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Testing Inter@ctive Pager Units

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# Summary

Each new Inter@ctive Pager must be rigorously tested as it is built to reduce the number of defective units shipped, hopefully down to zero. The more the unit is tested, and the more consistently it is tested, the better the quality control becomes.

The Inter@ctive Pager units are subjected to a series of tests as they are built up. The tests are divided into three categories: pre-assembly testing, integrated unit testing, and testing of fully assembled units. At each stage different tests are performed, with an eye to reducing the number of flaws as quickly and efficiently as possible.

Pre-assembly testing consists of: testing the functionality of the I/O board and its devices, programming the microprocessor, calibrating the radio, and testing the LCD module.

Integrated units are complete Inter@ctive Pager units that have not yet been fully assembled in the cases. These units require the following tests: a test of the RF section in the plastics, testing the functionality of all the devices in the pager, a live network test, and finally the unit is serialized and given a permanent radio address.

After the unit's cases has been fully attached together and ultrasonically welded, there is one final live network test performed to ensure that nothing was broken as it was put together. After that has been completed, the Inter@ctive Pager unit is ready to be shipped to the customer.

At every step, all important parameters and test results are put into a central database, whether in the form of traveller sheets or in a computerized database.

Although most people eschew the task of testing and performing quality control, it is a necessary part of any production process.

# Conclusions

Each time an Inter@ctive Pager device is manufactured, there is a finite chance that there will be some defect in the components or in the circuit boards. If the device is to be flawless when shipped, it is necessary to test it rigorously to be able to identify and repair any problems.

It is beneficial to find as many problems as possible as early in the testing process as can be managed, as this decreases the amount of redundant work necessary to test the replacement or repaired parts. To this end, the most time consuming detailed tests are performed at the beginning of the testing process. Such steps as calibrating the radio and testing the LCD module and the I/O board can take several times as long as the final steps of live network testing.

Since the circuit boards in the Inter@ctive Pager are very susceptible to static electricity (as are most circuits), all testing must be done with care given to proper handling of the circuits. Additionally, units that are not completely assembled are very easy to pull apart, so they must be handled with care.

Despite the problems inherent in testing the Inter@ctive Pager units, performing these tests can save hours in troubleshooting at a later time if the unit is returned. This is possible because the results from each test are stored in a central database which can be consulted whenever the unit is returned.

Although testing is often considered a drudgery by many technicians and engineers, it is one of the most important steps in the production of the Inter@ctive Pager, and all other technical devices.

# Recommendations

To make the testing procedure flow better and with fewer glitches, it would be a good idea for RIM to implement a homogeneous central database rather than the several disjoint databases that currently exist. This would make it easier to track the component boards through the testing, calibration and assembly processes.

It is also a good idea to sever the intrinsic ties between the ESN of the finished unit from the ESN of the radio board such that replacing a radio board in a returned unit does not entail changing the ESN of the unit and hence the radio address of the unit. Most customers would likely prefer to have the address of their radio modem staying constant and could care less that the physical radio inside has changed.

When creating the new ESN for the unit, it would be advisable to use a format that does not closely resemble either the ESN for the radio board or the ESN for the I/O board. This will reduce the amount of confusion that can be caused by similar formats that might easily be mistaken for each other.

Automating some of the tests even further would make testing the Inter@ctive Pager even faster and more fool-proof. This is especially important as the Inter@ctive Pager is being put into full production, and reducing the manpower necessary to test the units would be an incredible cost saver. A good candidate for further automation would be the I/O board tests.

As the procedures for building the Inter@ctive Pager become more stable and more reliable, it might be a good idea to cut out the live network testing of the units that is performed before the unit is fully assembled. This test can be foregone if the units are being built consistently enough that they nearly never fail the test. After all, the live network test is performed again after the unit is fully assembled. The downside to skipping the first instance of the test would be that if a unit *fails* the live network test, it would have to be opened up to be repaired.

Alternatively, it would be almost as good to skip the second of the live network tests. The consequences of a failed test would be less catastrophic, and the time savings would be equivalent. This would require that the final assembly of the Inter@ctive Pager be without incident.

# Contribution

The group I worked in consisted of up to five full-time employees and one co-op student (myself). Our group was tasked with designing and bringing into production RIM's Inter@ctive Pager product line.

My tasks included :

- designing testing and diagnostics applications for the Inter@ctive Pager
- performing the live network tests on each Inter@ctive Pager unit before shipping
- designing and implementing an encryption algorithm for use within a serial protocol
- assisting in documenting testing procedures

This report outlines the testing procedure that is followed to ensure that each pre-production Inter@ctive Pager is fully functional. The second of my above duties is one of the final steps in this testing procedure, although one of the most crucial ones.

# Chapter 1

## Background

### 1.1 Company Profile

Research In Motion (RIM) was founded in 1984, and has earned itself an international reputation for developing high performance RF technologies for narrowband data communications [Res96]. RIM's wireless technology has set new standards for battery life, transceiver performance, physical size and ease of use.

In 1988, RIM began developing software and hardware for wireless networks such as Mobitex and DataTAC, recognizing the huge potential that this market presented. Today, RIM products are sold world-wide through distributors, network operators, OEM partners, and software bundling agreements with companies such as Ericsson, IBM, and Megahertz/U.S. Robotics.

### 1.2 The Inter@ctive Pager

The RIM Inter@ctive Pager (see figure 1.1) is a hand-held wireless device that offers two-way paging capabilities over a narrow-band PCS service. Currently the Inter@ctive Pager is available for the Mobitex and DataTAC networks, both of which provide coverage in most of populated North America and elsewhere in the world (most significantly in Europe and South-East Asia).[Res97b]

The Inter@ctive Pager is equipped with a multitasking operating system that allows system developers to create new graphical applications for the pager. The unit has a custom LCD with capabilities to display 4 lines of 30 characters or bitmapped graphics, along with custom annunciators that can be used by applications. It is also equipped with a keypad that contains several function keys, cursor keys, a QWERTY-style keyboard, and a built-in numeric keypad. This allows for great flexibility in the design of applications for the Inter@ctive Pager.



Figure 1.1: Inter@ctive Pager Advertisement  
Source: [Res97a]

Possible uses for the Inter@ctive Pager include :

- Send an Email message while checking in at the airport
- Check your intranet site for inventory status from your customer's parking lot
- Locate a package on the courier's web site from the back seat of a taxi
- Place a stock order from the golf course
- Re-route a technician to make an urgent service call
- Send a replacement part order from your customer's office

## Chapter 2

# Introduction

All new technology requires time to develop. Although the concept of two-way radio has been around for many years, it hasn't been until very recently that it was viable to have small hand-held two-way radio modems. The Inter@ctive Pager is one of the newest of these devices. It is small enough to hold in one hand and operate with the other, and yet offers advanced features such as reloadable code and a full keyboard.

Such a device does not just fall together, but rather requires extensive design and testing to perfect. With the advent of computer-aided design and machines that can assemble circuit boards with little human intervention, it has become far easier to design and manufacture new devices.

However, before any device is sent to a customer, it is necessary to test its functionality to ensure that it operates correctly. If this is done correctly, the number of units returned for repair can be kept to a minimum, and very few customers appreciate having to send back a new item for repair.

This report follows the testing procedure used to ensure that each Inter@ctive Pager is fully operational before it is shipped to the customer. To prevent divulging confidential information, some of the details in the testing procedure have been generalized. It should be noted that the test procedure outlined in this report is in use for pre-production units. The procedure for production units has yet to be fully defined, and thus can not be described at this time.

## Chapter 3

# Pre-assembly Testing

Before a unit is assembled, it is important to test each individual component module sufficiently to ensure that each module is properly functioning. This will save both time and effort in troubleshooting the complete units as there will be some level of confidence that the problem would not be a simple malfunction that could have easily been detected earlier.

The Inter@ctive Pager is composed of several different modules. Apart from the plastic case (which will not be dealt with in this report), the major modules in the Inter@ctive Pager are :

- I/O Board (controls serial port, LCD screen, beeper, etc)
- Radio Board (contains the radio and the microcontroller)
- LCD Module (the custom LCD screen and the keypad)

Each of these three modules is tested separately before they are integrated to create an Inter@ctive Pager. This allows defective modules to be weeded out as early as possible to be repaired or discarded.

### 3.1 I/O Board

The I/O board in the Inter@ctive Pager is responsible for performing many input and output functions. While the microcontroller has some intrinsic I/O capabilities, it was necessary to augment its resources with many more ports and some more timers as well. Some of the resources added by the I/O board are :

- RS-232C compliant serial port for communications with a PC
- Vibrator motor
- Piezo speaker

- Several configurable timers
- Keypad (QWERTY-style with several function keys and embedded numeric keypad)
- Communications to the LCD module
- Battery-charging circuitry

As there are many functions to be tested on the I/O board, it becomes increasingly likely that some portion of this module will be defective at the time of manufacture. To ensure good quality control over this module, it has to be tested extensively.

To test this module, it is necessary to connect it to a radio board as the “brains” of the Inter@ctive Pager reside on the radio board. To this end, a jig has been made that includes a known-good radio board, and a known-good LCD module. Since the I/O board is the only unknown in the system it is then possible to use a single test procedure common to all I/O boards to pinpoint many of a particular board’s manufacturing defects. Since the radio and LCD modules in the test jig are known quantities (and in particular are known to operate correctly), an application for the Inter@ctive Pager was created that will systematically test the functionality of the I/O boards. This software application will be described in greater detail later in the report (Appendix A).

## 3.2 Radio Board

The radio board is perhaps the most important module in the Inter@ctive Pager. If the radio section does not work, a two-way pager is a useless piece of equipment. Additionally, the radio board contains the main processor of the Inter@ctive Pager. If this module is not perfectly operational, the whole concept of the pager is moot. Therefore, much care must be taken in ensuring the radio board is in working order.

As there are two logical sections of the radio board, they will be dealt with separately. These sections are the RF section, and the digital section (containing the microprocessor). Both sections must be rigorously checked, but since the radio section is controlled by the digital section, it is necessary to test the digital section first.

To test the digital section, it is first necessary to have appropriate code loaded into the microprocessor’s program space. While it is possible to use a “program once” style of ROM for storage of the code, it makes more sense to use a reprogrammable ROM as the testing code is not necessarily the same as the production code that will ultimately be shipped in the unit. In fact, assuming the code is written to accommodate it, it is possible to use a slight variant of the production code (that wouldn’t require an I/O board to be attached) to test the functionality of both the digital and RF sections. After the device has been programmed and the digital section has been given an appropriate test, the RF

section can be calibrated for proper operation on the desired narrow-band PCS network (either Mobitex or DataTAC).

### 3.2.1 Device Programming

The digital section communicates with the outside world by means of two asynchronous serial ports. One of these is dedicated for communicating with the I/O board, and the other is for an external RS-232C connection. Normally this is also routed through the I/O board which would provide signal translation from the 0 – 5V signals being produced by the microprocessor and –10V and 10V levels required by the RS-232 standard. While being tested, however, the I/O board is not available for level translation, so a custom level shifter board is used to perform the task and also to provide a few control signals that the I/O board would normally provide.

The digital section of the radio board contains a permanent “BootROM” image that allows for programming the pager with its operating system. With the help of a PC running a special loading program designed to communicate with the BootROM, the device is programmed with a testing version of what is known as the “radio code”. This radio code consists of a real-time multitasking operating system and several tasks that control the RF hardware providing a radio modem that can be interfaced by the “PagerOS” and its applications (more on the difference between the radio code, the PagerOS and the pager applications is included in appendix B).

The testing version of the radio code contains all of the functionality needed to calibrate the RF section and to communicate with a PC based debugger (via a serial connection) if necessary. Since, if the digital section is inoperable one can not program the code into the pager, therefore, it is not really necessary to consciously test the digital section itself in much detail. As long as the programming was successful, and the output of the debug stream seems to be what was expected, it is a pretty good bet that the digital section is fully functional. If it is not *completely* functional, the flaw will be readily apparent in the effort to calibrate the RF section which requires the digital section to be flawless.

### 3.2.2 RF Calibration

The calibration of the RF section is one of the most difficult steps in testing an Inter@ctive Pager unit. For proper operation on the radio network (whether it be a Mobitex or DataTAC network) the RF section must be precisely calibrated. As the Inter@ctive Pager is a two-way device, there is both a receiver and a transmitter to be calibrated if the unit is expected to work. If either part is not correctly calibrated, the pager will seem never to get into coverage correctly, either because it can not hear the network (if the receiver is uncalibrated), or because the network will never acknowledge any transmitted data (if the transmitter is uncalibrated).

The process of performing an RF calibration is not a simple one. Although the process has now been automated by using lab equipment capable of communicating with GPIB to each other and to a suitably equipped PC, it can also be done by hand, as it was when designing prototype units. The process itself is nearly unchanged, however.

To calibrate the radio, it is necessary to connect the radio to some lab equipment rather than to an antenna as there is a need for accurate measurements to be taken with minimal interference from radio signals that are propagating in the area.

### Receiver Calibration

The calibration of the receiver concerns involves steps, calibrating the receiver such that a known good pattern is consistently decoded, and correlating received signal strength (RSSI) measurements (as calculated by a DSP algorithm) to actual signal strengths (measured in dBm).

To ensure that received signals are correctly decoded, several calibration parameters are adjusted. These parameters include the limits on the AGC (automatic gain control) gain and also can include the amount of DC offset that is present in the signal amongst others. The exact parameters are somewhat dependent on the particular RF protocols being used. The Mobitex network uses an FSK (frequency shift keying) modulation scheme as does the DataTAC network's MDC protocol (although the precise modulation types are subtly different) whereas DataTAC's RD-LAP uses a 4-level Trellis code modulation scheme. Thus for the DataTAC pagers, it is necessary to perform two separate calibrations, one for MDC and one for RD-LAP.

To compare the received decoded signal with what was transmitted, it is simpler if the transmitted signal were a known repeating pattern such that the testing radio code can easily determine a bit error rate (BER) which can then be reported to the debugger running on the PC connected to the serial port. The operator would then adjust the calibration parameters striving for the smallest possible BER. Typically, a BER of up to about 3% would be acceptable as the data being sent generally has error correction codes embedded into them.

A skilled operator can also visually inspect the received demodulated waveform on an oscilloscope to aid in fine tuning the receiver parameters. A properly calibrated Inter@ctive Pager radio can generally demodulate data received at signal strengths of as low as  $-113\text{ dBm}$  (about  $5 \times 10^{-15}\text{ W}$  or  $5\text{ fW}$ ) so a careful calibration job is required.

To correlate the measured RSSI to an actual RSSI value in dBm, the operator simply injects signal at a series of known strengths, and notes the measurement values. The resulting table of measurements is then written in as calibration values which the radio code then can use to interpolate RSSI in dBm from any measured RSSI value. For accuracy, the actual signal strength injected into the receiver should account for any signal loss in the cables connecting the radio board to the RF signal generator that is injecting the signal.

### Transmitter Calibration

The transmitter calibration also involves two steps: calibration of modulation parameters, and correlation of raw power values to the output power level of the amplifier.

The modulation parameters again depend on the particular RF network the pager is designed for, but often include such values as the deviation to use for an FSK modulation and similar parameters. The method for setting these parameters is near to the converse of that used to calibrate the receiver. The radio code instructs the DSP to transmit a known repeating pattern which is then fed to RF test equipment. The waveform and frequency spectrum of the output is studied and adjustments are made to the parameters. It may also be necessary to calibrate the center frequency, gain and filters of the radio's PLL (phase-locked loop) frequency generator to ensure the transmitter is using the correct frequency at all times.

The purity of the transmitted signal is also inspected as the radio needs to conform to guidelines set by the FCC and Industry Canada that specify maximum spurious transmission levels at frequencies other than the "correct" frequency for the device. Such spurious transmissions are caused by most radio circuits, and the task is to ensure that the levels of such unwanted activity is kept very low. If the design of the circuitry does not attenuate these harmonics, it can be made necessary to shield the radio circuitry with thin copper sheet formed into "cans" around the circuits.

Once a satisfactory modulation has been verified, the radio's transmit levels are then correlated to the raw power levels that are sent from the radio code. To do this, the operator will have the radio use a series of raw power levels until a given set of output powers have been observed on an attached power meter. The resulting table of raw power values for varying output power levels is used by the radio code to specify what output power level to transmit at.

Once both the receiver and transmitter have been calibrated, the radio board is ready to be integrated with an I/O board and LCD module to become a full pager unit. At this time the calibration parameters are stored in a central database in case they somehow are erased from the radio board at a later date or get corrupted.

## 3.3 LCD Module

Testing the LCD module requires a similar jig to that used to test the I/O board. The jig for the LCD requires good radio and I/O boards and the same test application as used to test the I/O board.

The test involves turning on all the pixels on the dot-matrix screen and ensuring they all appear. The connection from the LCD screen to the board in the LCD module (which doubles as the circuitry for the keypad) is a thin flexible cable which is heat-sealed to the board, so often some manipulation is required to get proper connection of all of the lines in the cable. It is very

important to get all of the lines connected properly before heat-sealing as the operation is irreversible.

The heat-sealing process is done under considerable pressure, and is intended to be permanent. Care must be taken with the thin flex cable as it is easily disconnected until the pager is fully assembled, at which time additional stress relief is added to the connections.

At this point, the LCD module (both the screen and the keypad circuit board) are mounted into the respective plastic case parts in anticipation of integrating the unit. When this is done, the rubber keypad must be inserted between the circuit board and the plastic case. The assembly is fastened together by a process known as heat-staking. This process involves holding the circuit board in the correct position and melting several plastic stakes that protrude through the circuit board. As this is an irrevocable process, it must be done correctly the first time with no margin of error.

## Chapter 4

# Integrated Unit Testing

After the pre-assembly tests have been completed, the radio board, I/O board and LCD module are integrated into a single unit, and are placed into the plastic case. The result is a complete Inter@ctive Pager that has not been fully assembled, but should be fully functional. As long as the person testing the unit is careful not to disturb the connections between boards, the unit can be used as if it were fully assembled (with the case properly secured together).

At this point, the pager needs to be tested as a unit as the act of putting the components together and putting the assembly into a case can cause failures such as breaking connectors or shorting parts on different boards together. Also the plastic of the case can cause adverse effects on the RF performance of the antenna, so an additional RF test must be performed with possible tweaking of calibration parameters necessary.

Once the RF section seems to be properly calibrated again, it is necessary to test the pager on a live network to ensure that it will perform as expected. This test is a necessary step as often small mistakes in calibration and integration can be noticed by running the pager through its paces that may not otherwise have been noticed.

After a pager unit seems to be fully operational, the Inter@ctive Pager unit is given an electronic serial number (ESN) and a permanently allocated radio address (a MAN number for Mobitex devices or an LLI for DataTAC units). This combination of ESN and radio address is never changed for the lifetime of the unit (with the possible exception of changing the radio address under special circumstances such as moving to a separate RF network in some prototype units). The ESN is the identification by which the unit will be known from this point forward. It is quite important to ensure the unit works completely before allocating a radio address or ESN to the unit as the address will be permanently lost if the unit has to be replaced.

## 4.1 RF Test

Since the radio board is now integrated with the rest of the pager, the RF characteristics may well have changed. To counteract any adverse effects, it is necessary to check the RF performance of the radio board once again. Since the radio board is now attached to the antenna which resides in the lid of the case, all tests must be done with the test equipment attached to another antenna rather than a direct connection.

Assuming the initial calibration was performed correctly, the RF test will likely only be a “checkup” to ensure that nothing has been either changed or broken during the integration step. The radio is instructed to transmit a known pattern again at a known power level, and the resulting signal is demodulated by the lab equipment and the waveform is inspected. A slight modification of the calibration parameters may be required to compensate for small changes in the quality of the signal.

The radio is then told to expect BERT (bit error rate test) frames to be sent to it. At this point, the receiver should have been properly calibrated, but the plastic of the case may have adverse effects on the receiver performance. Minute changes to the calibration parameters may again be needed to allow the radio to perform correctly.

Once the radio is once more properly calibrated, the calibration parameters are stored in the central database again in case of future corruption within the radio. At this point the radio contains what should be its final calibration parameters.

## 4.2 Functionality Test

Although a functionality test has already been completed in the I/O board preassembly test, it is a good idea to do a complete functionality test after the pager has been integrated into a unit. The same test application that was previously used (and is described in Appendix A) can be used at this stage to ensure that all of the functions work correctly. As the interconnection between the I/O and radio boards is easily misaligned (especially in the older version of the boards), it is especially important to ensure that all of the external components (such as the beeper and vibrator) are operational.

## 4.3 Live Network Test

Once the pager has been proven to be functionally complete, and the radio is correctly calibrated, the pager is nearly complete. The only thing that is left to test is that it will operate correctly on a live network. Up until this point all RF tests were performed on isolated channels that were not occupied so that there would be no chance of interference from the live network, and so the radio would not interfere with the network.

The live network tests require that the entire software suite be loaded into the Inter@ctive Pager. This includes not only the production version of the radio code, but also the PagerOS and the latest Pager application. This application allows the user to send messages to other pagers and other radio modems through the live network.

To perform the live network test, the pager must be configured for the correct network radio channels so communication can occur. Since the tests are performed at Research In Motion which is located in Waterloo, Ontario, the channels must be set up for use in the Canadian networks. For Mobitex units, this requires the pager to be set up to use the Cantel network's Mobitex channels as they are the local carrier. For the DataTAC units, the pagers must be configured to use Bell Mobility's DataTAC (MDC only) channel. Since Bell Mobility has no RD-LAP coverage in Waterloo, it is necessary to use RIM's in-house RD-LAP basestation to test the proper operation of RD-LAP in the pager units. While this doesn't accurately reflect a busy live network, it is currently the only option available.

The live network test involves activating the radio within the pager, and sending a short message from the unit to itself through the network. If the pager is working correctly (and the network is not inoperative at the time), the message should be sent to the network and received back at the pager in under a minute. Typically, it will be received within less than ten seconds, but due to the use of the power saving protocols which put the pager's receiver to sleep for up to about 30 seconds, there is no guarantee that it will be that fast.

If the message is never sent to the network, or never returned from the network, there may be a problem with the unit that was not noticed before. Often the problem is easily solved by slight manipulation of the radio calibration parameters, but in some cases, it is indicative of a catastrophic failure of the radio. There is also the possibility that the network is not working correctly, so if a unit under test fails in this way, it is a good idea to try a known good unit to see if the problem is with the network or the unit. If the unit is failing at this juncture, it is returned to the technicians to be diagnosed, and hopefully repaired (rather than replaced).

In most cases, the unit having made it this far in the testing procedure works flawlessly on the network. If this is the case, the unit is completely working and is ready for the final stages of assembly immediately after the unit has been serialized and allocated a permanent radio address.

## 4.4 Unit Serialization

Now that the unit is known to be a good unit, it must be assigned a unique ESN (electronic serial number) and a unique and permanent radio address.

The radio addresses are network-dependent, and are the identifying addresses that specify how the network contacts individual units. In the Mobitex network the radio addresses are known as MAN numbers and are 24 bit numbers that are represented as a decimal number. For the DataTAC network, a

radio address is called an LLI and is a 31 bit number that is represented in hexadecimal.

The ESN of an Inter@ctive Pager is actually determined by the ESN of the radio board that is used in it. The I/O and radio boards have separate serial numbers that allow tracking of inventory as they are being built and tested. At the time of integration, the unit assumes the serial number of the radio board as its ESN, and the I/O board serial number is cross-referenced to this ESN in a central database.

The implication of using the radio's ESN as the unit's ESN is that if a pager fails at a later date, the ESN may need to be changed as the radio board will likely need replacing. As the radio address is permanently associated with the ESN, this also means that a repaired pager may have a new radio address. This is not really a desirable consequence, but the hope was that the situation would not occur very often. It would be beneficial to have a separate ESN for the complete unit such that modules within it could be replaced without changing the identity of the unit.

Once a radio address and ESN have been allocated to the unit, and labels identifying the unit have been affixed to it, the unit can be fully assembled.

## Chapter 5

# Completely Assembled Unit

Once the Inter@ctive Pager unit has been fully assembled and ultrasonically welded together, the unit is complete. However, before shipping the unit, it is beneficial to double check that it will still work on a live network. The assembly process brings with it the possibility of disconnecting the interconnections between the boards or accidentally breaking the LCD flex cable.

To ensure that the unit still operates correctly, the live network test is repeated. If the unit passes the live network test and does not seem to have any obvious LCD or beeper problems, then it is deemed a fully working unit.

At this point, the central databases are updated to include all pertinent data including the ESN, radio address, shipping date and destination. After that has been completed and the correct radio channel tables have been entered into the unit, the unit can be shipped to the appropriate customer.

# Appendix A

## I/O Board Test Application

To test the operation of the I/O board it was necessary to write an application to run within the PagerOS. This application was designed to test practically every device that was easily accessible from an application. These devices were :

- LCD screen
- piezo speaker
- vibrator motor
- keypad
- external serial port
- radio modem
- user configurable LEDs

For each device, an appropriate test sequence was determined, and was made available to an operator by means of a menu that listed the individual tests that were available. The test for each device will be briefly described.

### **LCD screen**

To test the LCD screen, there are two things to verify: contrast control, and the correct operation of every pixel. To this end, the contrast was cycled slowly so the operator could verify the contrast control was operative. To show that all the pixels worked, all pixels were illuminated, and then two alternating “checker-board” patterns were displayed. Also, all of the user-configurable annunciator icons were illuminated then extinguished to demonstrate their operation.

### **Piezo speaker**

To test the speaker, a simple beep pattern was output to the speaker.

**Vibrator motor**

To test the vibrator, it was turned on for a period of four seconds, then turned back off again.

**Keypad**

To test the keypad, the operator was prompted in turn to depress each key on the keypad. This test could possibly be made faster by asking only for such keys to be depressed as would test every row and column in the keyboard matrix.

**External serial port**

The serial port test required a small program to be written for the PC that would be on the other end of the serial cable. This test involved a simple protocol that had the pager and the PC exchange first single (but differing) characters, and then longer differing strings. This ensures that the serial port is operational.

**Radio modem**

To test the radio modem functionality (which requires a working radio board to be attached), the pager sends a short message to itself via the radio network, and expects it back within under a minute. It then compares the received message to the one it sent and expects them to be the same.

**User configurable LEDs**

To test the user configurable LEDs, they were turned on, then set to flashing then turned back off, with the operator indicating when to switch states.

## Appendix B

# Inter@ctive Pager Software Architecture

The software architecture in the Inter@ctive Pager is one of several layers. Figure B.1 shows the structure of the software used to operate the pager. The Inter@ctive Pager contains two separate multitasking operating systems, one of which runs within the other. The applications that the user sees runs within the PagerOS which in turn is run as a task within the radio code's task switcher. Each level will be briefly described.

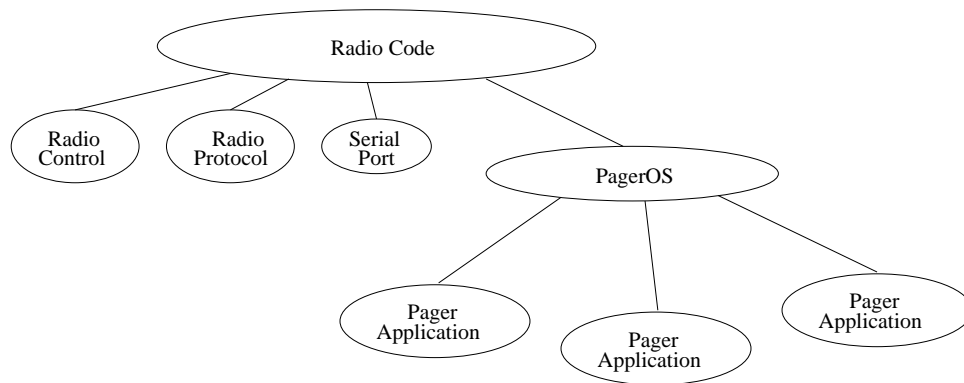


Figure B.1: Inter@ctive Pager Software Architecture

### Radio Code

The radio code within the Inter@ctive Pager consists of a pre-emptive cooperative multitasking operating system. The tasks that run within this task switcher control the radio hardware, the radio protocols (queuing, etc), and optionally, the external serial port. The PagerOS operates as the idler task within the radio

code.

### **PagerOS**

The PagerOS is a nonpreemptive cooperative multitasker. It provides a series of API calls to support the applications and to allow them access to the radio, the LCD screen and the external serial port amongst other things. The applications are allowed to register for many different events, and are sent messages when these events occur. These events include timers, radio messages received, serial port events, and many others.

### **Pager Applications**

The pager applications run within the PagerOS, and are event-driven in nature. The mainline of an application is essentially a message handler. This allows multiple applications to co-exist as long as each application is designed to either yield control of the processor or to block on messages at suitable intervals, and to use unique timer identifiers and similar constraints.

The PagerOS was designed to allow pager applications to be loaded into the Inter@ctive Pager and erased at any time through the use of the external serial port.



## Appendix C

# Glossary

ASIC	Application-Specific Integrated Circuit
dBm	A logarithmic representation of RF power ( $Power_{(dBm)} = 10 \log_{10}(Power_{(mW)})$ )
DCE	Data Circuit-Terminating Equipment (modem, printer, etc.)
DSP	Digital Signal Processor
DTE	Data Terminal Equipment (usually a computer)
I/O	Input / Output
LCD	Liquid Crystal Display
MASC	Mobile Asynchronous Communications protocol
NCL	Native Control Language
RF	Radio Frequency
RPM	Radio Packet Modem
RSSI	Received Signal Strength Indicator

# Bibliography

- [Res96] Research In Motion, Ltd. *About RIM.* Via URL <http://www.rim.net/rim.htm>, 1996.
- [Res97a] Research In Motion, Ltd. *Product Photo — RIM Interactive Pager.* Via URL <http://www.rim.net/phtopgr.htm>, 1997.
- [Res97b] Research In Motion, Ltd. *RIM Products — Pager.* Via URL <http://www.rim.net/pager.htm>, 1997.