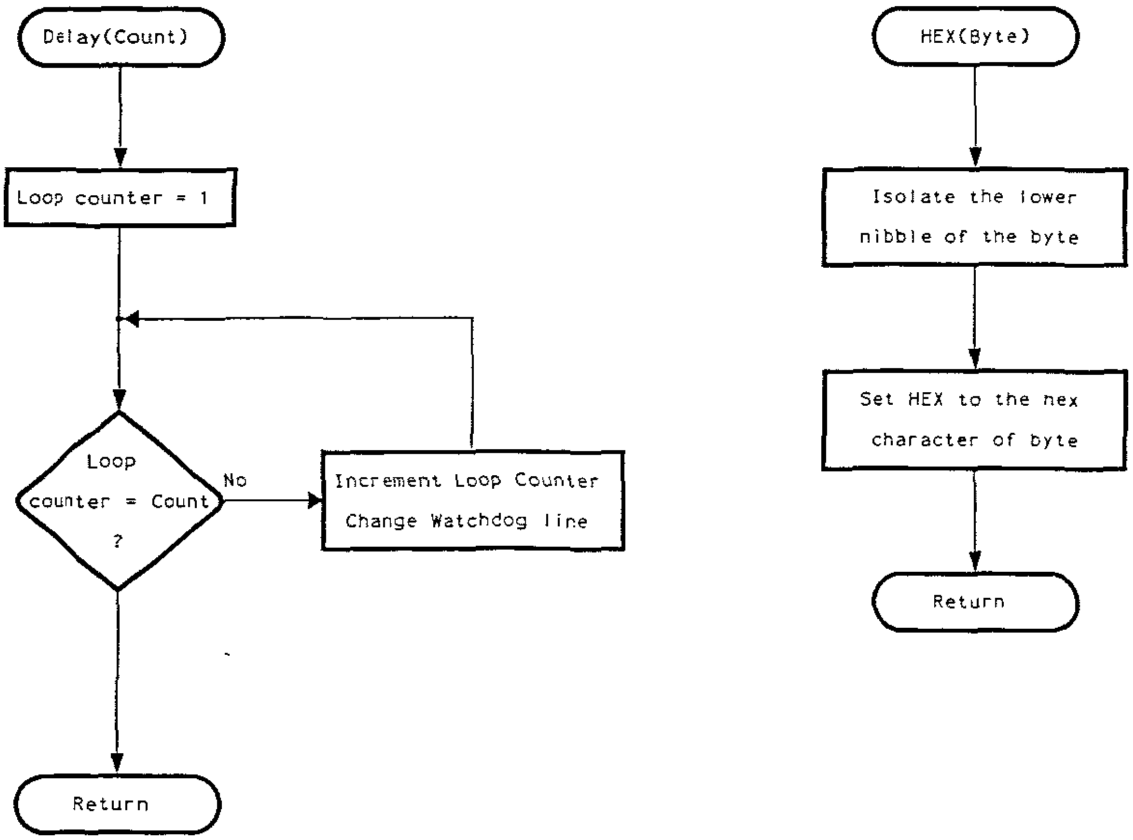
MUPC CARD : INITIALISATION

FILE : INIT-11A.FCD

DATE : 10-10-1996

MODULE : MUPCSOFT.PAS

Section 1.1 : Delay Procedure & Hex Function



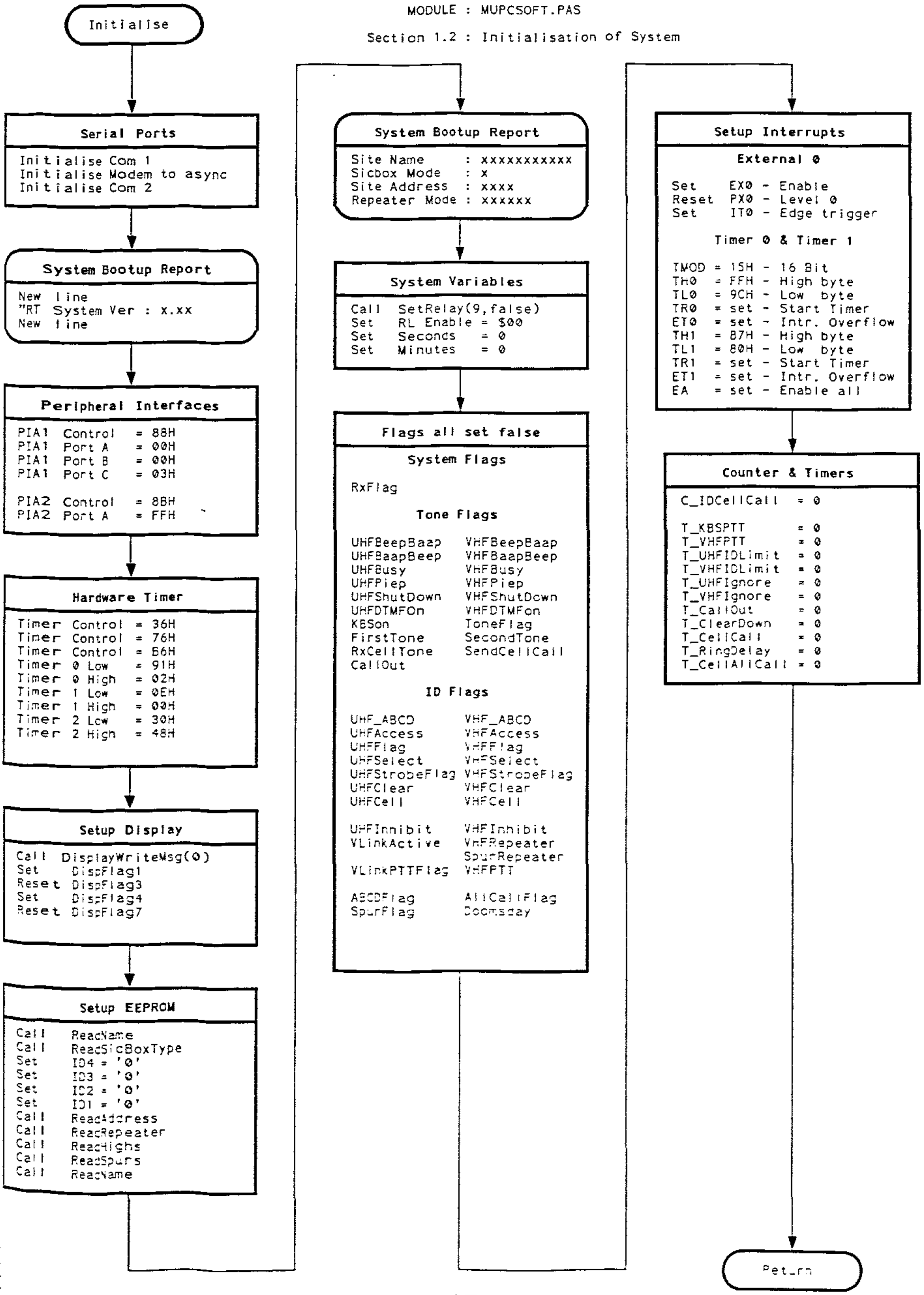
MUPC CARD : INITIALISATION

FILE : INIT-12A.FCD

DATE : 28-08-1998

MODULE : MUPCSOFT.PAS

Section 1.2 : Initialisation of System



3.2 MAIN MODULE.

The main module is the system control section for the UHF and VHF radios.

File Names	Description	Page
RT_MAIN.PAS	Pascal source file in appendix C.	---
MAIN-10A.FCD	DTMF Activity.	19
MAIN-11A.FCD	UHF DTMF Activity & First ID code.	23
MAIN-12A.FCD	VHF DTMF Activity & First ID code.	25
MAIN-20A.FCD	Display & Timeout control.	26
MAIN-20B.FCD	Cell Call control.	27
MAIN-20C.FCD	VHF control.	28
MAIN-20D.FCD	KBS control.	29
MAIN-30A.FCD	UHF access control section.	30
MAIN-31A.FCD	Respond to VLink code.	32
MAIN-32A.FCD	*Decode second digit of ID code.*	33
MAIN-33A.FCD	Test for ring code.	34
MAIN-34A.FCD	Respond to UHF DTMF A B C D codes.	35
MAIN-40A.FCD	VHF access control section.	37
MAIN-41A.FCD	Respond to VLink and Repeater code.	38
MAIN-42A.FCD	Decode second digit of ID code.	39
MAIN-43A.FCD	Test for ring code.	40
MAIN-44A.FCD	Respond to VHF DTMF A B C D codes.	41
MAIN-50A.FCD	UHF, VHF and System Cell Call.	43

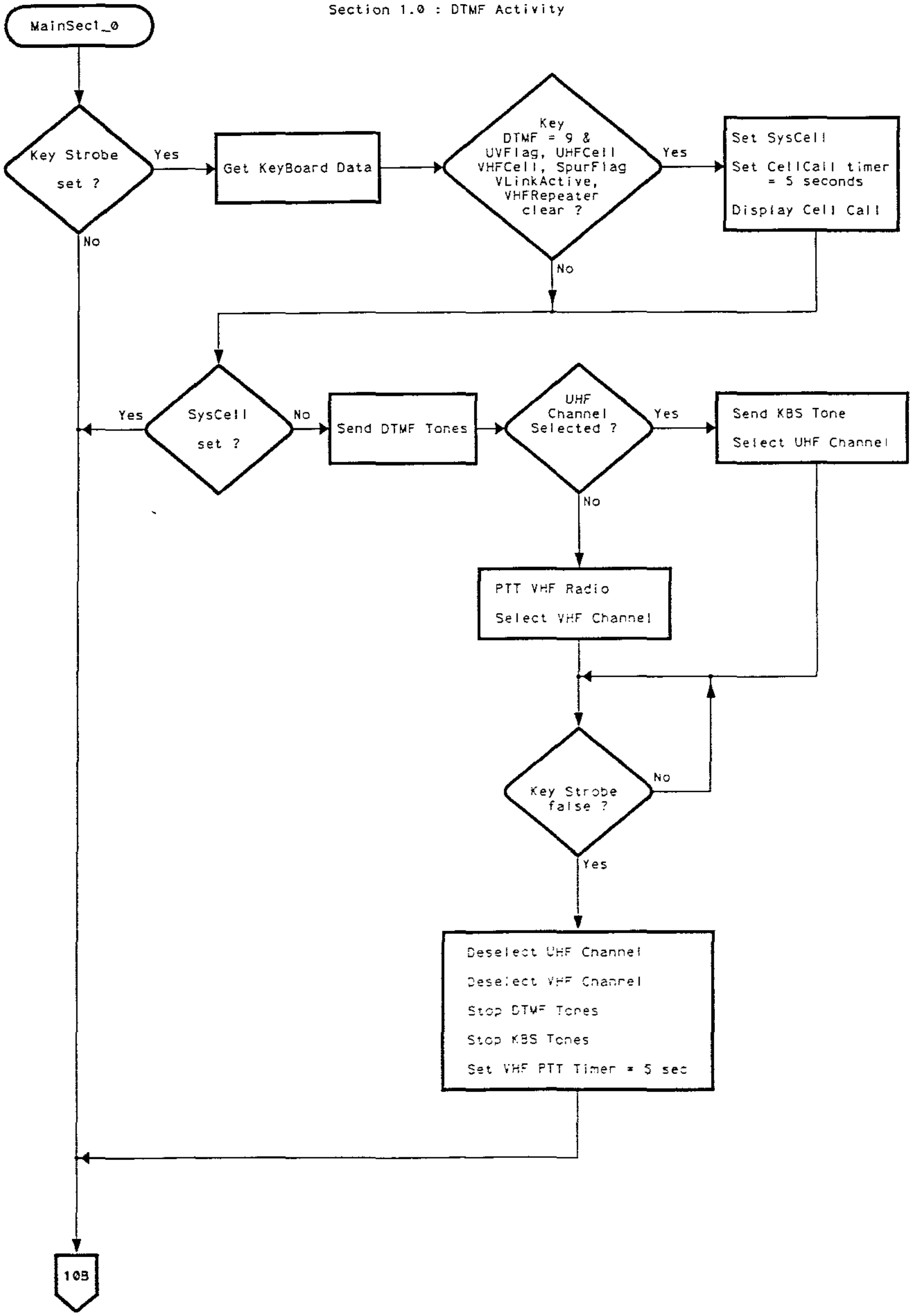
MUPC CARD : MAIN ROUTINE

FILE : MAIN-10A.FCD

DATE : 15-07-1998

MODULE : RT_MAIN.PAS

Section 1.0 : DTMF Activity



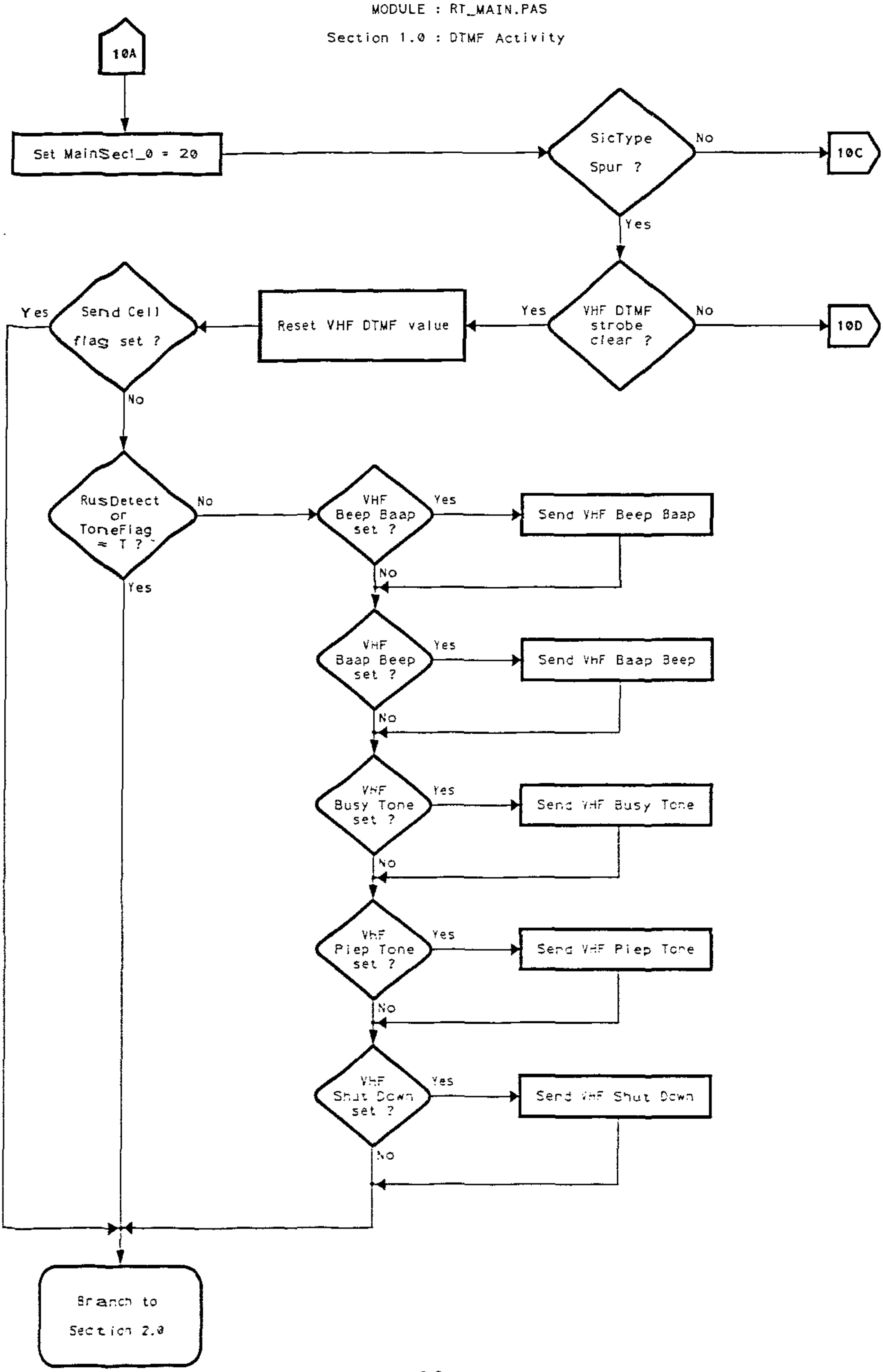
MUPC CARD : MAIN ROUTINE

FILE : MAIN-10B.FCD

DATE : 15-07-1998

MODULE : RT_MAIN.PAS

Section 1.0 : DTMF Activity



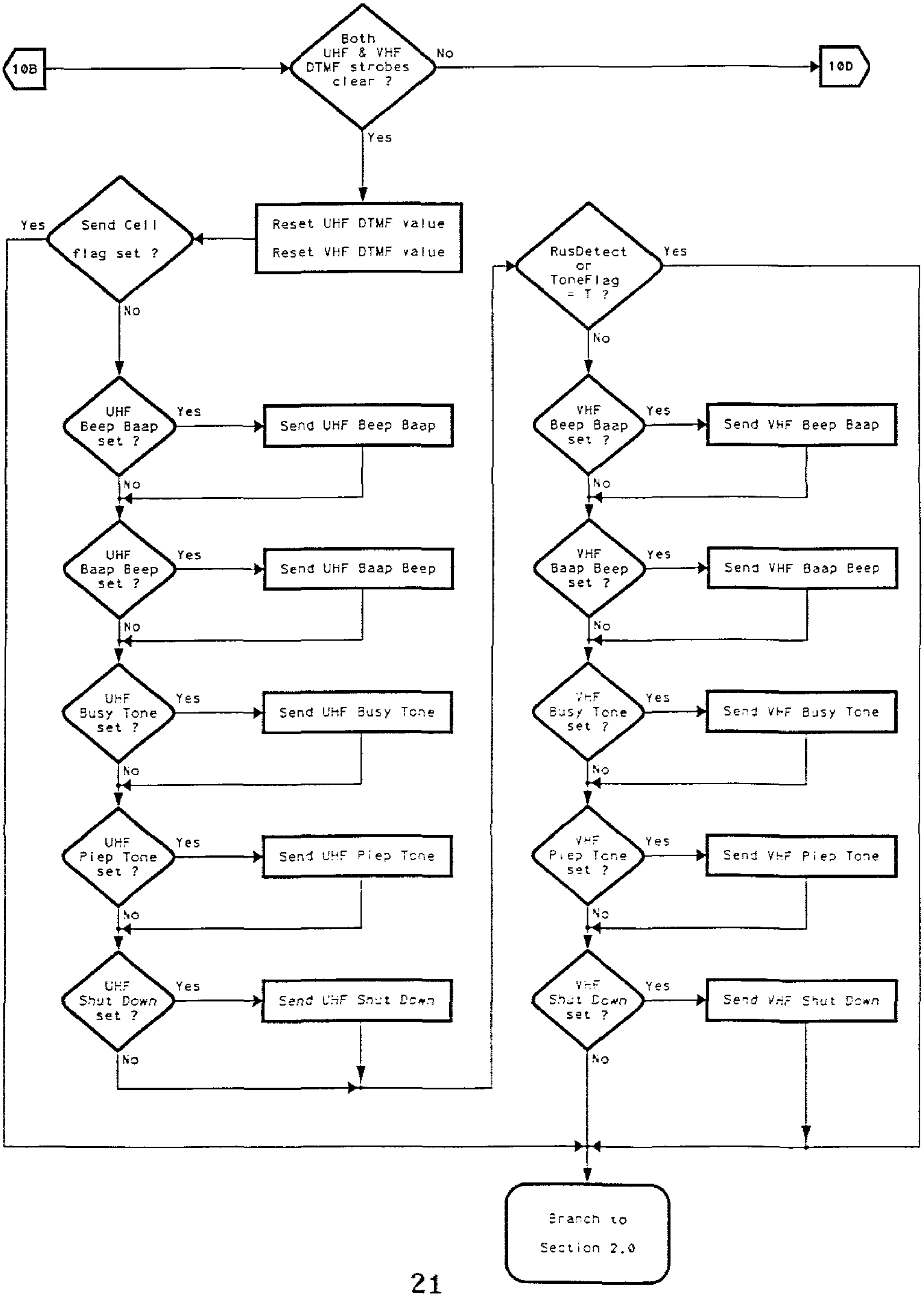
MUPC CARD : MAIN ROUTINE

FILE : MAIN-10C.FCD

DATE : 15-07-1998

MODULE : RT_MAIN.PAS

Section 1.0 : DTMF Activity



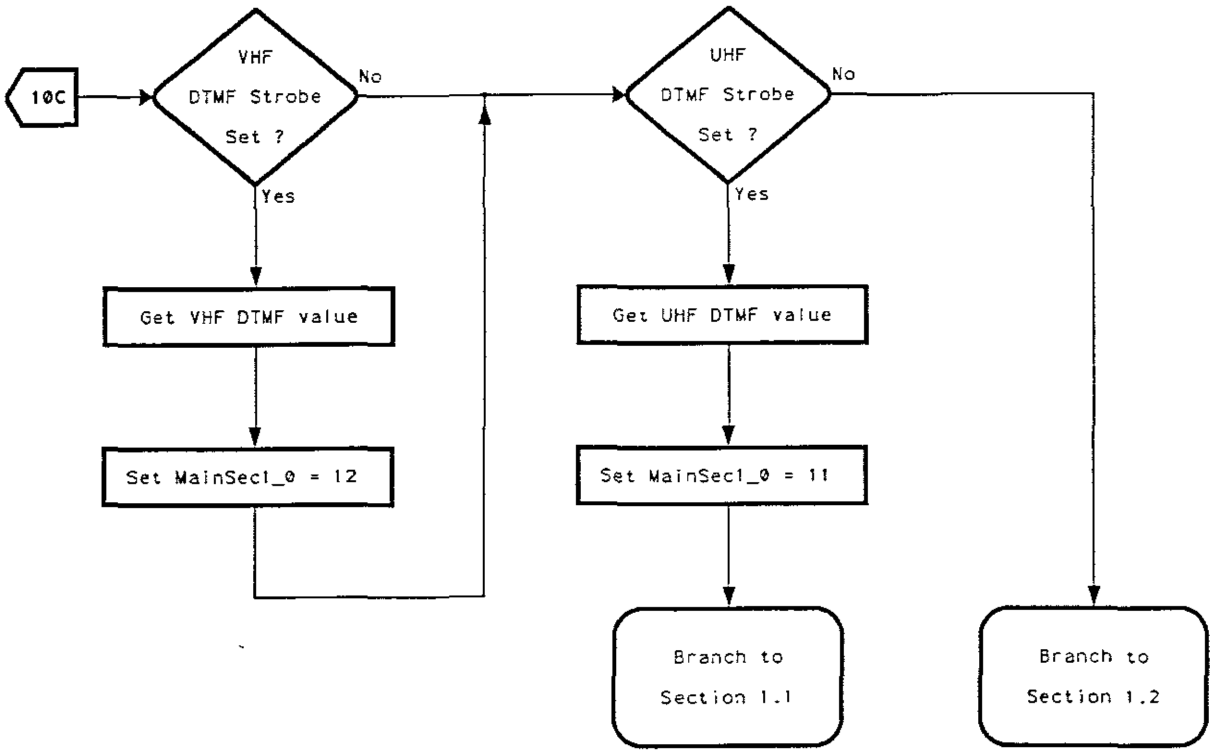
MUPC CARD : MAIN ROUTINE

FILE : MAIN-10D.FCD

DATE : 25-09-1996

MODULE : RT_MAIN.PAS

Section 1.0 : DTMF Activity



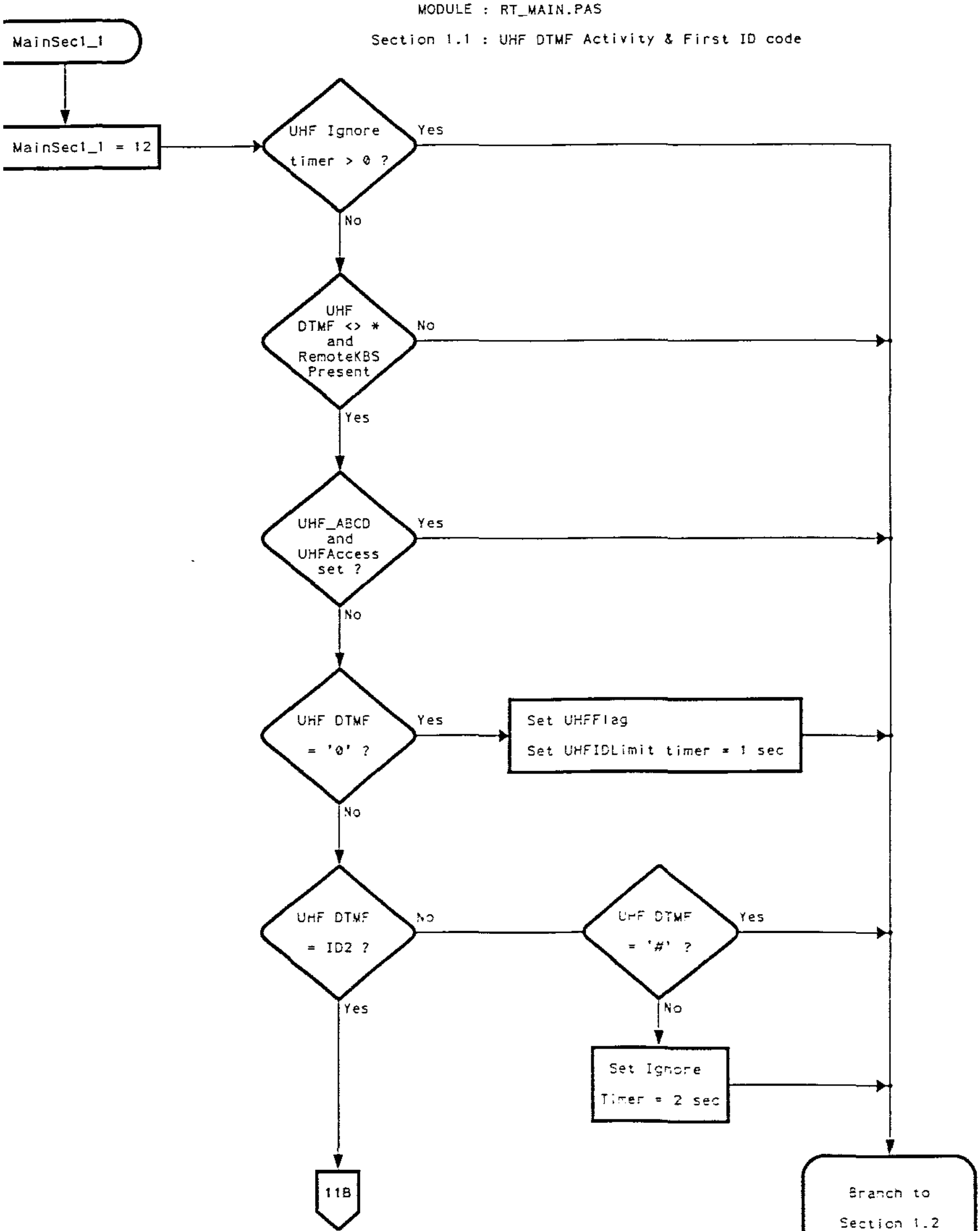
MUPC CARD : MAIN ROUTINE

FILE : MAIN-11A.FCD

DATE : 27-09-1996

MODULE : RT_MAIN.PAS

Section 1.1 : UHF DTMF Activity & First ID code



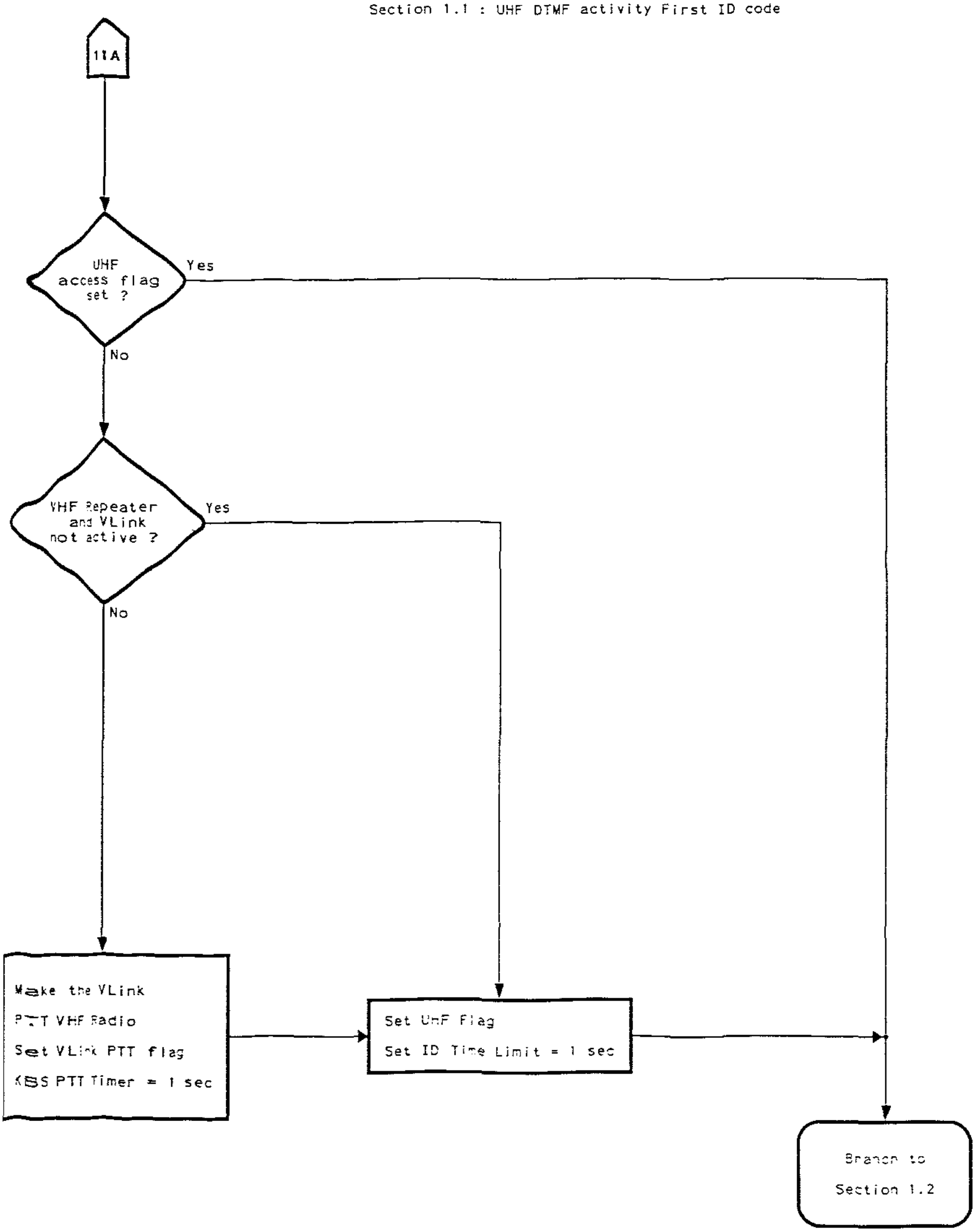
MUPC CARD : MAIN ROUTINE

FILE : MAIN-11B.FCD

DATE : 27-09-1996

MODULE : RT_MAIN.PAS

Section 1.1 : UHF DTMF activity First ID code



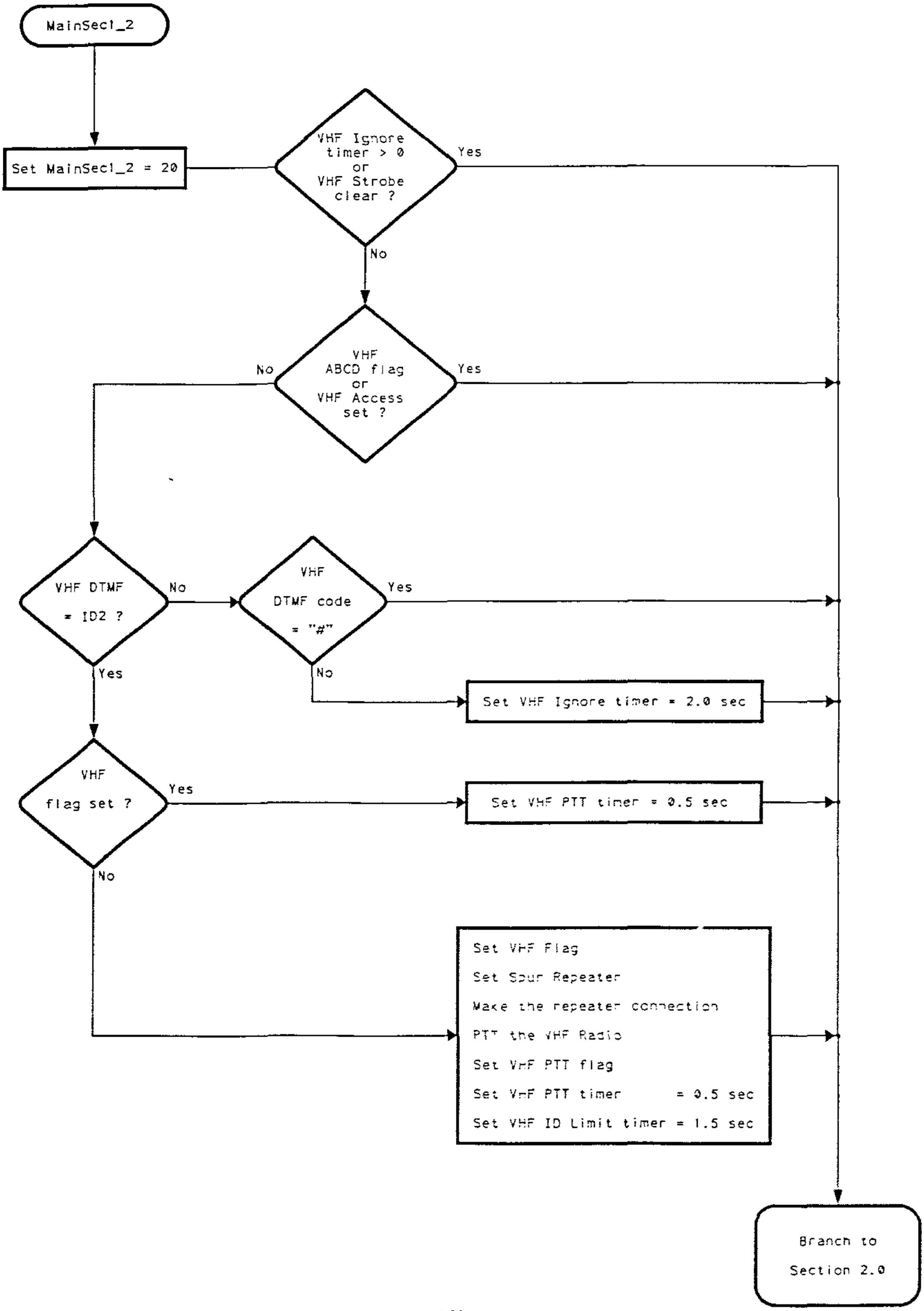
MUPC CARD : MAIN ROUTINE

FILE : MAIN-12A.FCD

DATE : 15-07-1998

MODULE : RT_MAIN.PAS

Section 1.2 : VHF DTMF Activity & First ID code



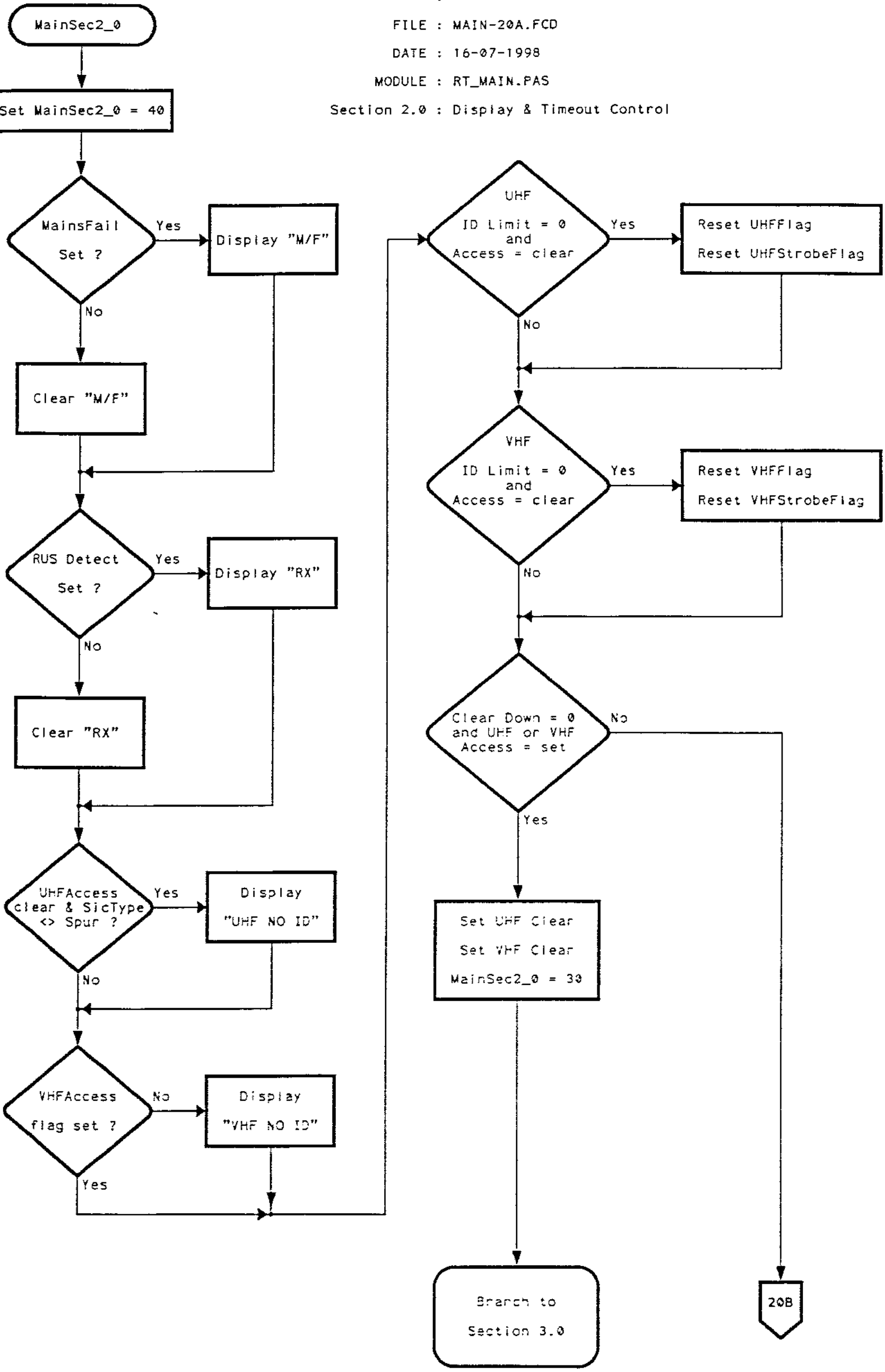
MUPC CARD : MAIN ROUTINE

FILE : MAIN-20A.FCD

DATE : 16-07-1998

MODULE : RT_MAIN.PAS

Section 2.0 : Display & Timeout Control



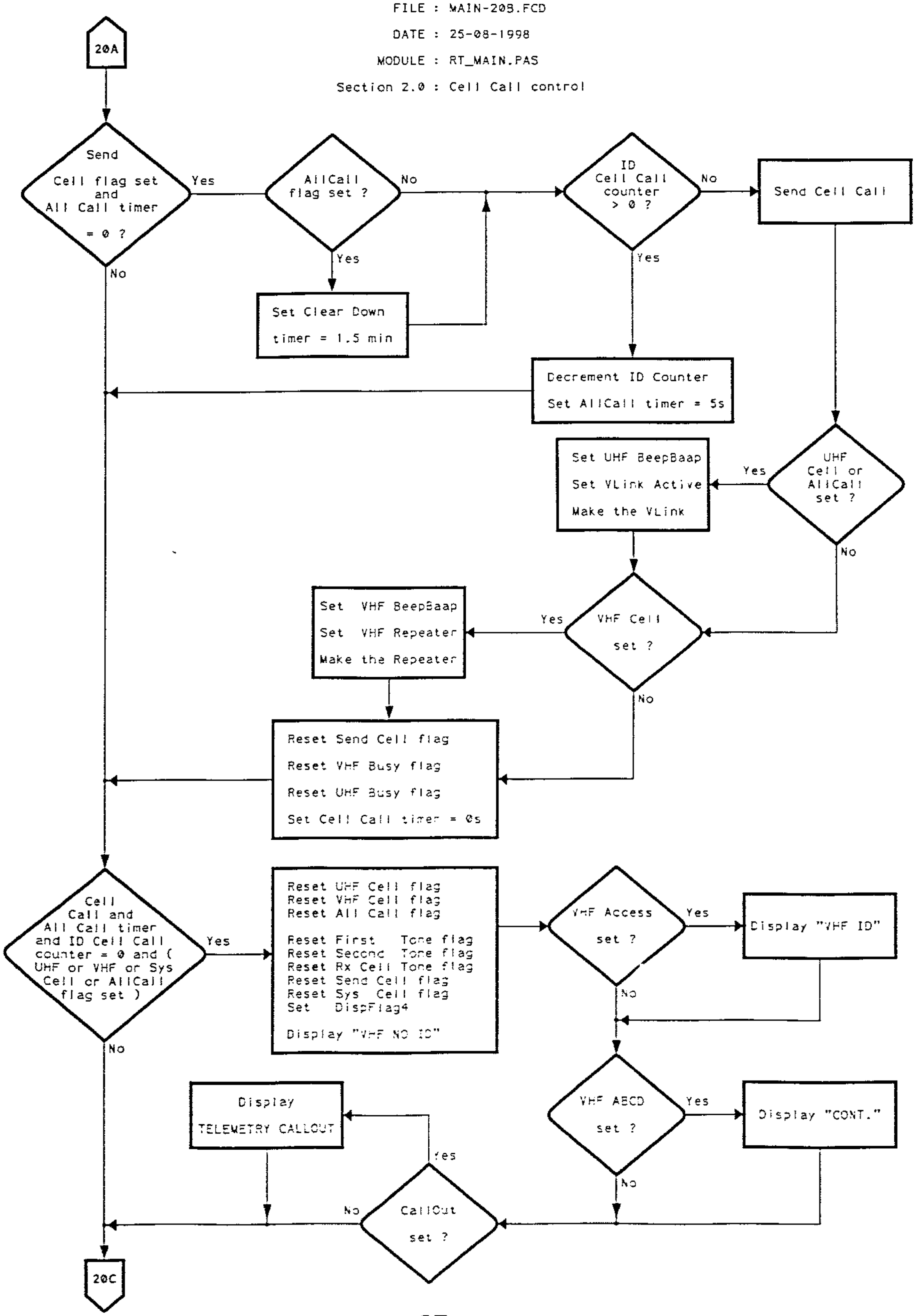
MUPC CARD : MAIN ROUTINE

FILE : MAIN-20B.FCD

DATE : 25-08-1998

MODULE : RT_MAIN.PAS

Section 2.0 : Cell Call control



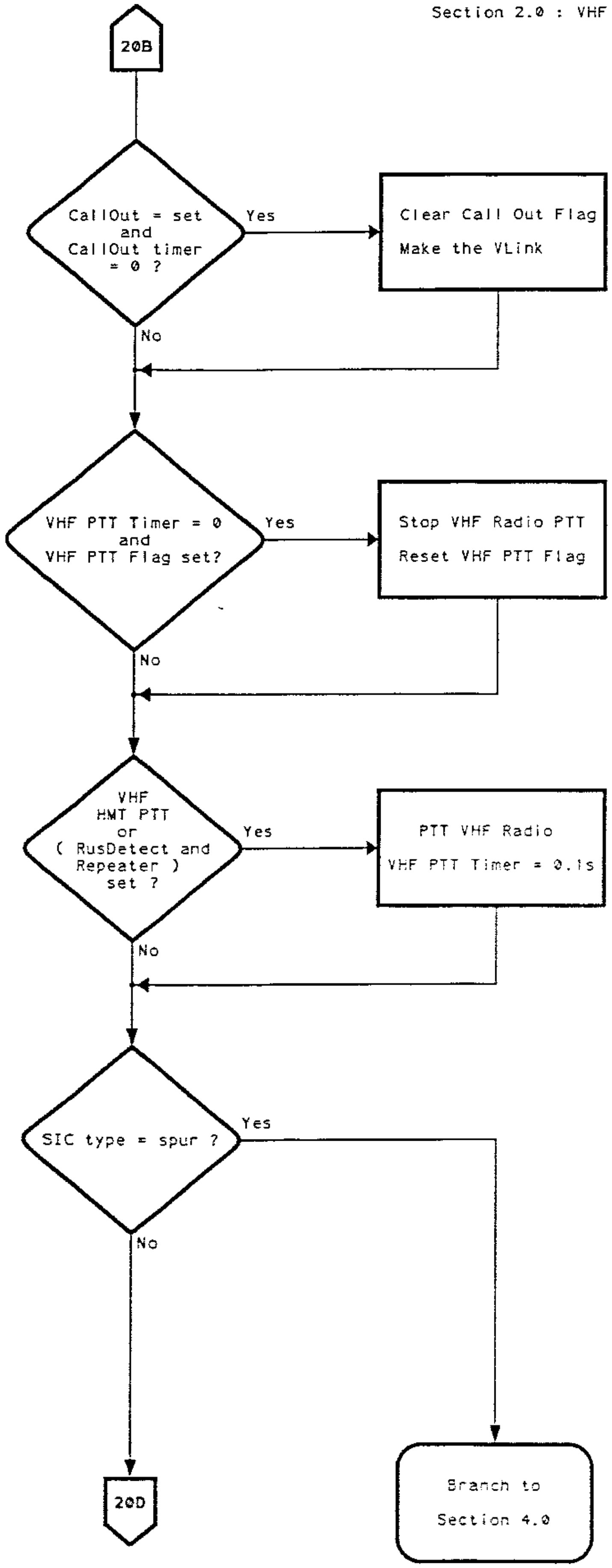
MUPC CARD : MAIN ROUTINE

FILE : MAIN-20C.FCD

DATE : 28-08-1998

MODULE : RT_MAIN.PAS

Section 2.0 : VHF control



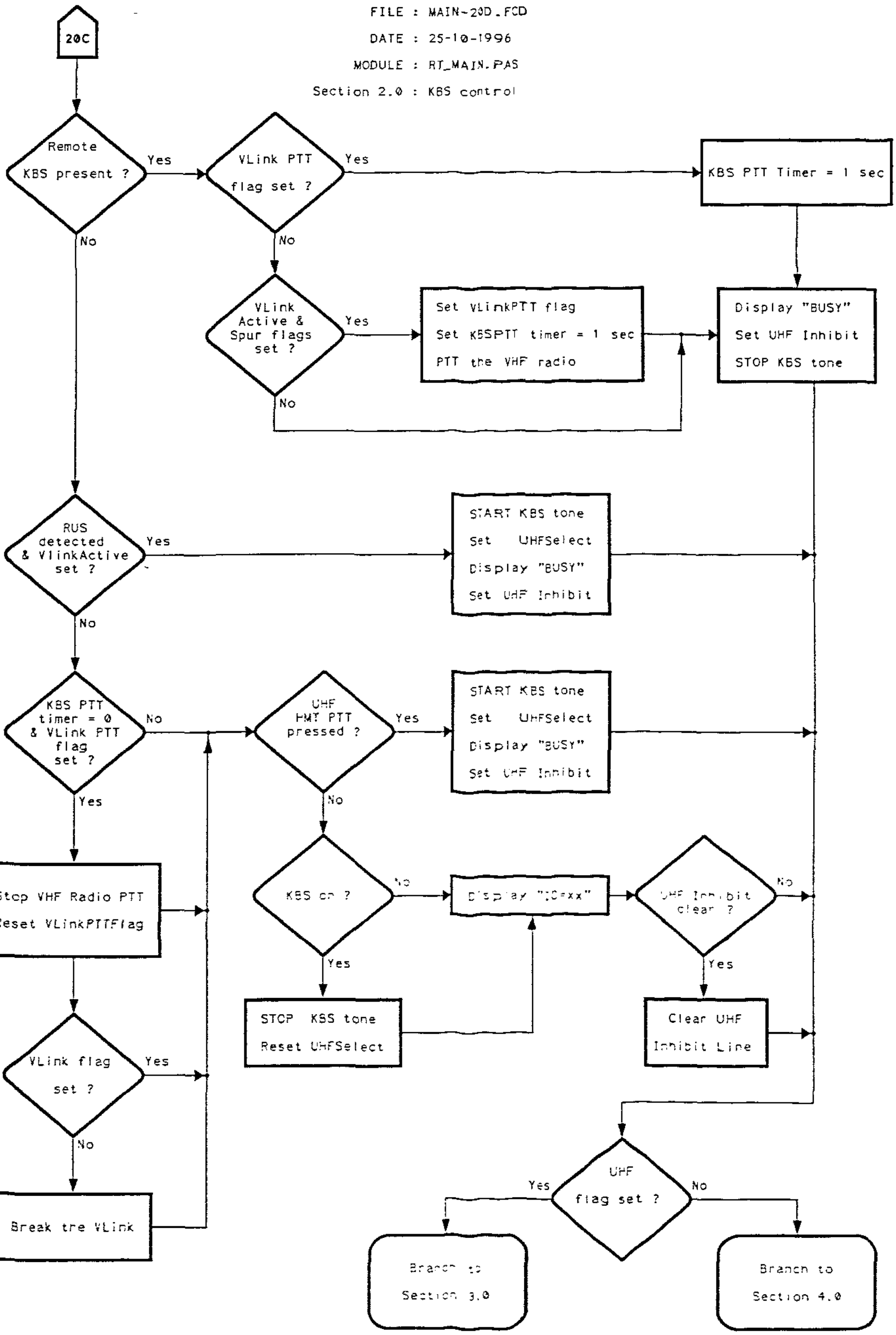
MUPC CARD : MAIN ROUTINE

FILE : MAIN-20D.FCD

DATE : 25-10-1996

MODULE : RT_MAIN.PAS

Section 2.0 : KBS control



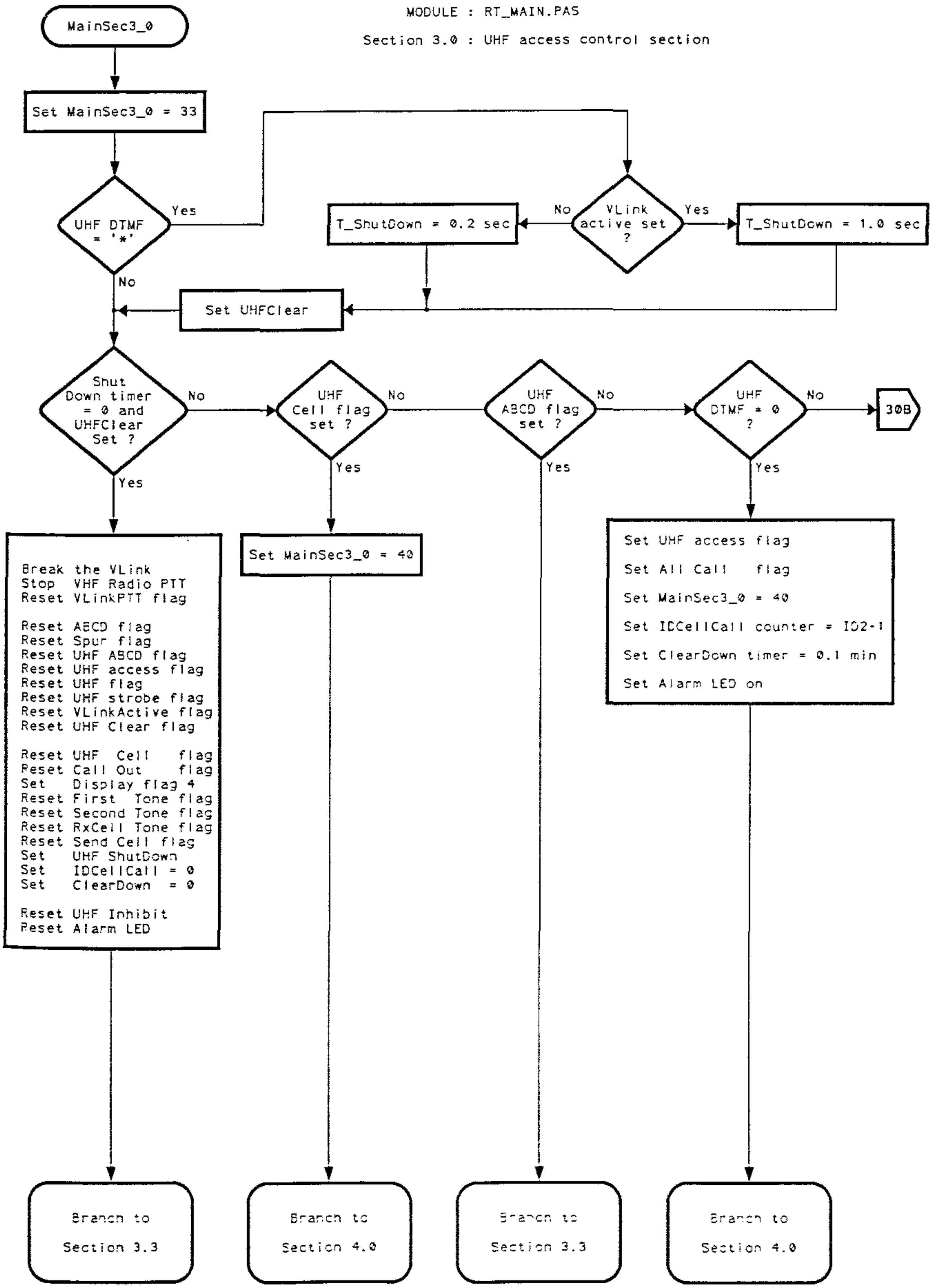
MUPC CARD : MAIN ROUTINE

FILE : MAIN-30A.FCD

DATE : 25-08-1998

MODULE : RT_MAIN.PAS

Section 3.0 : UHF access control section



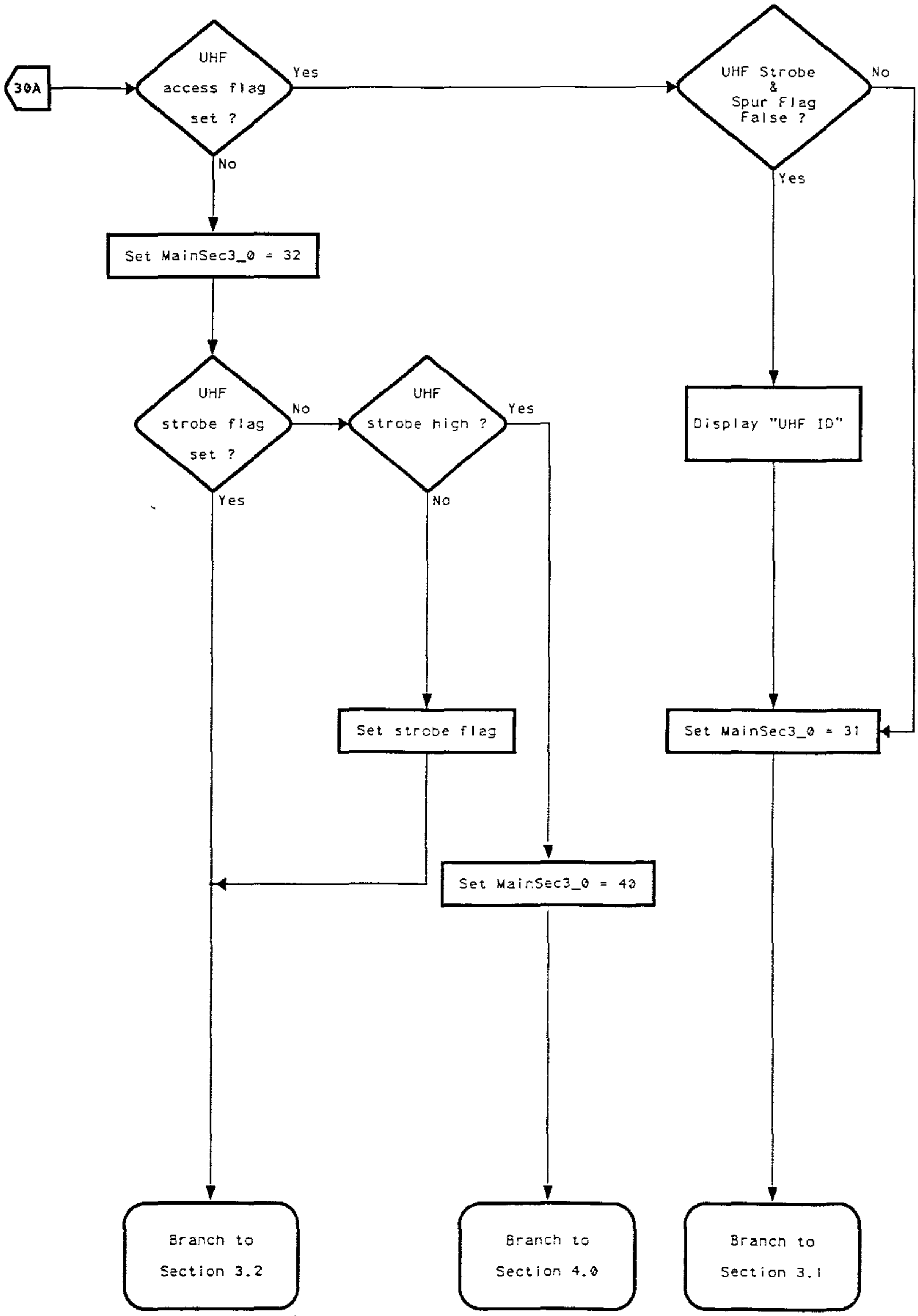
MUPC CARD : MAIN ROUTINE

FILE : MAIN-308.FCD

DATE : 16-07-1998

MODULE : RT_MAIN.PAS

Section 3.0 : UHF access control section



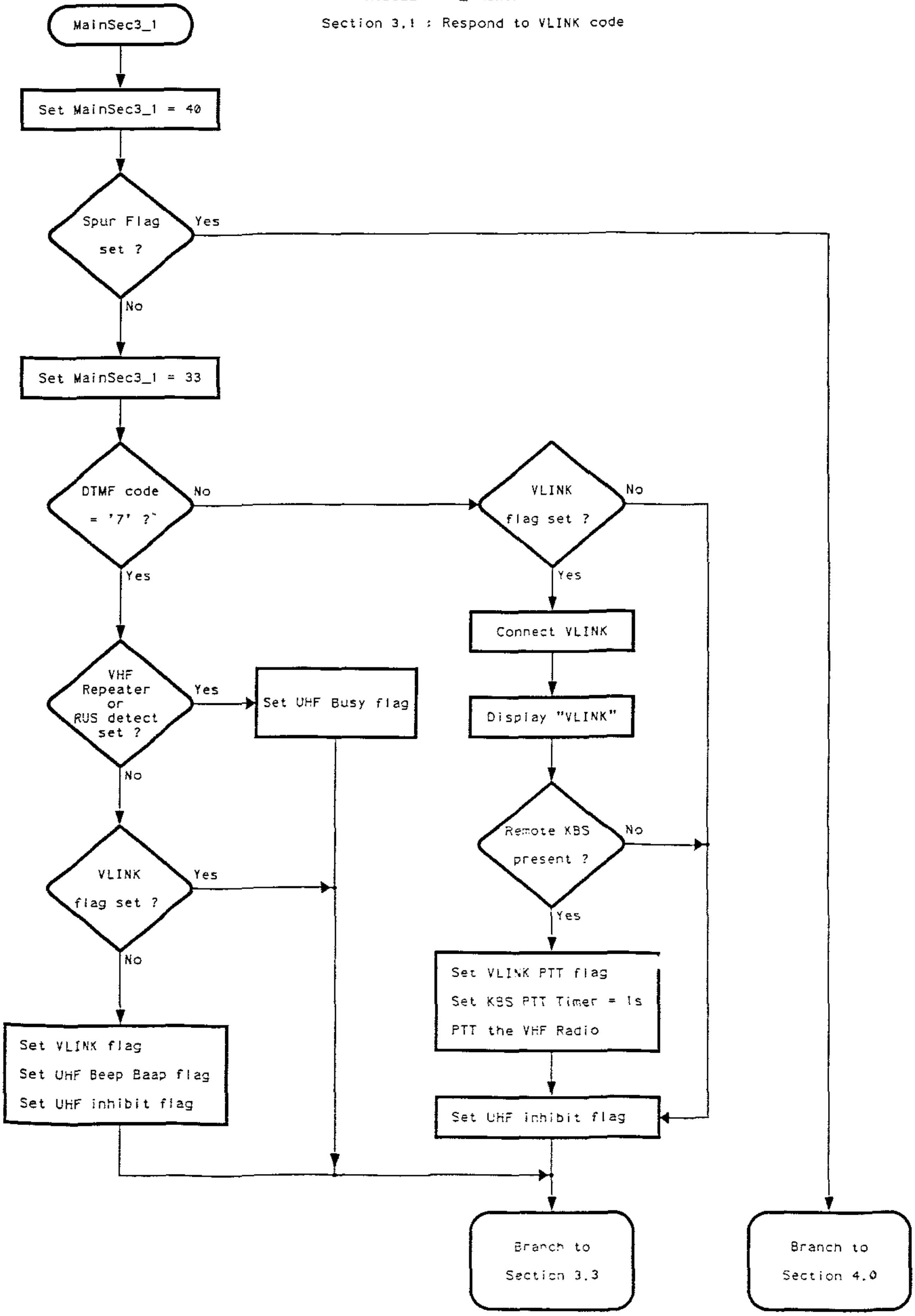
MUPC CARD : MAIN ROUTINE

FILE : MAIN-31A.FCD

DATE : 16-07-1998

MODULE : RT_MAIN.PAS

Section 3.1 : Respond to VLINK code



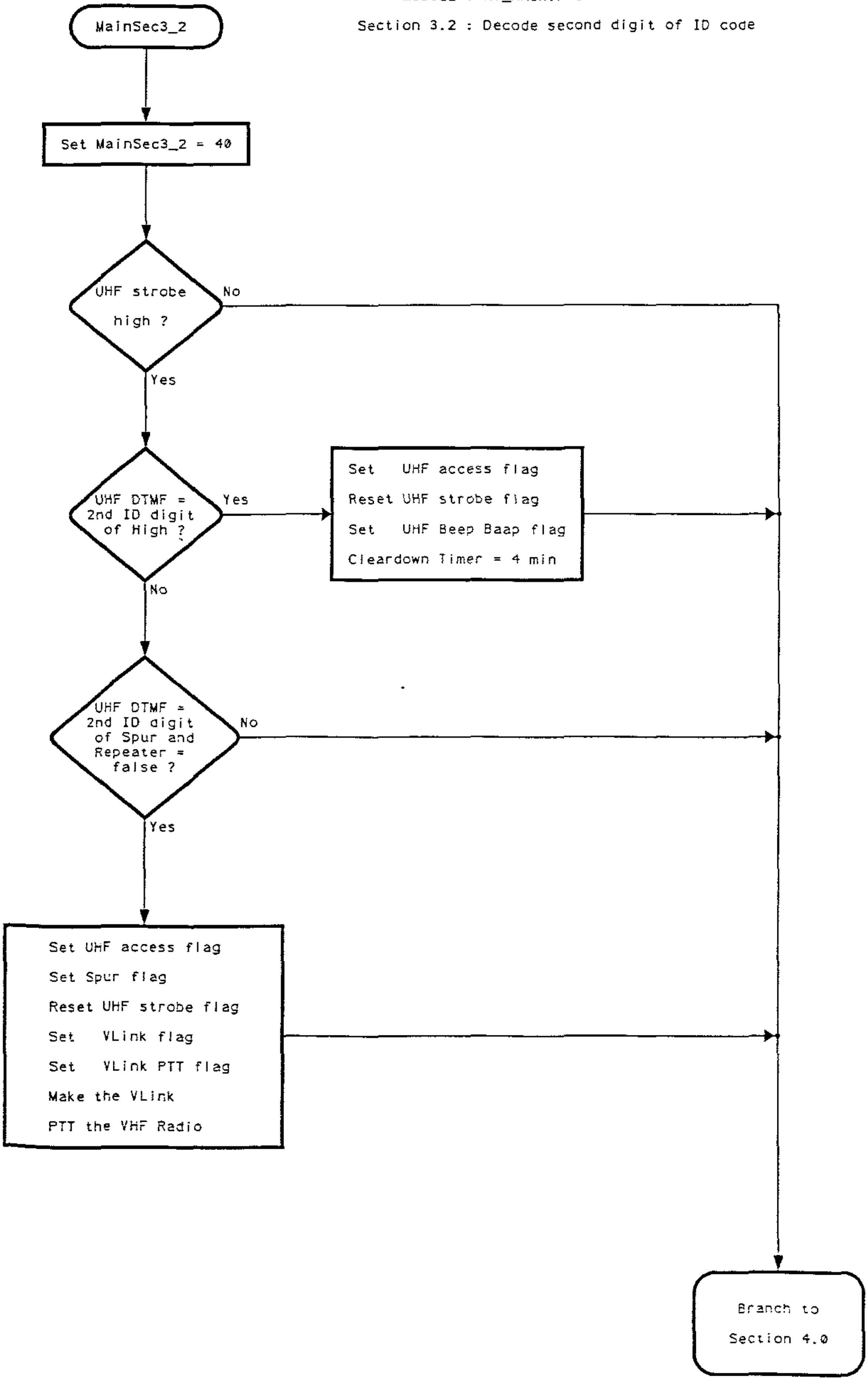
MUPC CARD : MAIN ROUTINE

FILE : MAIN-32A.FCD

DATE : 16-07-1998

MODULE : RT_MAIN.PAS

Section 3.2 : Decode second digit of ID code



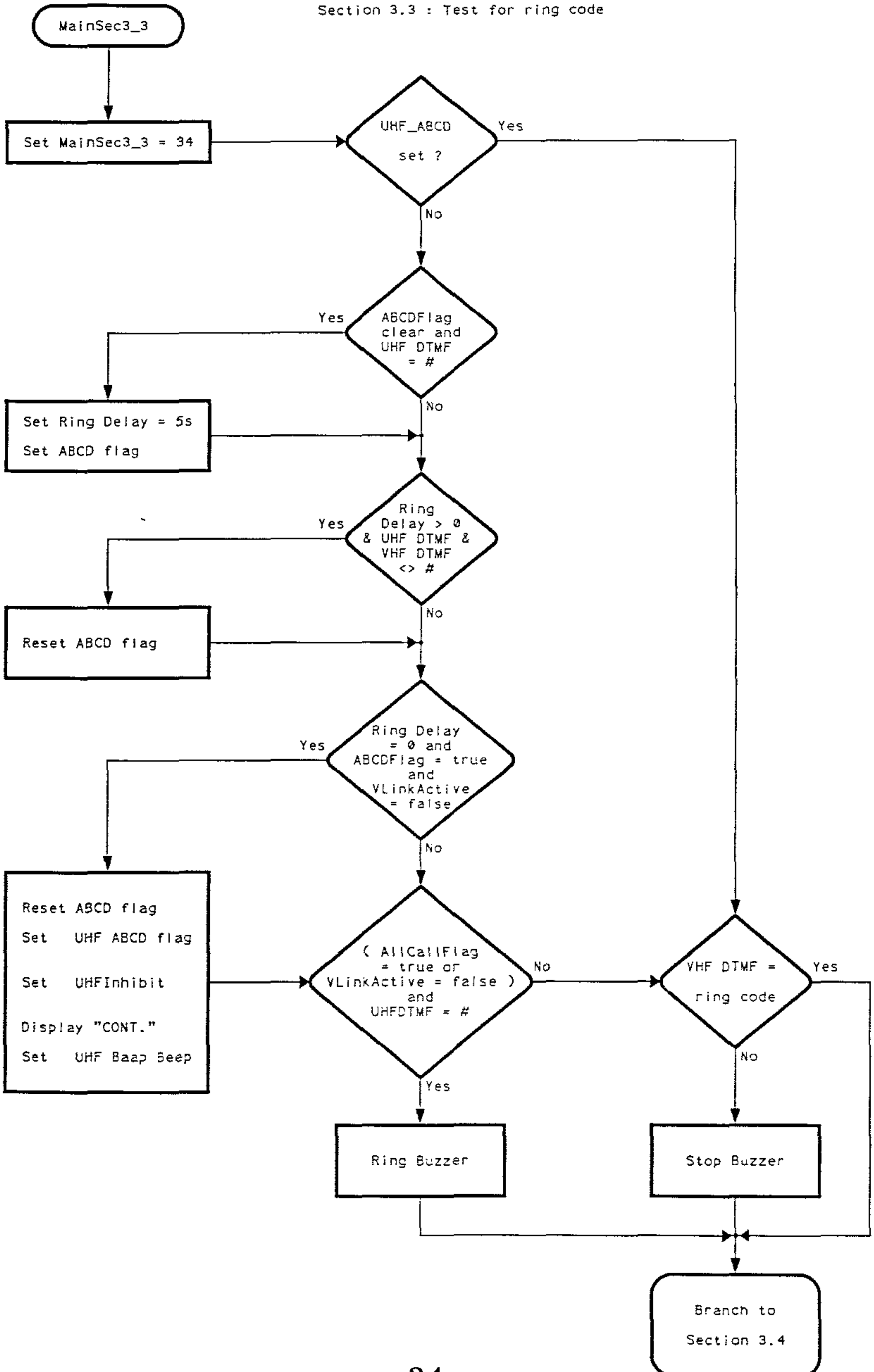
MUPC CARD : MAIN ROUTINE

FILE : MAIN-33A.FCD

DATE : 20-07-1998

MODULE : RT_MAIN.PAS

Section 3.3 : Test for ring code



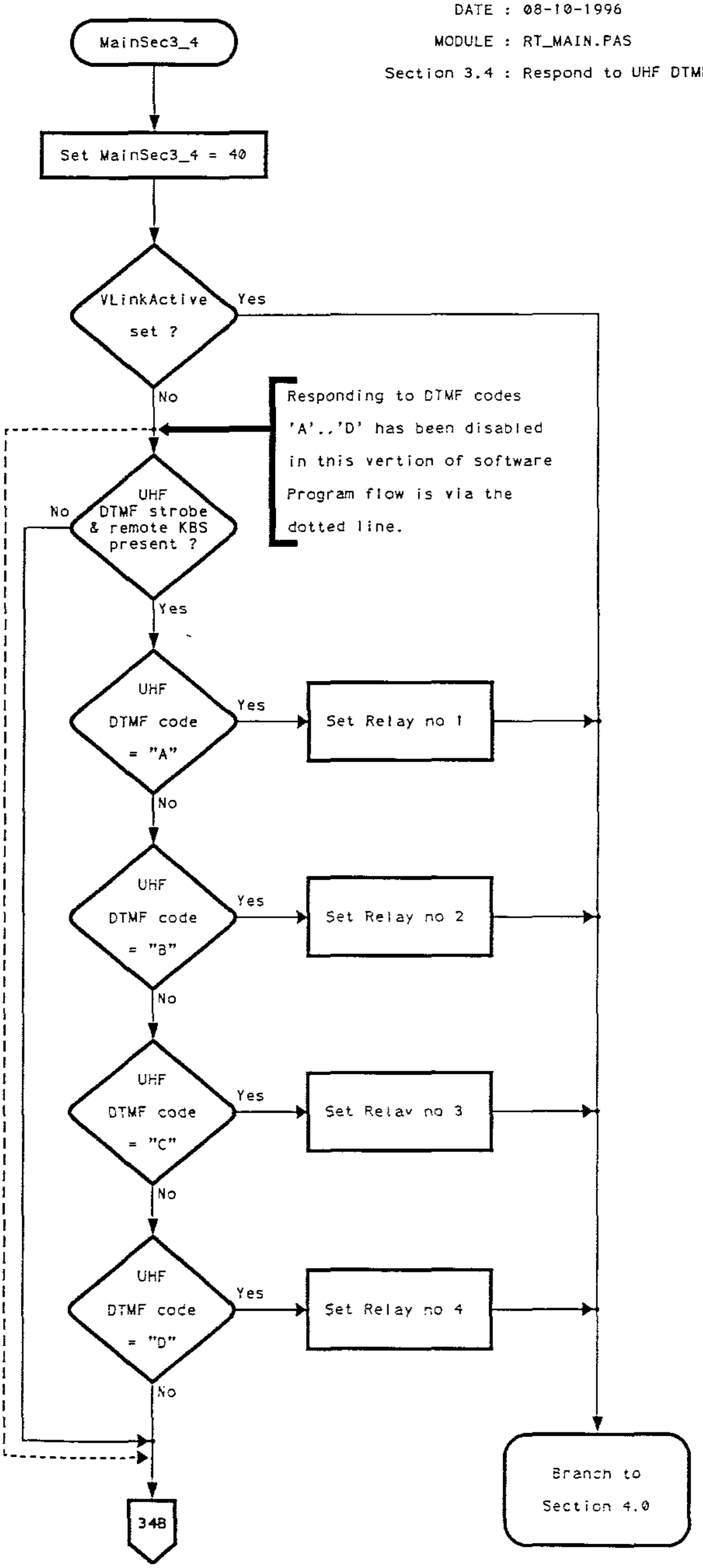
MUPC CARD : MAIN ROUTINE

FILE : MAIN-34A.FCD

DATE : 08-10-1996

MODULE : RT_MAIN.PAS

Section 3.4 : Respond to UHF DTMF A B C D codes



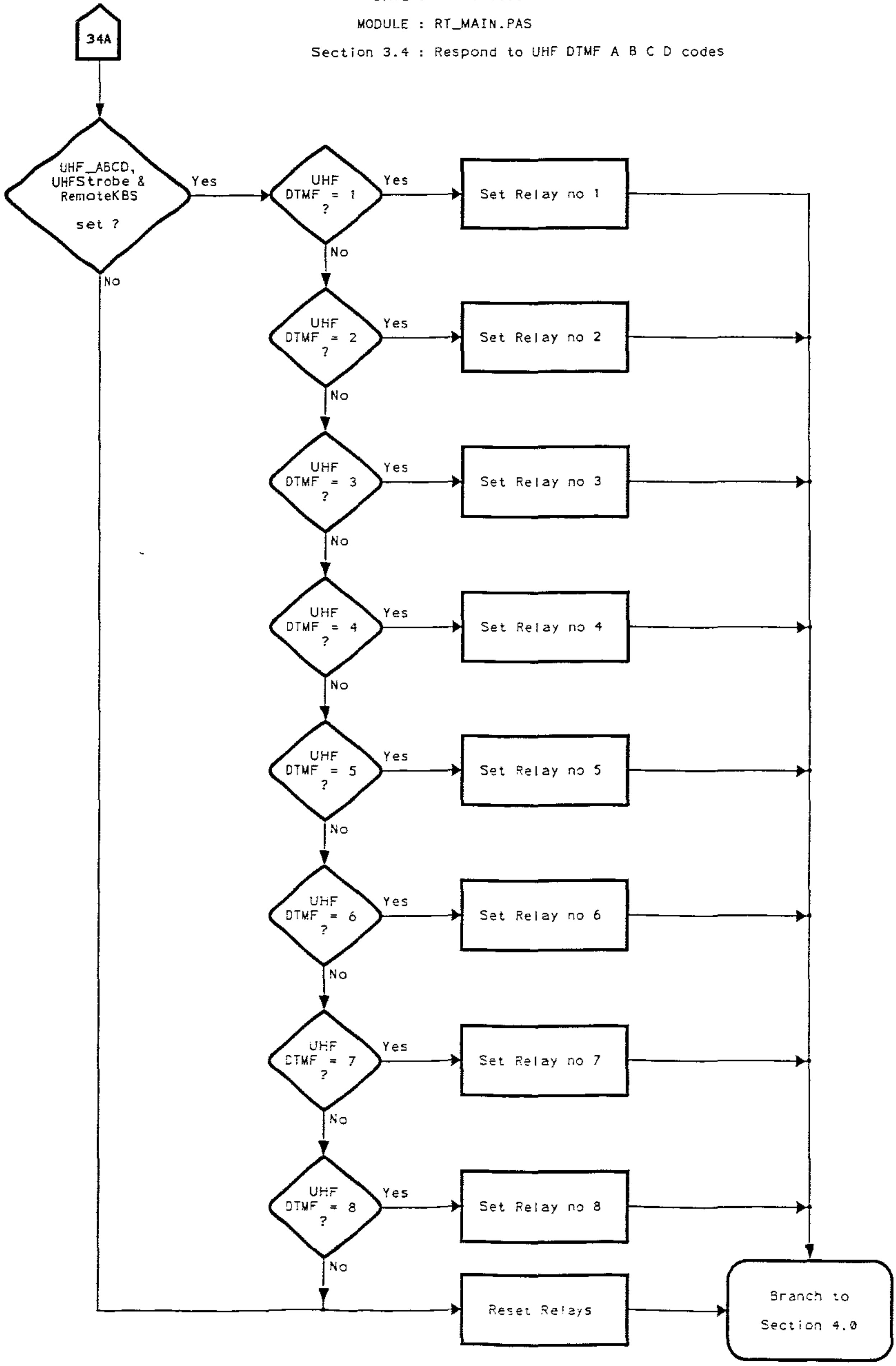
MUPC CARD : MAIN ROUTINE

FILE : MAIN-34B.FCD

DATE : 10-09-1996

MODULE : RT_MAIN.PAS

Section 3.4 : Respond to UHF DTMF A B C D codes



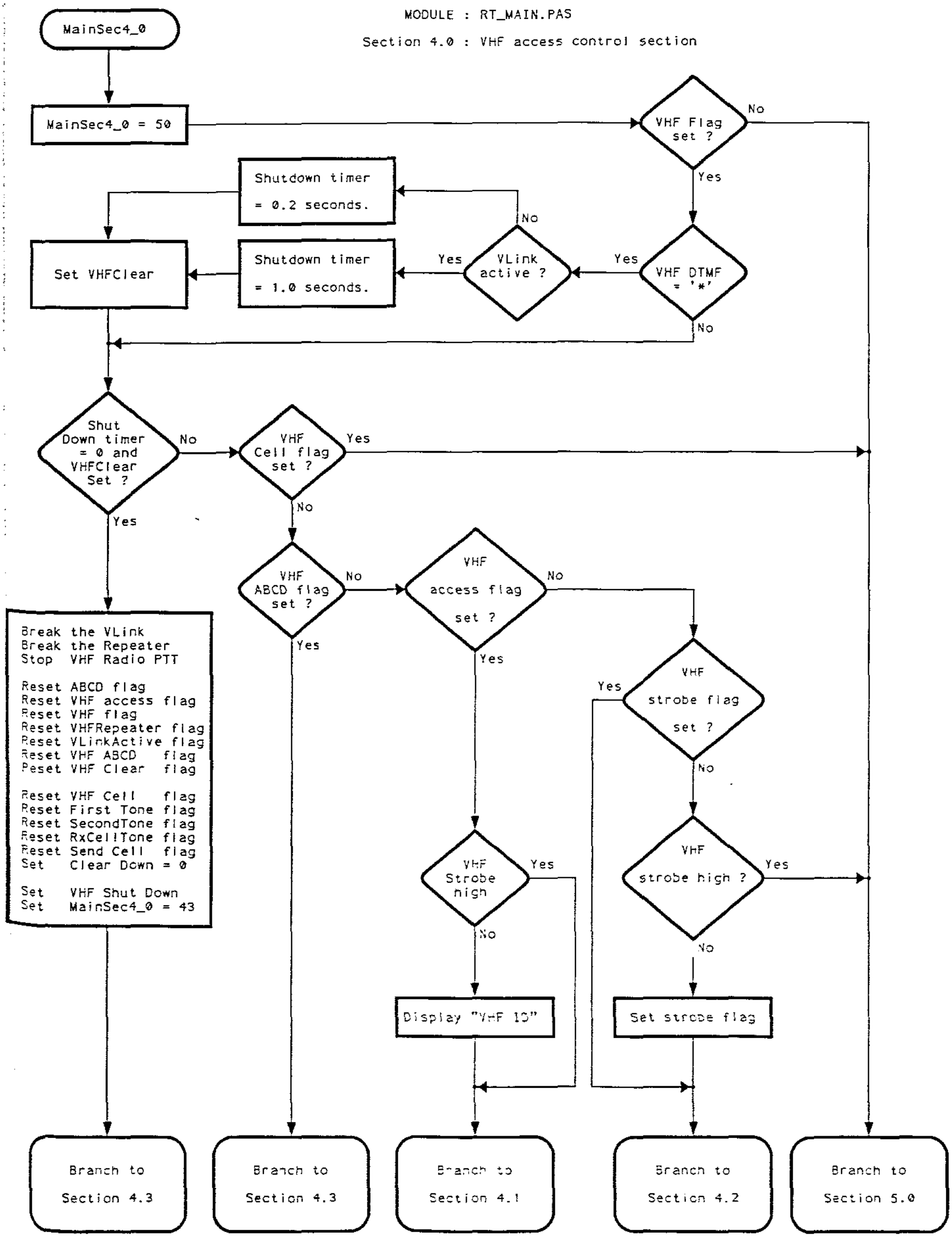
MUPC CARD : MAIN ROUTINE

FILE : MAIN-40A.FCD

DATE : 20-07-1998

MODULE : RT_MAIN.PAS

Section 4.0 : VHF access control section



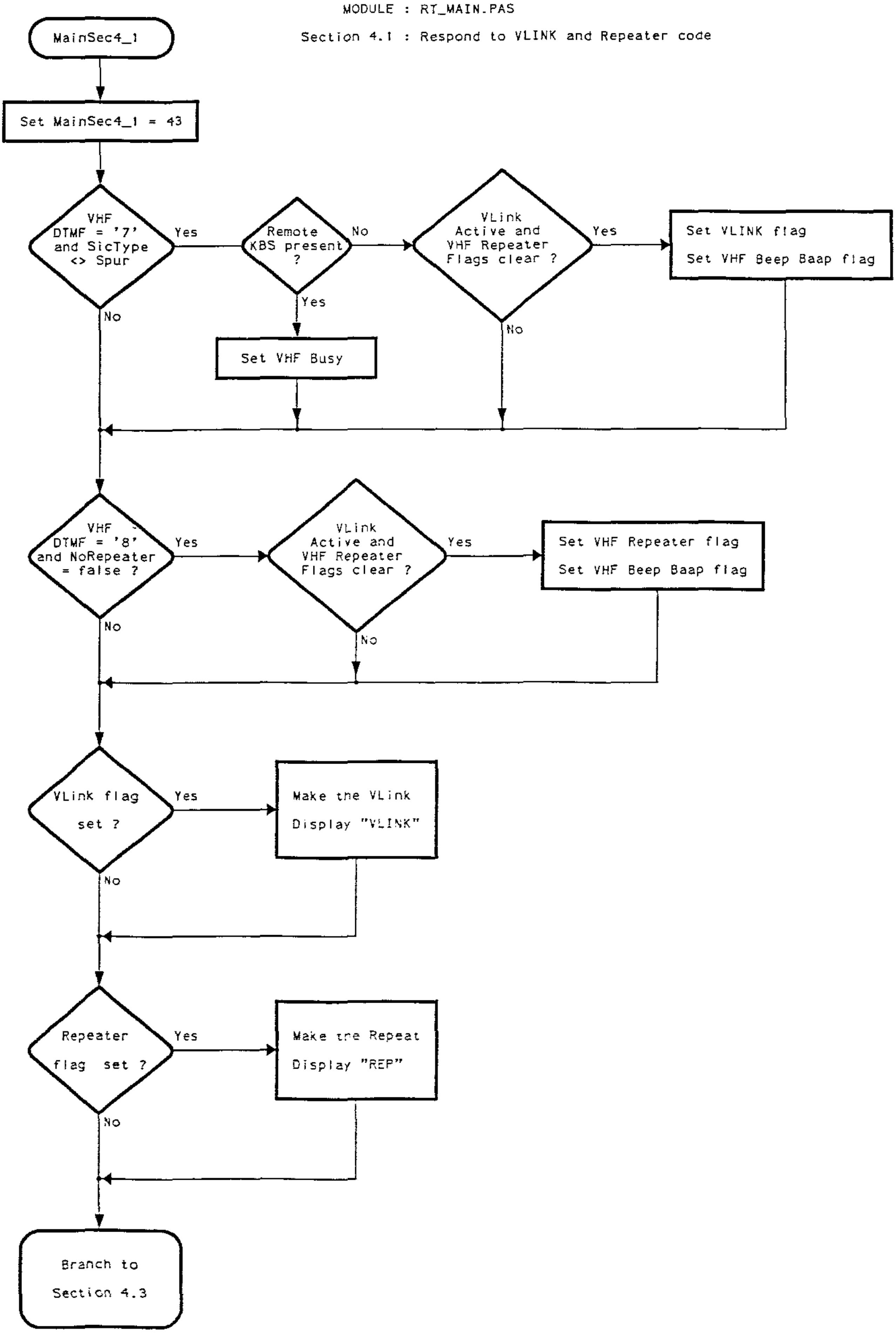
MUPC CARD : MAIN ROUTINE

FILE : MAIN-41A.FCD

DATE : 20-07-1998

MODULE : RT_MAIN.PAS

Section 4.1 : Respond to VLINK and Repeater code



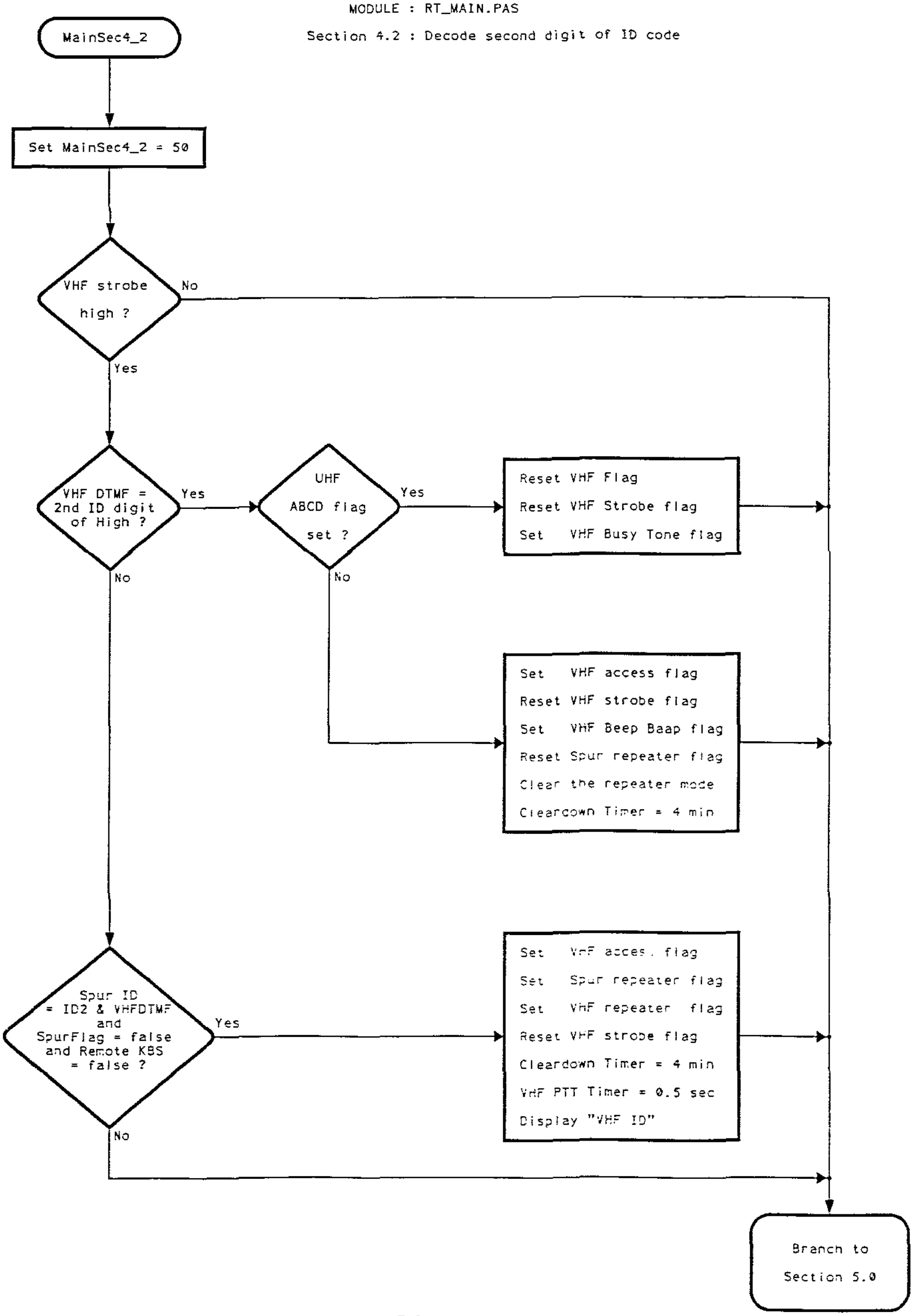
MUPC CARD : MAIN ROUTINE

FILE : MAIN-42A.FCD

DATE : 20-07-1998

MODULE : RT_MAIN.PAS

Section 4.2 : Decode second digit of ID code



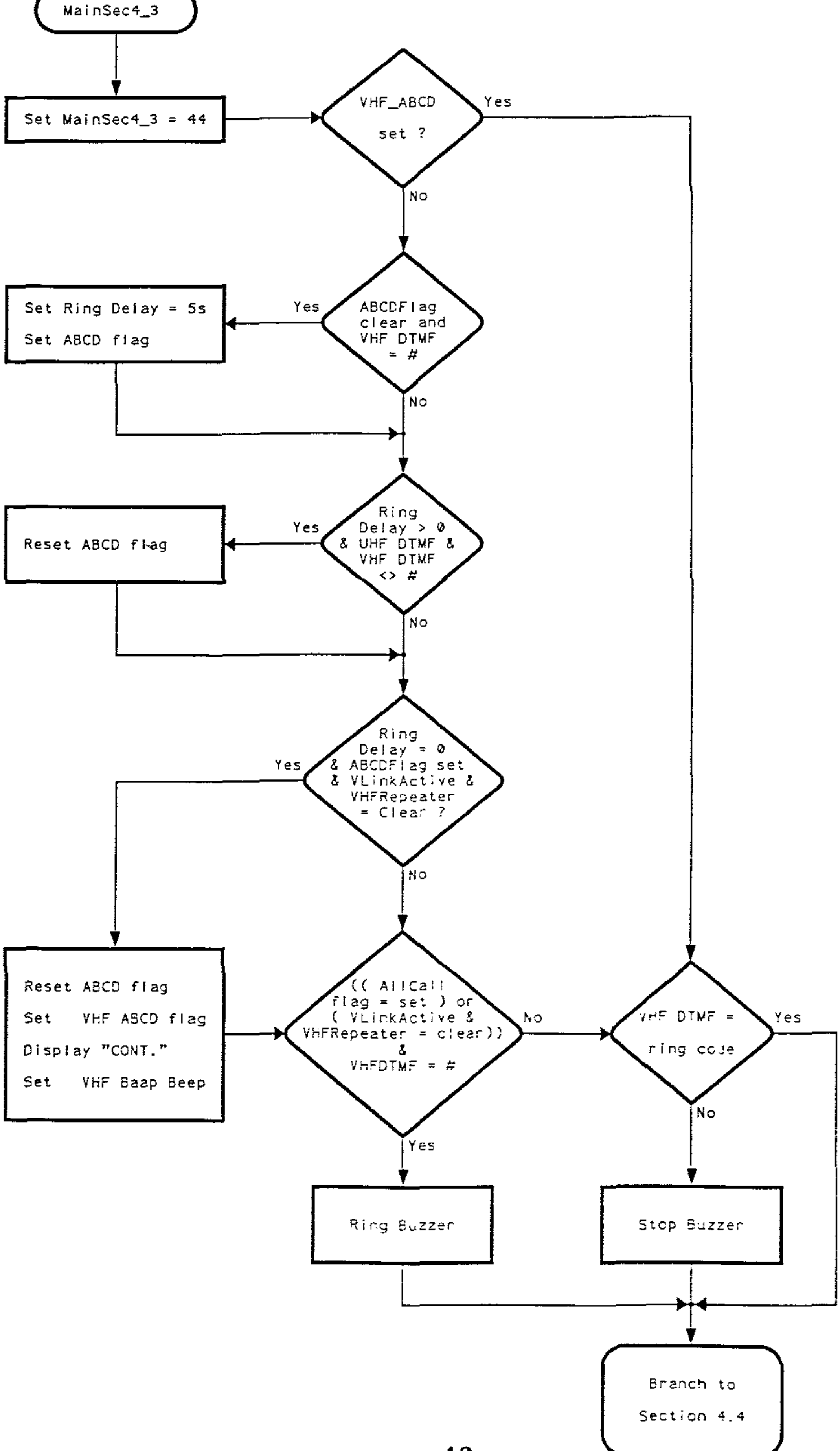
MUPC CARD : MAIN ROUTINE

FILE : MAIN-43A.FCD

DATE : 20-07-1998

MODULE : RT_MAIN.PAS

Section 4.3 : Test for ring code



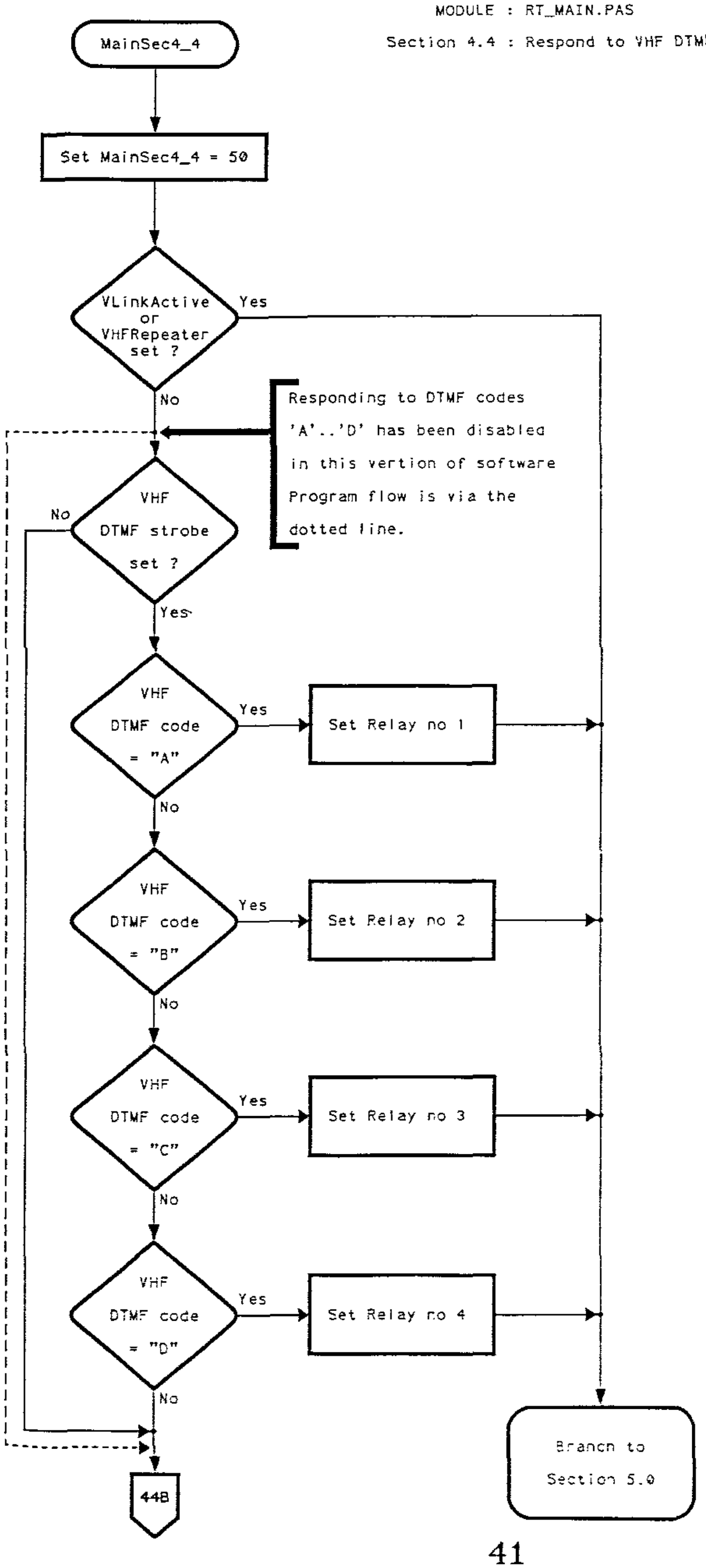
MUPC CARD : MAIN ROUTINE

FILE : MAIN-44A.FCD

DATE : 08-10-1996

MODULE : RT_MAIN.PAS

Section 4.4 : Respond to VHF DTMF A B C D codes



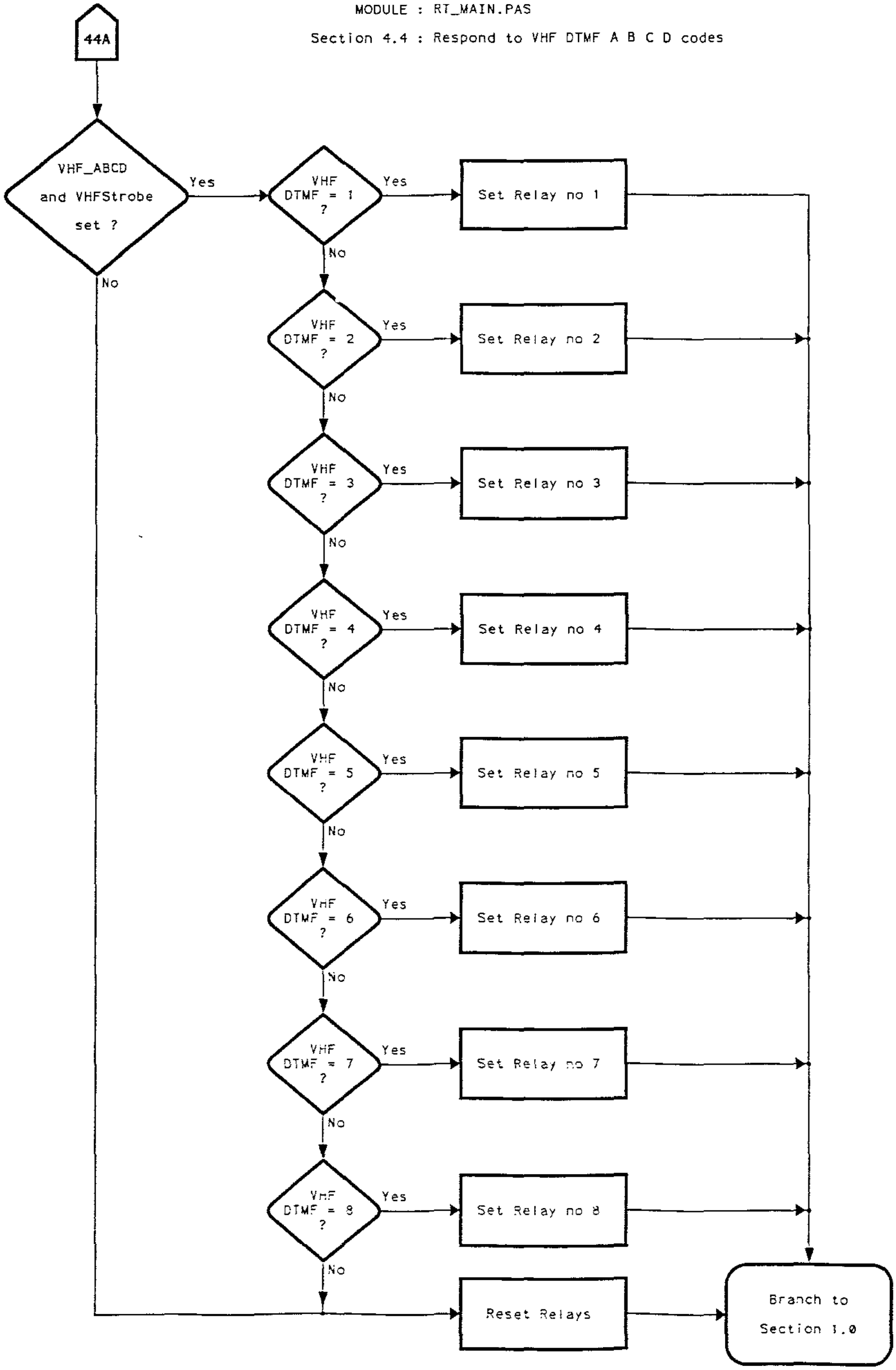
MUPC CARD : MAIN ROUTINE

FILE : MAIN-44B.FCD

DATE : 19-09-1996

MODULE : RT_MAIN.PAS

Section 4.4 : Respond to VHF DTMF A B C D codes



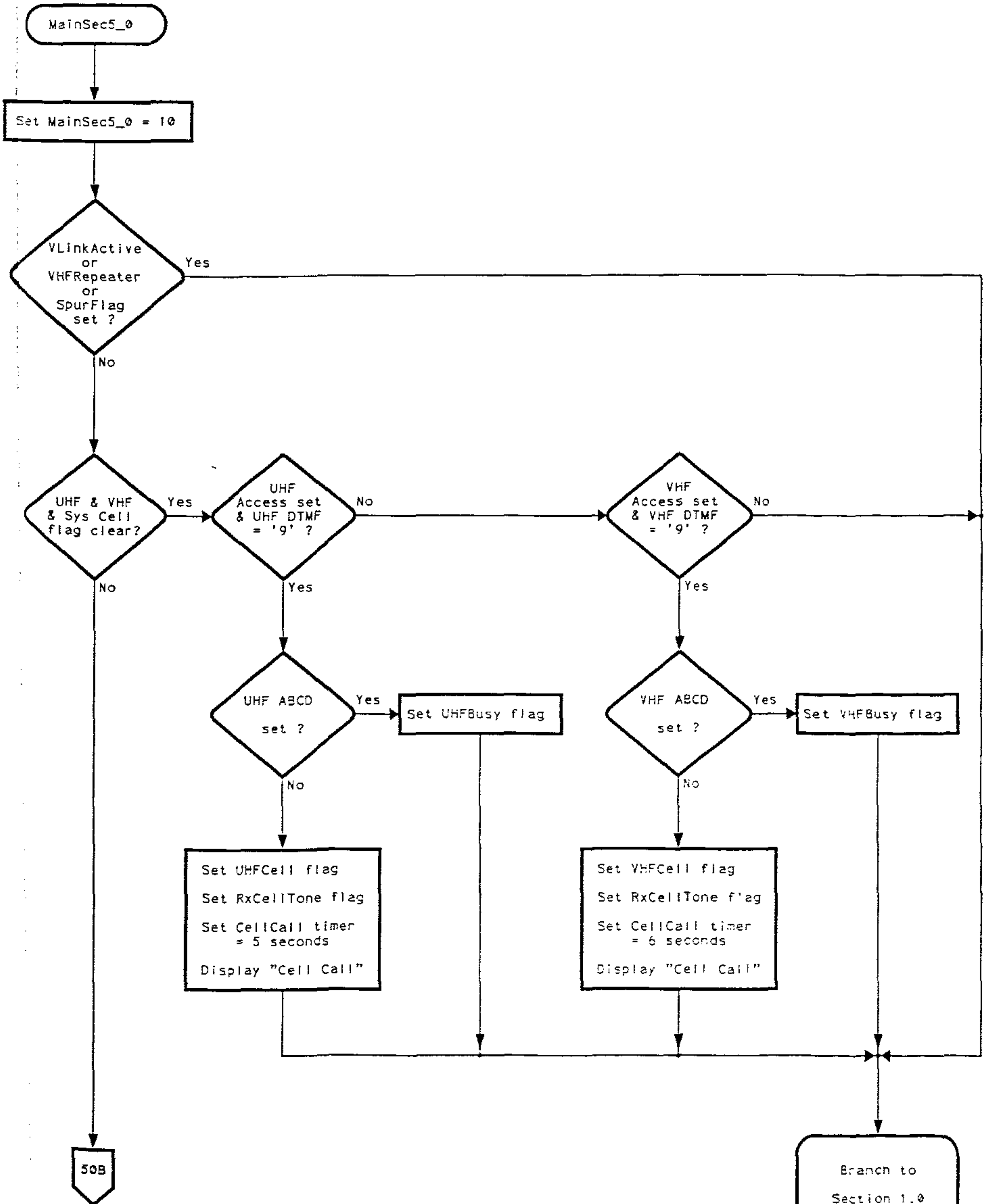
MUPC CARD : MAIN ROUTINE

FILE : MAIN-50A.FCD

DATE : 18-10-1996

MODULE : RT_MAIN.PAS

Section 5.0 : UHF, VHF and System Cell call



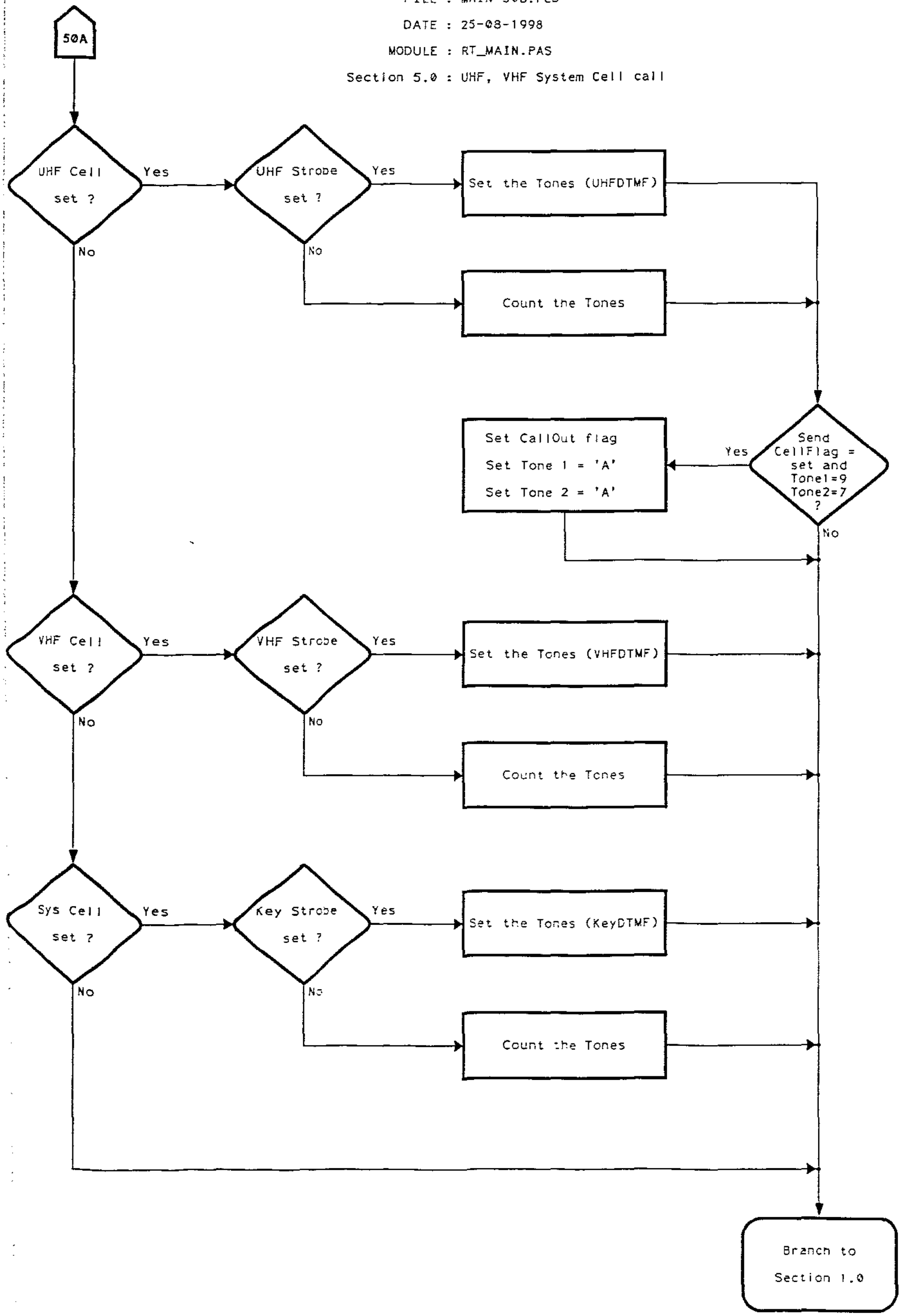
MUPC CARD : MAIN ROUTINE

FILE : MAIN-50B.FCD

DATE : 25-08-1998

MODULE : RT_MAIN.PAS

Section 5.0 : UHF, VHF System Cell call



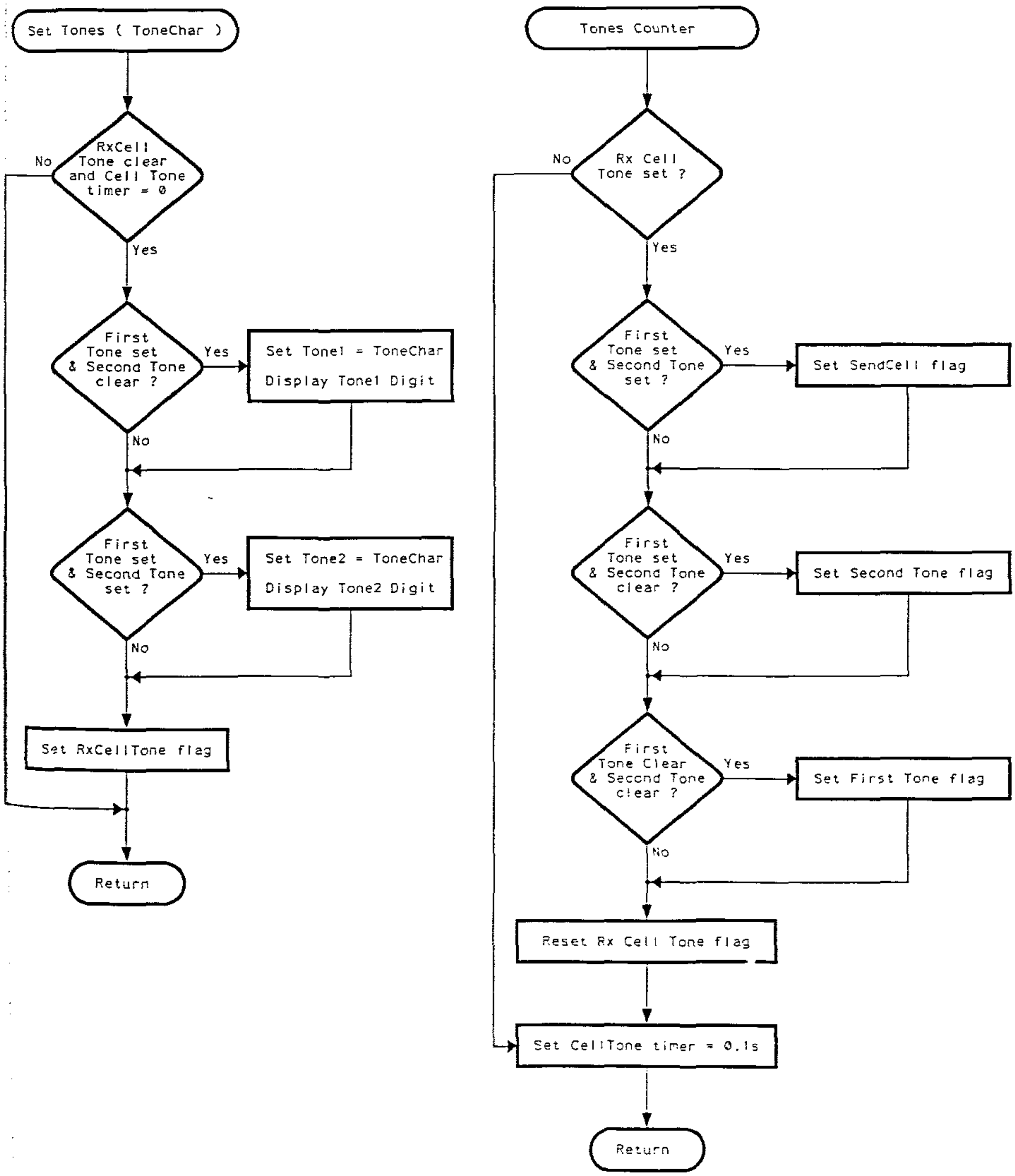
MUPC CARD : MAIN ROUTINE

FILE : MAIN-50C.FCD

DATE : 18-10-1996

MODULE : RT_MAIN.PAS

Section 5.0 : Set Tones and Tone Count



3.3 DIAGNOSTICS MODULE.

The diagnostics module is the system hardware testing and faultfinding software. It is activated by setting dip switch 1 to on.

File Names	Description	Page
MUPCDIAG.PAS	Pascal source file in appendix C.	---
INIT-00A.FCD	Interrupt and Genearal Routines.	47
INIT-00B.FCD	System Initialisation.	48
SYST-10A.FCD	Basic RT KBS & RUS Service routine.	49
SYST-20A.FCD	Basic RT UHF & VHF handset PTT.	50
SYST-30A.FCD	Basic RT Keyboard service routine.	51
SYST-41A.FCD	Basic RT Detected UHF DTMF service routine.	52
SYST-42A.FCD	Basic RT Detected VHF DTMF service routine.	53
SYST-51A.FCD	Basic RT Buzzer service routine. Basic RT VLink service routine. Basic RT VHF PTT from RUS service routine.	54
SYST-54A.FCD	Basic RT Send the Beep Baap tone. Basic RT send the Busy tone. Basic RT Send the Shutdown tone.	55
DIAG-10A.FCD	Main Startup Routine.	56
DIAG-10B.FCD	Keyboard Test Main Routine.	57
DIAG-10C.FCD	Keyboard Configuration Main Routine.	58
DIAG-10D.FCD	Main Routine Computer Configuraion.	59

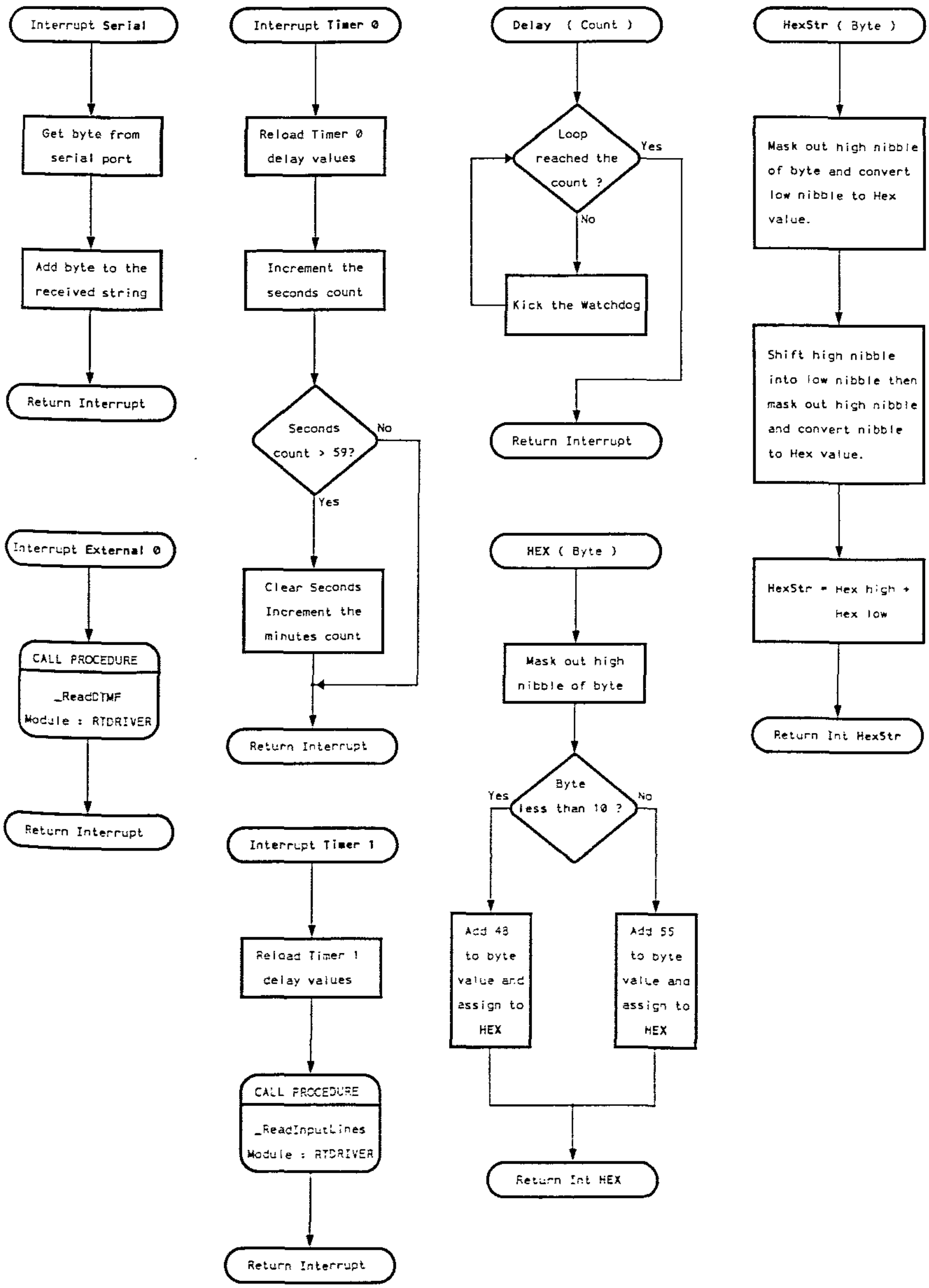
MUPC CARD : INITIALISATION

FILE : INIT-00A.FCD

DATE : 11-05-2000

MODULE : MUPCDIAG.PAS

Section 0.0 : Interrupt and General Routines



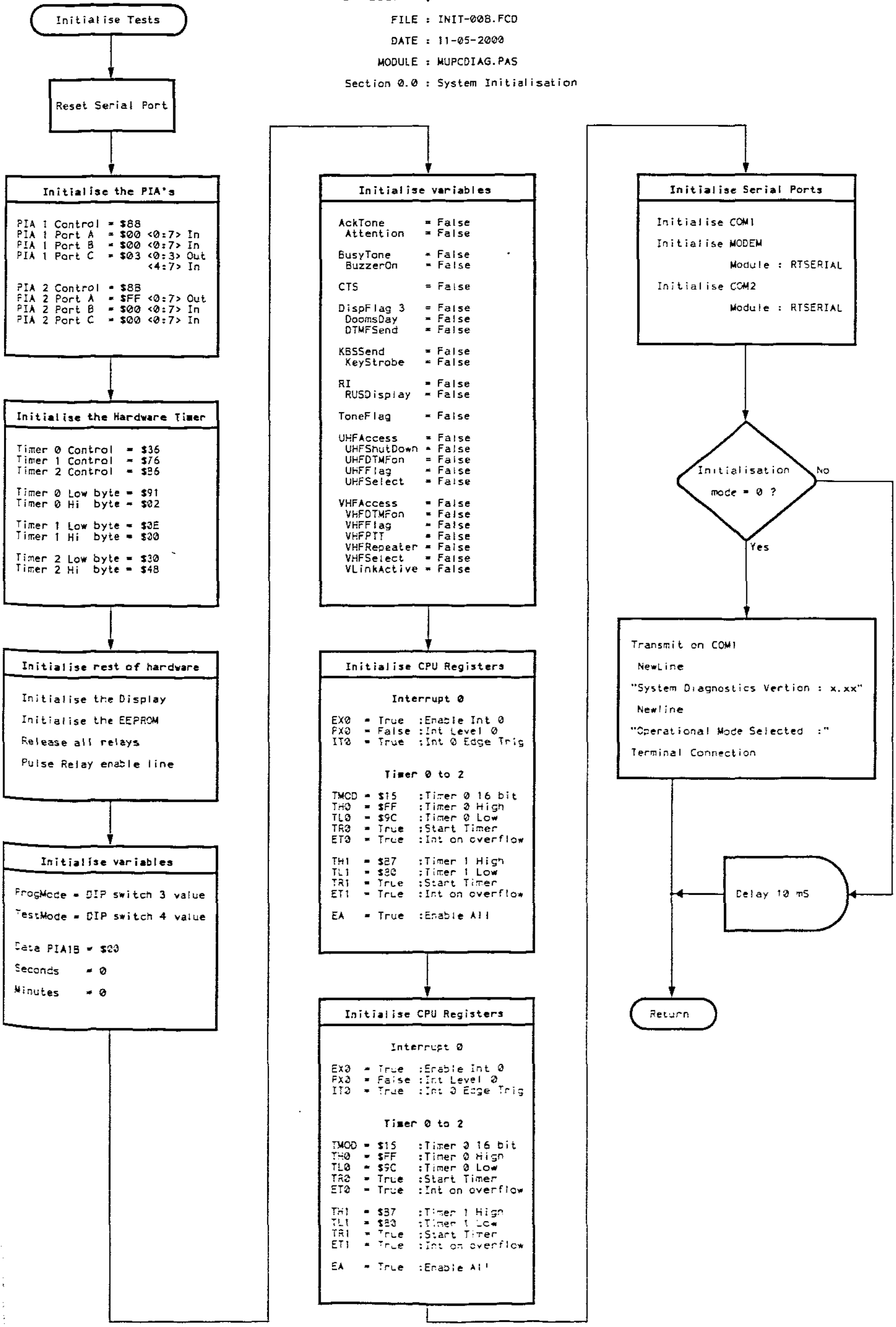
MUPC CARD : INITIALISATION

FILE : INIT-008.FCD

DATE : 11-05-2000

MODULE : MUPCDIAG.PAS

Section 0.0 : System Initialisation



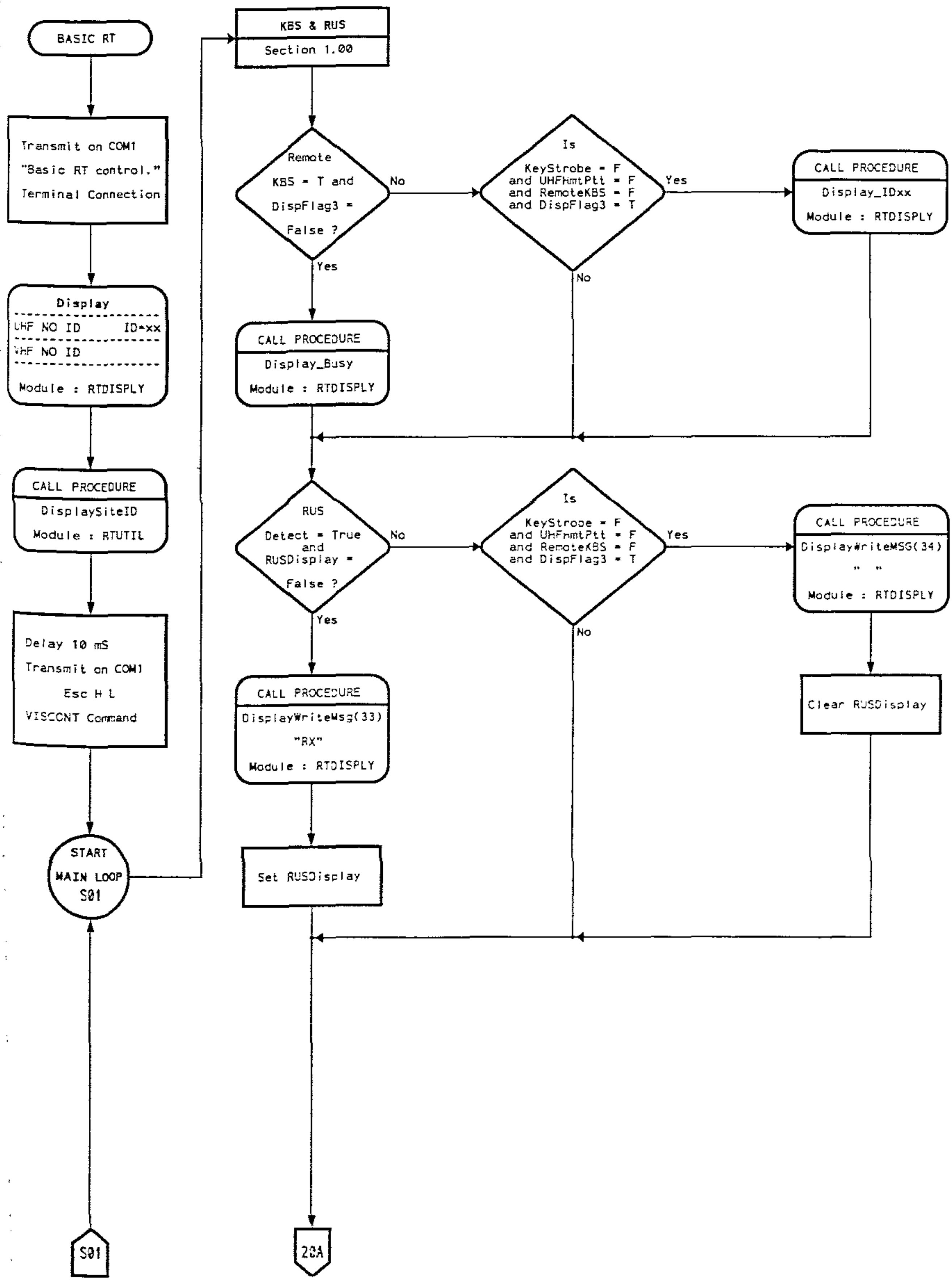
MUPC CARD : BASIC RT SYSTEM

FILE : SYST-10A.FCD

DATE : 12-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : KBS & RUS Service routine



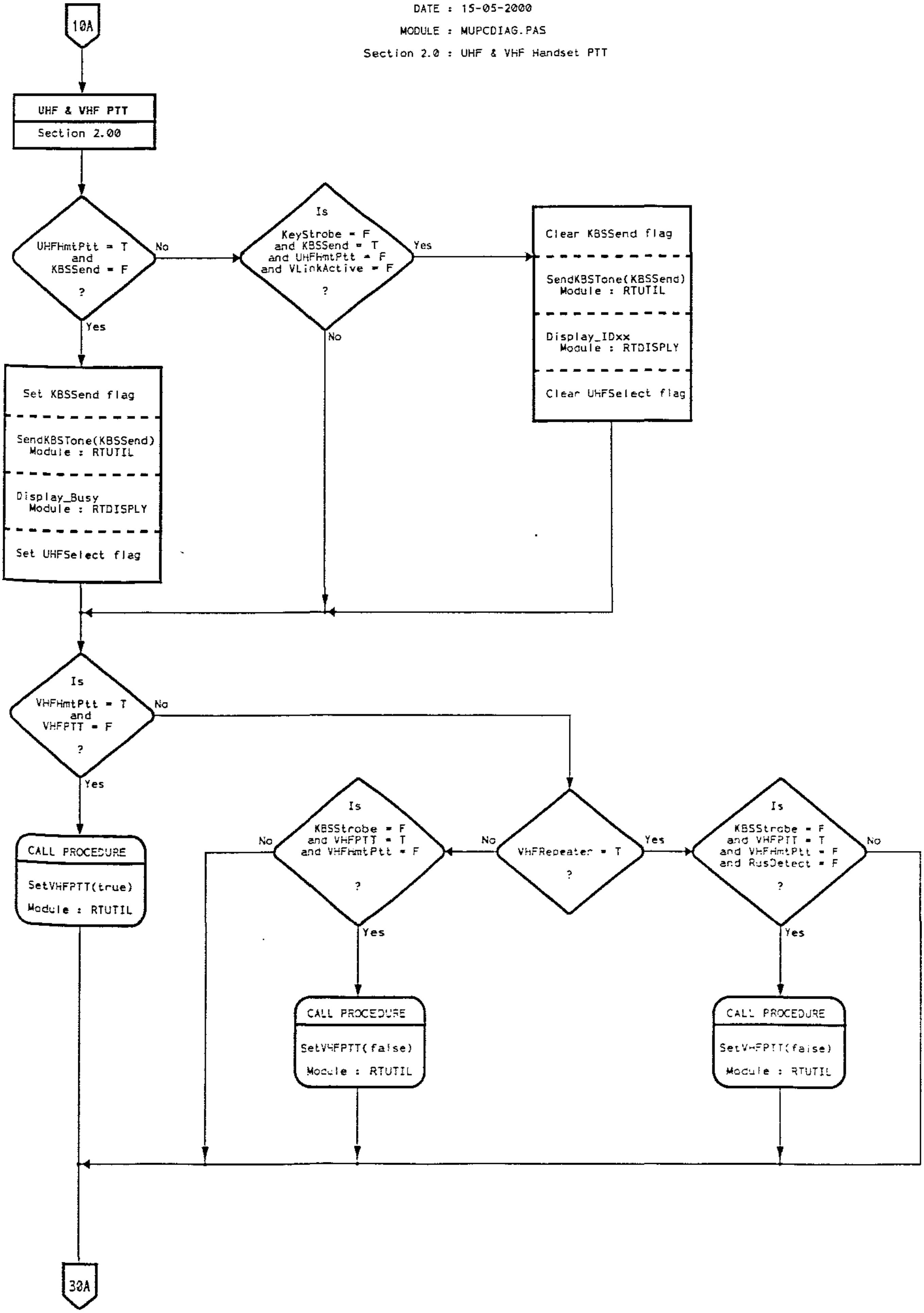
MUPC CARD : BASIC RT SYSTEM

FILE : SYST-20A.FCD

DATE : 15-05-2000

MODULE : MUPCDIAG.PAS

Section 2.0 : UHF & VHF Handset PTT



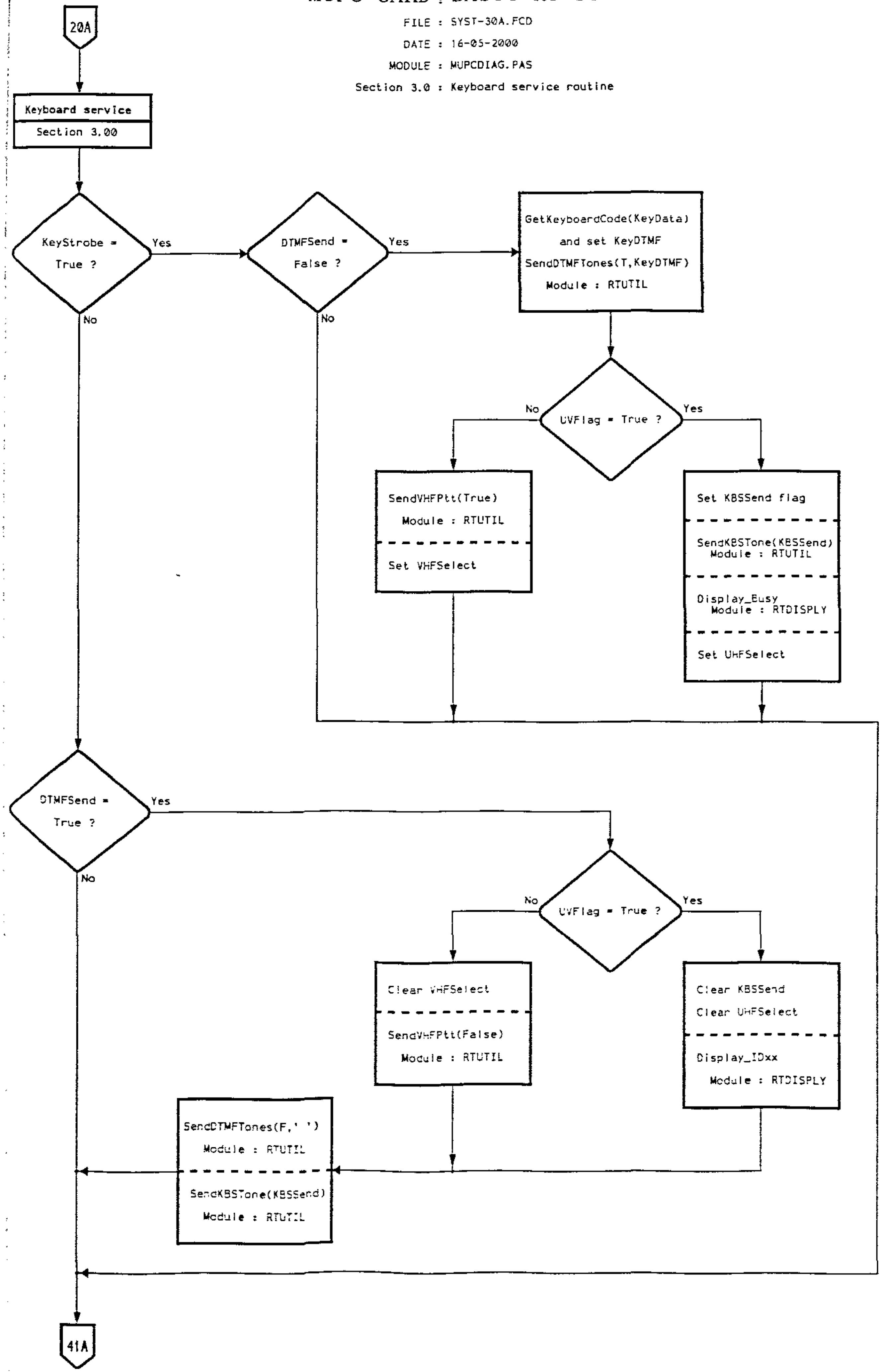
MUPC CARD : BASIC RT SYSTEM

FILE : SYST-30A.FCD

DATE : 16-05-2000

MODULE : MUPCDIAG.PAS

Section 3.0 : Keyboard service routine



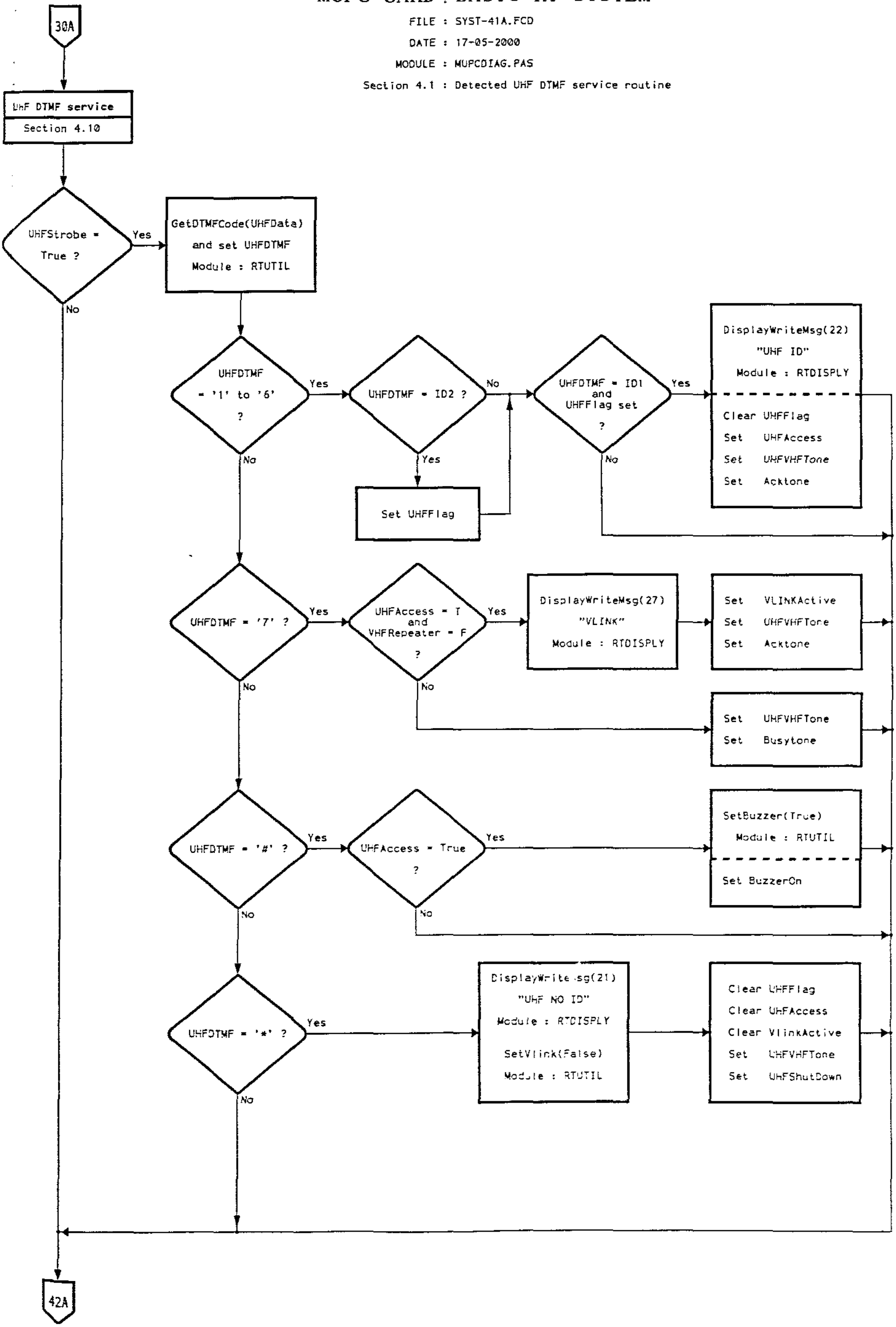
MUPC CARD : BASIC RT SYSTEM

FILE : SYST-41A.FCD

DATE : 17-05-2000

MODULE : MUPCDIAG.PAS

Section 4.1 : Detected UHF DTMF service routine



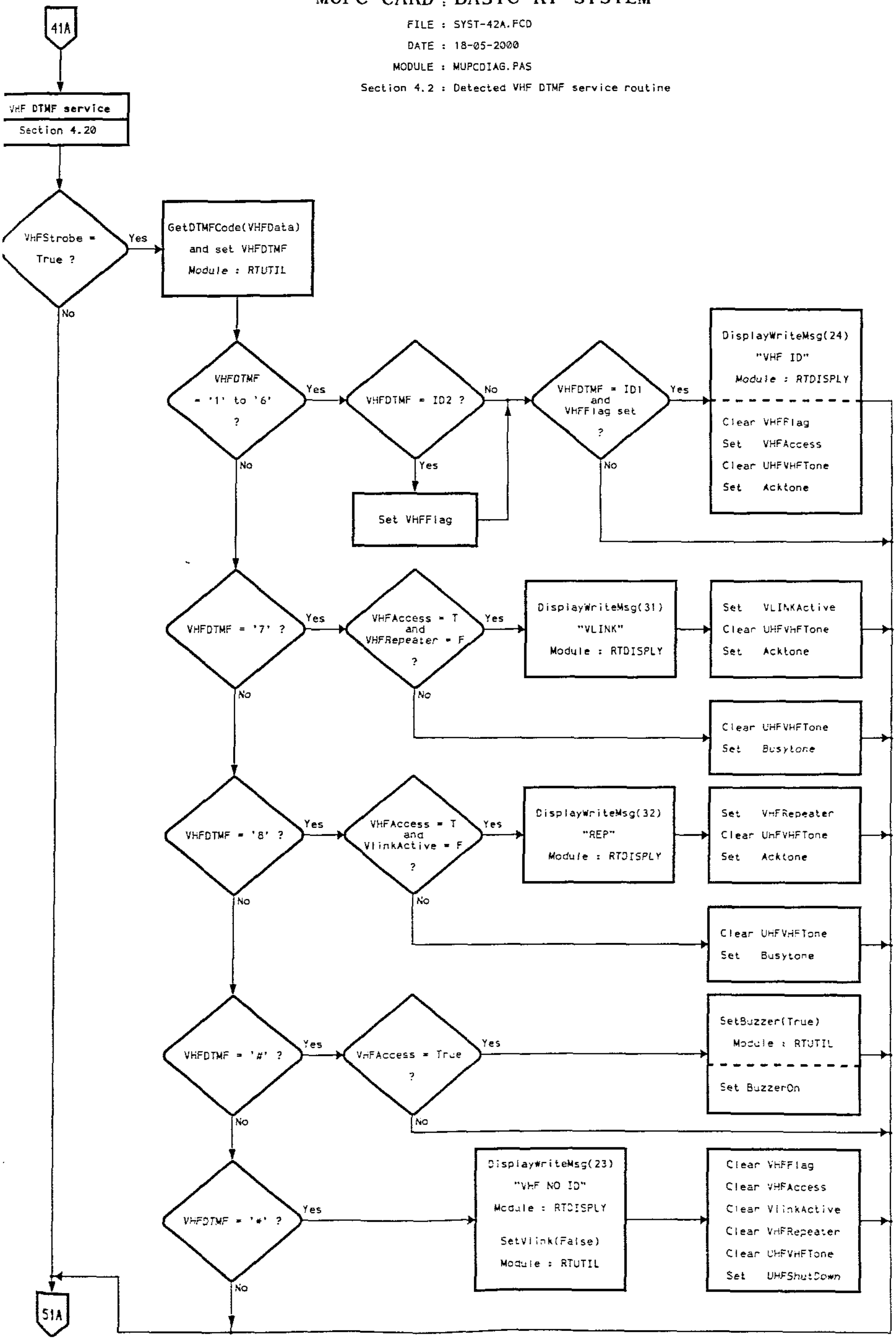
MUPC CARD : BASIC RT SYSTEM

FILE : SYST-42A.FCD

DATE : 18-05-2000

MODULE : MUPCDIAG.PAS

Section 4.2 : Detected VHF DTMF service routine



MUPC CARD : BASIC RT SYSTEM

FILE : SYST-51A.FCD

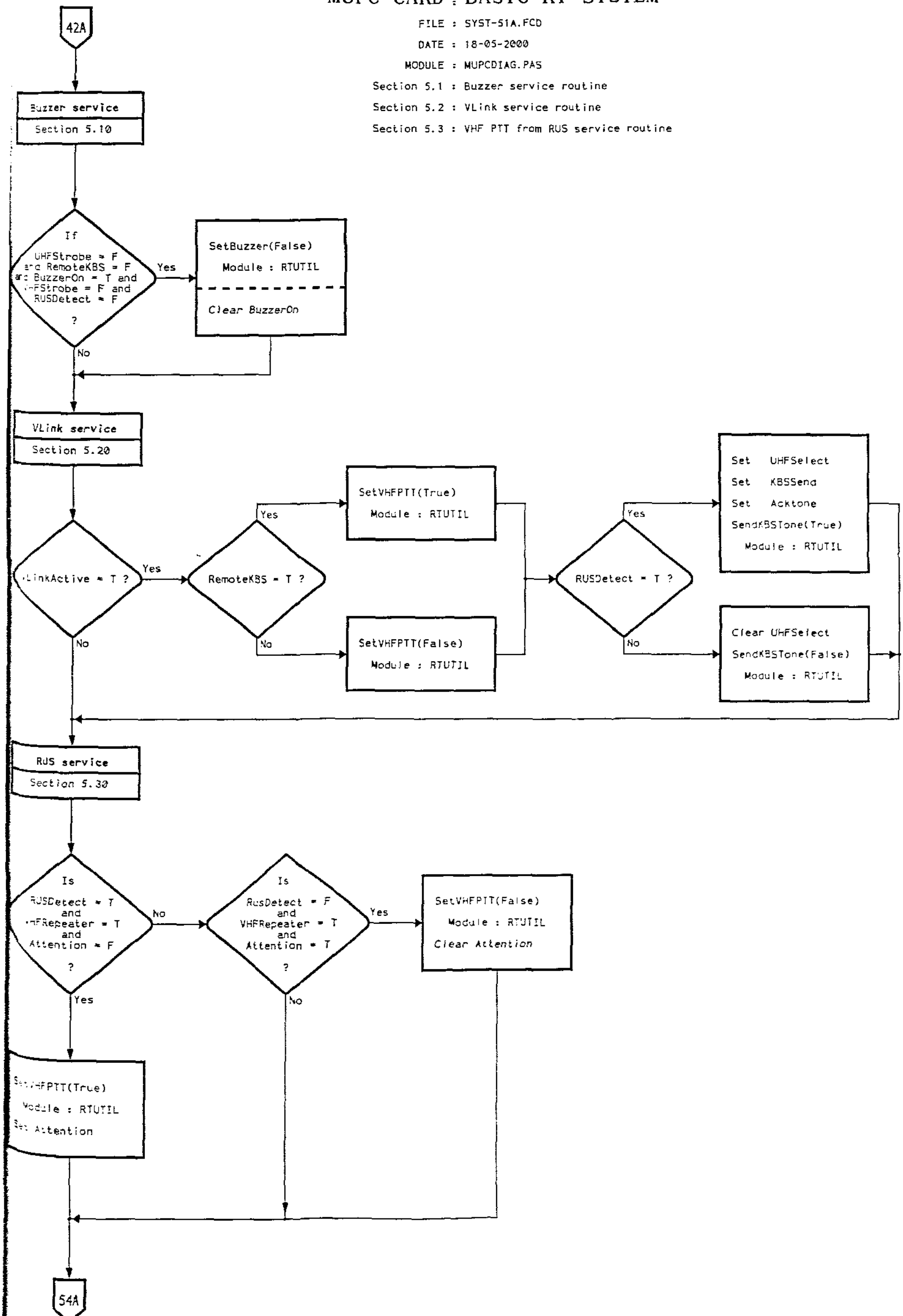
DATE : 18-05-2000

MODULE : MUPCDIAG.PAS

Section 5.1 : Buzzer service routine

Section 5.2 : VLink service routine

Section 5.3 : VHF PTT from RUS service routine



MUPC CARD : BASIC RT SYSTEM

FILE : SYST-54A.FCD

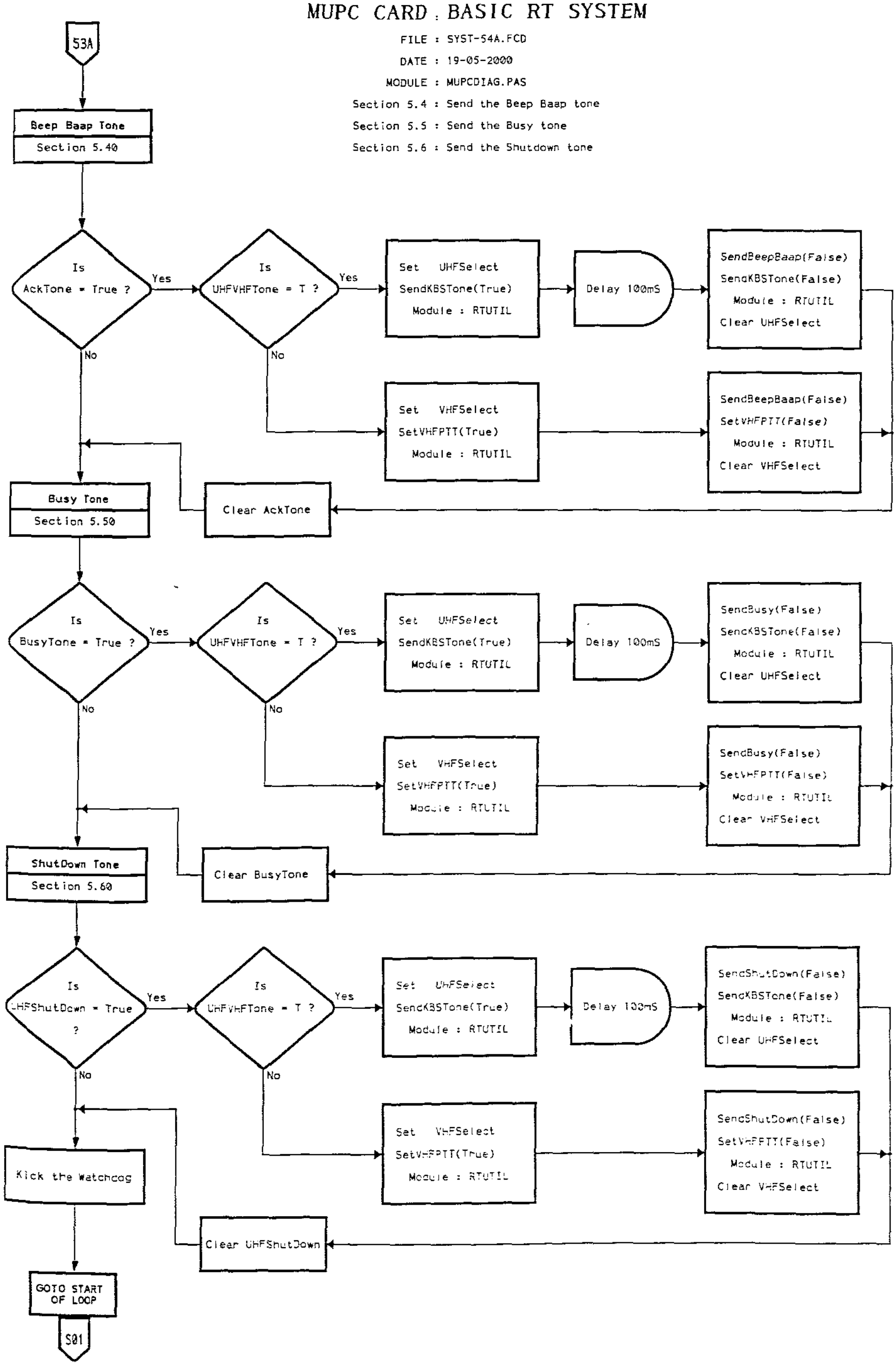
DATE : 19-05-2000

MODULE : MUPCDIAG.PAS

Section 5.4 : Send the Beep Baap tone

Section 5.5 : Send the Busy tone

Section 5.6 : Send the Shutdown tone



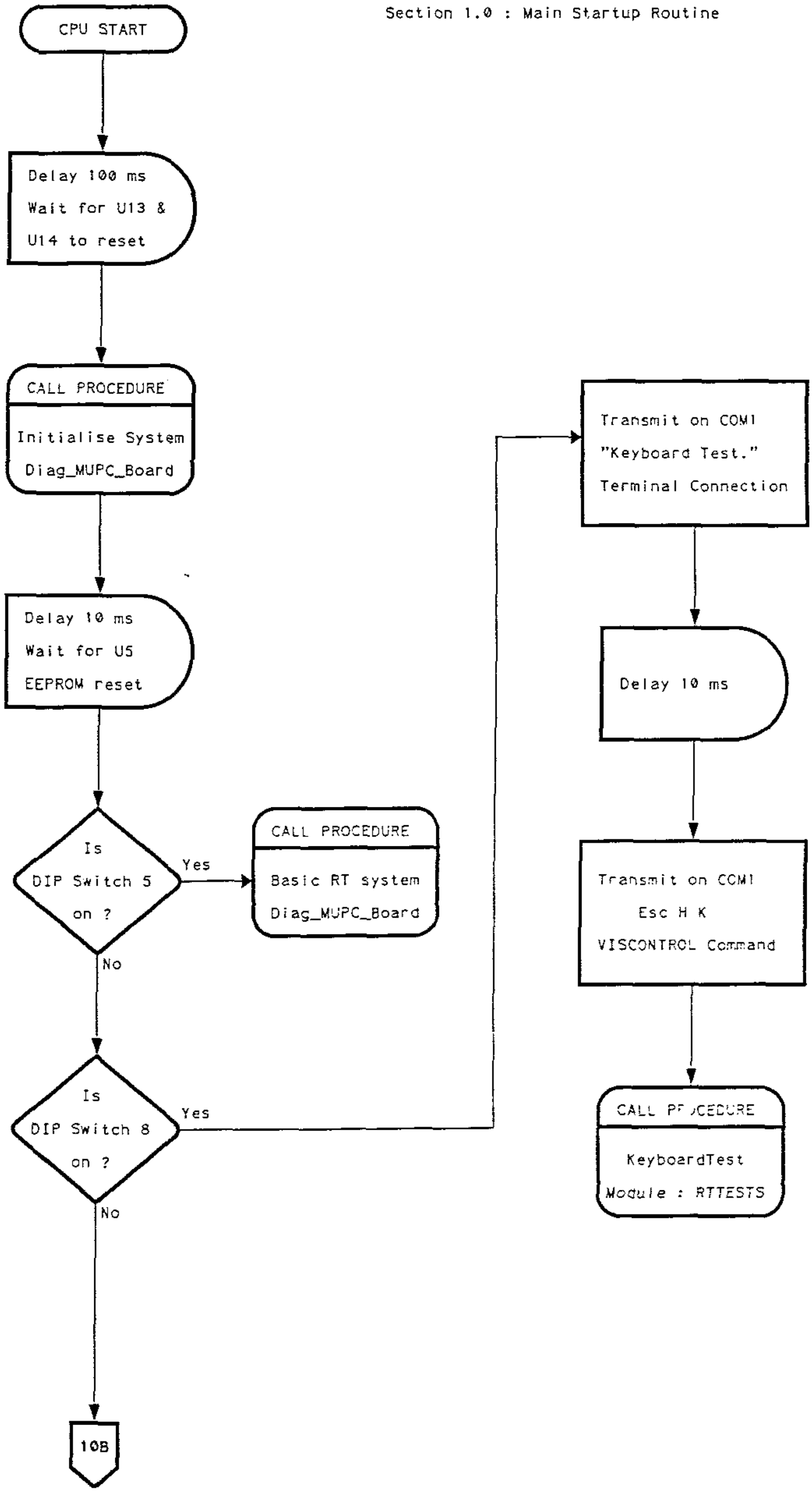
MUPC CARD : DIAGNOSTICS

FILE : DIAG-10A.FCD

DATE : 08-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : Main Startup Routine



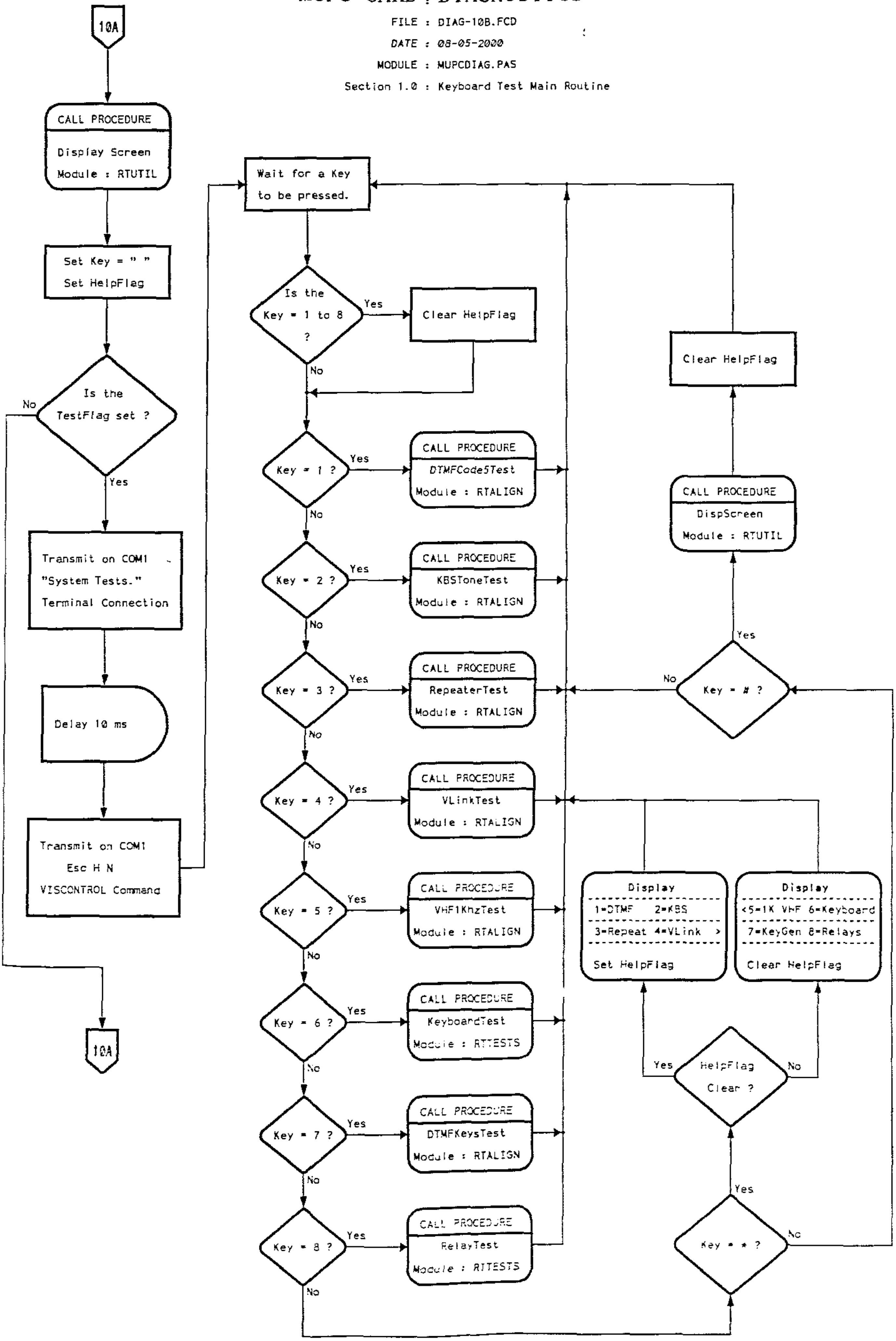
MUPC CARD : DIAGNOSTICS

FILE : DIAG-10B.FCD

DATE : 08-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : Keyboard Test Main Routine



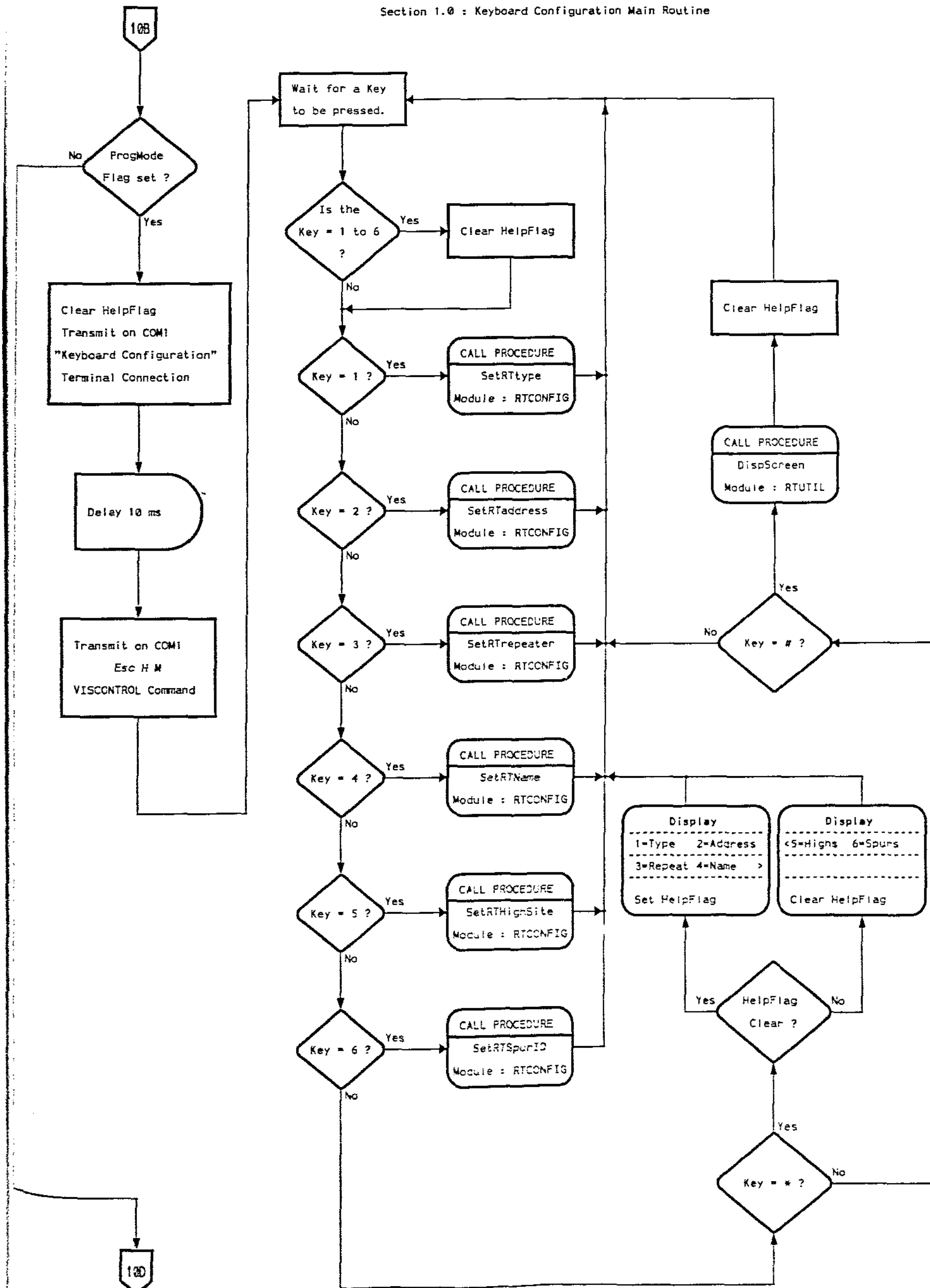
MUPC CARD . DIAGNOSTICS

FILE : DIAG-10C.FCD

DATE : 09-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : Keyboard Configuration Main Routine



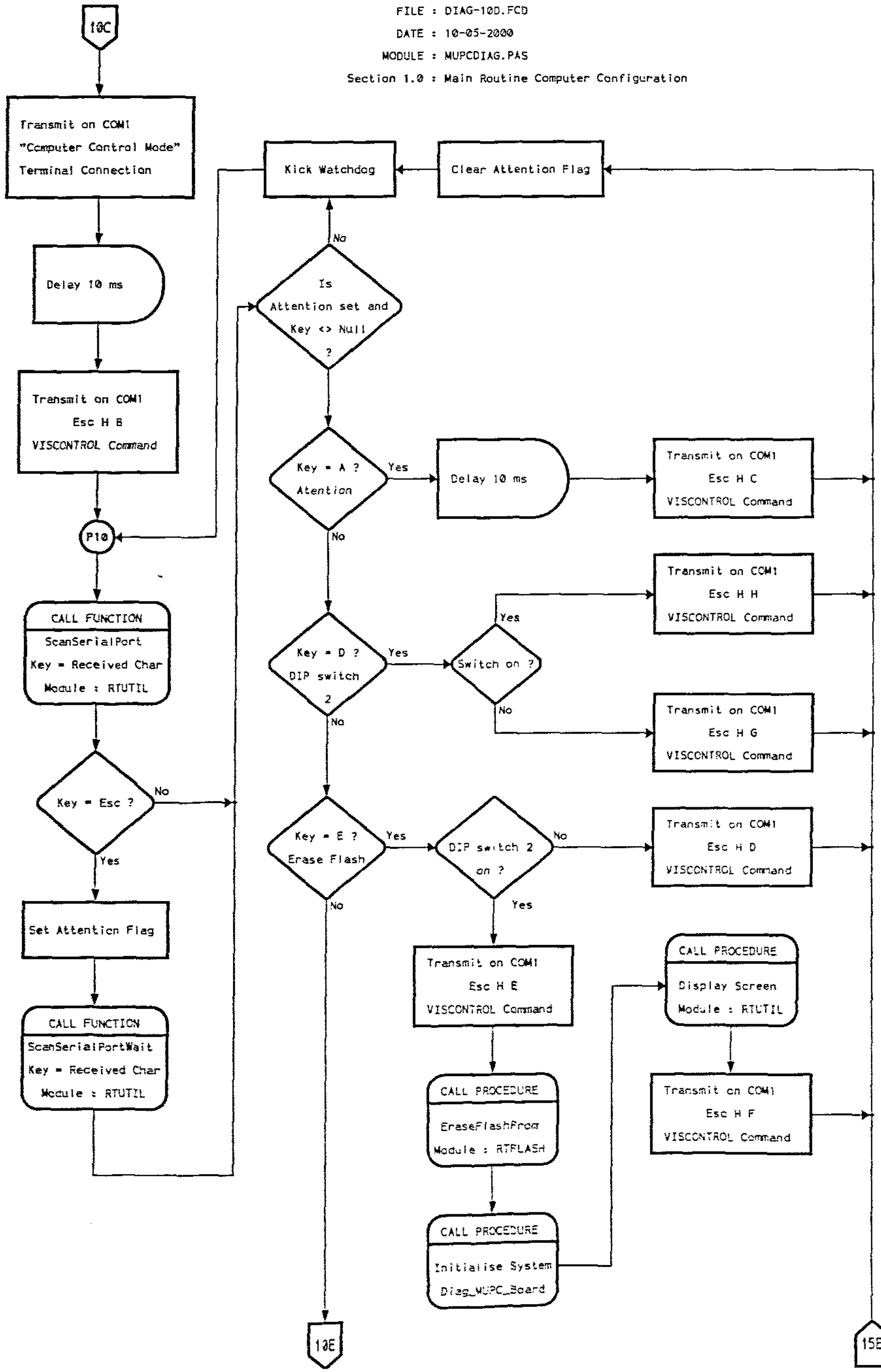
MUPC CARD : DIAGNOSTICS

FILE : DIAG-10D.FCD

DATE : 10-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : Main Routine Computer Configuration



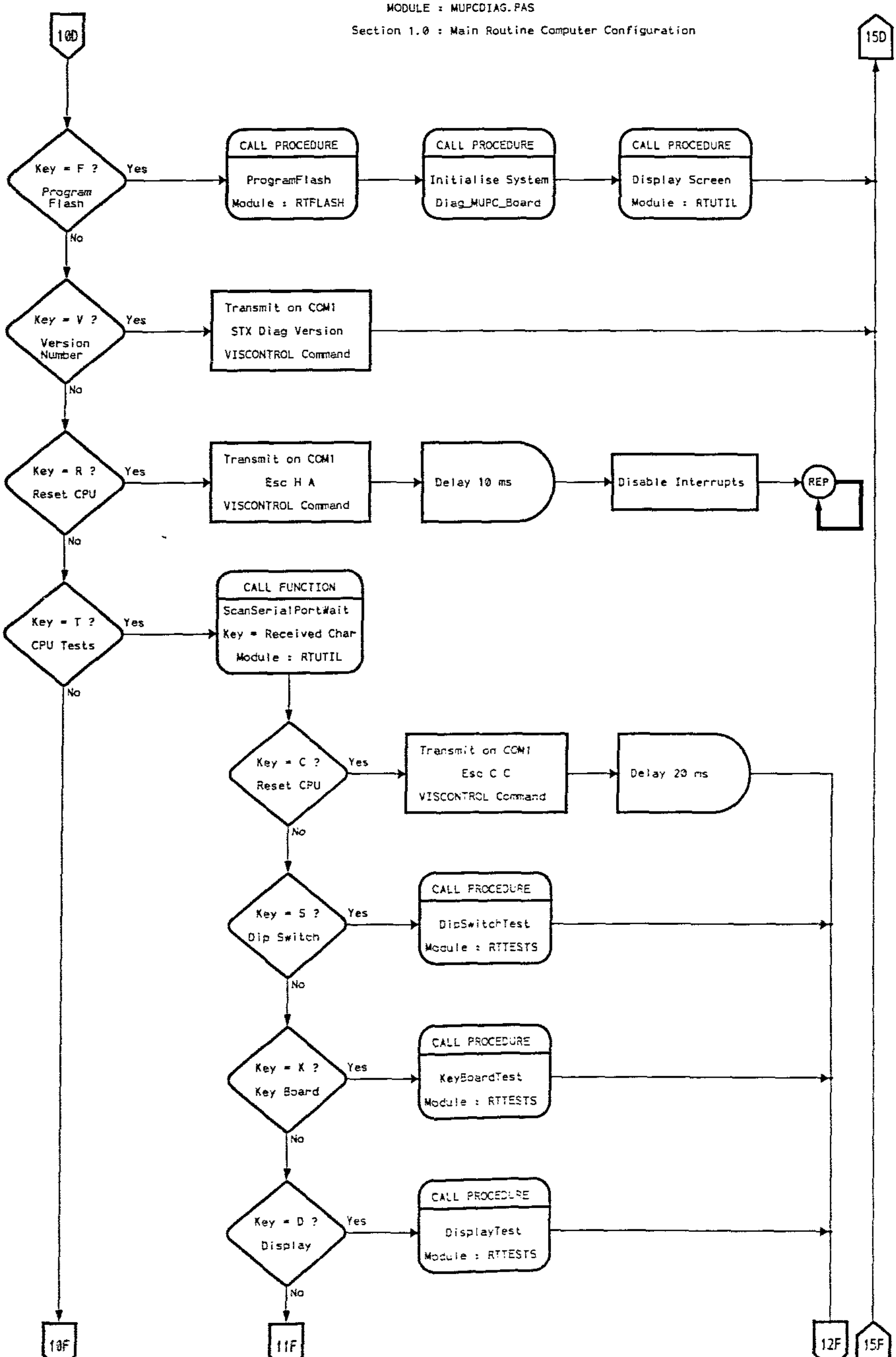
MUPC CARD : DIAGNOSTICS

FILE : DIAG-10E.FCD

DATE : 11-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : Main Routine Computer Configuration



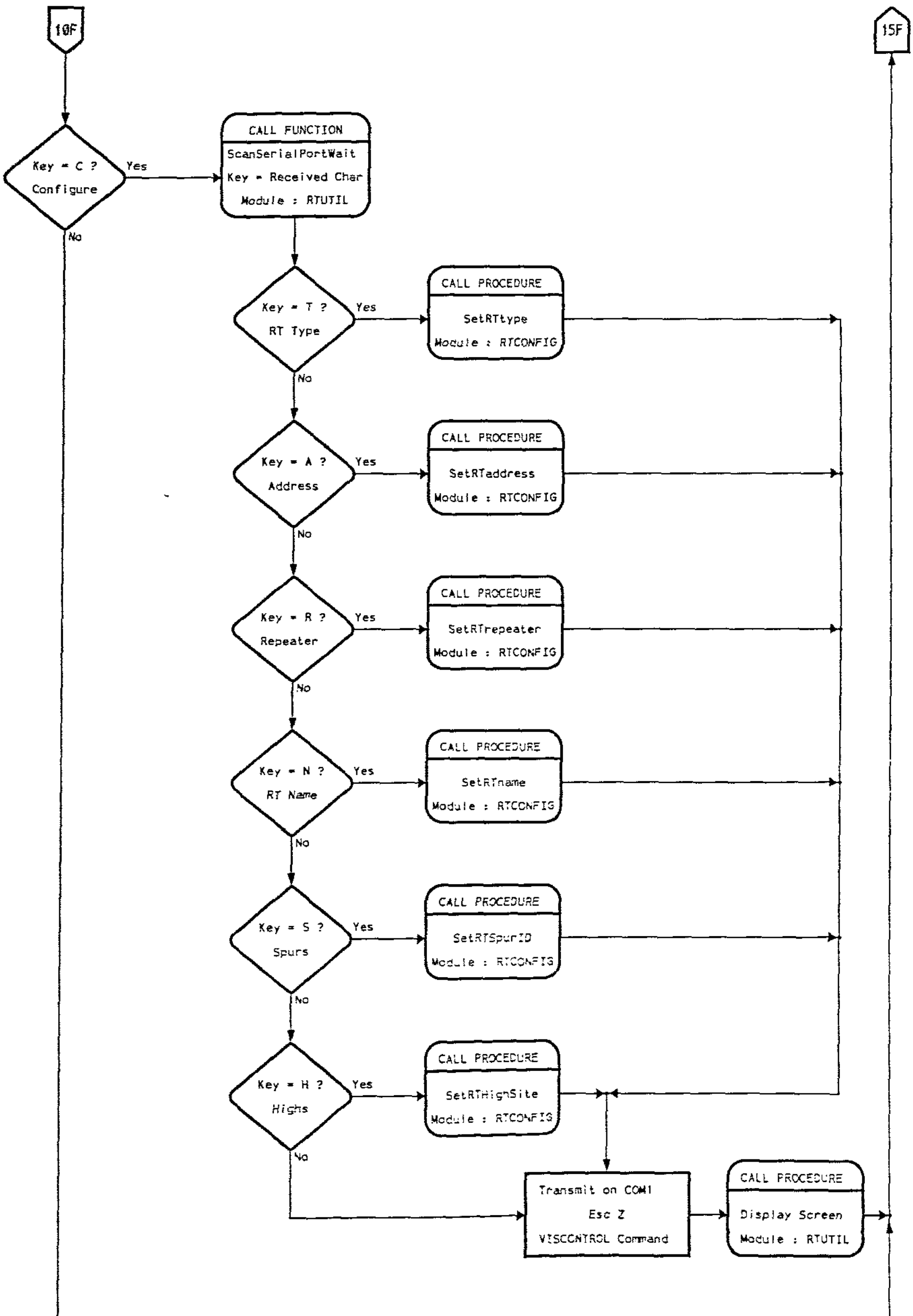
MUPC CARD : DIAGNOSTICS

FILE : DIAG-10G.FCD

DATE : 11-05-2000

MODULE : MUPCDIAG.PAS

Section 1.0 : Main Routine Computer Configuration



3.4 SYSTEM TESTS MODULE.

The test module checks the operation of the diferent hardware sections on the MUPC board.

File Names	***Description***	***Page***
RTTESTS.PAS	Pascal source file in appendix C.	---
TEST-10A.FCD	CPU card DIP switch test routine. CPU card Keyboard test routine.	64
TEST-10B.FCD	CPU card Display test routine.	65
TEST-20A.FCD	CPU card Function tone test routine.	66
TEST-30A.FCD	CPU card Relay test routine.	69
TEST-40A.FCD	CPU card Output lines test routine.	70
TEST-40B.FCD	CPU card Input lines test routine.	71
TEST-50A.FCD	CPU card EEPROM test routine.	72
TEST-60A.FCD	CPU card Modem and COM2 test routine.	73

MUPC CARD : SYSTEM TESTS

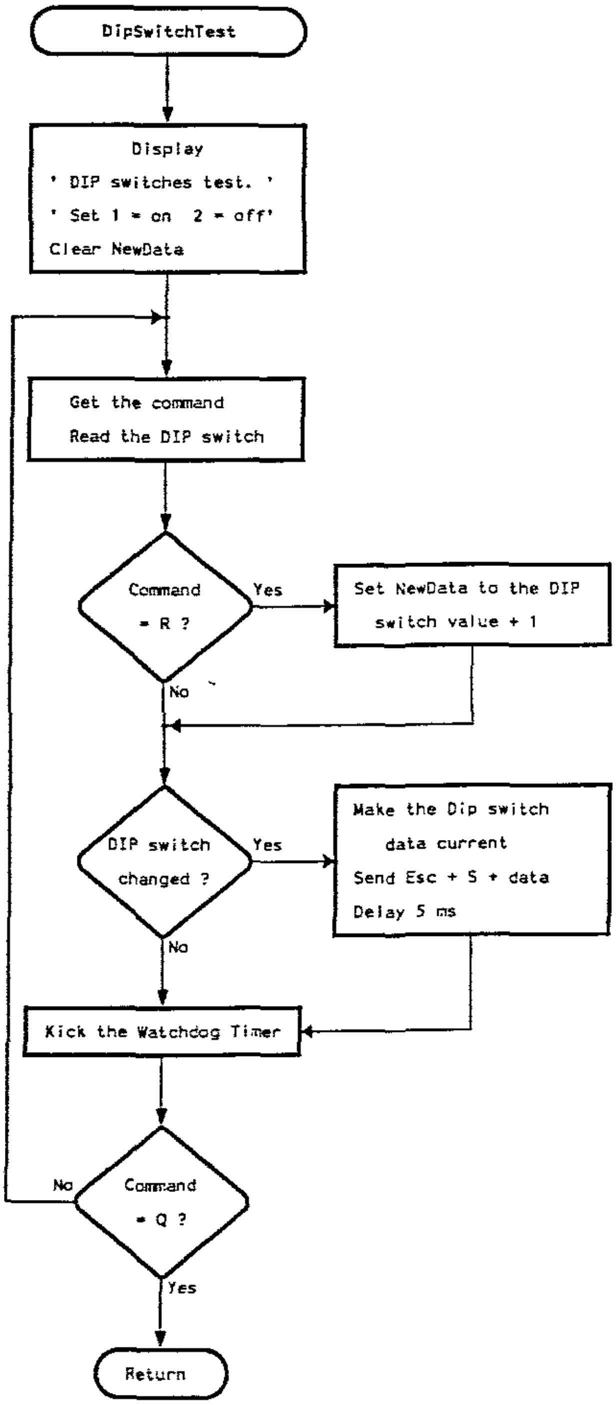
FILE : TEST-10A.FCD

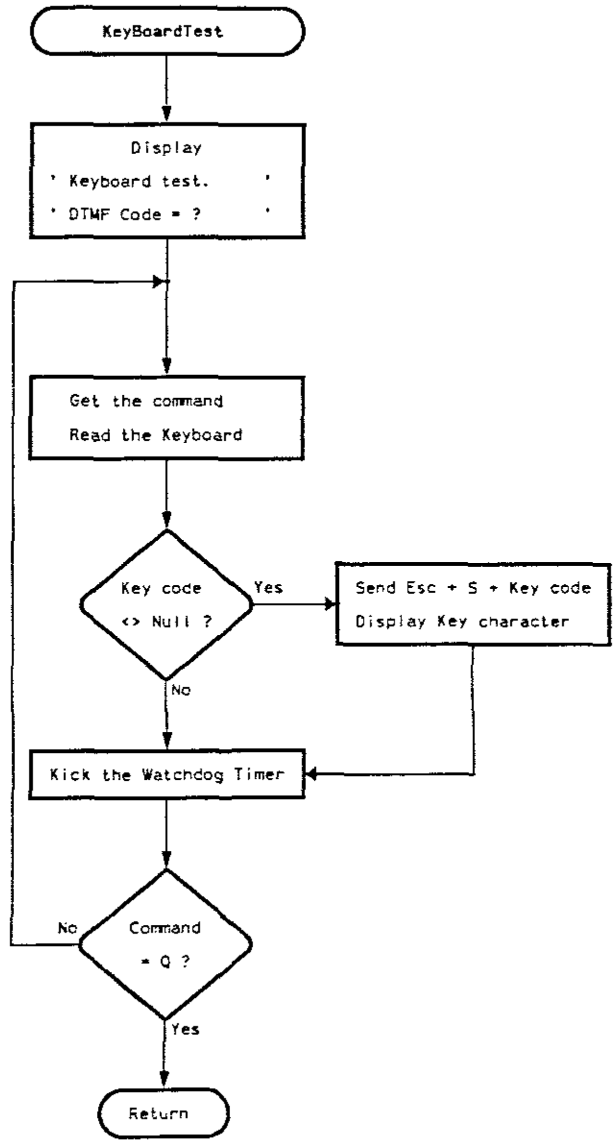
DATE : 26-06-2000

MODULE : RTTESTS.PAS

Section 1.0 : CPU card DIP switch test routine

Section 1.1 : CPU card Keyboard test routine





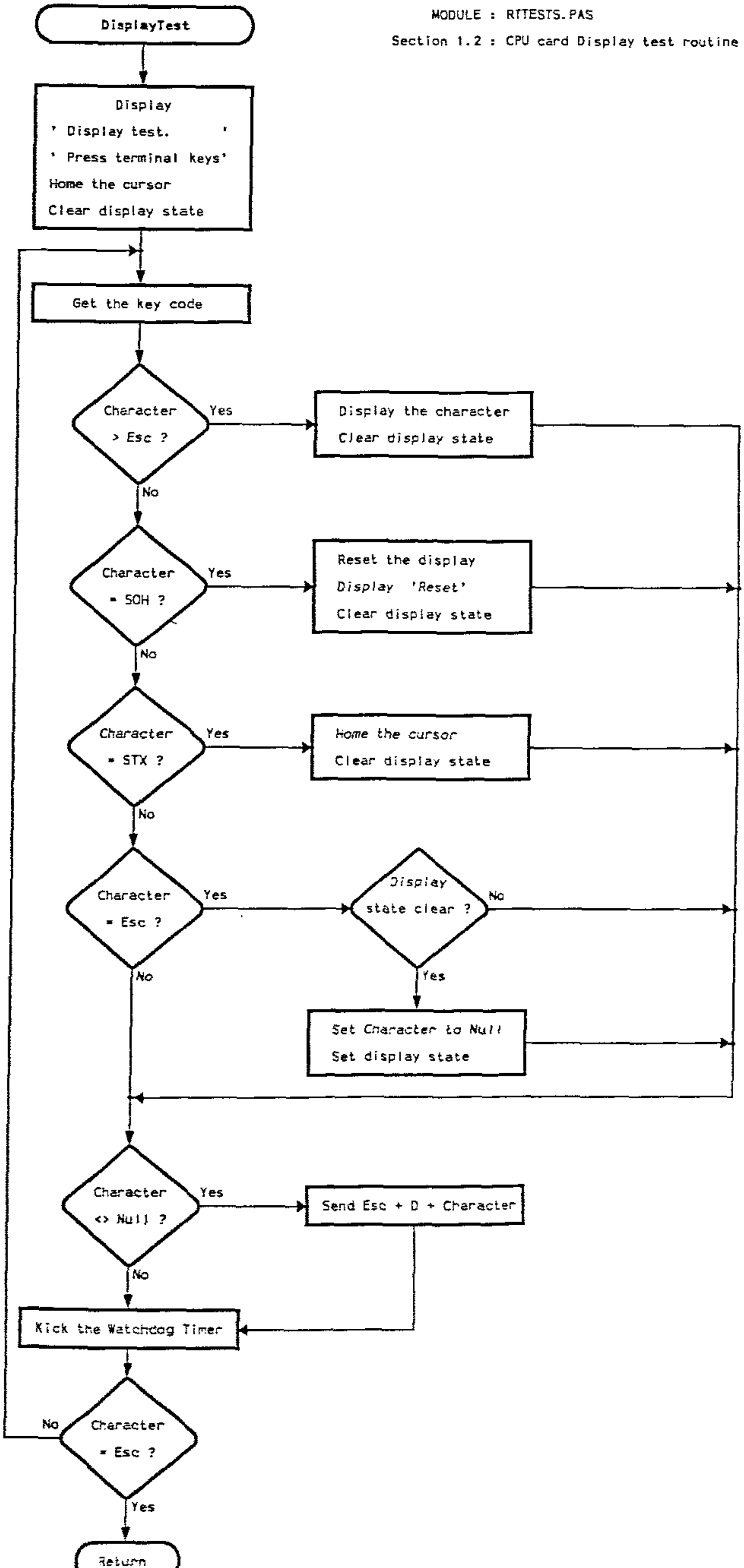
MUPC CARD : SYSTEM TESTS

FILE : TEST-10B.FCD

DATE : 26-06-2000

MODULE : RTTESTS.PAS

Section 1.2 : CPU card Display test routine



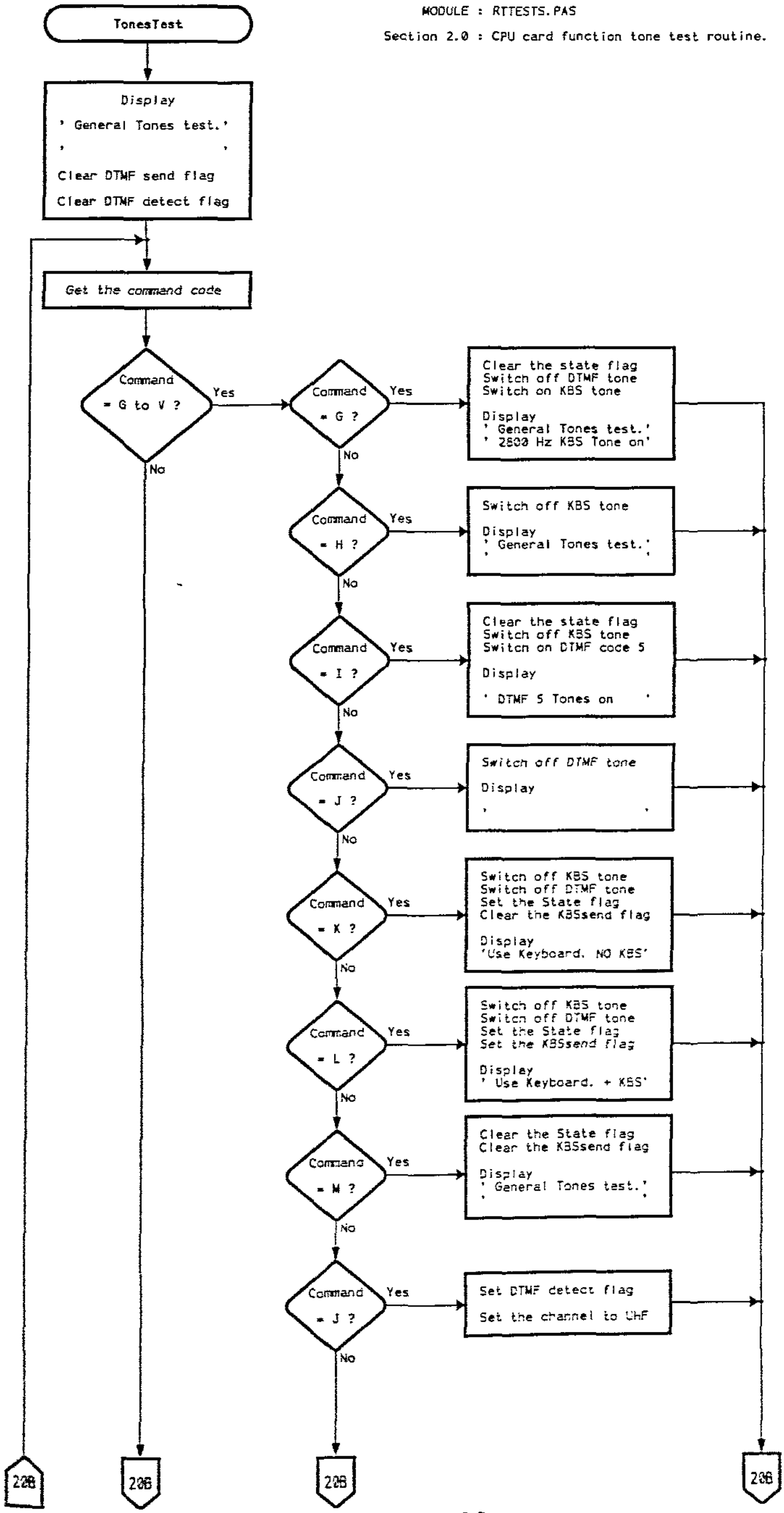
MUPC CARD : SYSTEM TESTS

FILE : TEST-20A.FCD

DATE : 27-06-2000

MODULE : RTTESTS.PAS

Section 2.0 : CPU card function tone test routine.



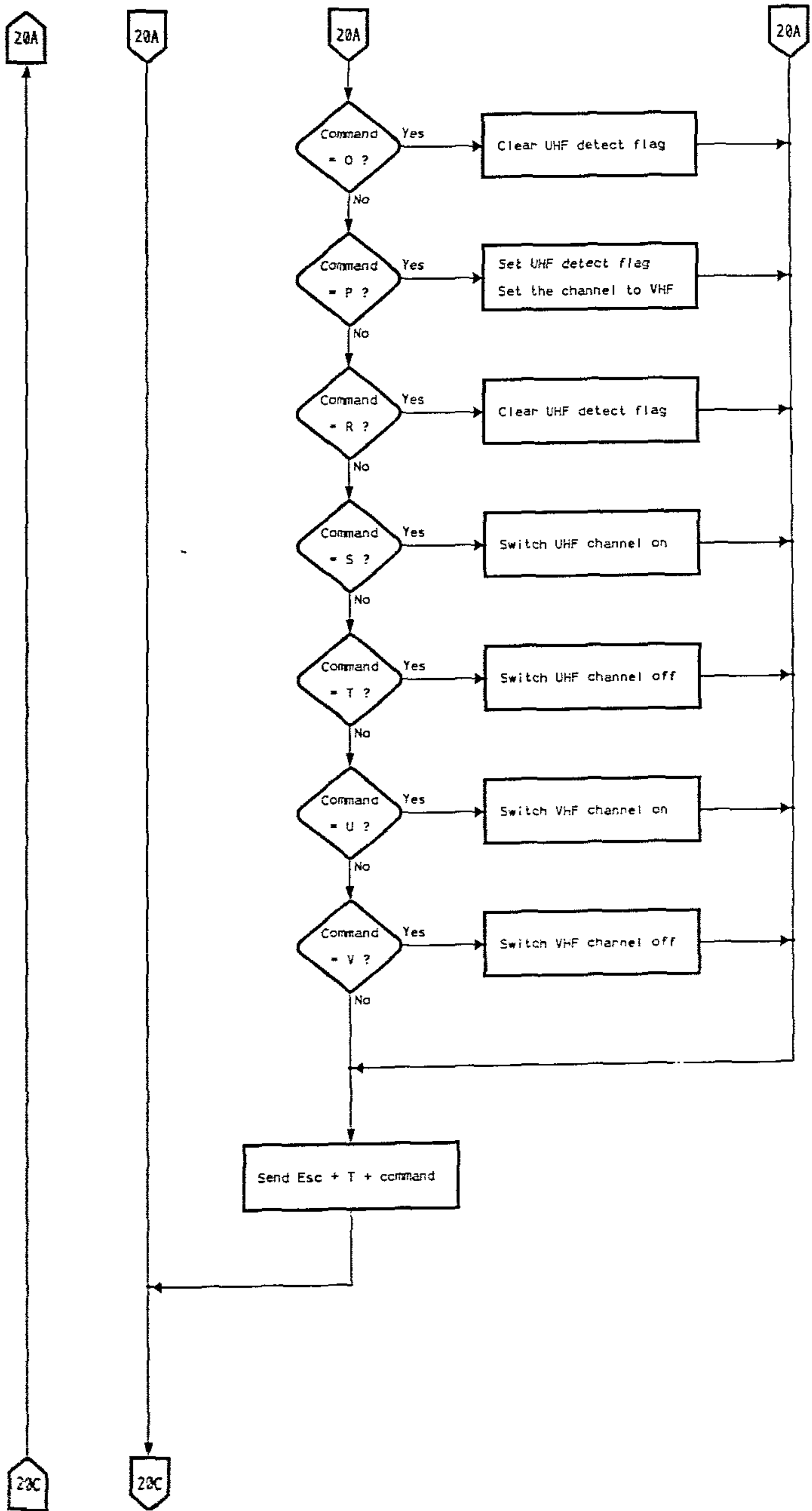
MUPC CARD : SYSTEM TESTS

FILE : TEST-20B.FCD

DATE : 27-06-2000

MODULE : RTTESTS.PAS

Section 2.0 : CPU card function tone test routine.



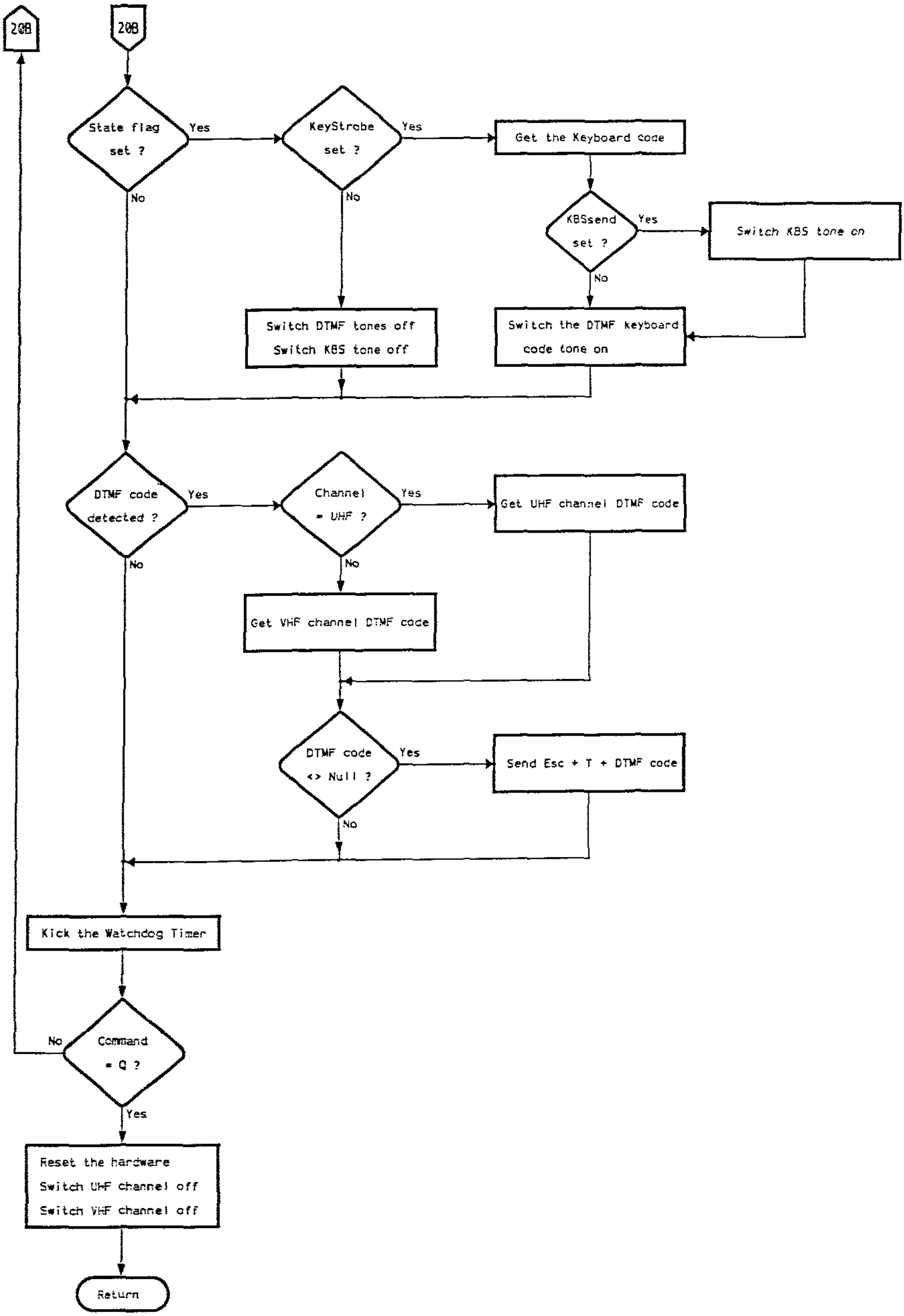
MUPC CARD : SYSTEM TESTS

FILE : TEST-20C.FCD

DATE : 27-06-2000

MODULE : RTTESTS.PAS

Section 2.0 : CPU card function tone test routine.



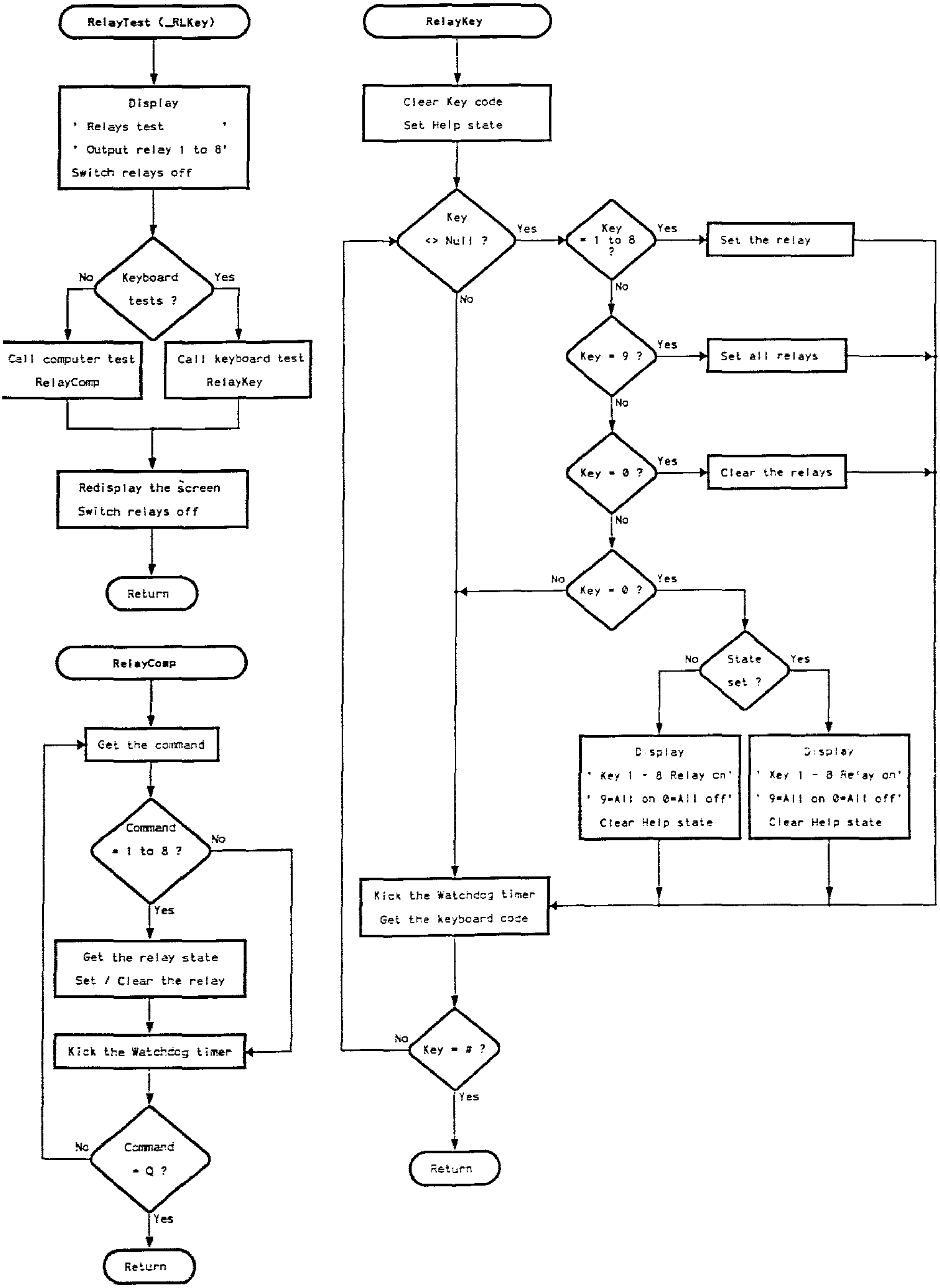
MUPC CARD : SYSTEM TESTS

FILE : TEST-30A.FCD

DATE : 27-06-2000

MODULE : RTTESTS.PAS

Section 3.0 : CPU card relay test routine.



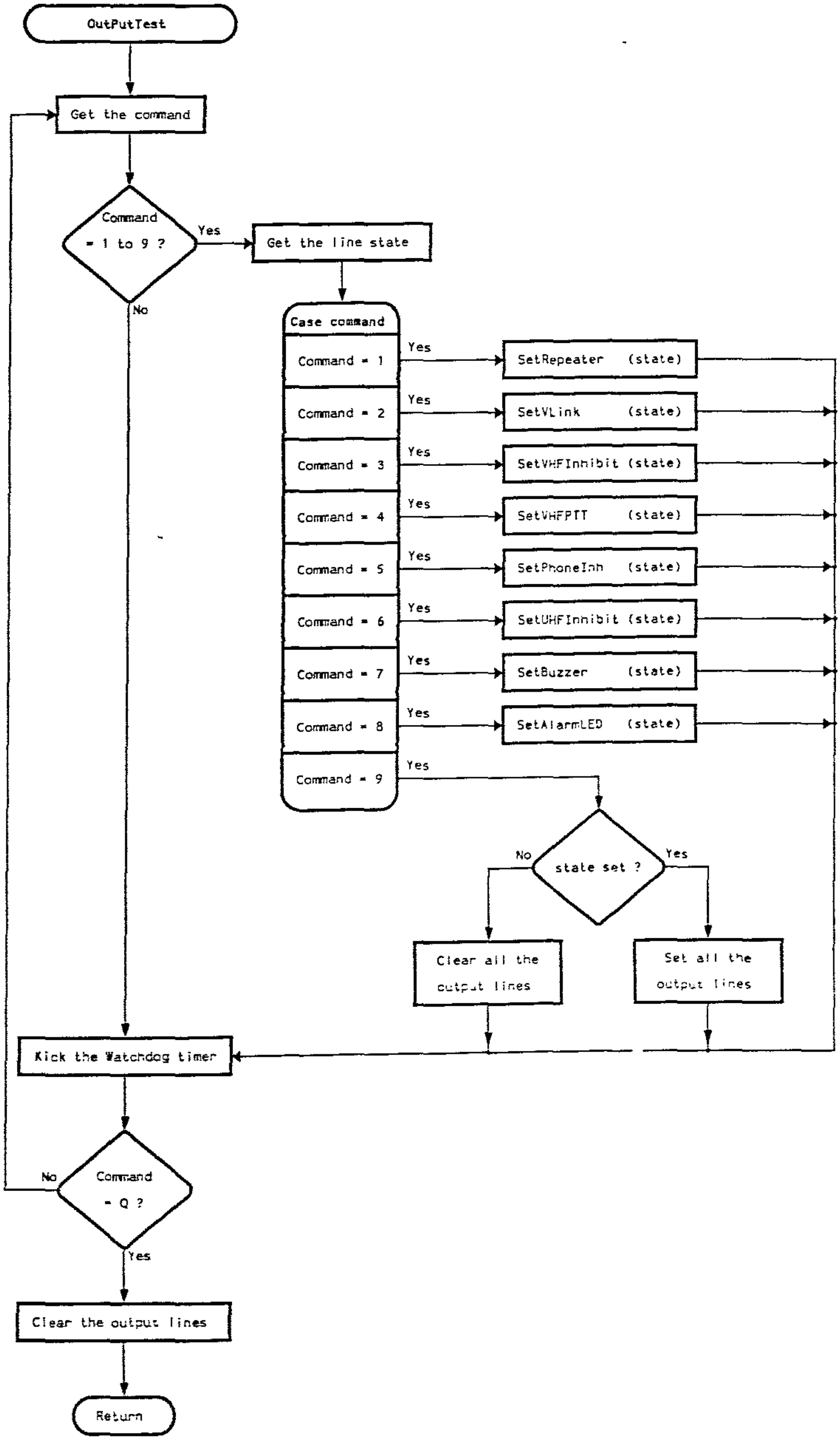
MUPC CARD : SYSTEM TESTS

FILE : TEST-40A.FCD

DATE : 28-06-2000

MODULE : RTTESTS.PAS

Section 4.0 : CPU card output lines test routine.

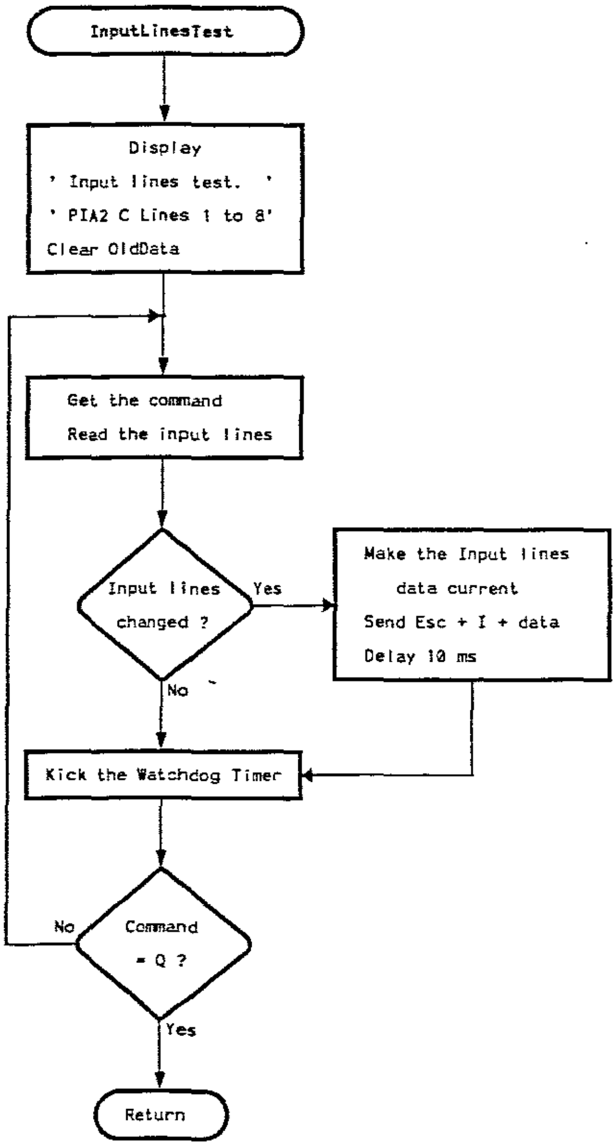


FILE : TEST-40B.FCD

DATE : 28-06-2000

MODULE : RTTESTS.PAS

Section 4.1 : CPU card Input lines test routine



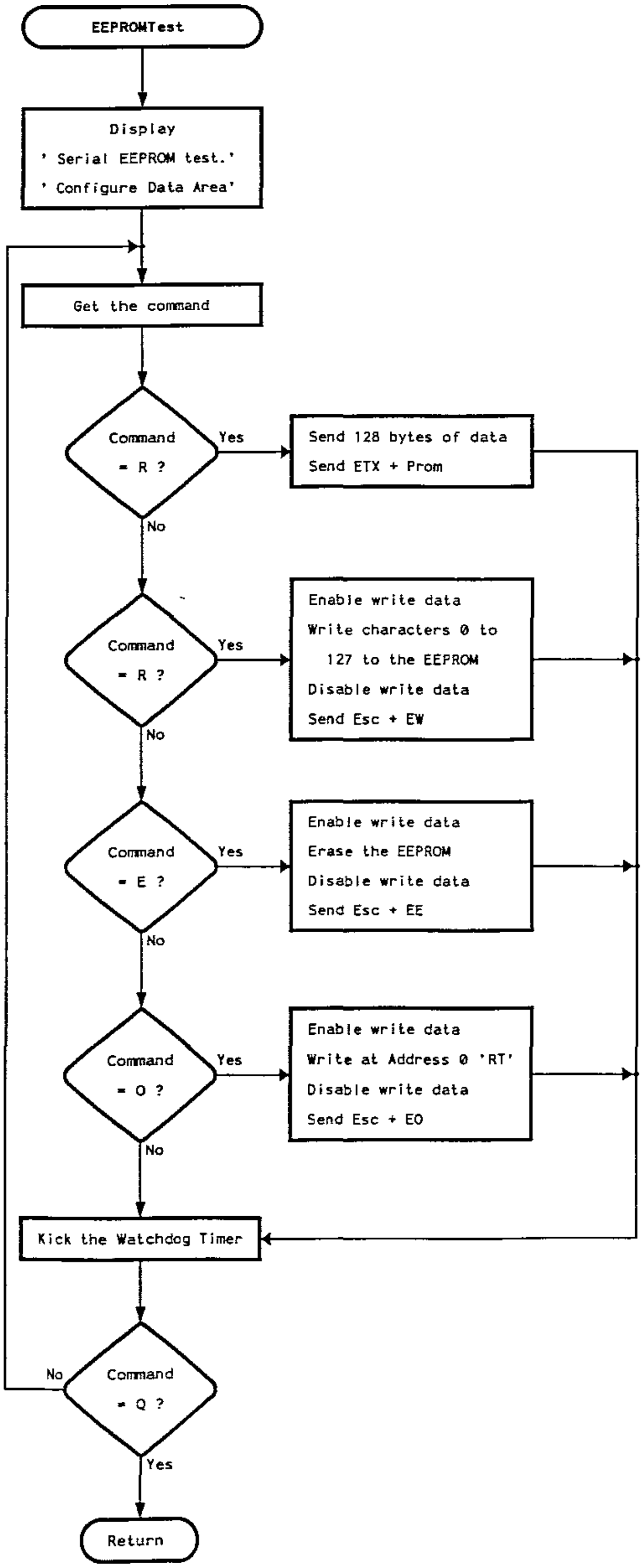
MUPC CARD : SYSTEM TESTS

FILE : TEST-50A.FCD

DATE : 29-06-2000

MODULE : RTTESTS.PAS

Section 5.0 : CPU card EEPROM test routine



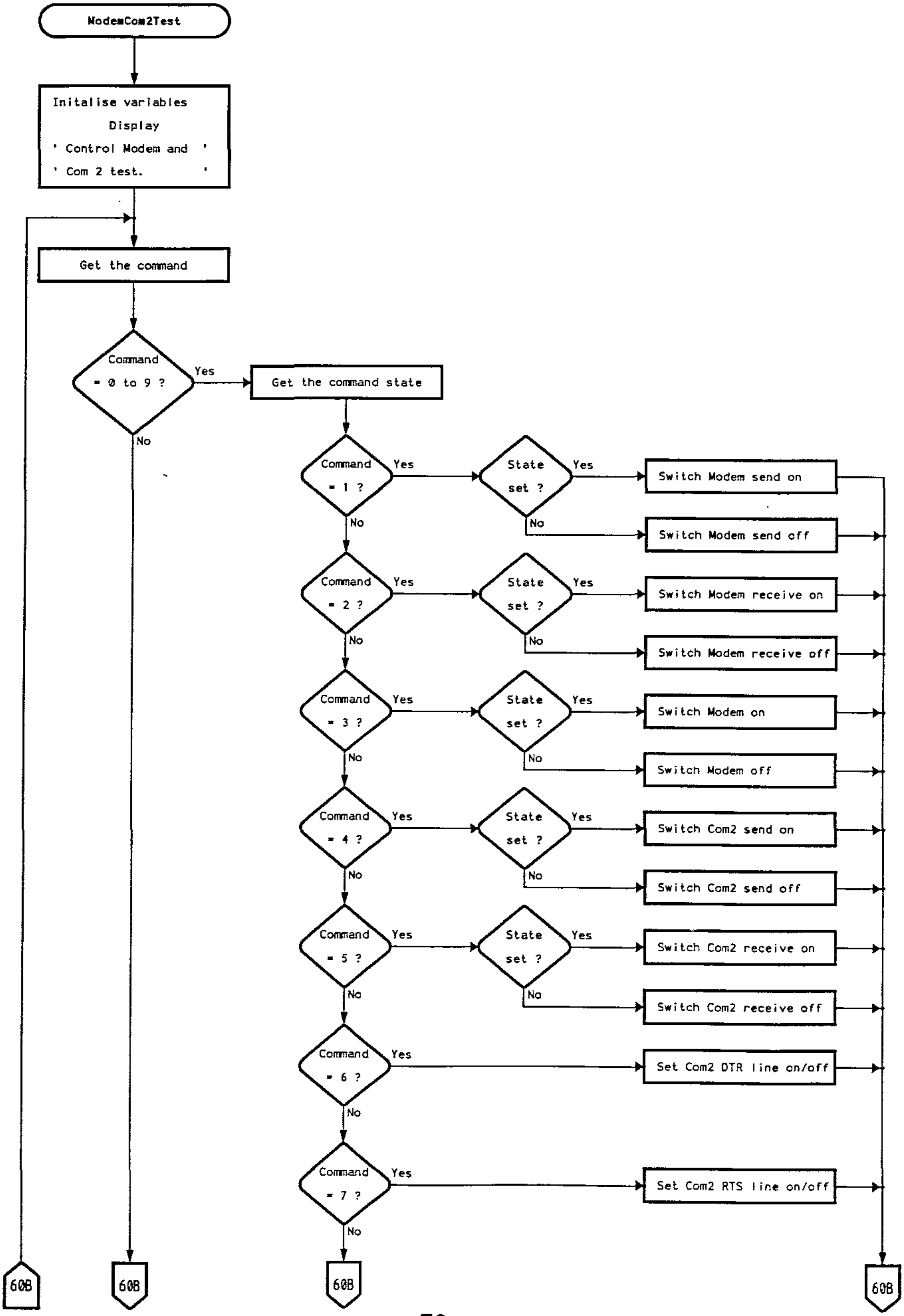
MUPC CARD : SYSTEM TESTS

FILE : TEST-60A.FCD

DATE : 29-06-2000

MODULE : RTTESTS.PAS

Section 6.0 : CPU card Modem and COM2 test routine



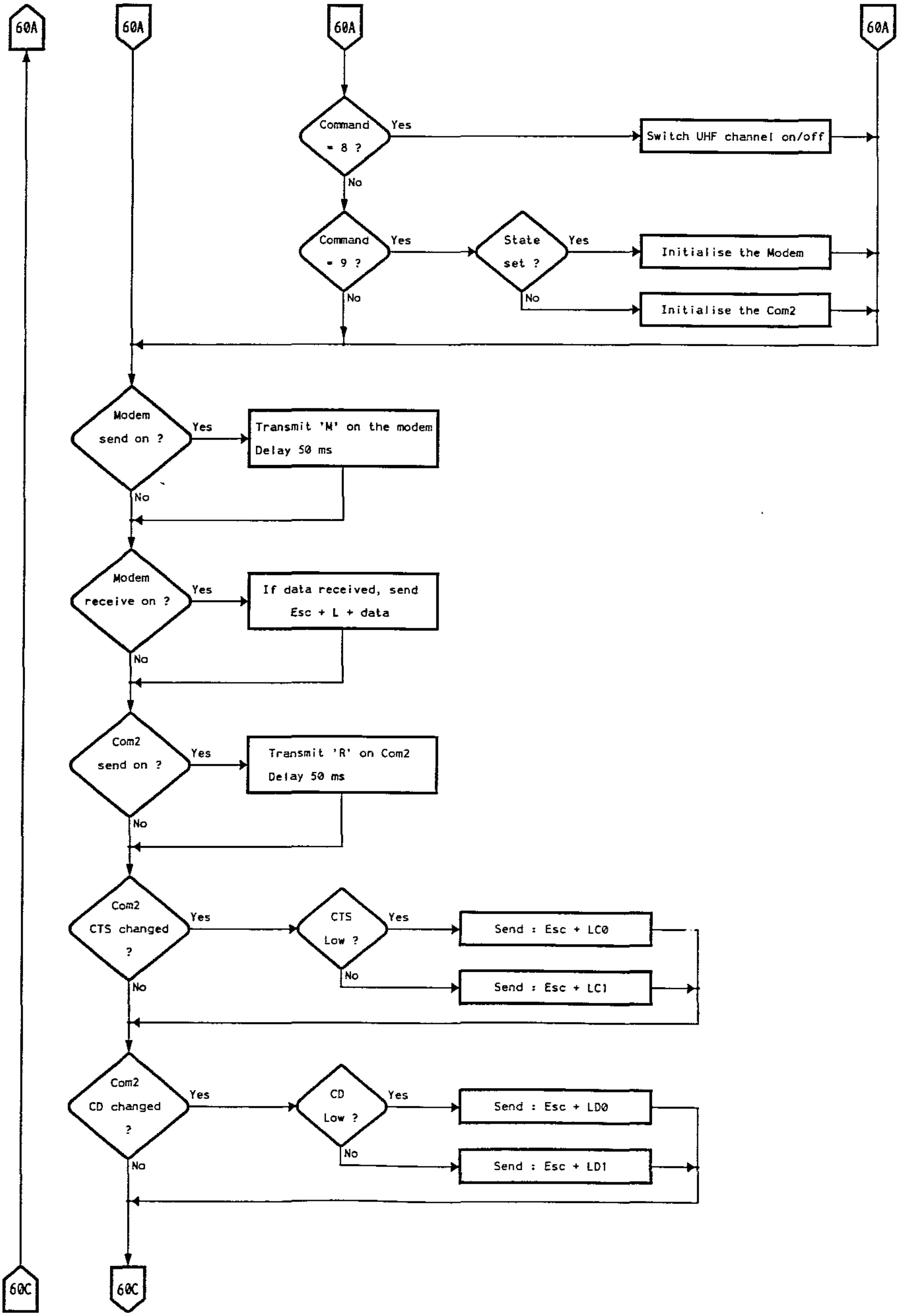
MUPC CARD : SYSTEM TESTS

FILE : TEST-60B.FCD

DATE : 29-06-2000

MODULE : RTTESTS.PAS

Section 6.0 : CPU card Modem and COM2 test routine



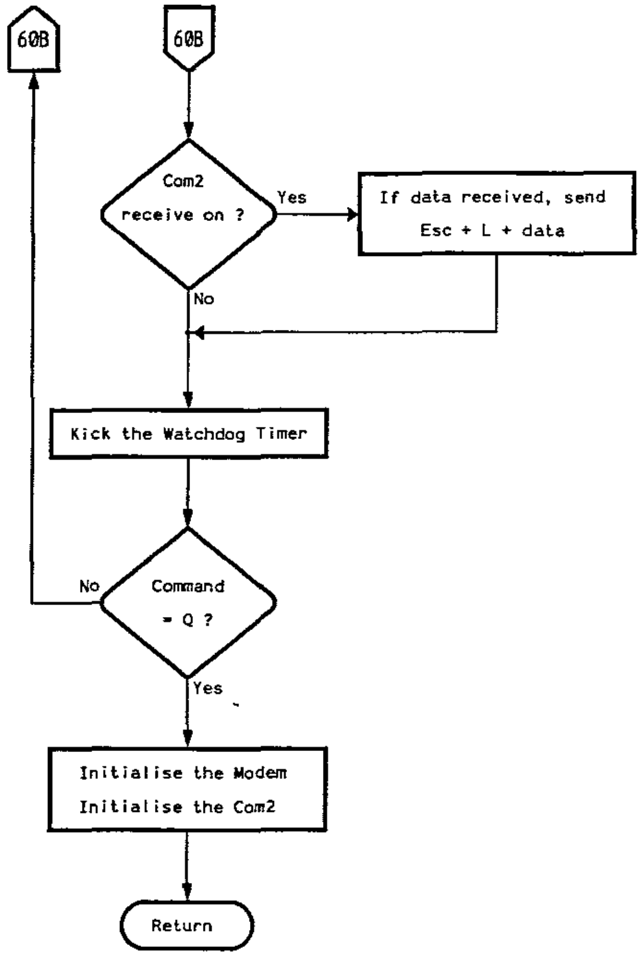
MUPC CARD : SYSTEM TESTS

FILE : TEST-60C.FCD

DATE : 29-06-2000

MODULE : RTTESTS.PAS

Section 6.0 : CPU card Modem and COM2 test routine



3.5 SYSTEM CONFIGURATION MODULE.

The configuration module sets the operating parameters of the radio telephone system.

File Names	Description	Page
RTCONFIG.PAS	Pascal source file in appendix C.	---
CONF-10A.FCD	System type configuration routines.	77
CONF-20A.FCD	System address configuration routines.	80
CONF-30A.FCD	System repeater configuration routines.	83
CONF-40A.FCD	System name configuration routines.	86
CONF-50A.FCD	System Spur sites ID configuration routines.	90
CONF-60A.FCD	System High sites ID configuration routines.	93

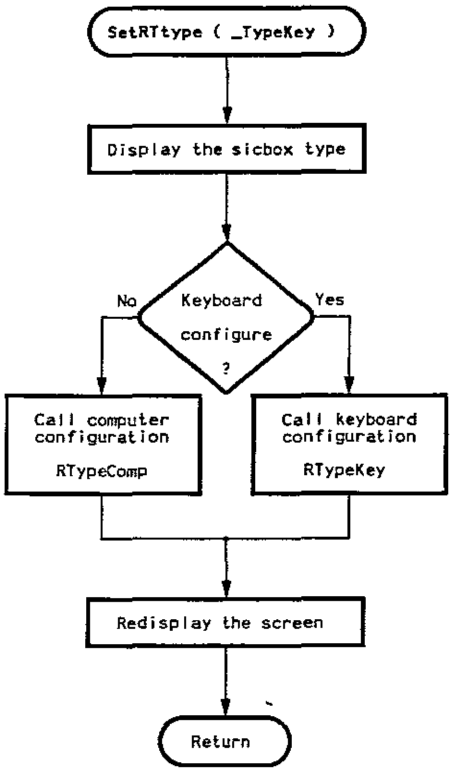
MUPC CARD : SYSTEM CONFIGURATION

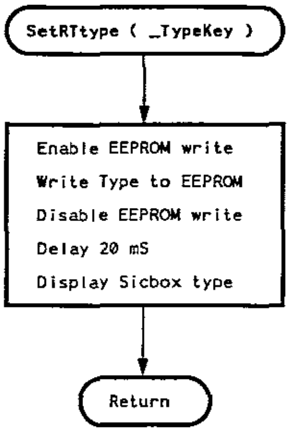
FILE : CONF-10A.FCD

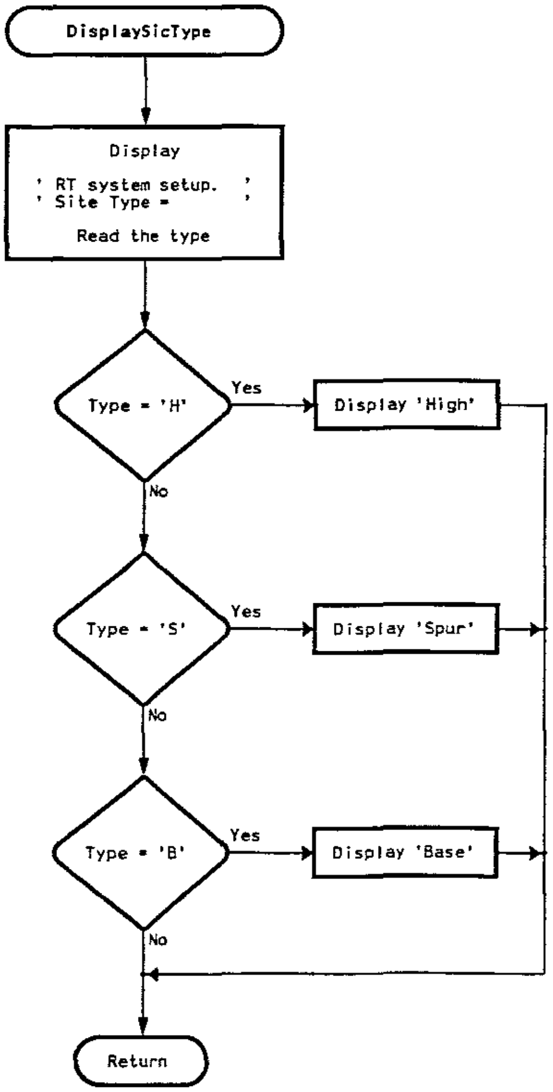
DATE : 20-06-2000

MODULE : RTCONFIG.PAS

Section 1.0 : System type configuration routines







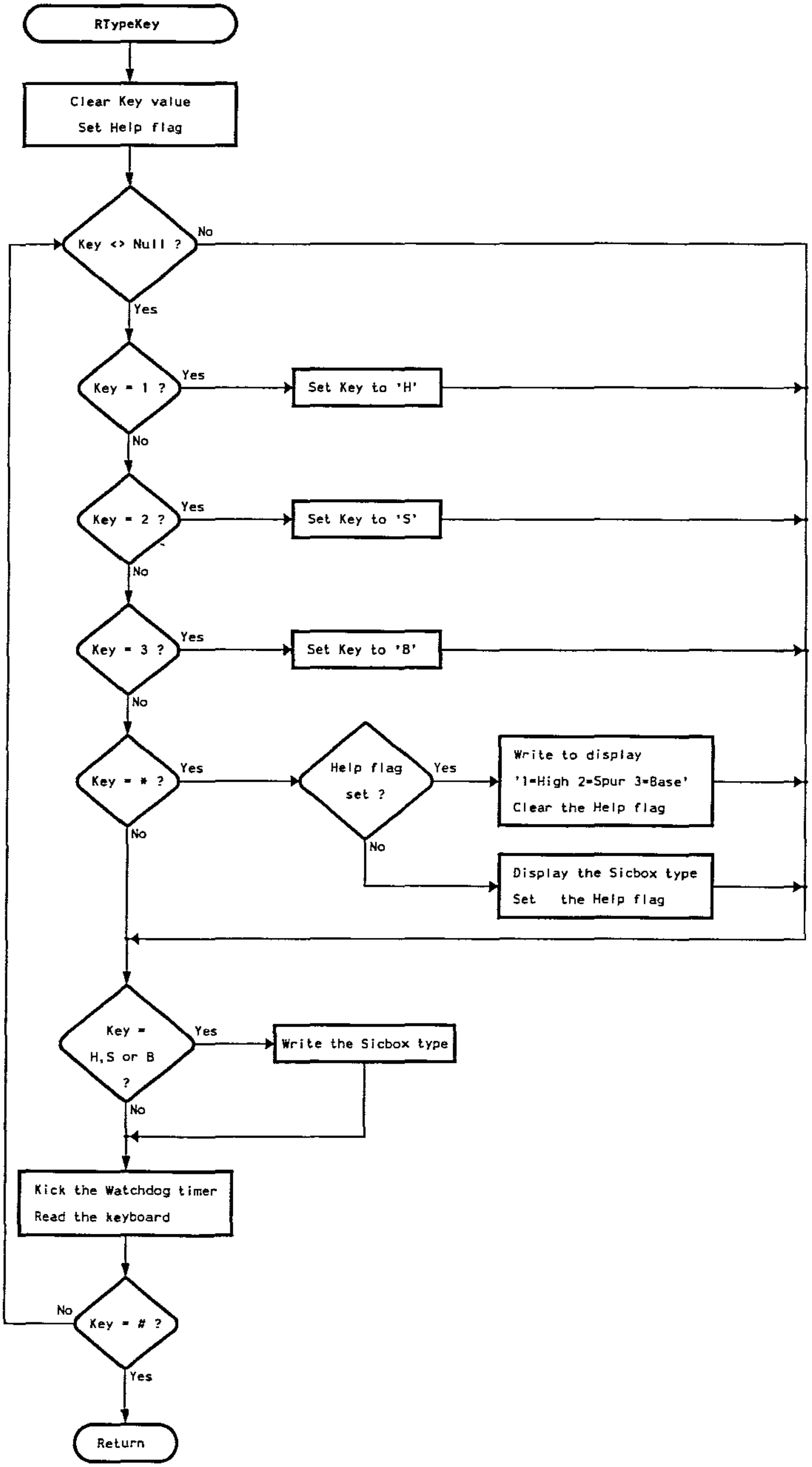
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-10B.FCD

DATE : 20-06-2000

MODULE : RTCONFIG.PAS

Section 1.0 : System type configuration routines



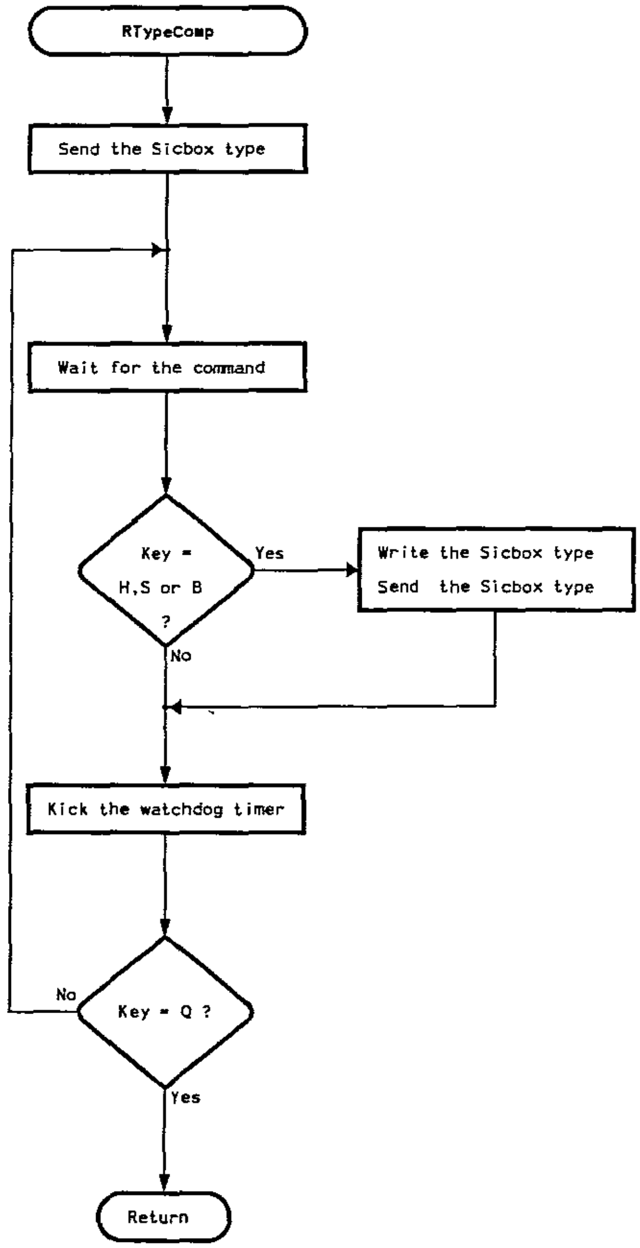
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-10C.FCD

DATE : 20-06-2000

MODULE : RTCONFIG.PAS

Section 1.0 : System type configuration routines



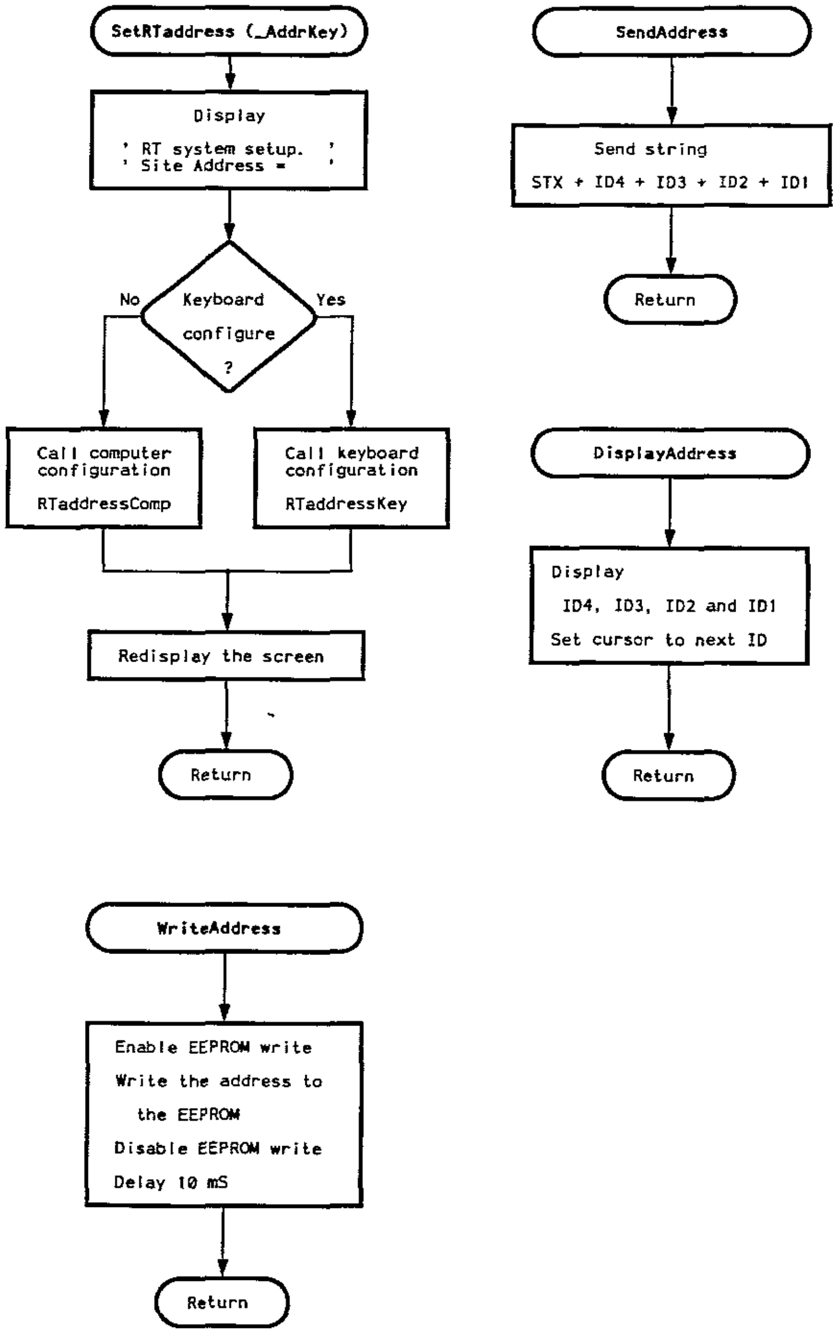
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-20A.FCD

DATE : 20-06-2000

MODULE : RTCONFIG.PAS

Section 2.0 : System address configuration routines



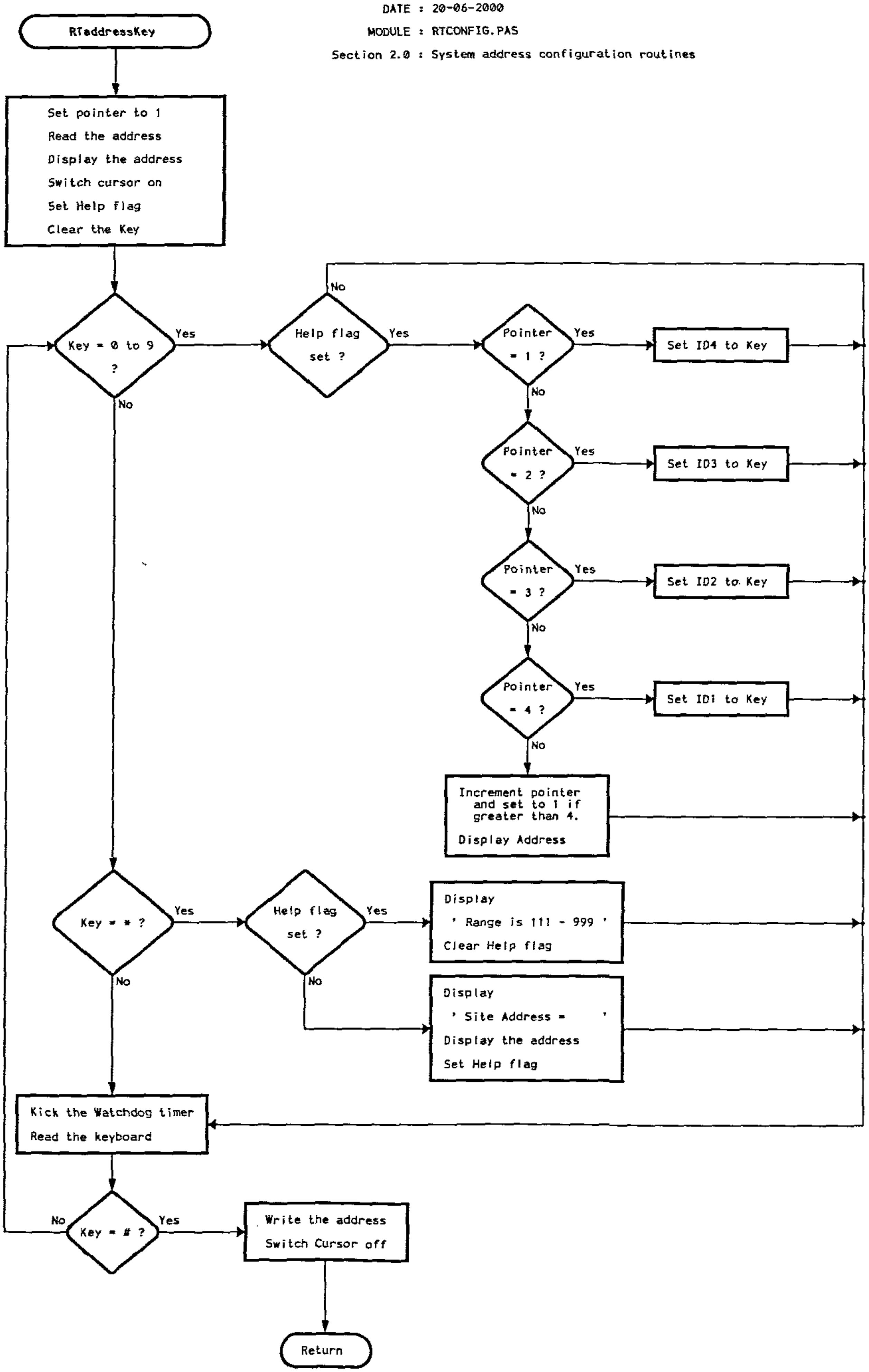
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-20B.FCD

DATE : 20-06-2000

MODULE : RTCONFIG.PAS

Section 2.0 : System address configuration routines



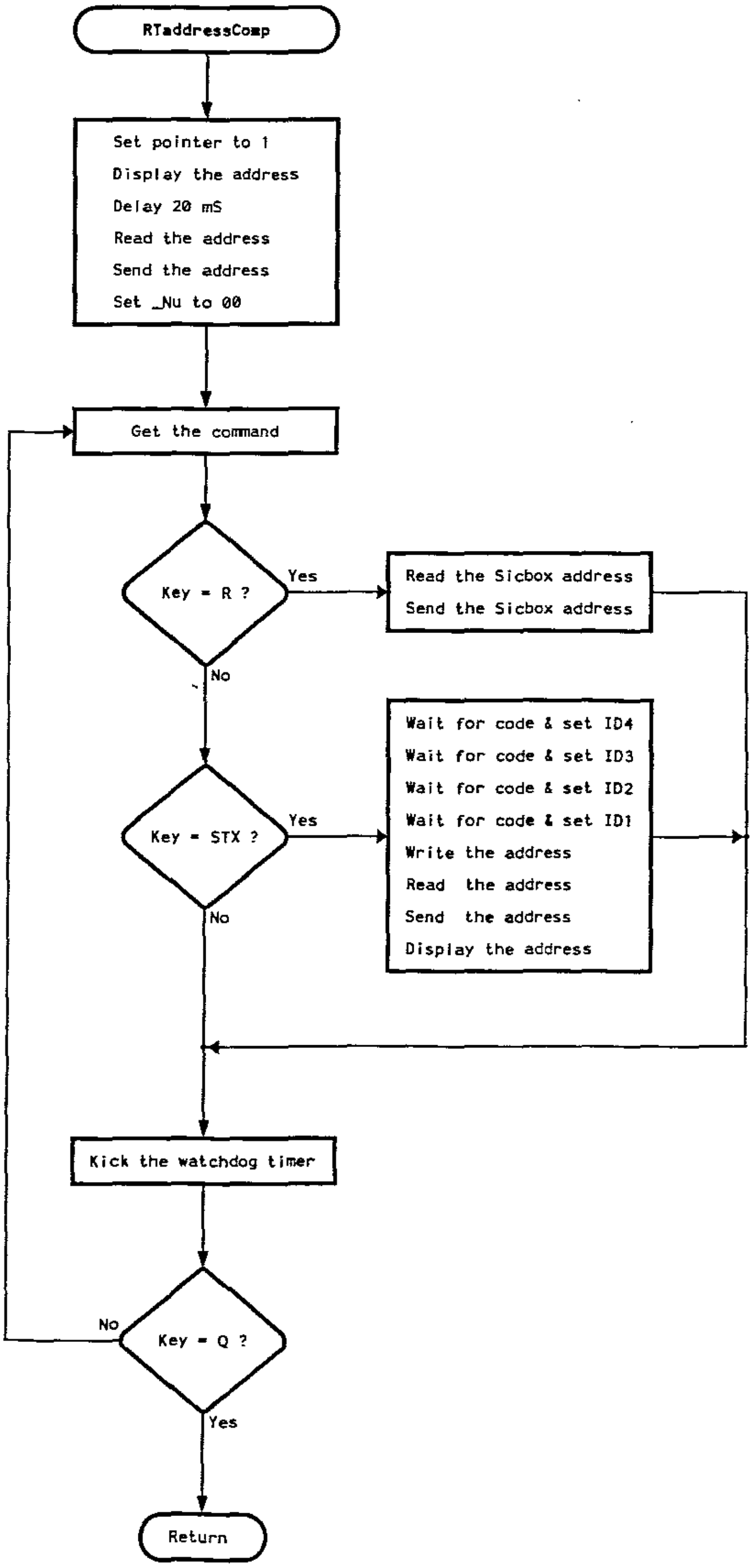
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-20C.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 2.0 : System address configuration routines



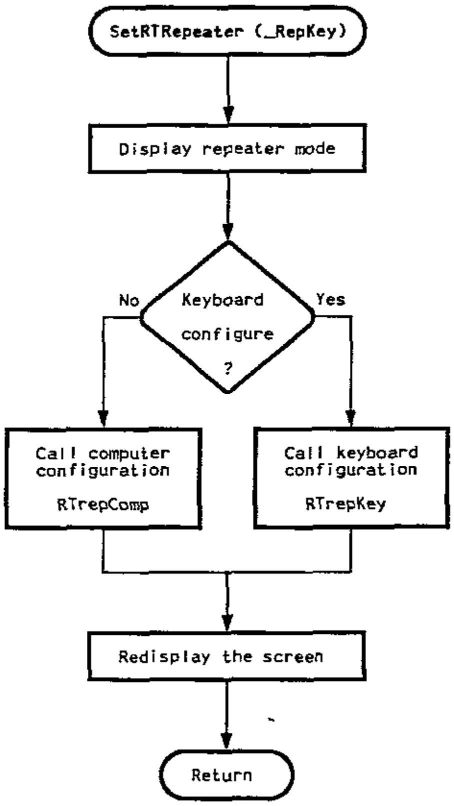
MUPC CARD : SYSTEM CONFIGURATION

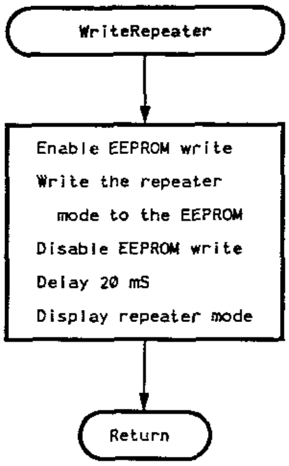
FILE : CONF-30A.FCD

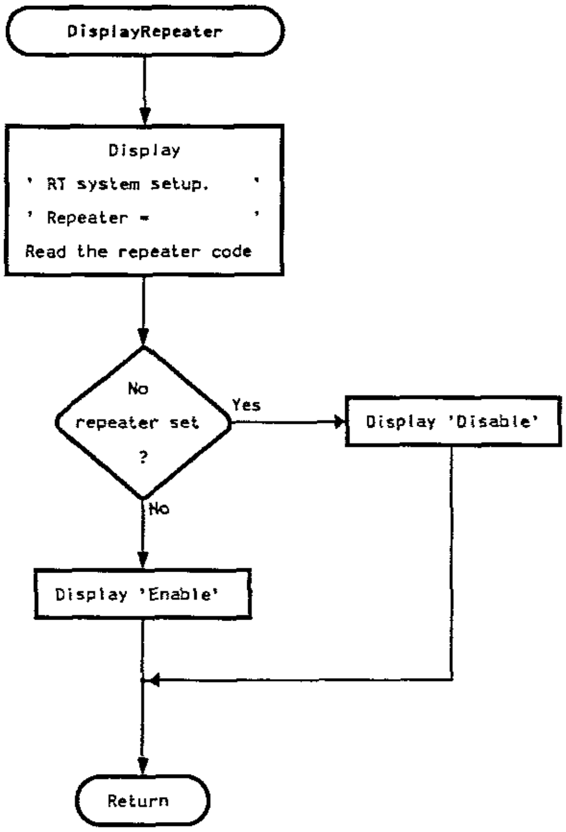
DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 3.0 : System repeater configuration routines







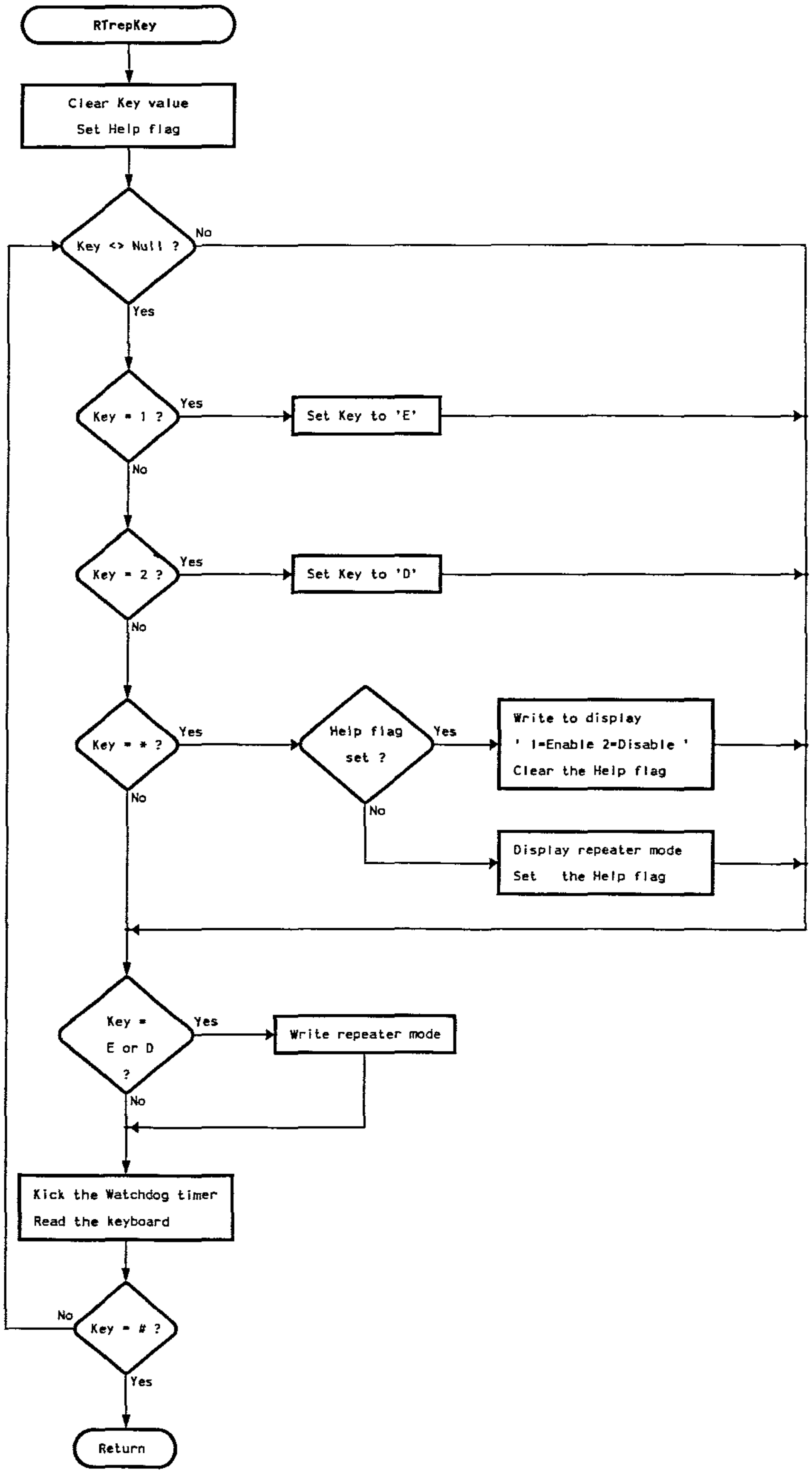
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-308.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 3.0 : System repeater configuration routines



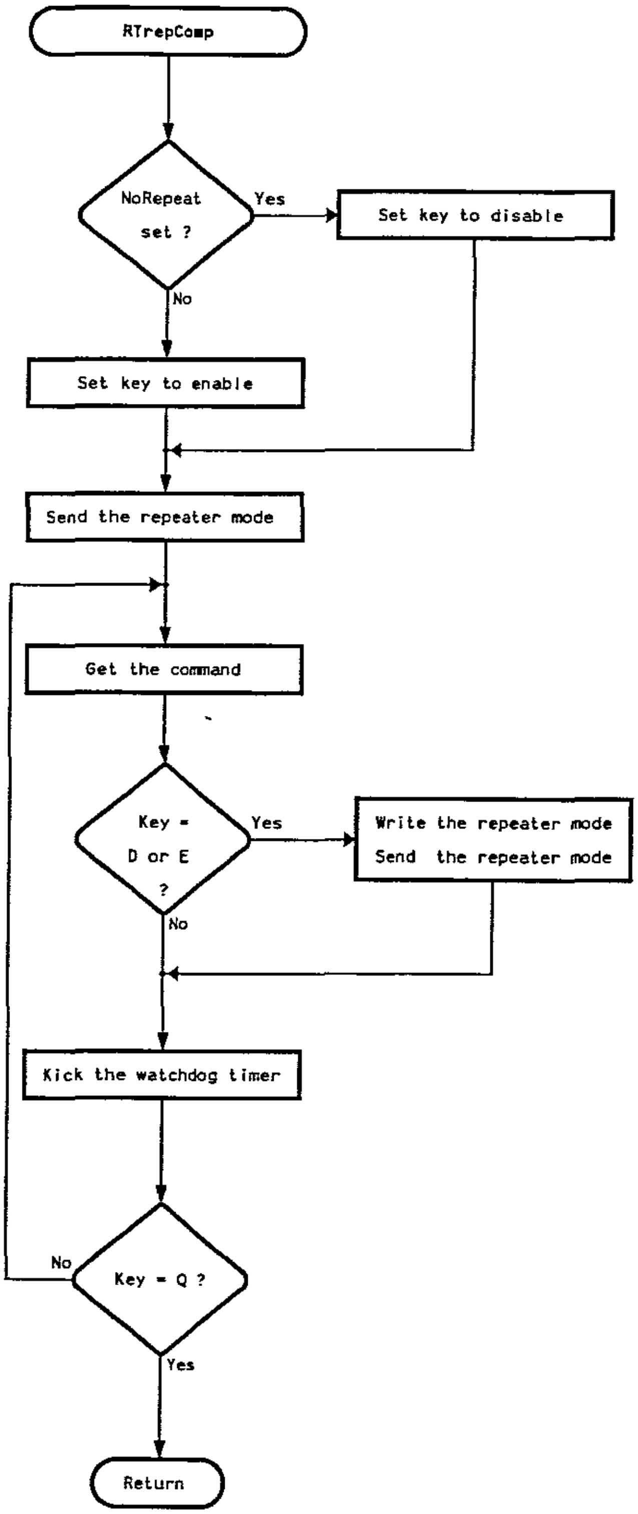
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-30C.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 3.0 : System repeater configuration routines



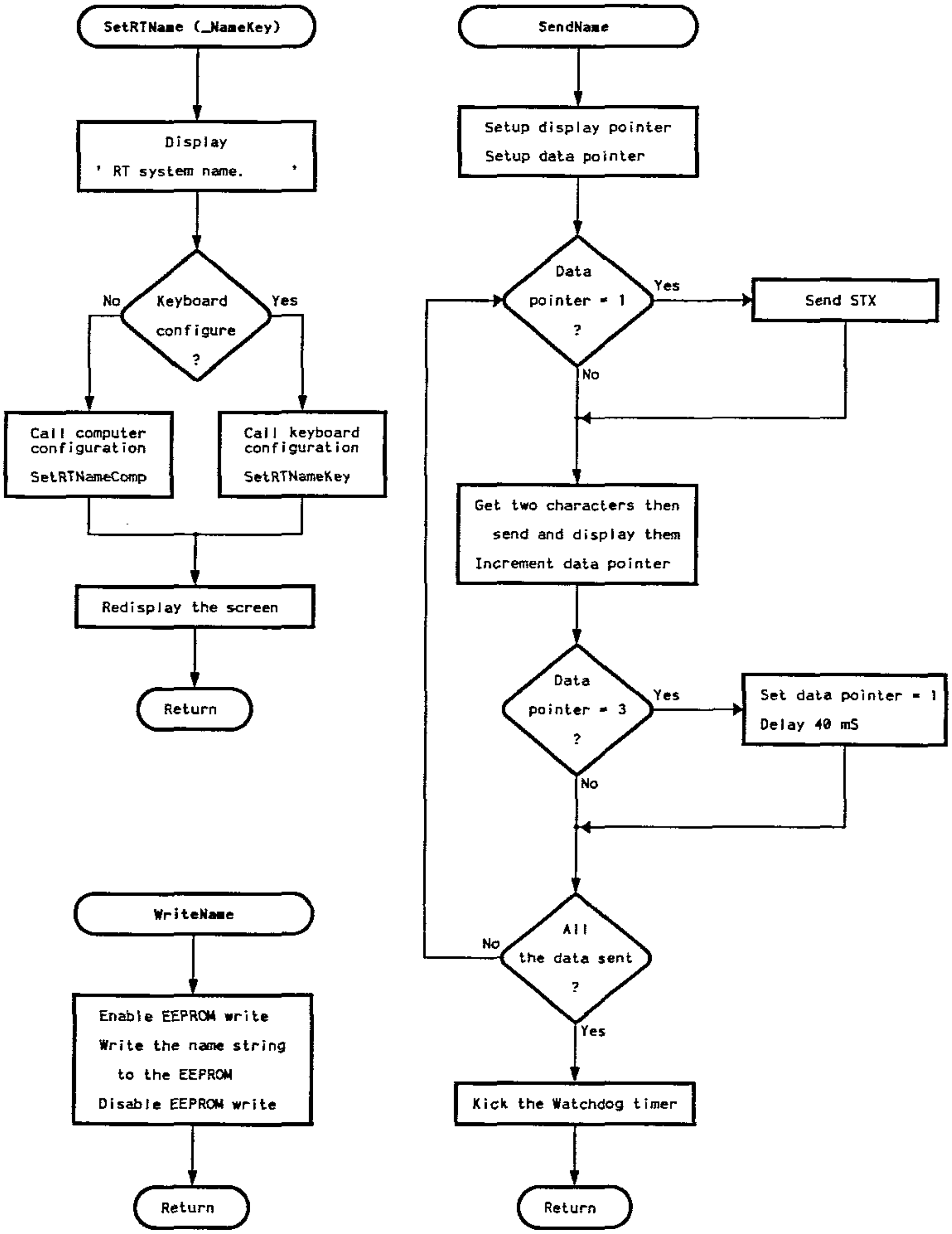
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-40A.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 4.0 : System name configuration routines



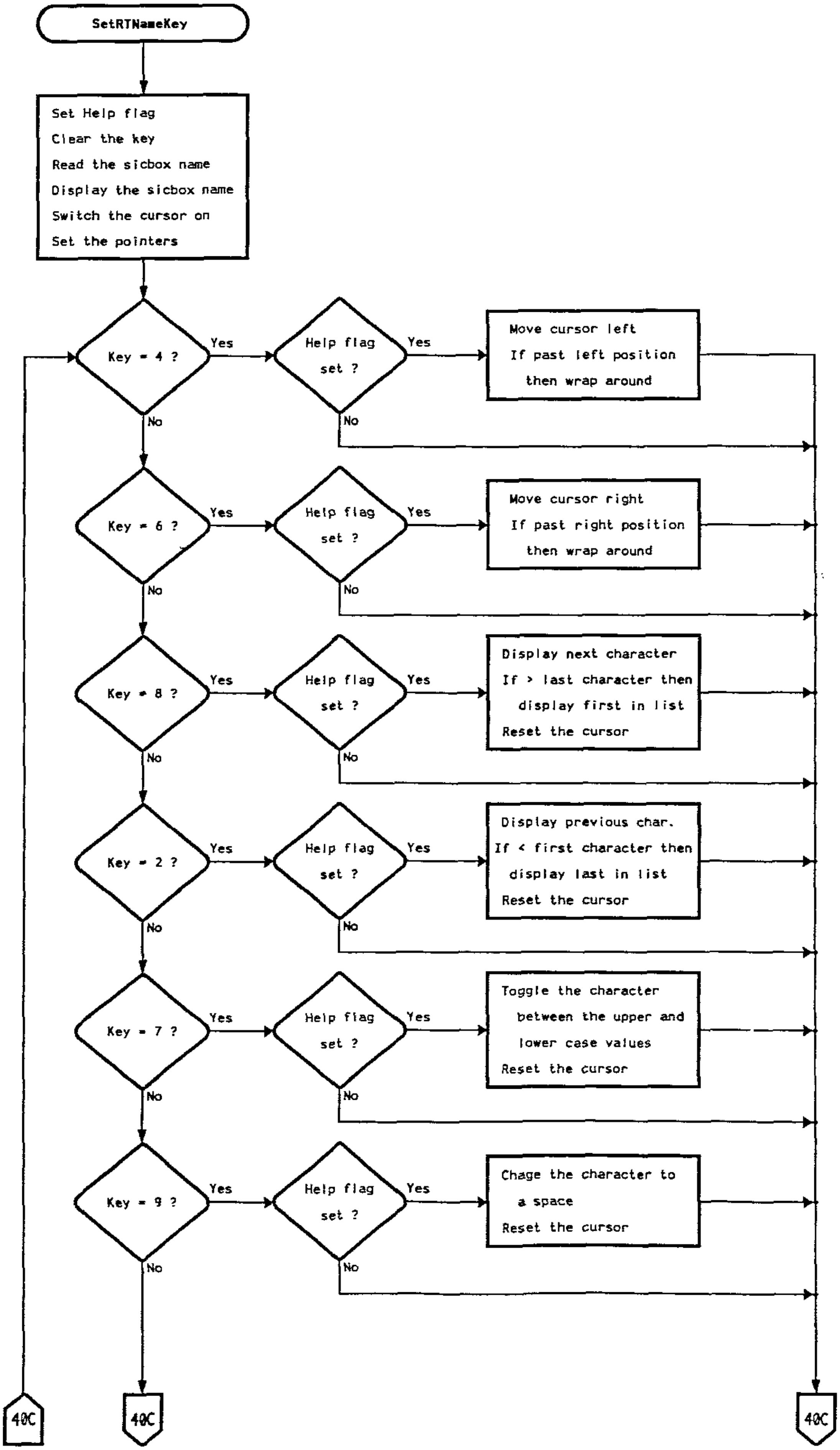
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-40B.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 4.0 : System name configuration routines



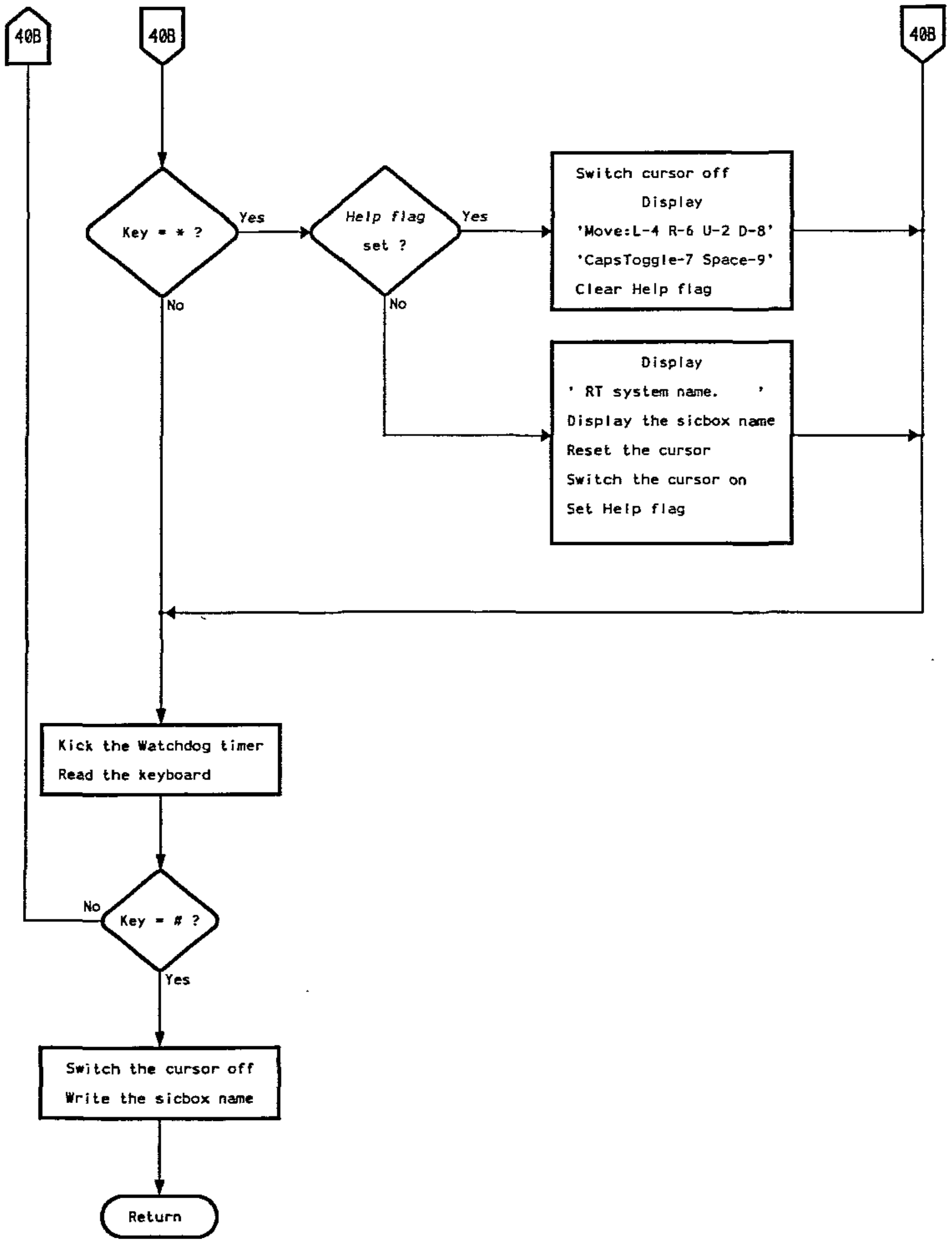
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-40C.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 4.0 : System name configuration routines



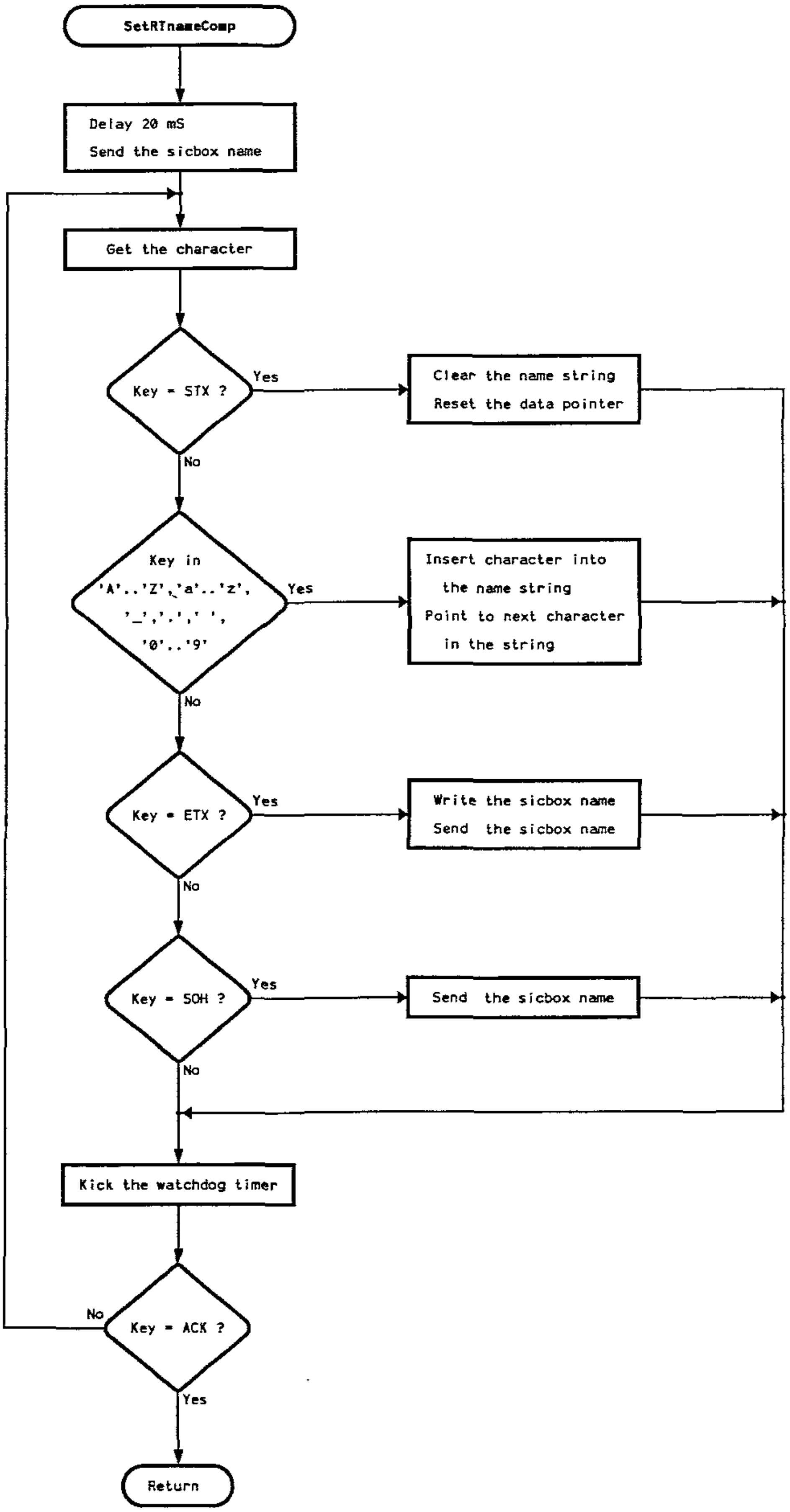
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-40D.FCD

DATE : 21-06-2000

MODULE : RTCONFIG.PAS

Section 4.0 : System name configuration routines



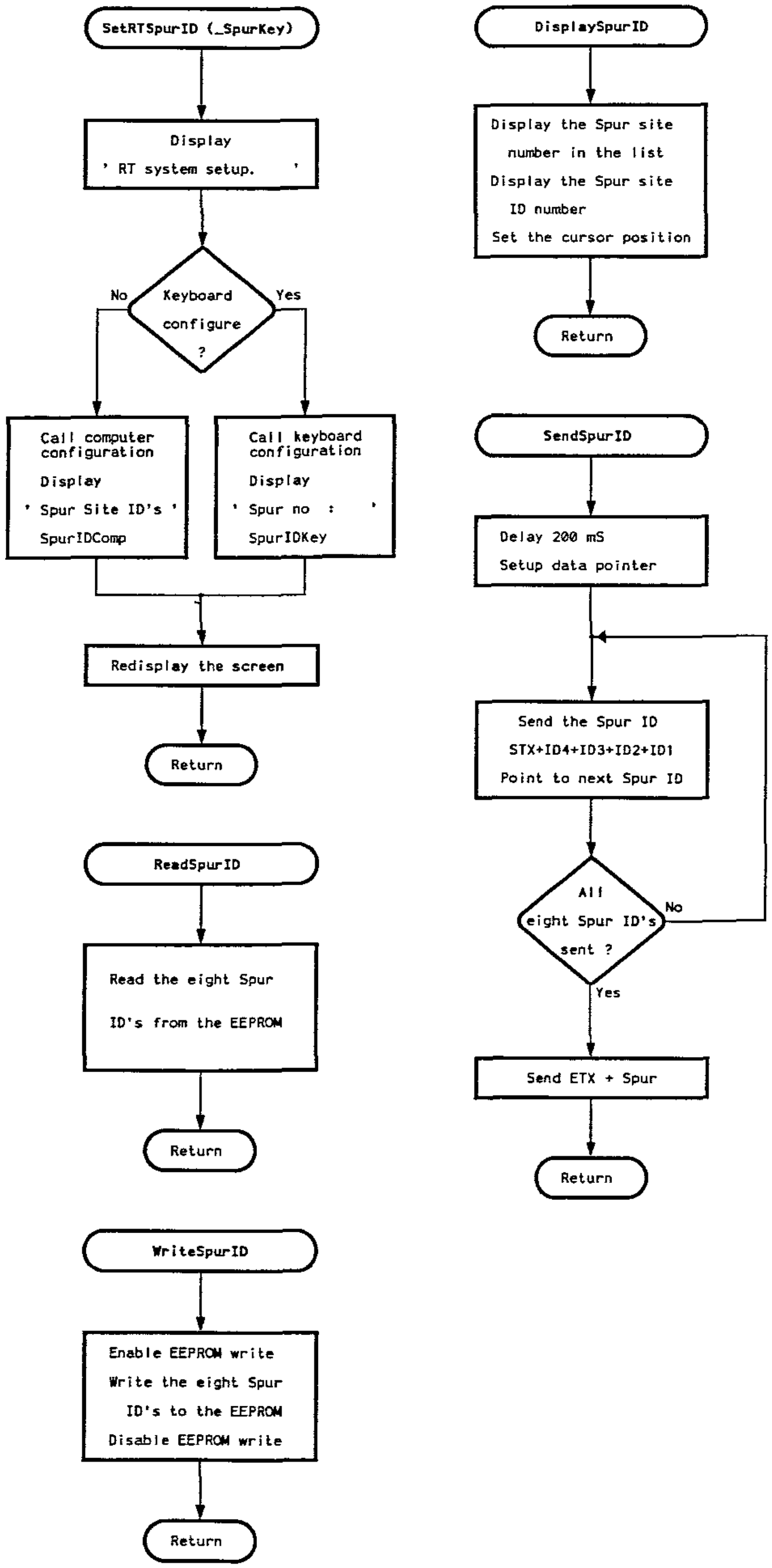
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-50A.FCD

DATE : 22-06-2000

MODULE : RTCONFIG.PAS

Section 5.0 : System Spur sites ID configuration routines



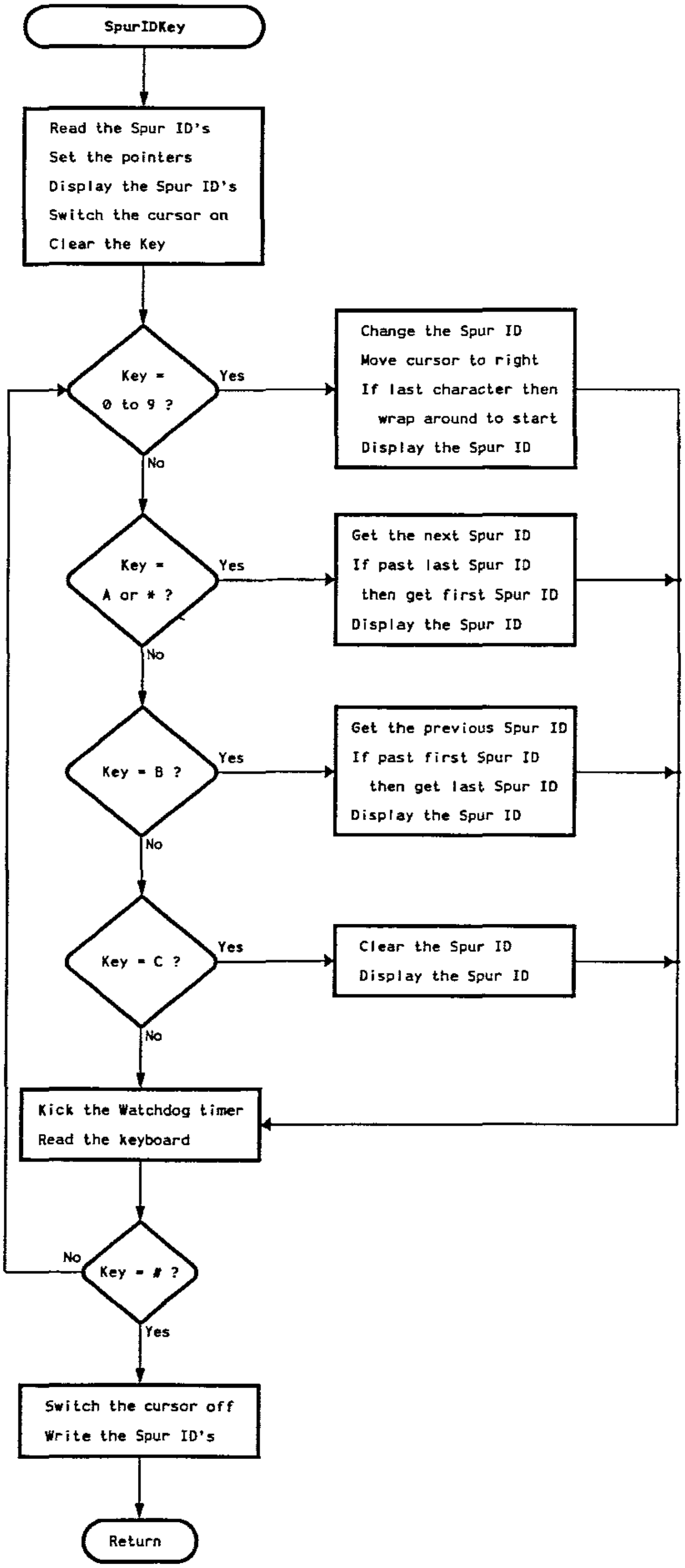
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-50B.FCD

DATE : 22-06-2000

MODULE : RTCONFIG.PAS

Section 5.0 : System Spur sites ID configuration routines



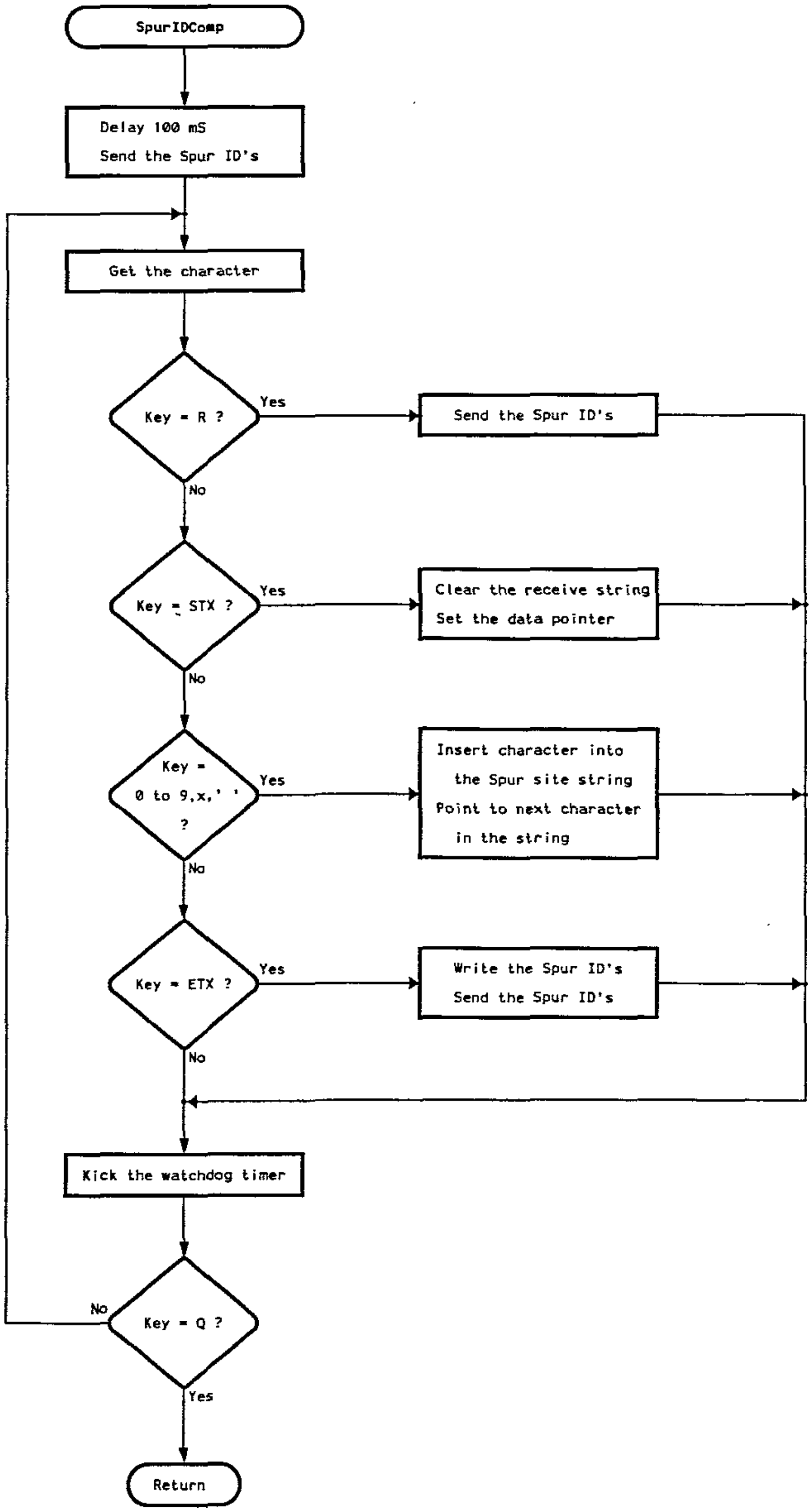
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-50C.FCD

DATE : 22-06-2000

MODULE : RTCONFIG.PAS

Section 5.0 : System Spur sites ID configuration routines



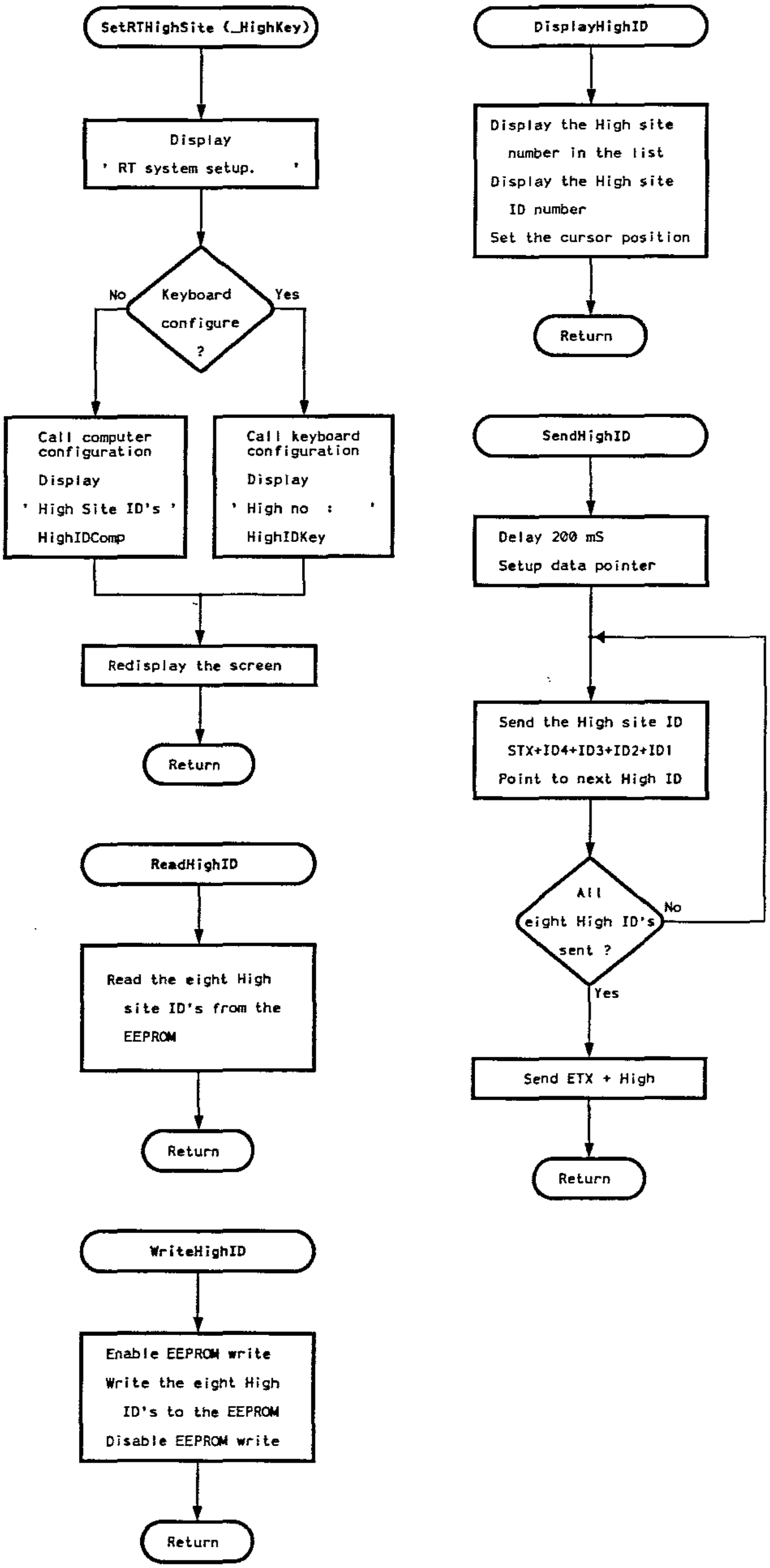
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-60A.FCD

DATE : 22-06-2000

MODULE : RTCONFIG.PAS

Section 6.0 : System High sites ID configuration routines



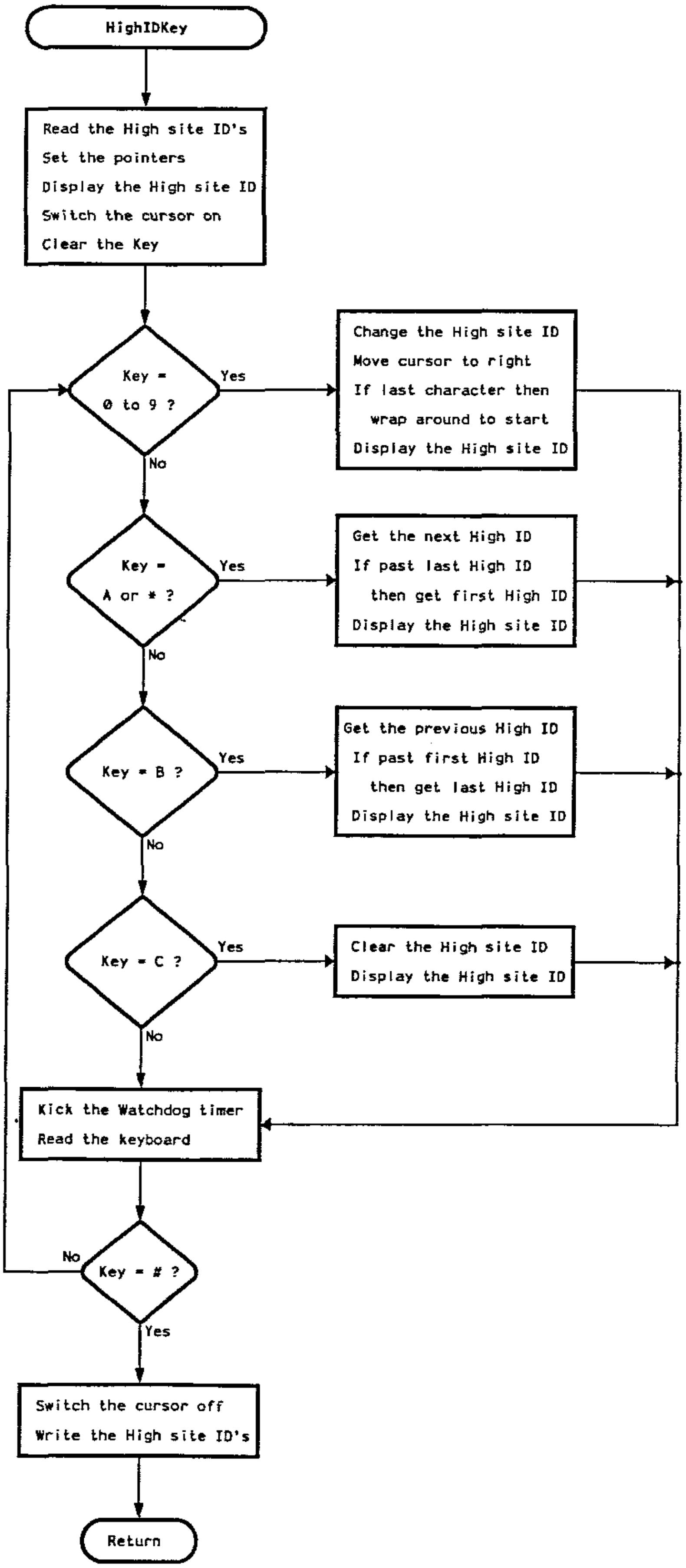
MUPC CARD : SYSTEM CONFIGURATION

FILE : CONF-60B.FCD

DATE : 22-06-2000

MODULE : RTCONFIG.PAS

Section 6.0 : System High sites ID configuration routines

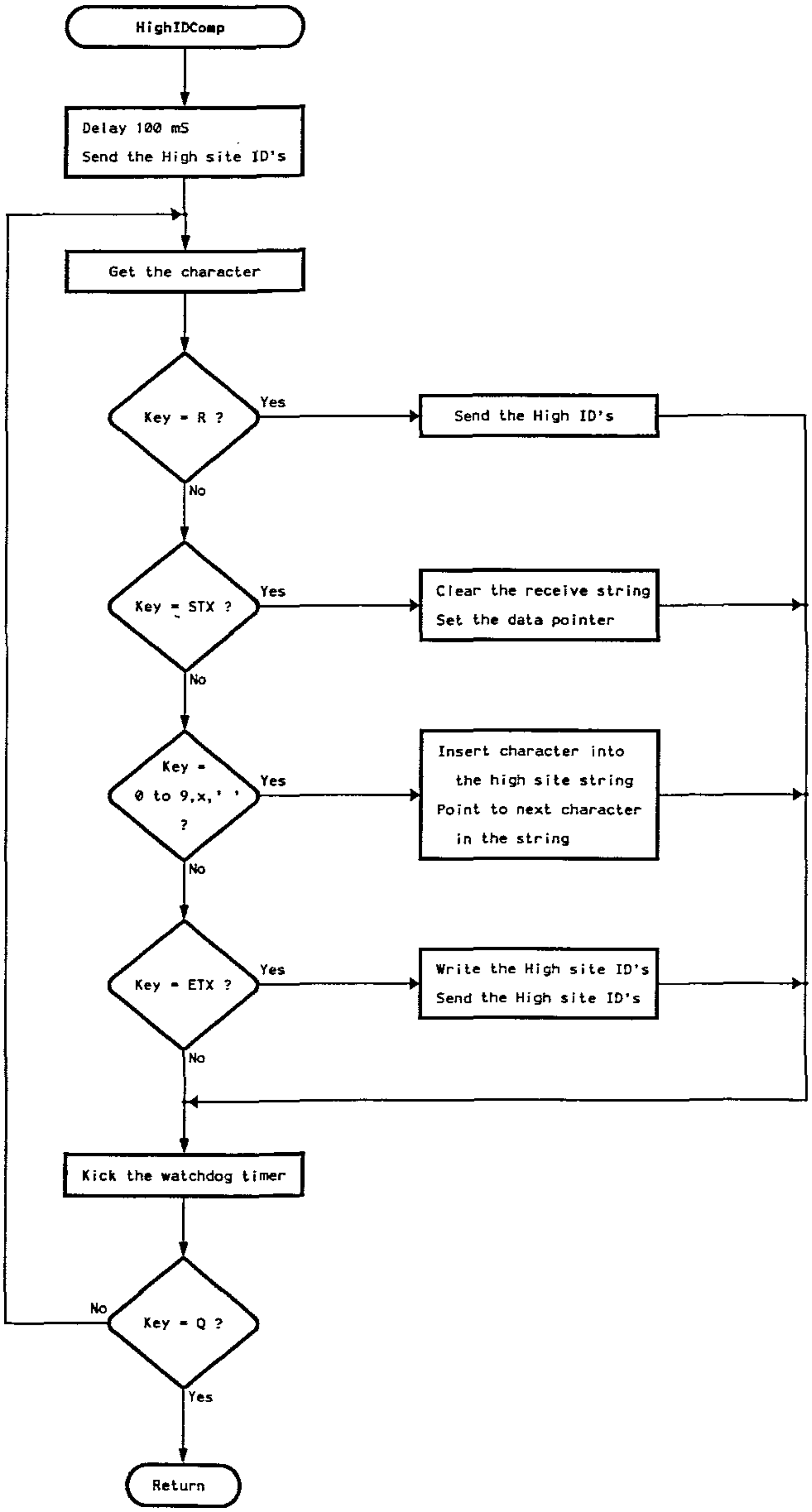


FILE : CONF-60C.FCD

DATE : 22-06-2000

MODULE : RTCONFIG.PAS

Section 6.0 : System High sites ID configuration routines



3.6 SYSTEM ALIGNMENT MODULE.

The alignment module generates the tones that is used to align the radio telephone system.

File Names	Description	Page
RTALIGN.PAS	Pascal source file in appendix C.	---
ALGN-10A.FCD	System alignment test signals.	97

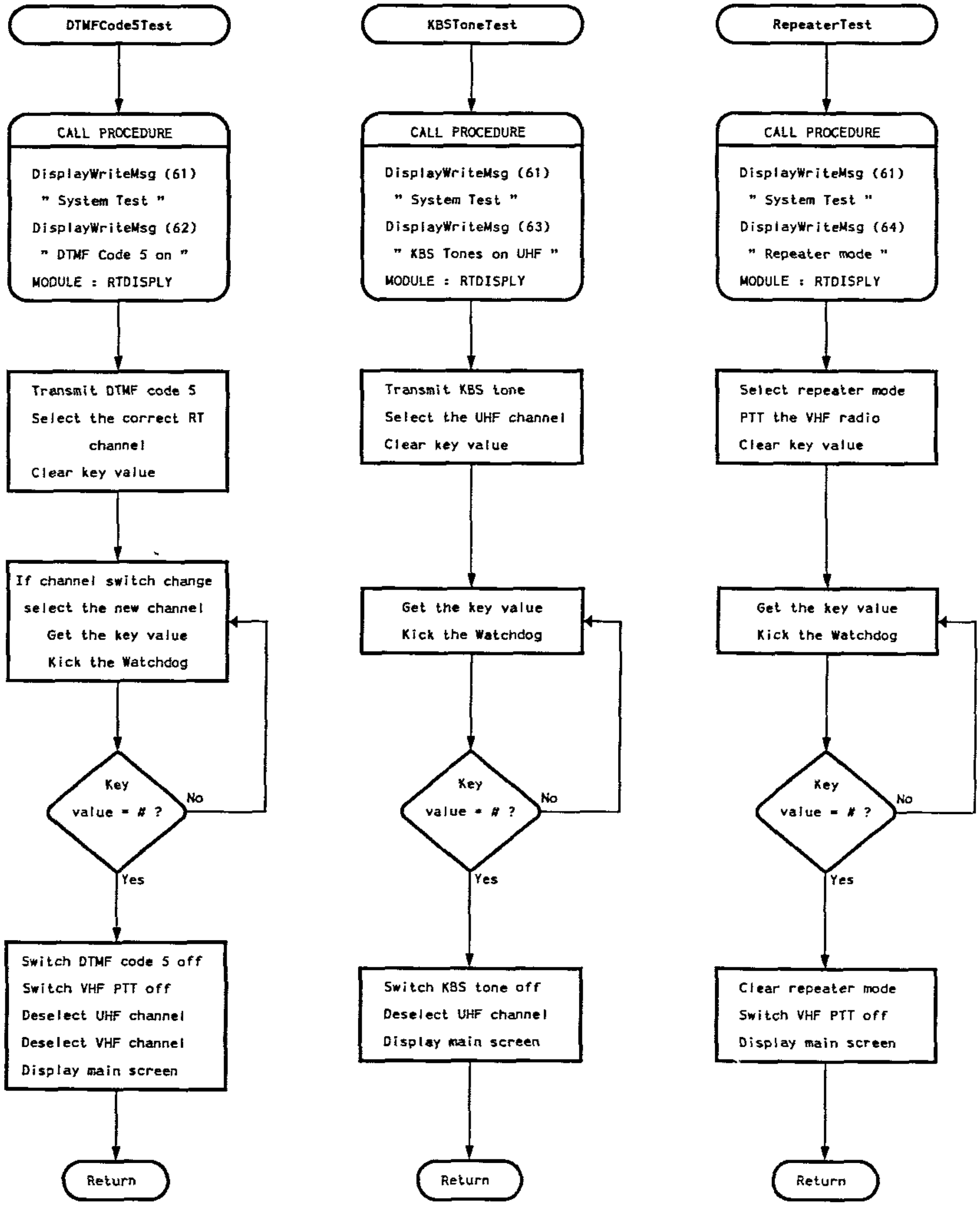
MUPC CARD : SYSTEM ALIGNMENT

FILE : ALGN-10A.FCD

DATE : 14-06-2000

MODULE : RTALIGN.PAS

Section 1.0 : System alignment test signals



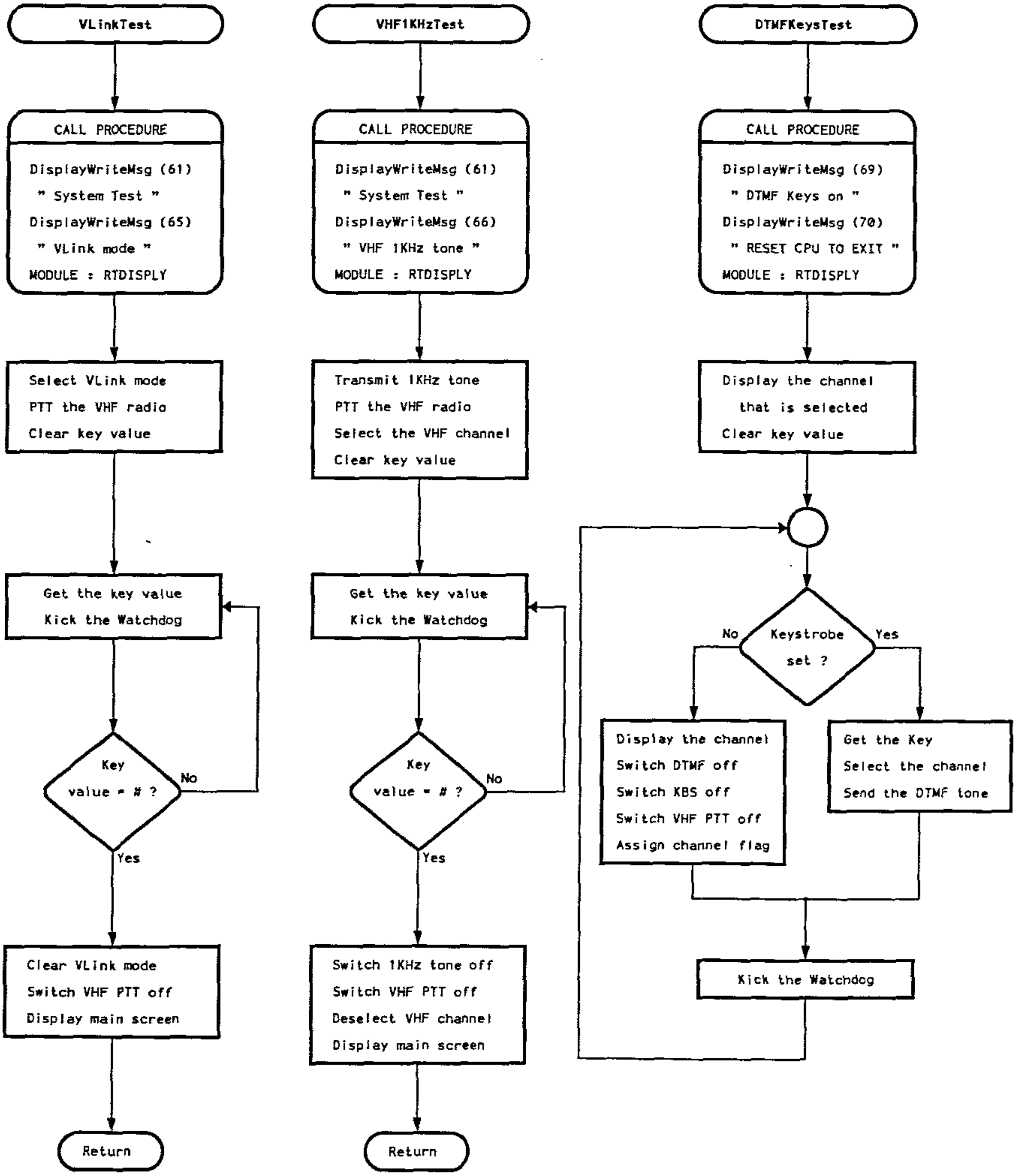
MUPC CARD : SYSTEM ALIGNMENT

FILE : ALGN-10B.FCD

DATE : 14-06-2000

MODULE : RTALIGN.PAS

Section 1.0 : System alignment test signals



3.7 DISPLAY MODULE.

The display module controls and displays all the system messages on the LCD display of the radio telephone system.

File Names	Description	Page
RTDISPLY.PAS	Pascal source file in appendix C.	---
DISP-10A.FCD	Display control routines.	100
DISP-20A.FCD	Display messages for top line.	102
DISP-30A.FCD	Display messages for bottom line.	104

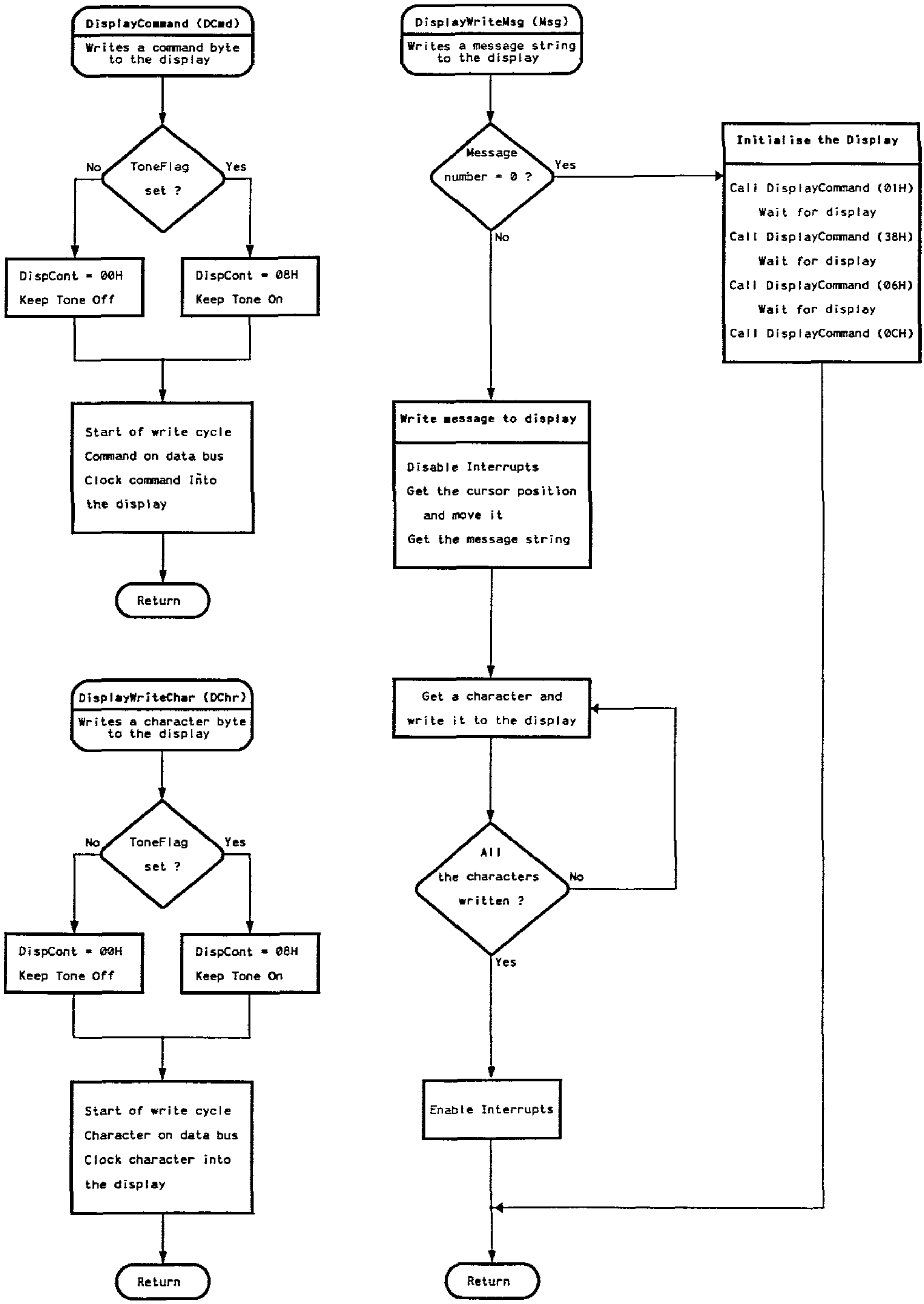
MUPC CARD : DISPLAY CONTROL

FILE : DISP-10A.FCD

DATE : 19-05-2000

MODULE : RTDISPLY.PAS

Section 1.0 : Display control routines



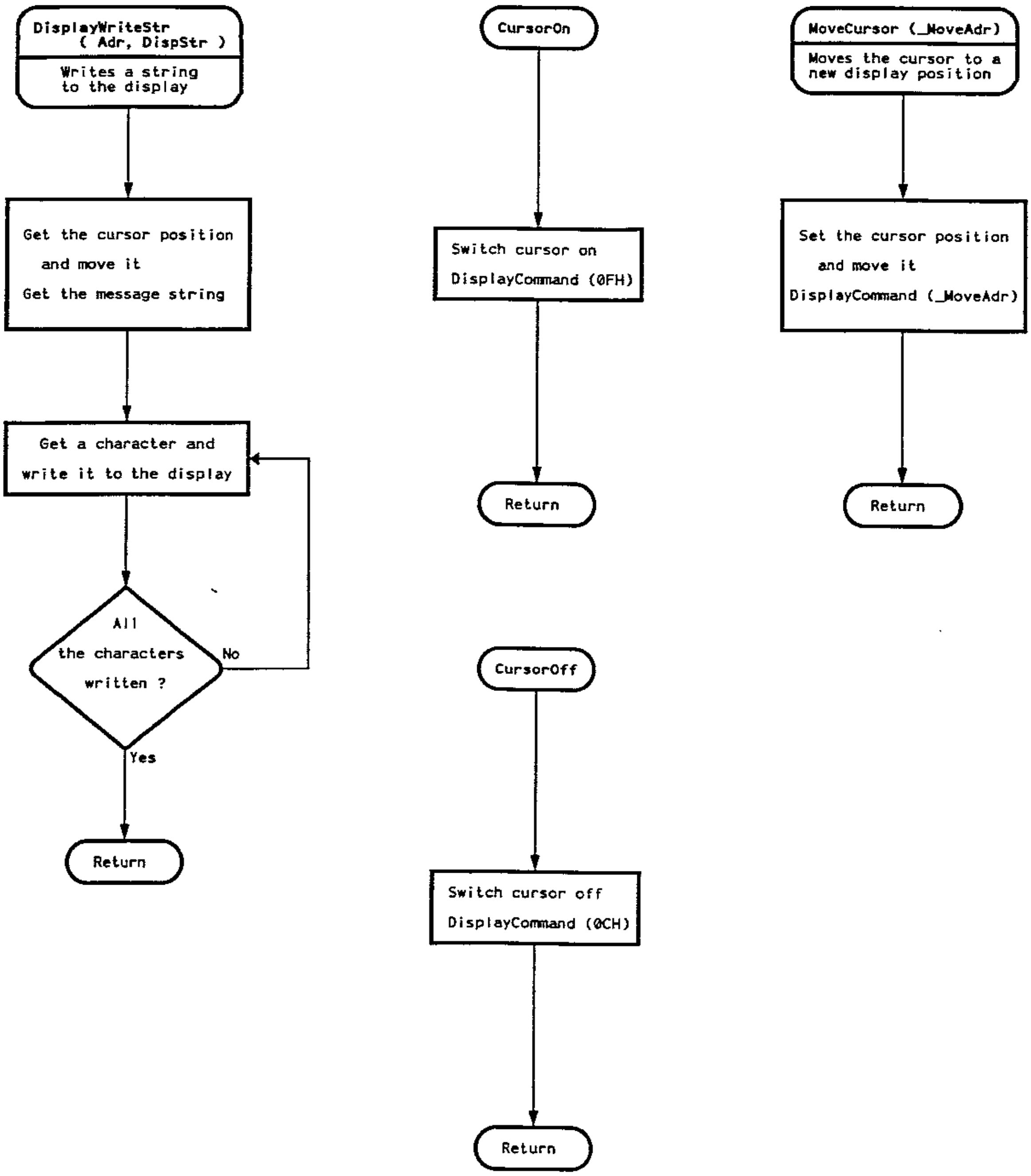
MUPC CARD : DISPLAY CONTROL

FILE : DISP-10B.FCD

DATE : 24-05-2000

MODULE : RTDISPLY.PAS

Section 1.0 : Display control routines



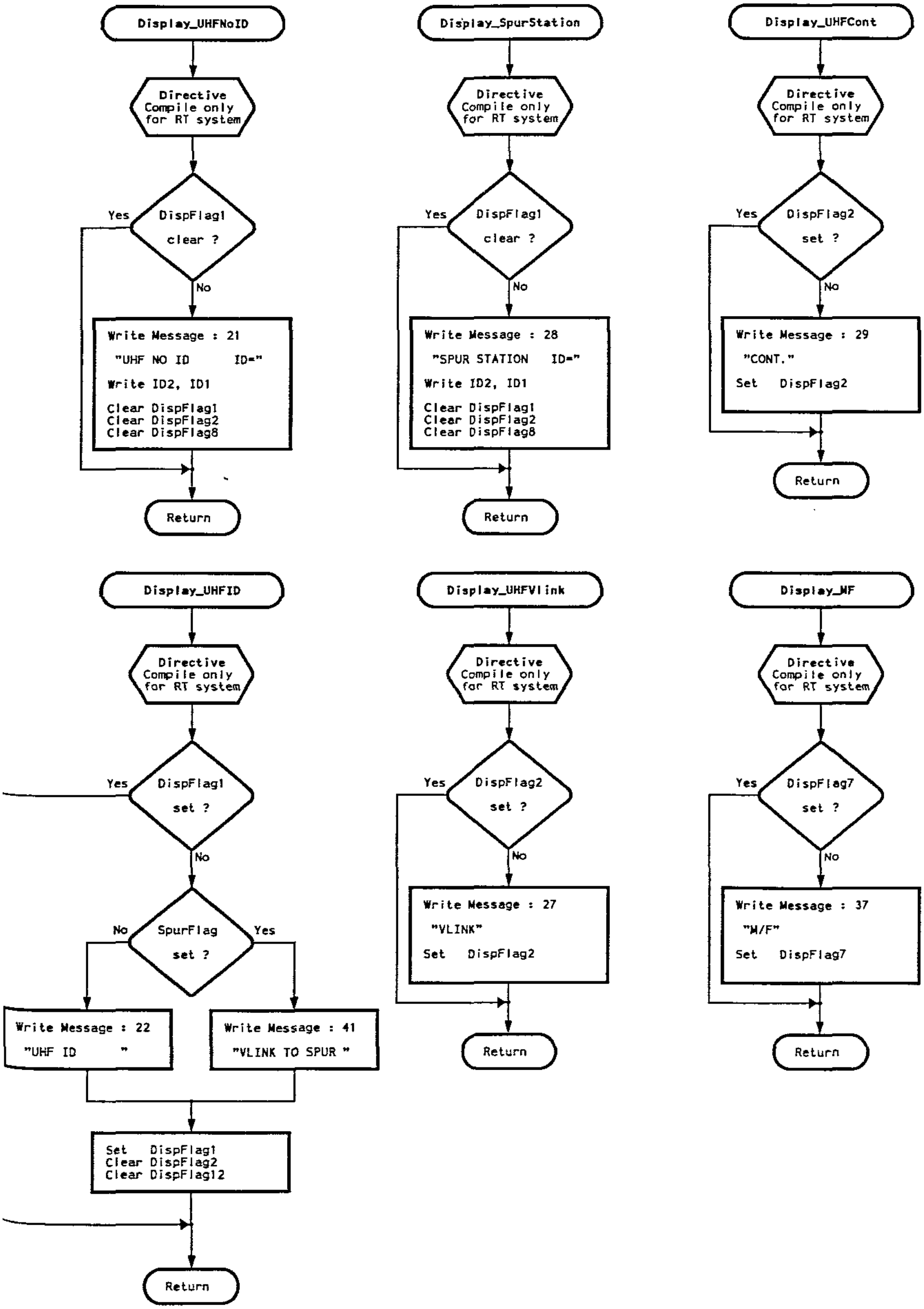
MUPC CARD : DISPLAY CONTROL

FILE : DISP-20A.FCD

DATE : 24-05-2000

MODULE : RTDISPLY.PAS

Section 2.0 : Display messages for top line



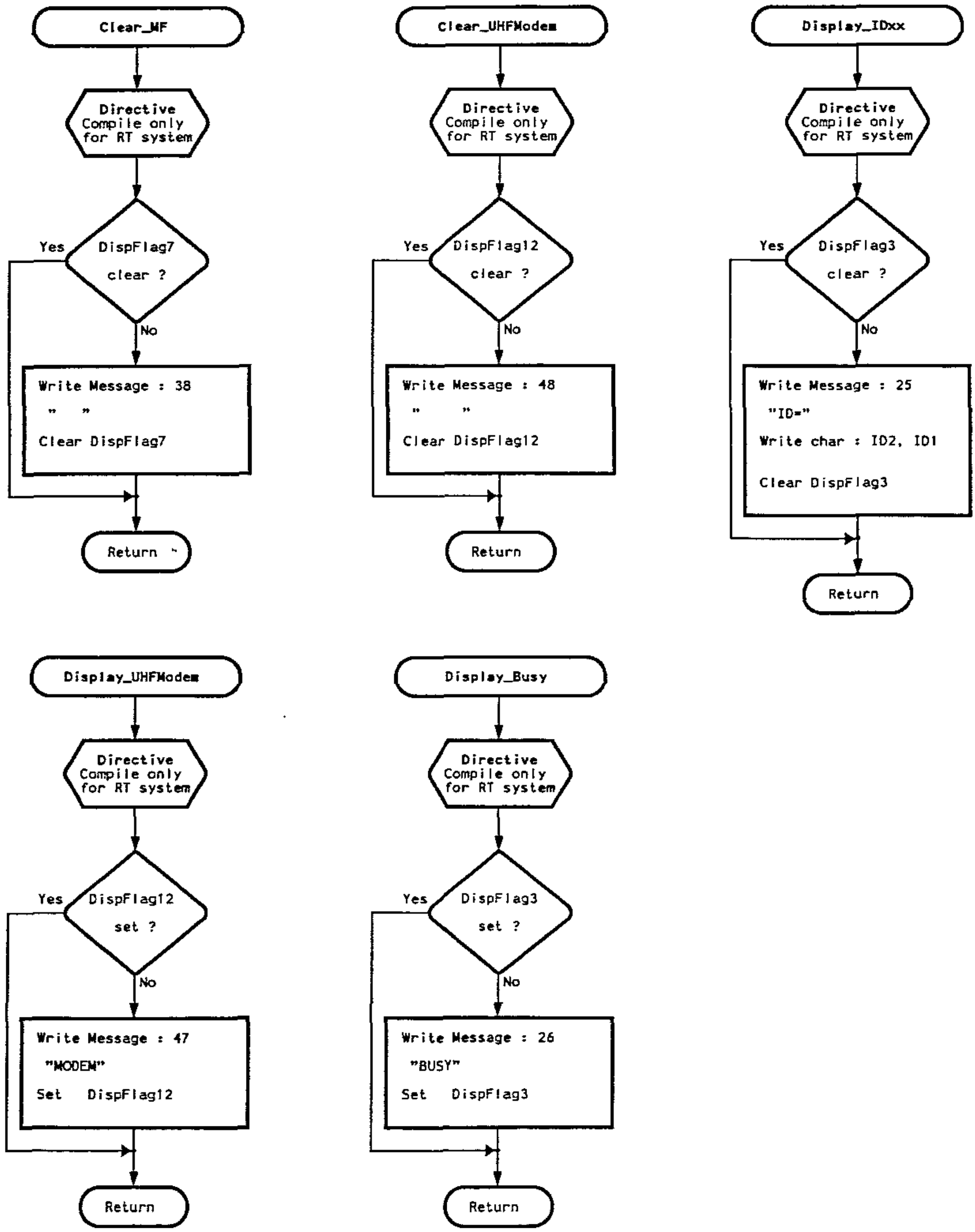
MUPC CARD : DISPLAY CONTROL

FILE : DISP-20B.FCD

DATE : 26-05-2000

MODULE : RTDISPLY.PAS

Section 2.0 : Display messages for top line



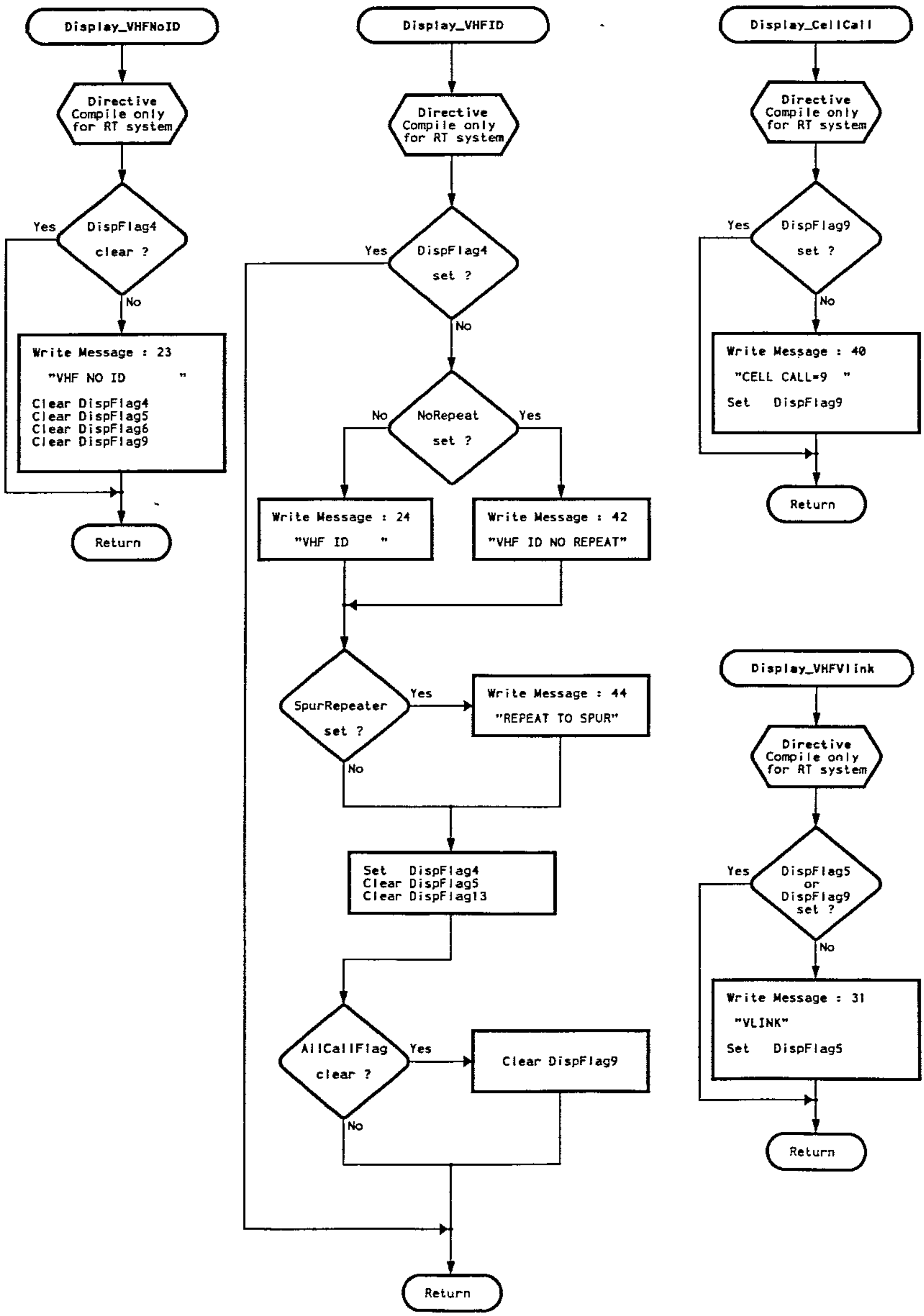
MUPC CARD : DISPLAY CONTROL

FILE : DISP-30A.FCD

DATE : 26-05-2000

MODULE : RTDISPLY.PAS

Section 3.0 : Display messages for bottom line



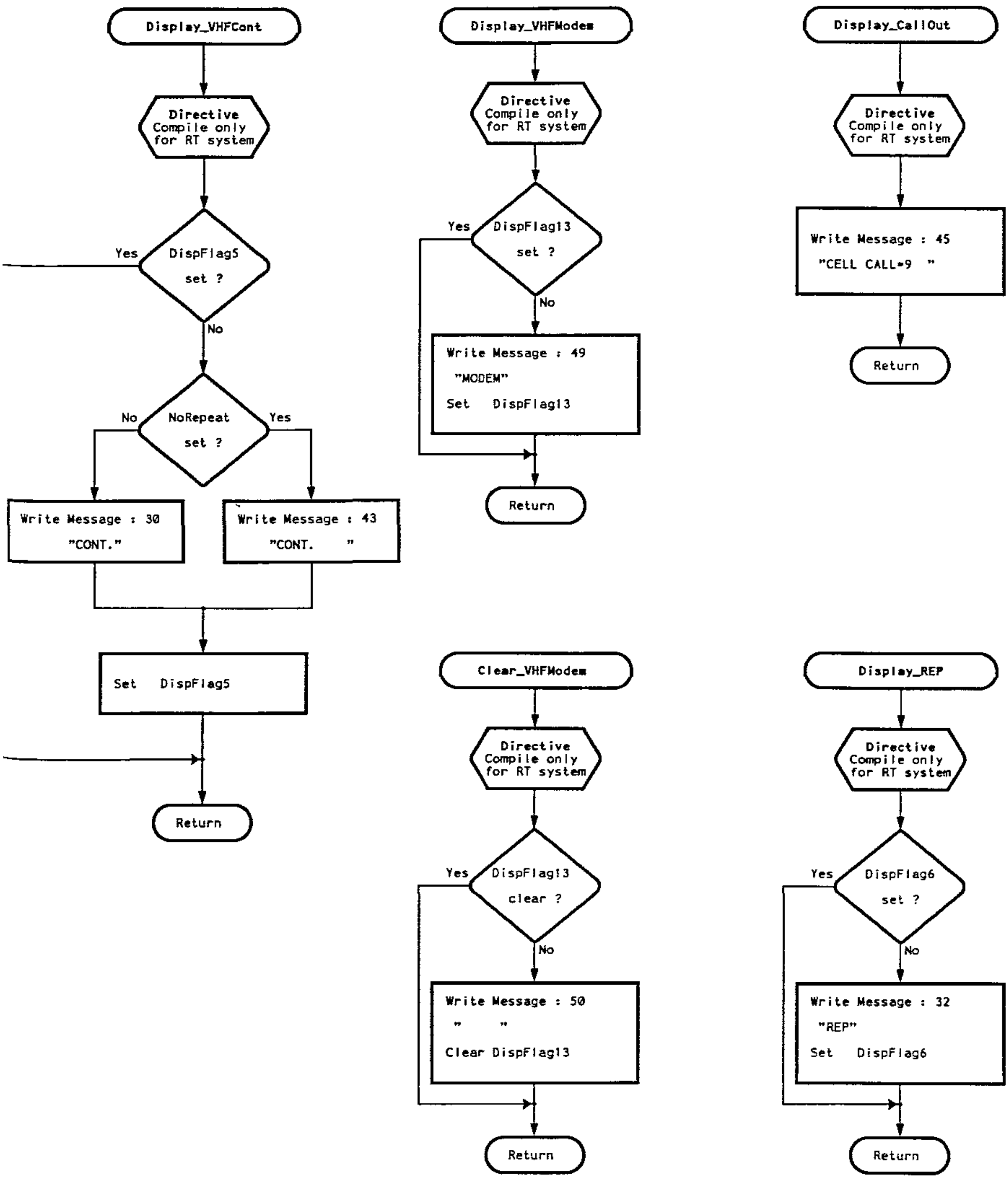
MUPC CARD : DISPLAY CONTROL

FILE : DISP-30B.FCD

DATE : 26-05-2000

MODULE : RTDISPLY.PAS

Section 3.0 : Display messages for bottom line



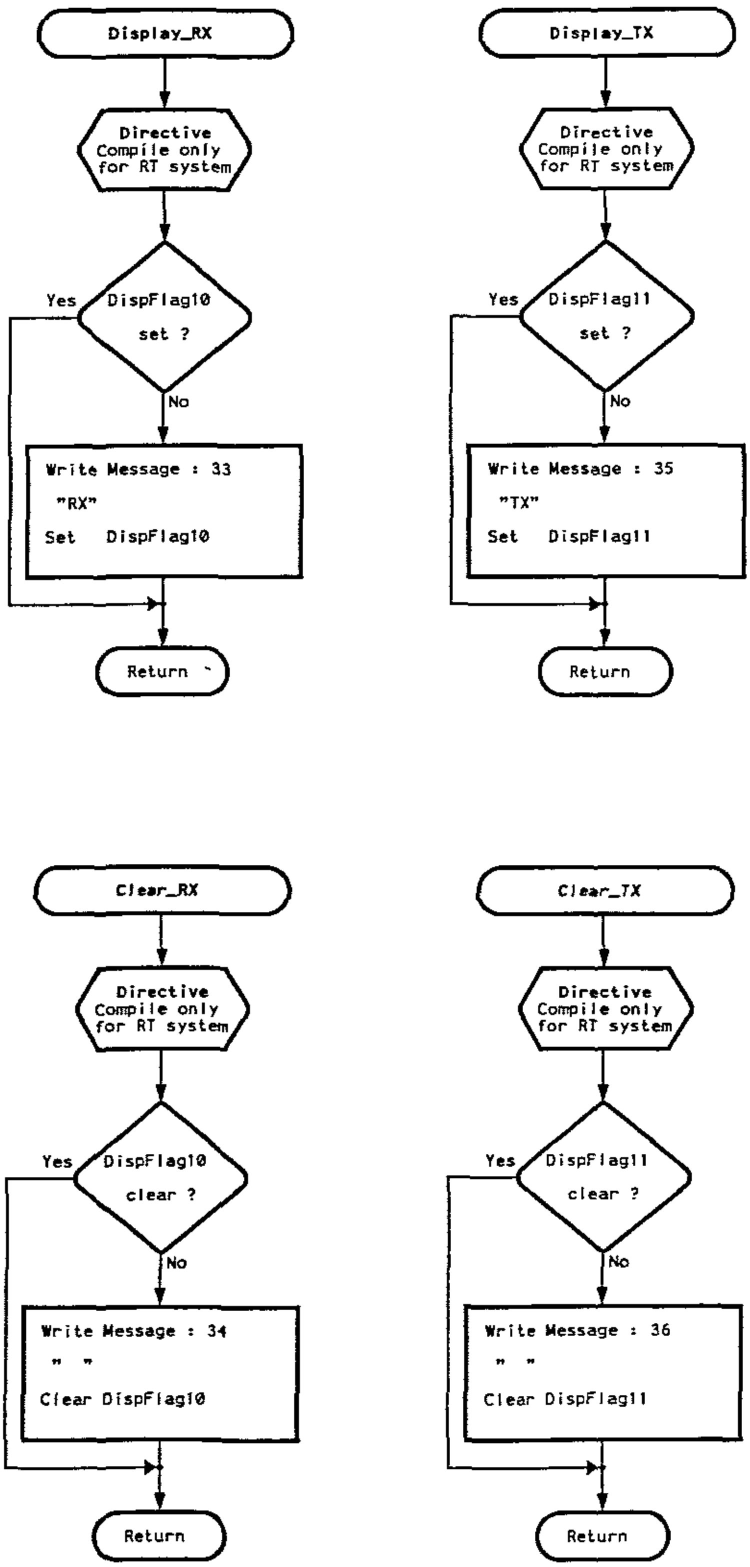
MUPC CARD : DISPLAY CONTROL

FILE : DISP-30C.FCD

DATE : 26-05-2000

MODULE : RTDISPLY.PAS

Section 3.0 : Display messages for bottom line



3.8 FLASH PROM PROGRAMMING MODULE.

The flash prom module tests and programs the flash prom where the system operational software is stored for the radio telephone system.

File Names	Description	Page
RTFLASH.PAS	Pascal source file in appendix C.	---
FLSH-10A.FCD	Flash prom erasure and test routines.	108
FLSH-20A.FCD	Flash prom programming routines.	109

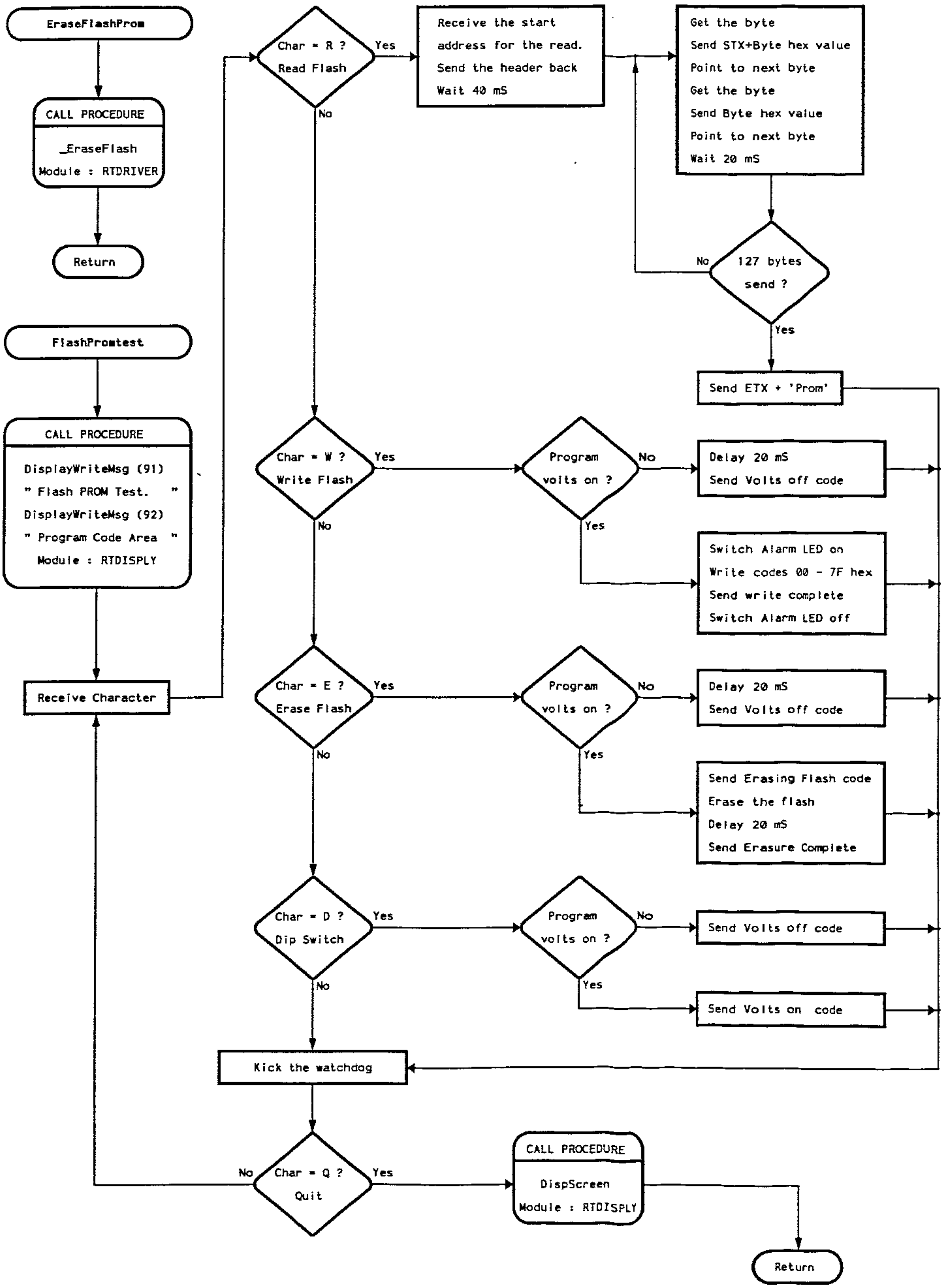
MUPC CARD : FLASH PROM CONTROL

FILE : FLSH-10A.FCD

DATE : 13-06-2000

MODULE : RTFLASH.PAS

Section 1.0 : Flash prom erasure and test routines



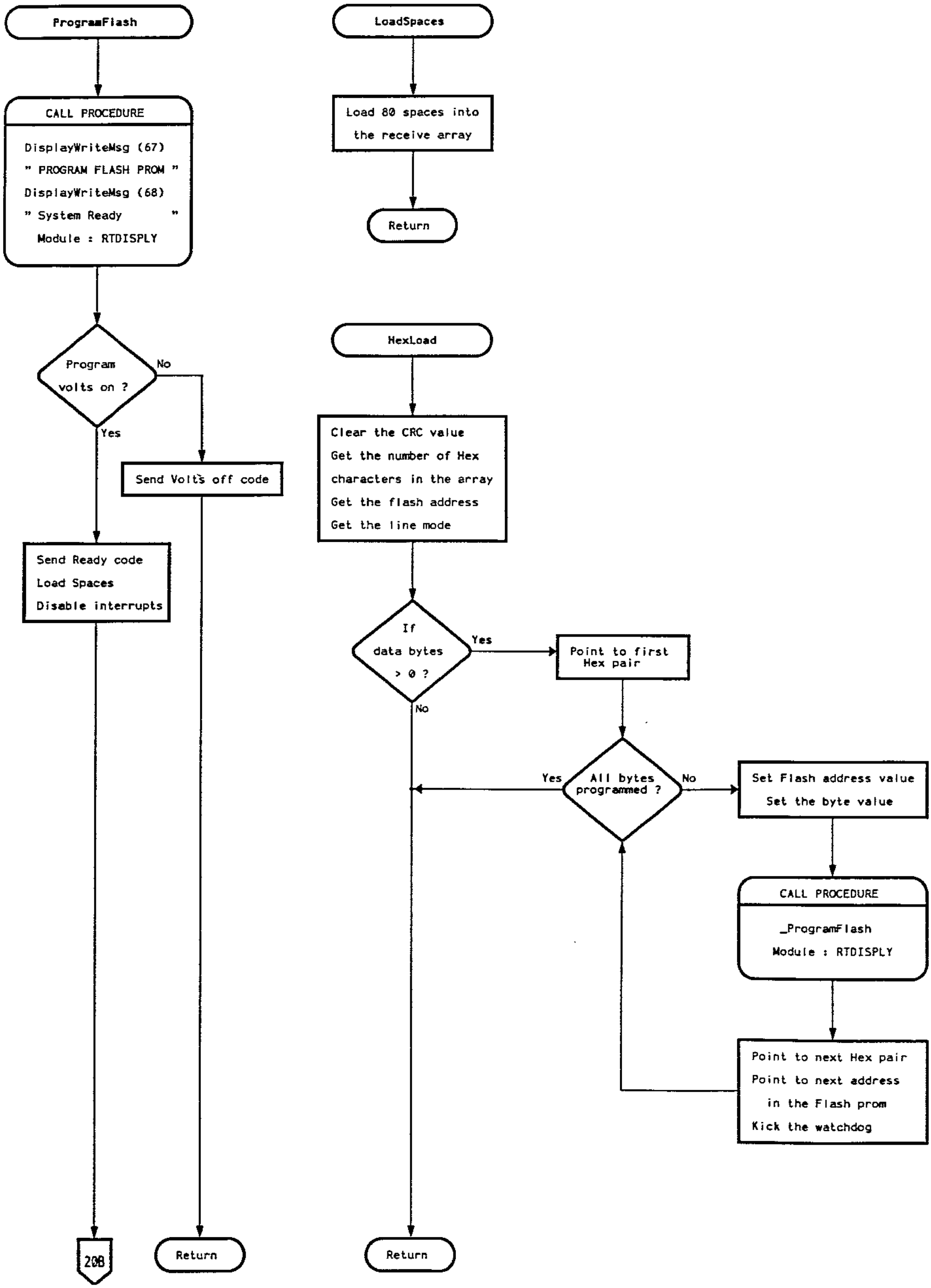
MUPC CARD : FLASH PROM CONTROL

FILE : FLSH-20A.FCD

DATE : 13-06-2000

MODULE : RTFLASH.PAS

Section 2.0 : Flash prom programming routines



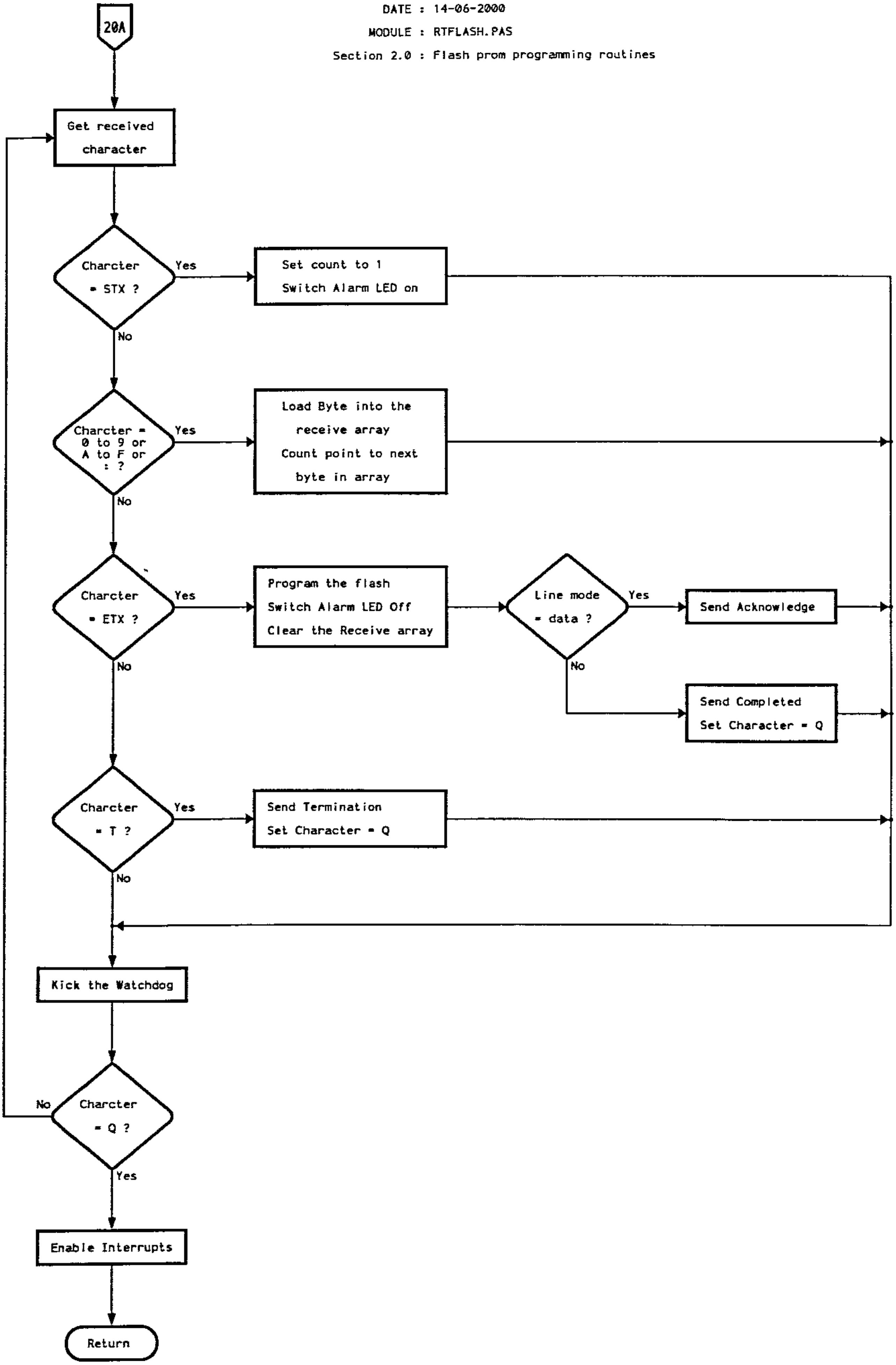
MUPC CARD : FLASH PROM CONTROL

FILE : FLSH-20B.FCD

DATE : 14-06-2000

MODULE : RTFLASH.PAS

Section 2.0 : Flash prom programming routines



3.9 EEPROM PROGRAMMING MODULE.

The EEPROM module controls and programs the system parameters into the EEPROM of the radio telephone system.

File Names	Description	Page
RTEEPROM.PAS	Pascal source file in appendix C.	---
PROM-10A.FCD	EEPROM driver routines.	112

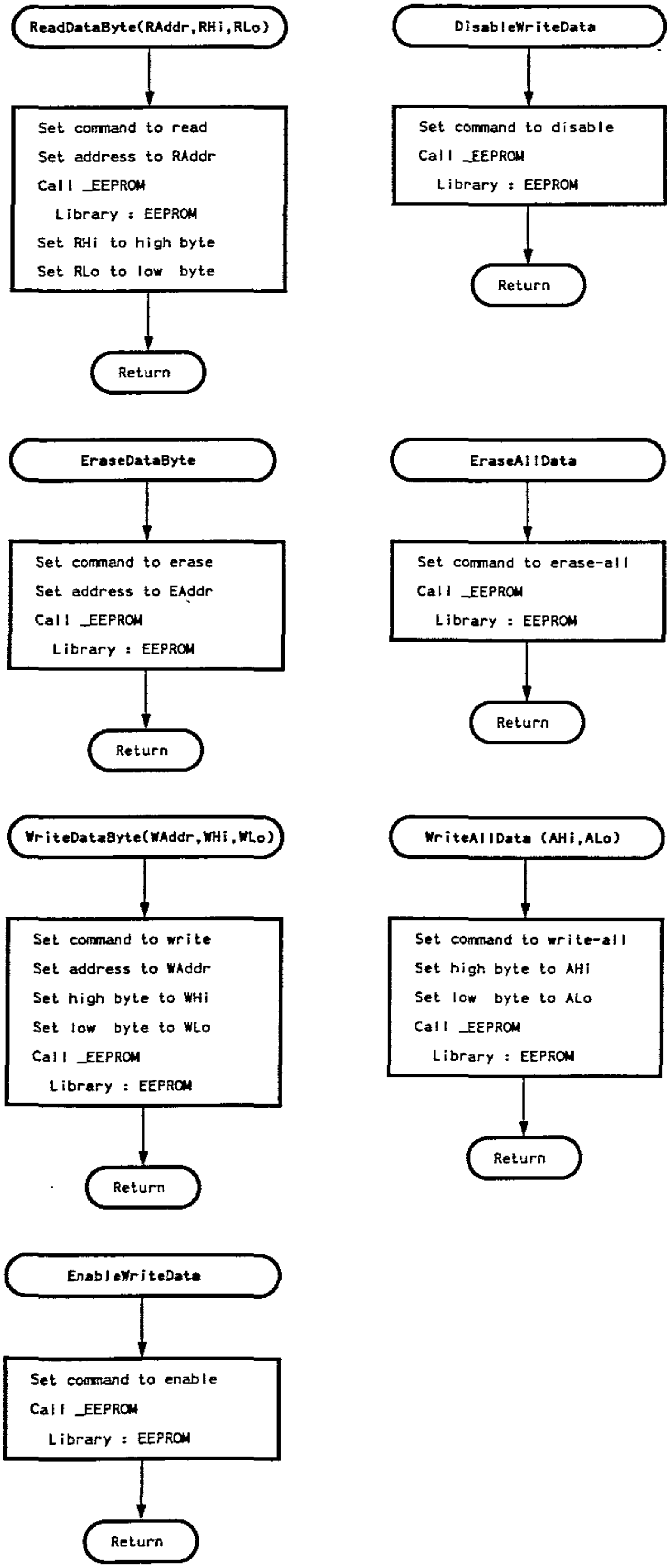
MUPC CARD : EEPROM ROUTINES

FILE : PROM-10A.FCD

DATE : 01-06-2000

MODULE : RTEEPROM.PAS

Section 1.0 : EEPROM driver routines



3.10 SERIAL PORTS CONTROLLING MODULE.

The serial ports module controls the Modem and com2 ports of the radio telephone system.

File Names	Description	Page
RTSERIAL.PAS	Pascal source file in appendix C.	---
COMS-10A.FCD	Serial communications routines.	114

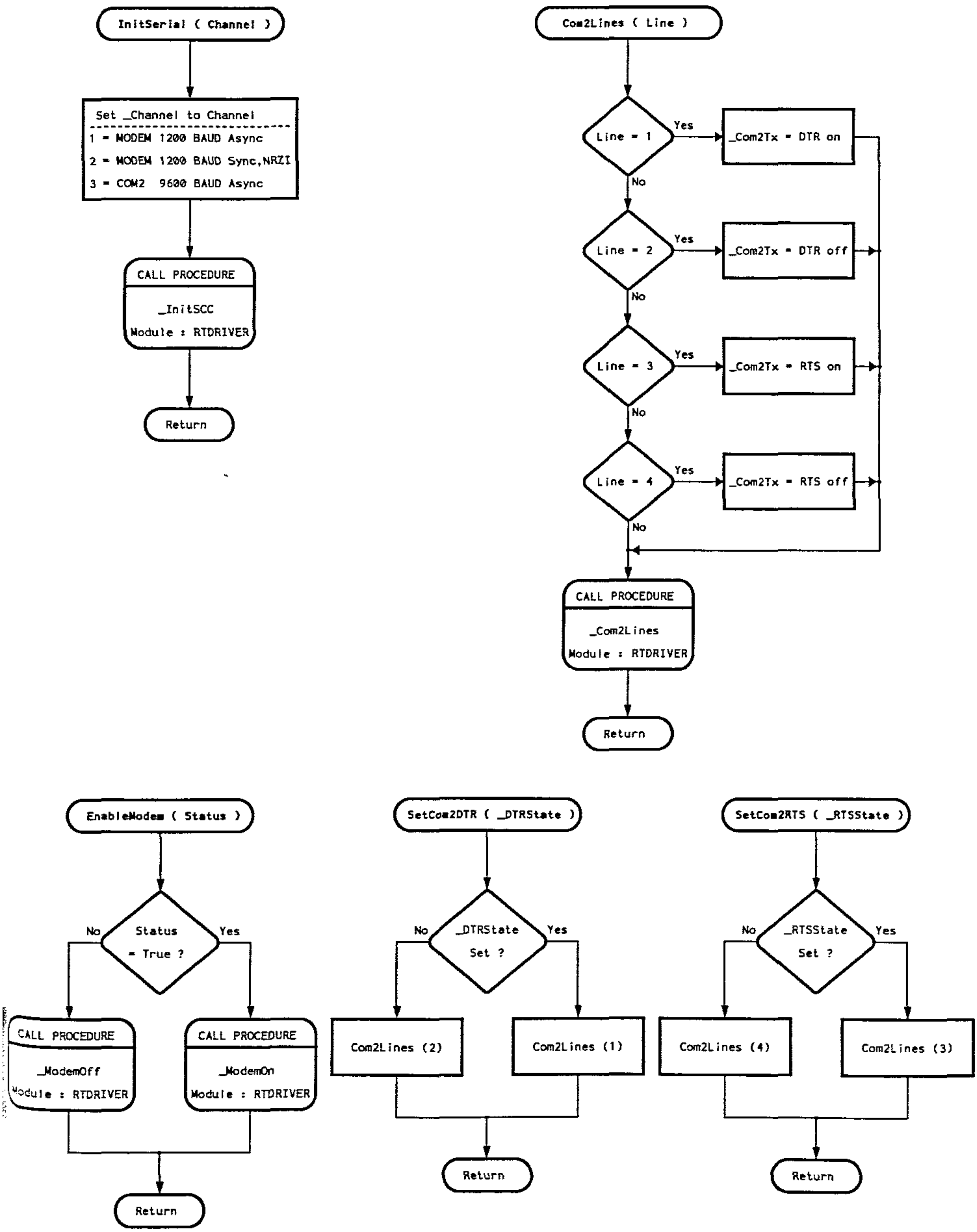
MUPC CARD . COMMUNICATIONS

FILE : COMS-10A.FCD

DATE : 12-06-2000

MODULE : RTSERIAL.PAS

Section 1.0 : Serial communications routines



3.11 SYSTEM UTILITY ROUTINES.

The utility module contains all the routines that perform controlling tasks in the radio telephone system.

File Names	Description	Page
RTUTIL.PAS	Pascal source file in appendix C.	---
UTIL-10A.FCD	Utility routines.	116

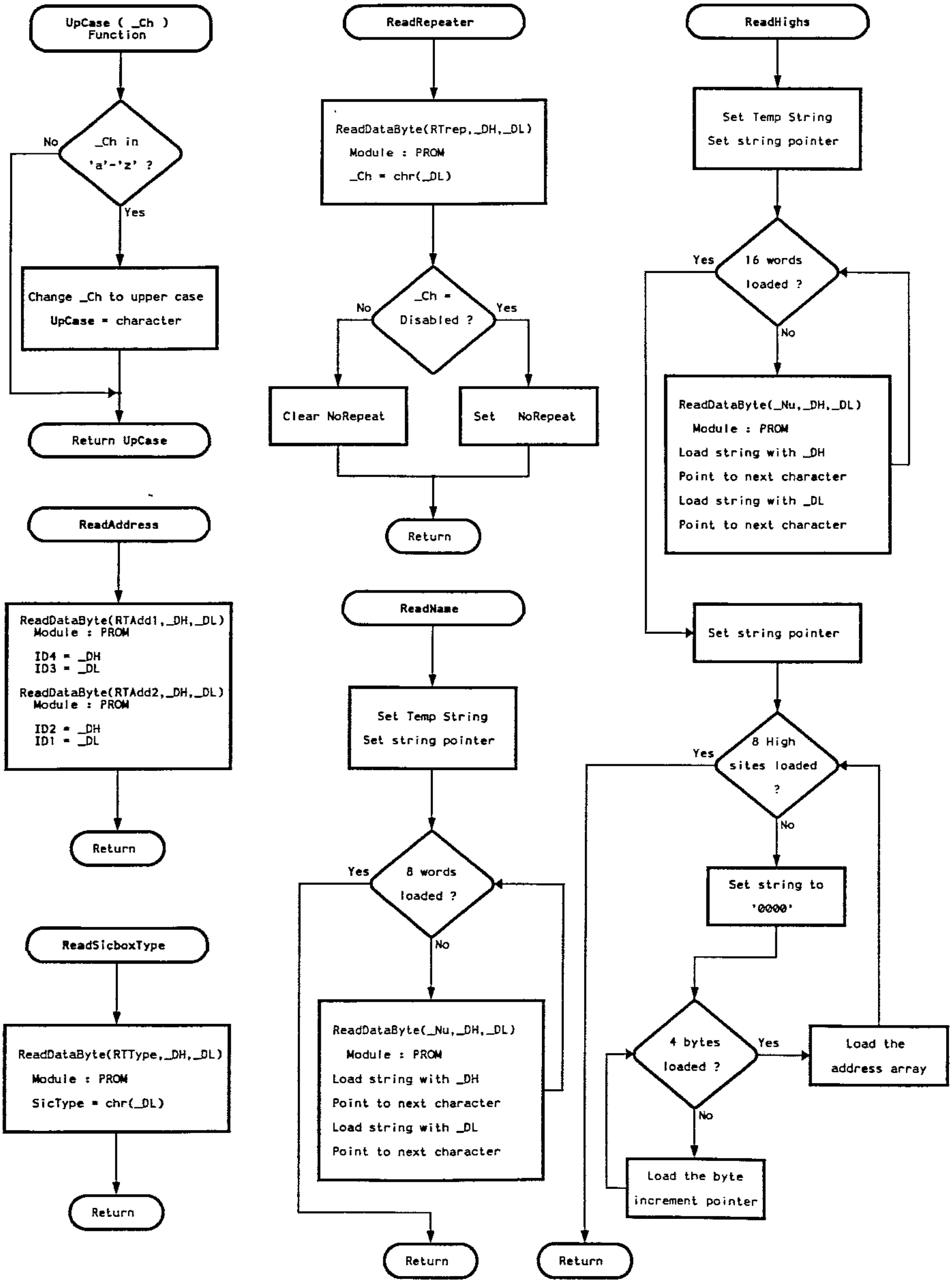
MUPC CARD : UTILITIES

FILE : UTIL-10A.FCD

DATE : 29-05-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



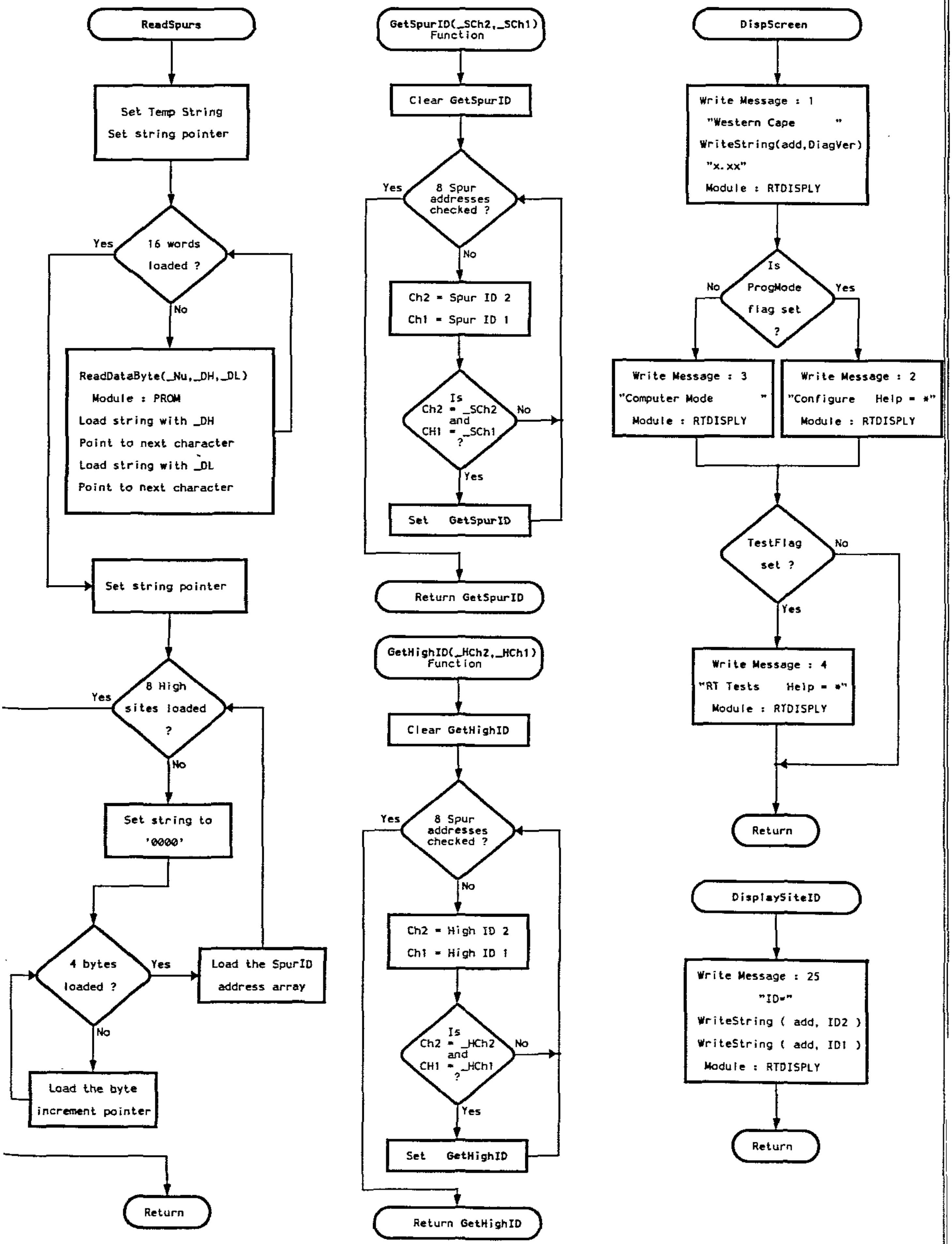
MUPC CARD ; UTILITIES

FILE : UTIL-10B.FCD

DATE : 30-05-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



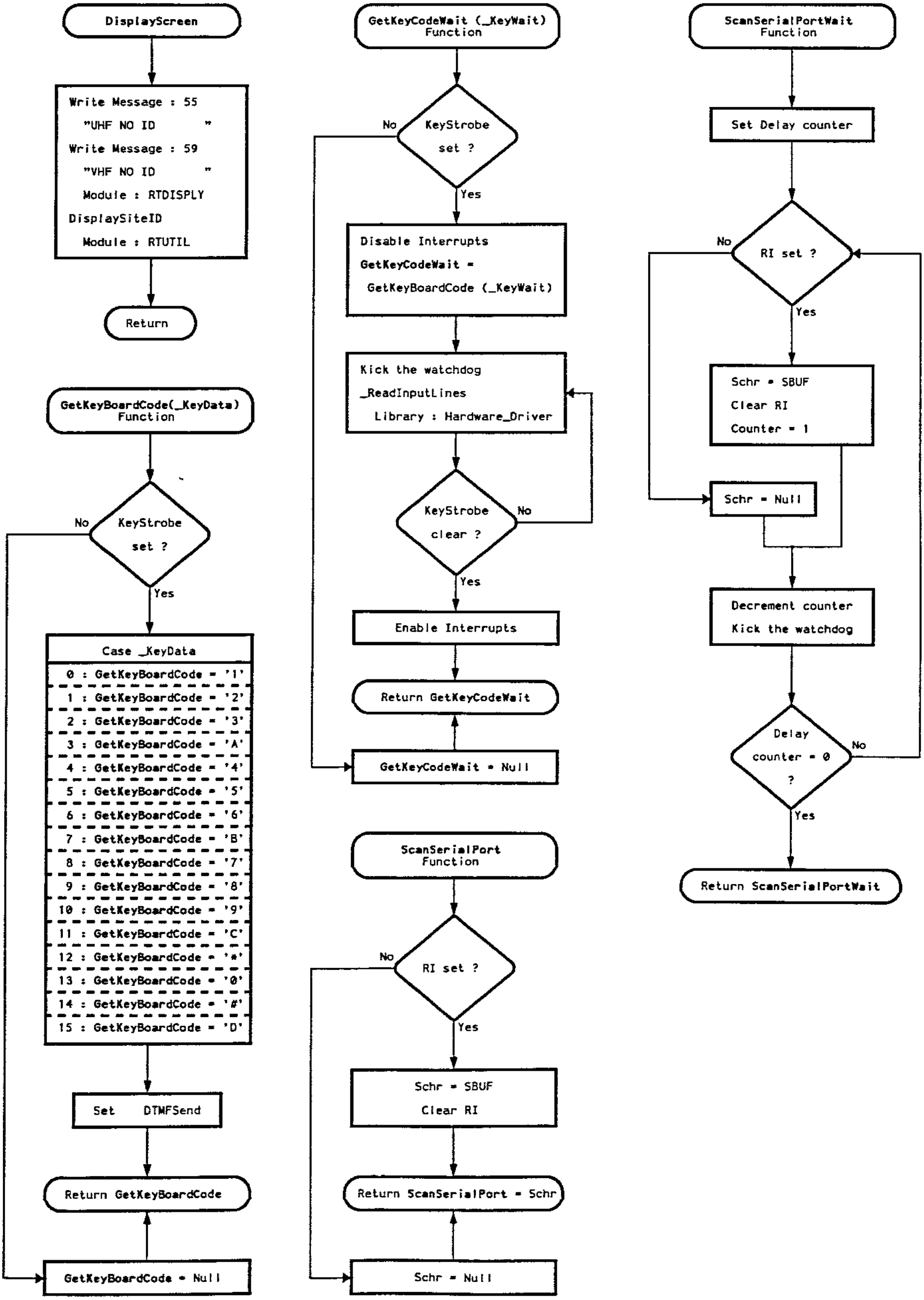
MUPC CARD : UTILITIES

FILE : UTIL-10C.FCD

DATE : 30-05-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



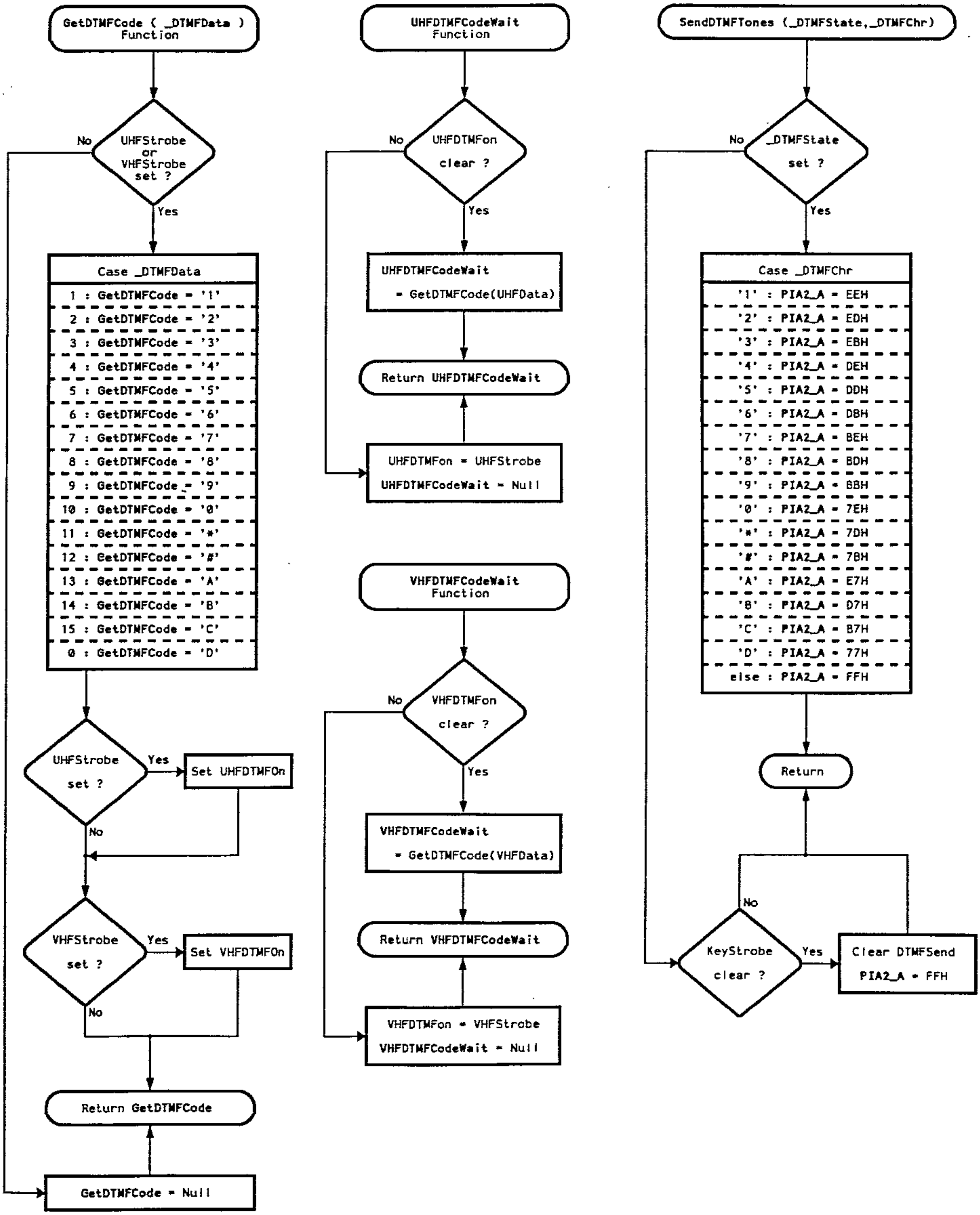
MUPC CARD : UTILITIES

FILE : UTIL-10D.FCD

DATE : 31-05-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



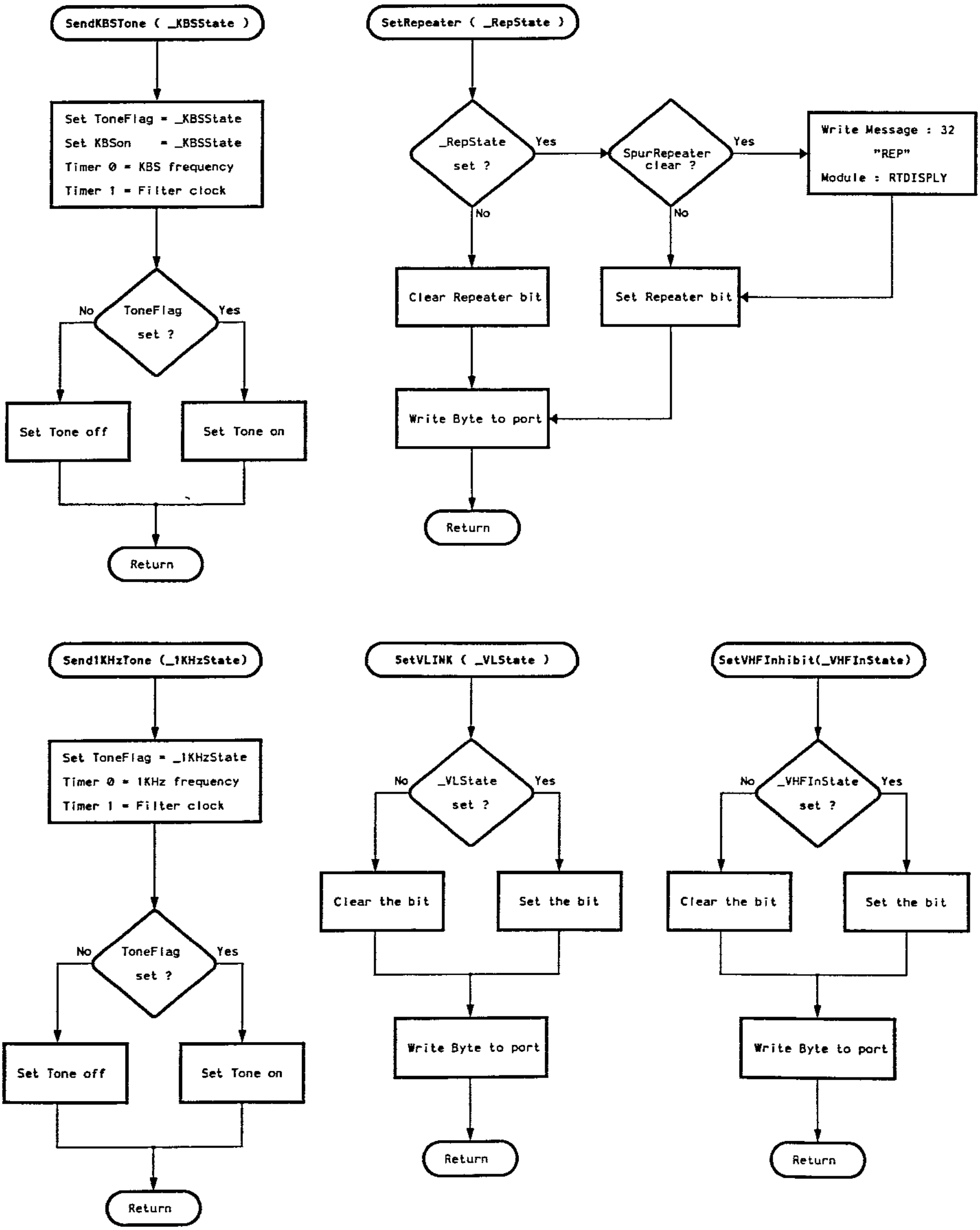
MUPC CARD : UTILITIES

FILE : UTIL-10E.FCD

DATE : 31-05-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



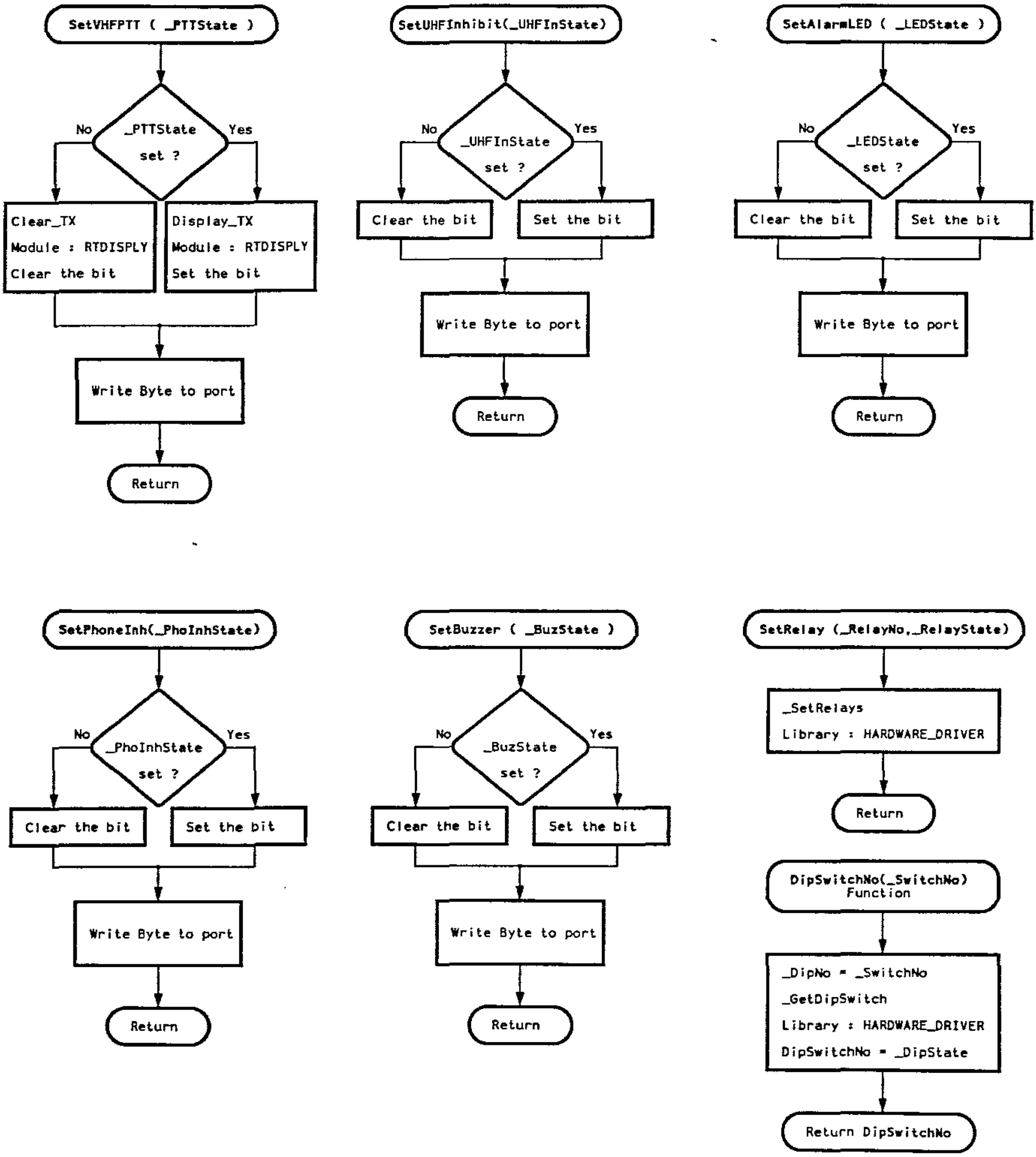
MUPC CARD : UTILITIES

FILE : UTIL-10F.FCD

DATE : 01-06-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



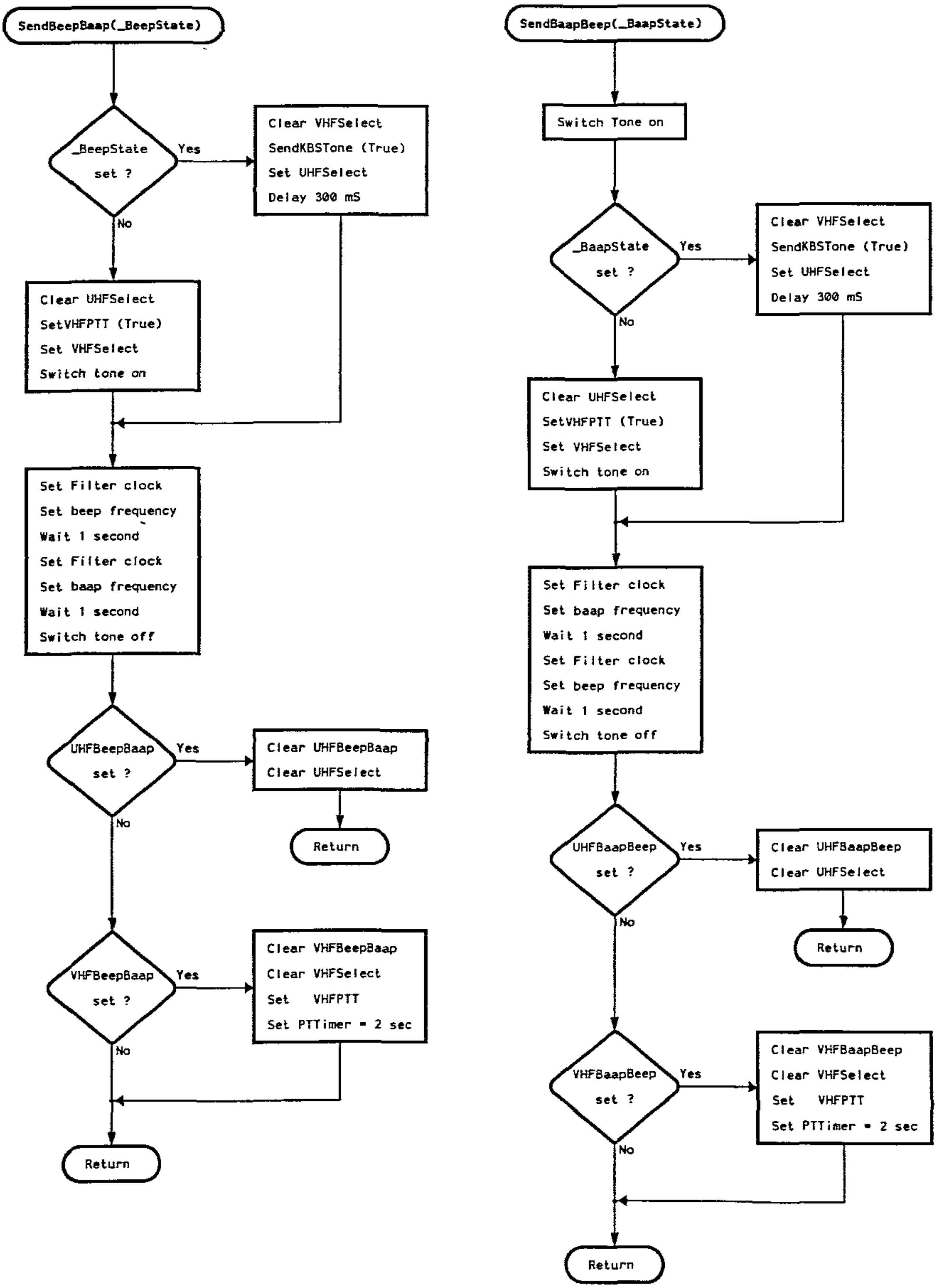
MUPC CARD : UTILITIES

FILE : UTIL-10G.FCD

DATE : 01-06-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



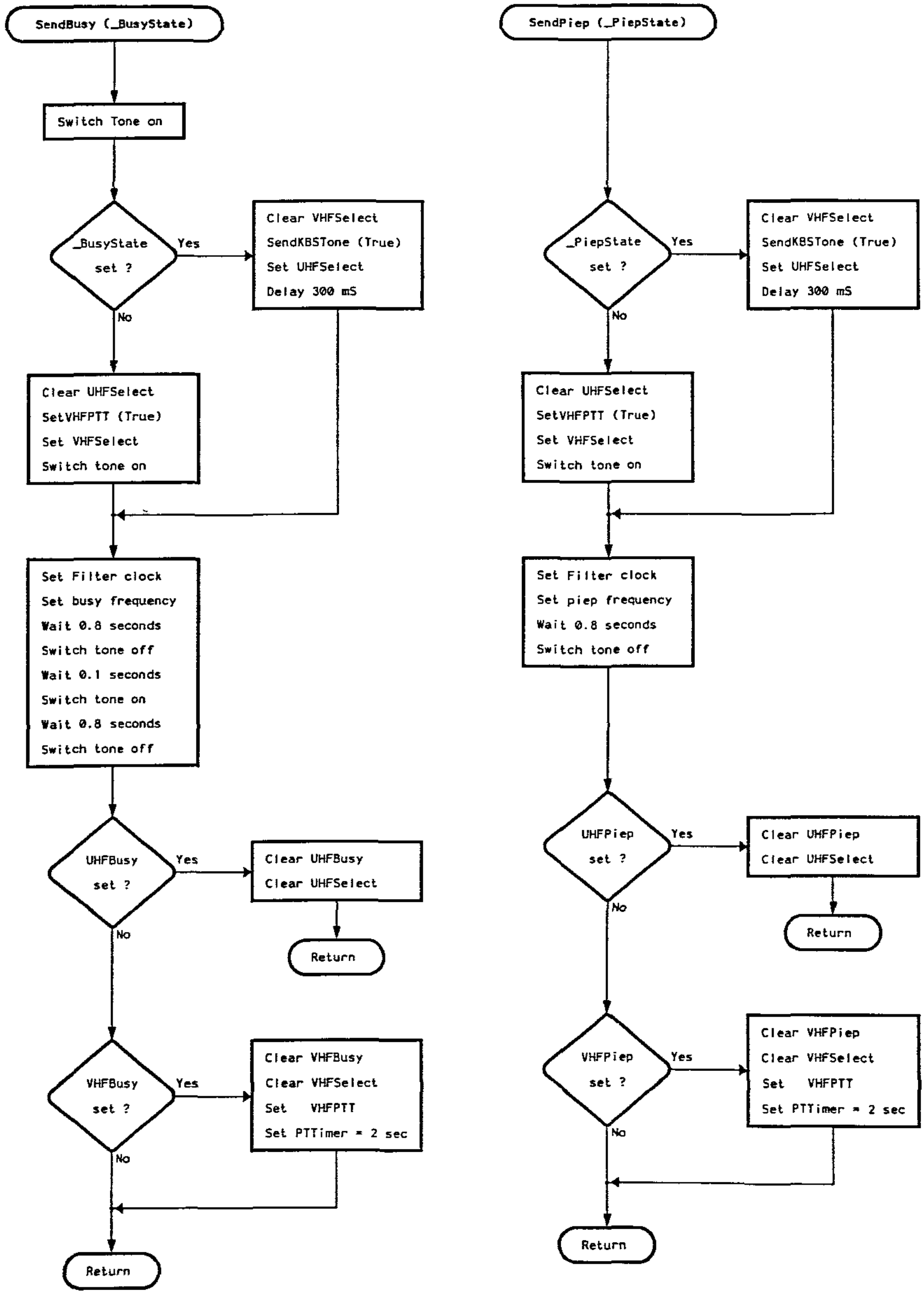
MUPC CARD : UTILITIES

FILE : UTIL-10H.FCD

DATE : 01-06-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



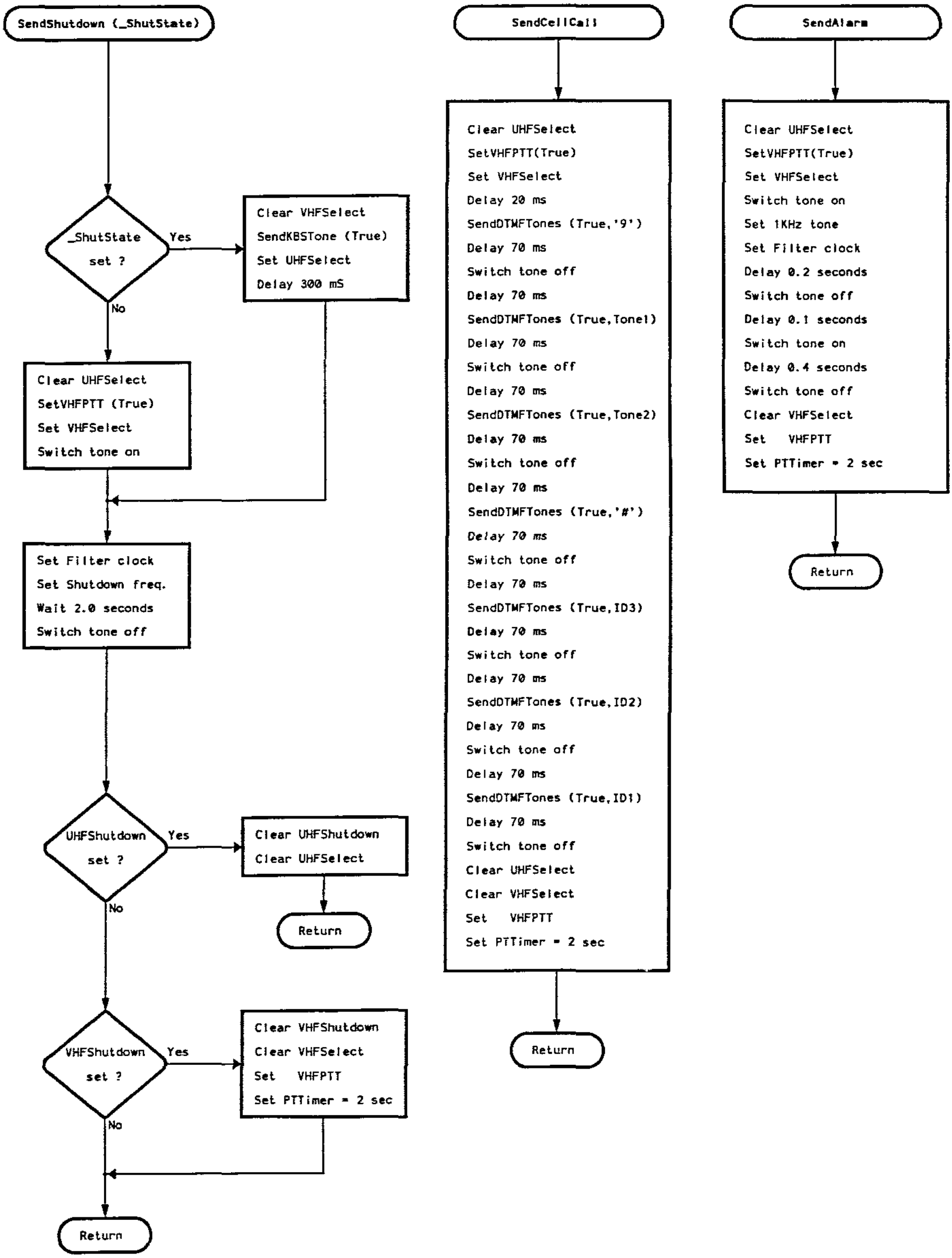
MUPC CARD : UTILITIES

FILE : UTIL-10I.FCD

DATE : 01-06-2000

MODULE : RTUTIL.PAS

Section 1.0 : Utility routines



3.12 INTERRUPT SERVICE ROUTINES.

The Interrupt service module controls all the timer variables in the system and is called every second.

File Names	Description	Page
RT_INTER.PAS	Pascal source file in appendix C.	---
INTR-00A.FCD	System timers routine.	126

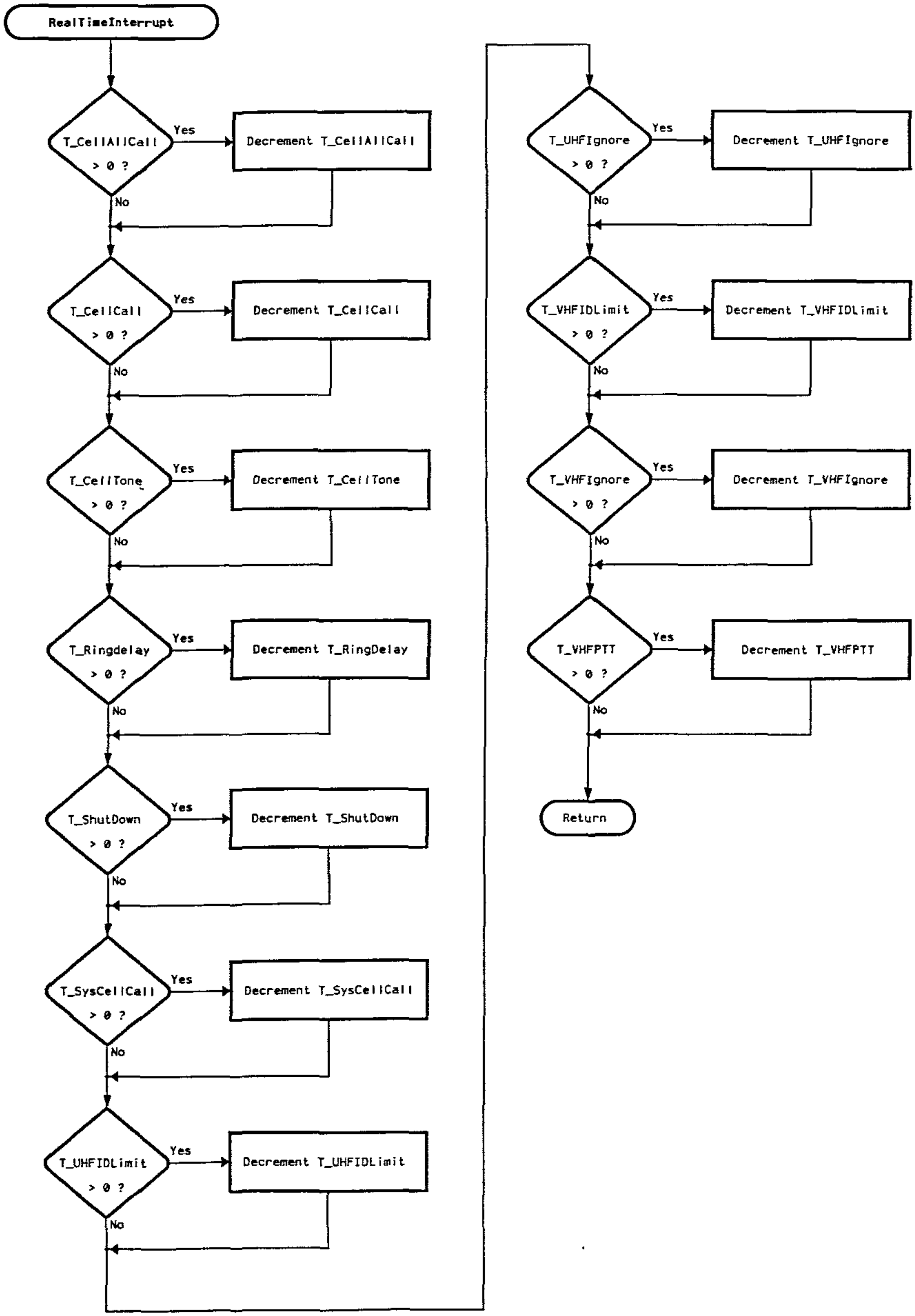
MUPC CARD : REAL TIME INTERRUPT

FILE : INTR-00A.FCD

DATE : 01-06-2000

MODULE : RT_INTER.PAS

Section 1.0 : System timers routine



3.13 SYSTEM HARDWARE DRIVER ROUTINES.

The system hardware driver module is a library of hardware control routines that is used by the pascal routines.

File Names	Description	Page
RTDRIVER.ASM	Assembler source file in appendix C.	---