Design of a Bluetooth Enabled Android Application for a Microcontroller Driven Robot

by

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LIST OF ACCRONYMS

CTS – Clear to send

RTS – Request to send

API – Application programming interface

RC – Radio controlled

SDK – Software development kit

IDE – Integrated development environment

MAC – Media Access Control

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ACKNOWLEDGMENT

To my parents who have taught me the importance and value of education and to my loving wife whose support has kept me going when I might have otherwise quit.

ABSTRACT

The objective of this paper is to show that it is possible to create a single Android application capable of working with a number of electronic devices typically used within the hobby and armature robotics field, without the devices creator having to know anything about developing an Android application. To do this, a standard communication protocol must be established between Android powered devices and other electronic devices. To limit the scope of this task, this paper considers communication between an electronic device powered by a typical microcontroller and an Android 4.0 (Jelly Bean) or later powered device. Additionally communication between the two devices takes place over Bluetooth communication channels V2.1 or later.

1. INTRODUCTION/BACKGROUND

1.1 Background

All communications between devices require that the devices agree on the format of the data. The set of rules defining said format is called a protocol [1]. Communication protocols are almost everywhere we look from computers to televisions to basic mp3 players. They can even be compared to social mannerisms in today's culture. Take the activity of answering a phone, when someone answers the phone they say "Hello" or some other equivalent greeting. This first phrase lets the person on the other end of the phone know that its their turn to speak and that the person they have called is ready to receive information. This can be equated to flow control within a communication protocol which is used to let one device know that another device is ready for some communication or data transfer to occur.

If a product developer wishes to make an electronic device that allows the end user to control said electronic device from their smart phone or tablet, since there is currently no industry standard open source communication protocol applicable to this scenario, they would be forced to develop their own basic protocol. They would not only have to develop the software on the electronic device side but they would also have to design a custom application for the end users cell phone or tablet. As a basic example consider, a company which designs keyboards for computers. There is a standard communication protocol and standard human interface driver for all modern USB keyboards. This allows the keyboard manufacture to develop and produce a keyboard without requiring them to write custom software for the computer

1.2 Prior Work

Much work has been done amongst the amateur robotic community to develop platforms that are controlled by mobile devices as shown in [3] and [4]. Additionally several companies offer small robotic devices that can be controlled by mobile devices typically from the Android of Apple operating systems. These systems come with proprietary software for both the robot and the mobile device that is specifically designed to control only the device sold by the manufacture. Figure 1, the Rover Revolution available from

Brookstone, is one such example which allows the end user to remotely operate the device from an application on an Apple or Android device. This device also has advanced capabilities that allow the user to remotely control the vehicle while also streaming video from an onboard camera. Due to the high bandwidth requirements to support streaming video the device utilizes WIFI instead of Bluetooth or other lower frequency RF communication protocols. [2] Note that this software nor the communication protocol is distributed as open source software for others to modify, or implement in their own projects and applications.

Figure 1 - Rover Revolution Available from Brookstone [2]

Parallax a popular supplier of microcontrollers and other components commonly used by armature robotic developers, offers tutorials and educational material for many of their products. In one such tutorial, shown in Figure 2, Parallax demonstrates the ability to send commands to a Propeller microcontroller remotely from a PC via a Bluetooth Serial Port Profile. [3] Additionally the example provides open source software for the microcontroller, mainly programs that were already available as published open source library’s tied together with a single custom application. The example utilizes an RN-42 Bluetooth adapter and the user sends commands to the microcontroller via a serial terminal like HyperTerminal or in the case of the example the Parallax Serial Terminal. This example will be used a starting point for my work on the microcontroller side of the task. While this application demonstrates the ability to send data over a Bluetooth connection it has essentially used the Bluetooth connection to replace the wired connection with the computer. User input is no different than if the computer was directly wired to the computer and no generic communication protocol is established.

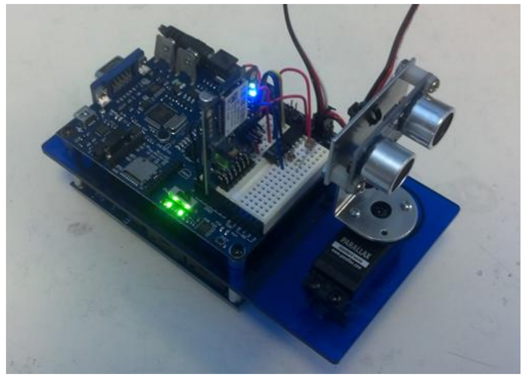


Figure 2 - Parallax RN-42 Bluetooth Demo [3]

An alternative approach to controlling a robot via a cell phone was demonstrated by MicroTronics Technologies [4] the device is shown in Figure 3. In this application a call is placed from a user's cell phone to a cell phone mounted on the remote platform. The platform mounted cell is connected to the microcontroller through a decoding module which interprets the tones of the numeric keys being pressed through the headphone jack. Commands are sent by pressing one of the numeric key on the operator's cell phone, frequencies are transmitted over the cell network / towers, received on the platform mounted cell and interpreted by the microcontroller as commands. The benefits of this set up is that it requires no additional software to be installed on the cellphone, as it utilizes existing functionality built in to make phone calls.

Figure 3 - MicroTronics Technologies Mobile Control Robot [4]

The downside is that the system is limited to only 12 unique codes correlating to the 12 keys on / frequencies created by a phone (10 Numeric keys 0 through 9, the pound key and the asterisk key) and only one command can be sent at a time. Another difference is that the signals are sent over a cellphone network, so the range is only limited by the size of the cell network, however the devices will only work where cell service exists and are dependent on a network outside the users control. The Bluetooth connection I have proposed does have a limited range which is many times smaller than that of a modern cell network. However, it is not subject to the infrastructure requirements of a cell network, i.e. it will operate where cell coverage is not provided. Additionally the Bluetooth network is completely in the users control and can be optimized to meet the requirements of the application.

1.3 Objective

I have developed a communication protocol that meets the prescribe definition of a communication protocol as discussed earlier. Additionally I have implemented said communication protocol and demonstrate its use in the communication between an Android powered mobile device and a robotic platform over a Bluetooth connection. Finally I have shown that the communication protocol and its application / implementation produce a responsive user experience that is on par with existing radio controlled robotic platforms.

2. METHODOLOGY/IMPLEMENTATION

Developing a communication protocol for use between typical electronic devices and mobile devices such as tablets and cell phones requires that the foundation and principles / rules i.e. the protocol, should be transferable across any platform. However due to the number of mobile platforms available (Windows, iOS, Blackberry, Android), the number of data transfer methods (Bluetooth, Peer to Peer Wi-Fi, Internet, Cell Network) and the number or electronic devices it would be an extensive task to demonstrate/implement the communication protocol across all of the available platforms. It would also be a trivial task in that, relatively no unique work would be required. For the most part it would be a task of translating the code from one language to another. Instead I plan to demonstrate a communication protocol and the communication between an android device and a microcontroller over Bluetooth using only open source hardware and software. This will allow me to develop the communication protocol in a cost effective manner while still remaining flexible so that it can be expanded to other operating systems and devices as need dictates.

2.1 Component and Software Selection

To develop and implement a communication protocol between a mobile device and another electronic device several pieces of both software and hardware are required. On the mobile device side both an IDE (Integrated Development Environment) and SDK (Software Development Kit) are required for programming the electronic device. Additionally a physical device will be required for implementation / testing. On the Electronic device side an IDE and SDK are required for programming the microcontroller as well a physical microcontroller and robotic platform for implementation/testing. Additionally since Bluetooth will be used for data transfer between the devices, a Bluetooth module that is compatible with the selected microcontroller is required.

2.1.1 Selecting a Mobile Operating System and a Mobile Device

There are many choices to pick from when it comes to selecting a mobile platform / operating system to demonstrate communication via Bluetooth with a microcontroller.

The leading operating systems include Google's Android, Apple's IOS, Windows Mobile, and Blackberry all of which offer products of similar technological implementations. That is all of these devices are available with similar processing power, memory (RAM and ROM), screen size, screen resolution, touch screen capability, battery life, Bluetooth, Wi-Fi, GPS and cell network capabilities. With no limiting factors on the selection of an OS from an available / required hardware standpoint, the decision came down to two factors, the market share or number of devices in service for the operating system and the ability to provide an open source solution. Googles Android OS is known for its open source developer friendly environment and as of May 2012 it has surpassed Apple IOS in terms of market share in mobile devices, Figure 4. As of the end of 2013 Android represents over 43% of the market compared to Apple its closest competitor which has just over 20% of the market.

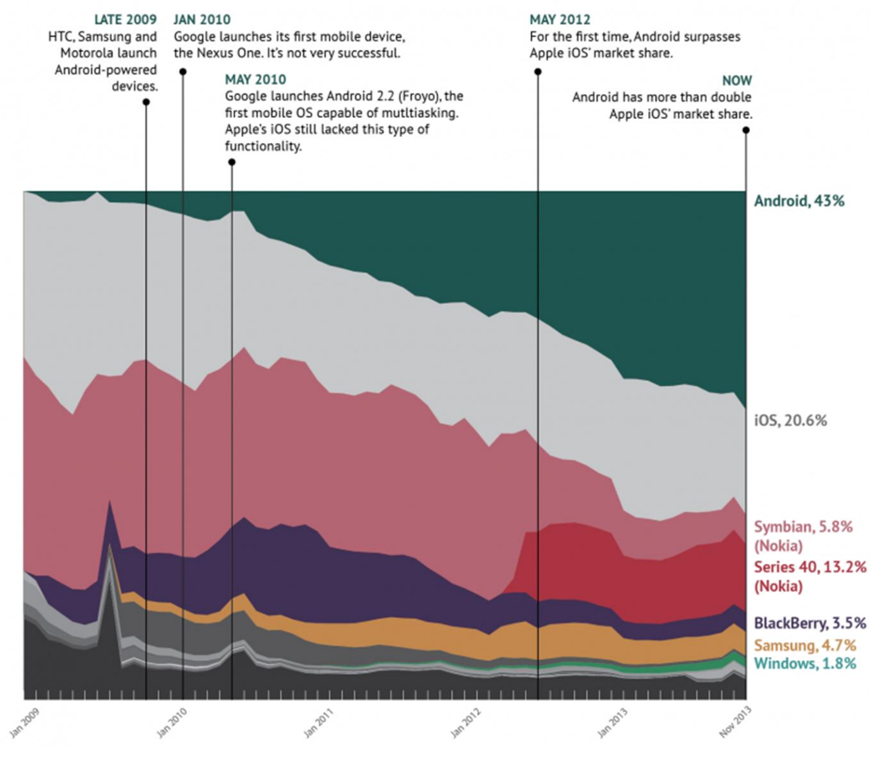


Figure 4 – World Wide Mobile OS Market Share [5]

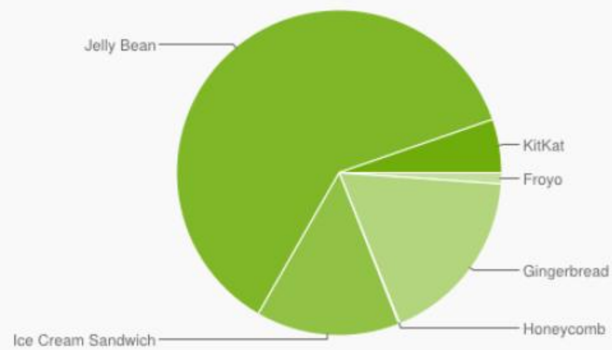
With the Android OS selected as the operating system of choice for development, the next question that arises is which variant or platform version will be targeted for the application development. Platform versions in Android are tracked by API level, and to most they are known by their clever nick-names like Gingerbread, Ice-Cream Sandwich or Kit-Kat. Google has made a pattern out of naming their new platform versions after desserts or snacks in alphabetical order. Table 1 contains a list of the current API levels, Android version numbers and platform code names from version 1.0 or "Base" to their latest version Android 4.4 / API 19 or "Kit Kat". API levels are analogous to the different versions of Windows operating system like XP, Vista, Windows 7 or Windows 8. Each new API brings in various software and hardware support updates like the ability to support a GPS module or the ability to support multi-point touch screen displays.

Table 1 - List of Android API Levels and Corresponding Code Names [6]

Platform Version	API Level	VERSION_CODE
Android 4.4	19	KITKAT
Android 4.3	18	JELLY_BEAN_MR2
Android 4.2, 4.2.2	17	JELLY_BEAN_MR1
Android 4.1, 4.1.1	16	JELLY_BEAN
Android 4.0.3, 4.0.4	15	ICE_CREAM_SANDWICH_MR1
Android 4.0, 4.0.1, 4.0.2	14	ICE_CREAM_SANDWICH
Android 3.2	13	HONEYCOMB_MR2
Android 3.1.x	12	HONEYCOMB_MR1
Android 3.0.x	11	HONEYCOMB
Android 2.3.4 Android 2.3.3	10	GINGERBREAD_MR1
Android 2.3.2 Android 2.3.1 Android 2.3	9	GINGERBREAD
Android 2.2.x	8	FROYO
Android 2.1.x	7	ECLAIR_MR1
Android 2.0.1	6	ECLAIR_0_1
Android 2.0	5	ECLAIR
Android 1.6	4	DONUT
Android 1.5	3	CUPCAKE
Android 1.1	2	BASE_1_1
Android 1.0	1	BASE

Android applications designed for and that utilize features available only in later versions of Android will not be capable of running on earlier version or API levels of the operating system. Therefore the selection of a platform will mean that all devices running an older version of Android will be incompatible, reducing the number of devices capable of running the application. Since our application will require Bluetooth functionality we can eliminate any platform versions that did not support Bluetooth. The Bluetooth Adapter Class [7] was first incorporated into Android 2.0, API level 5 AKA Eclair, which sets the minimum API level that will be able to support our needs. Additionally Android publishes statistics on a monthly basis that tells us the relative number of devices that run a given platform version [8].

Version	Codename	API	Distribution
2.2	Froyo	8	1.1%
2.3.3 - 2.3.7	Gingerbread	10	17.8%
3.2	Honeycomb	13	0.1%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	14.3%
4.1.x	Jelly Bean	16	34.4%
4.2.x		17	18.1%
4.3		18	8.9%
4.4	KitKat	19	5.3%



Data collected during a 7-day period ending on April 1, 2014.
Any versions with less than 0.1% distribution are not shown.

Figure 5 - Relative Number of Devices by Platform Number / API level / Code Name [8]

Based on Figure 5 as of April 2014 approximately 81% of Android devices run Android 4.0 (API 15) or later. Since we want to maintain a similar user experience and style to what the majority of users are currently used to experiencing, and selecting an older android version as the target version may make the application appear older and outdated compared to newer applications Android 4.0 (API15) "Ice Cream Sandwich" will be selected as the target Android platform. Ultimately this means that the application developed will not be capable of running on 19% of Android devices currently in use, however this number will continue to decrease as these devices older are phased out and users upgrade to newer devices.

With a target mobile operating system selected the next choice is selecting a mobile device that utilizes the selected operating system. Fortunately I currently own two mobile device that uses the Android operating system, a cellphone and a tablet. Both devices run Android Ice Cream Sandwich or later operating systems, and while the tablet may boast higher performance / processing power I have selected the cell phone Figure 6 as the test platform. The reason for this selection was due to the form factor of the device, the 10” tablet was difficult to hold with two hands and still use my thumbs to control the device, however the smaller 5” cell phone fit nicely within my hands similar to a game controller or an R/C car controller. Additionally a 7” or 8” tablet would also likely work just as well, and ultimately it’s a matter of personal taste.

Figure 6 – Mobile Platform, Samsung Galaxy Note II Running Android 4.3 Ice Cream Sandwich

2.1.2 Selecting a Microcontroller and Robotic Platform

The robotic platform could take many forms for one to demonstrate control of it. It could be as simple as just a microcontroller with an output to a monitor / terminal showing the change in variables being controlled. However this method of implementation would not provide a good feel for the speed and responsiveness of the control of the robot. To better perceive / judge these qualities I decided it would be best to implement a robotic platform capable of movement. This would provide a platform that could be compared to the responsiveness found and expected by users of existing “Radio” controlled robotic platforms. I selected the ActivityBot Robot Kit, Figure 7 (as shown with optional Propeller Activity Board Attached) manufactured by Parallax. The ActivityBot Kit provides a platform that is capable of movement as provided by the two wheels connected directly to continuous rotation servos. Since it only has two wheels a third sliding post is provided for stability. It also changes direction using skid steering, that is to turn left the right wheel must be rotating faster than the left wheel. It is also capable of turning in place by rotating the wheels in opposite directions. Additionally the

ActivityBot is compatible with a number of microcontroller boards produced by Parallax.

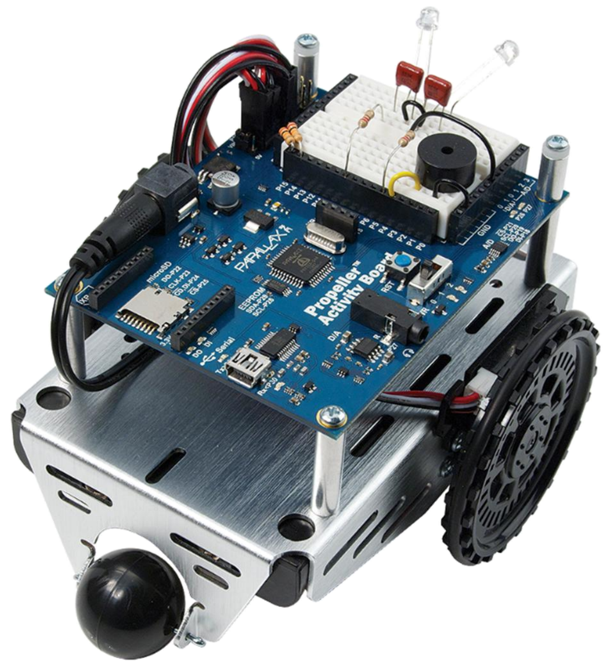


Figure 7 - ActivityBot Robot Kit [9]

When selecting a microcontroller for this project I considered a number of factors to help make my decision. Factors considered included startup cost, open source IDE, compatibility with existing add-ons / robotic platforms, the availability of documentation and the architecture / processing power of the microcontroller. I found that there were two microcontroller platforms at the forefront of the hobby / armature robotics community, the Arduino platform and the Parallax Propeller platform. Both platforms compared equally across many aspects as both offered products with a 32-bit processor, both offer free open source IDE's, both are in the same price range, both offer a large number of add-ons / compatible robotic platforms and both have a large online support community. I did however find two differences that for my application were the deciding factor in selecting the Propeller Activity Board from Parallax Figure 8 over a similar board from Arduino. The Propeller microcontroller has a unique architecture unlike many others including the Arduino, while most contain a single processor or cog the Propeller contains 8 independent 32-bit processors.

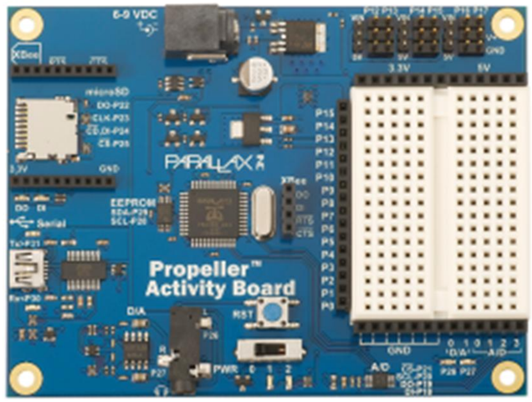


Figure 8 - Propeller Activity Board [10]

This allows for a consolidated package that can perform multiple time sensitive tasks without issues or delays. This translates into the ability to constantly monitor the incoming Bluetooth communication channel, while simultaneously updating and sending the time sensitive pulse commands required to control the servo motors driving the platform. To do this with an Arduino a second motor controller board would be required to off load the time sensitive pulse commands from the main microcontroller. The second reason for selecting the Parallax Propeller platform / Propeller Activity Board for this project was a matter of convenience and available documentation / product support. From a compatibility standpoint by selecting a robotic platform and microcontroller both from the same manufacturer, compatibility was guaranteed. Additionally Parallax offered supporting documentation for the use of the Propeller Activity Board with the ActivityBot which can be found on the product's web page [9].

The same methodology of selecting components from the same vendor, Parallax in this case, was also leveraged when selecting a Bluetooth adapter for use on the project. The RN-42 Bluetooth adapter Figure 9 manufactured by Parallax [11] provided Bluetooth 2.1/2.0/1.2/1.1 communication support to the project. The RN-42 Bluetooth adapter provides a standard pin breakout connector which can easily be connected to the breadboard on the Parallax Activity Board and wired to its I/O pins. Additionally it can be set to operate off of and controlled by 3.3V which aligns with the 3.3V powered Propeller microcontroller.

Figure 9 - RN-42 Bluetooth Adapter [11]

The RN-42 module communicates with the Propeller microcontroller via asynchronous serial interface with RTS/CTS flow control at a user programmed baud rate which was set to 9600 bps for compatibility with the microcontroller. Further support information and examples of use with the Propeller microcontroller can be found on the product's web page [11].

The fully assembled Robotic Platform is shown in Figure 10,

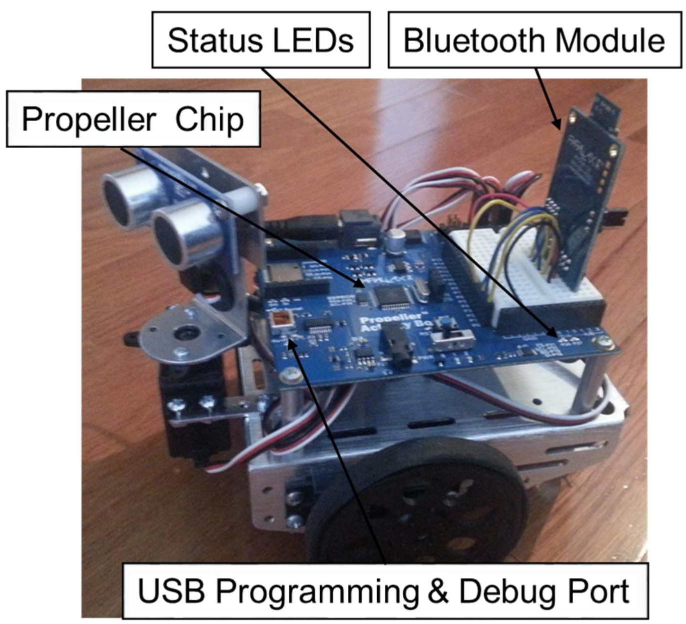


Figure 10 - Assembled Robotic Platform with Bluetooth Adapter

while the system wiring schematic is shown in Figure 11.

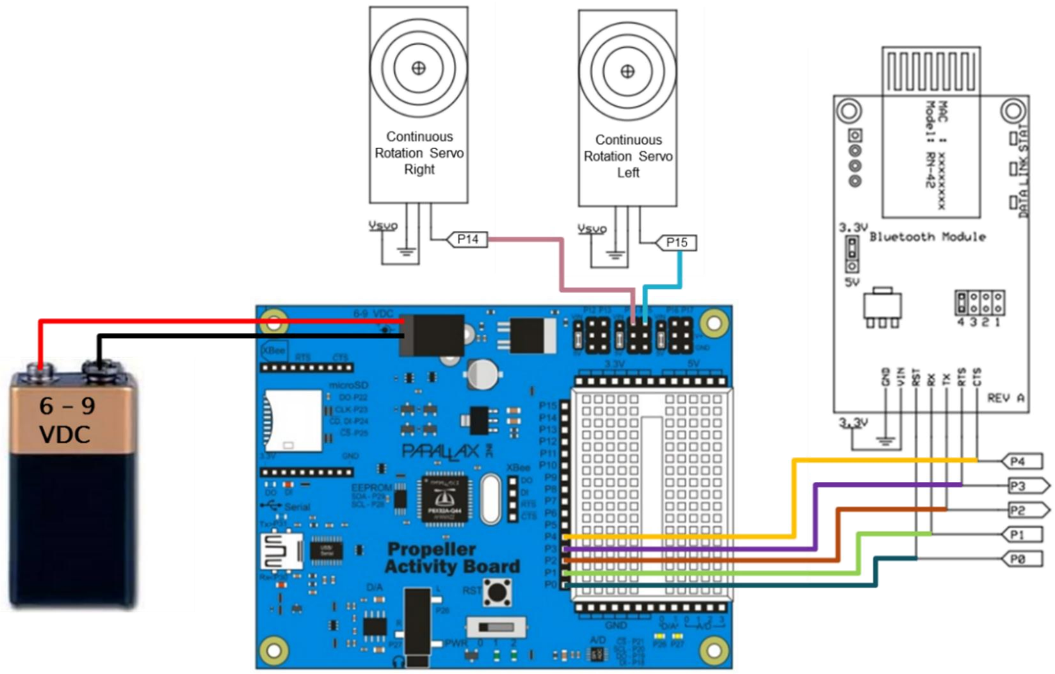


Figure 11 - System Wiring Diagram for the Robotic Platform and Bluetooth Adapter

2.1.3 Setting up the Development Environment, Android & Propeller

Providing a full description of how to download, install, and configure the Android and Propeller development environments is outside the scope of this project. However below is a brief description of the software required as well as links to web pages that will go into full detail on the subject.

Google has a website [12] completely devoted to Android Developers, this site provides developers with free training modules, full library support of the Android APIs (Application Programming Interfaces) and instructions on how to download and install the latest Android development environment also called the Android SDK (Software Development Kit) [13]. The kit includes the Eclipse IDE (Integrated Development Environment) the ADT (Android Developer Tools) plugin and other required items. A full list of system and software requirements is available on the webpage as well. Java is the foundation or base of the Android programming language with specific libraries added for the increased or specific functionality of Android powered devices. The

Android development environment and Eclipse IDE is shown in Figure 12 with a code snippet from the BlueTest3 application.

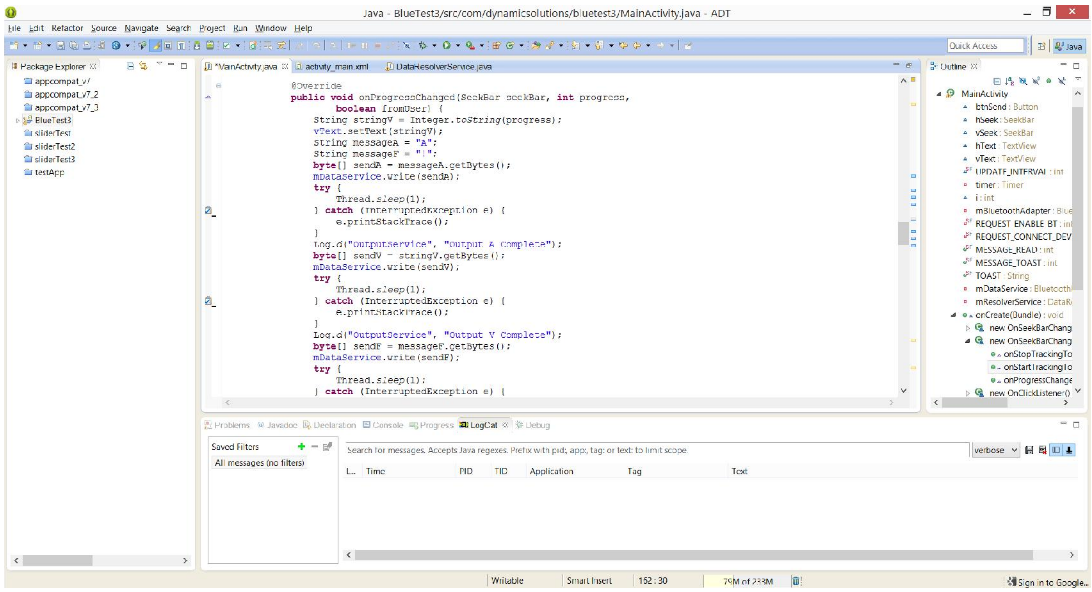


Figure 12 - Android Environment and Eclipse IDE with Code Snippet from BlueTest3 Application

Parallax [14] also provides an abundant amount of support information for the Propeller microcontroller. Additionally the software and drivers required to set up the Propeller development environment can be found on the company's main web page [15]. One downside to the Propeller microcontroller is that the language used to program it, is specific to the microcontroller, and is known as Spin, shown in Figure 13 with a code snippet. However in recent months Parallax has launched a new complier for the Propeller microcontroller that utilizes the C programming language, information about this compiler can also be found on the company's webpage [16]. I have chosen to use the Spin language for this project as at the time of writing this paper there are more support libraries and examples written for the Spin language and compiler than its C based counterparts.

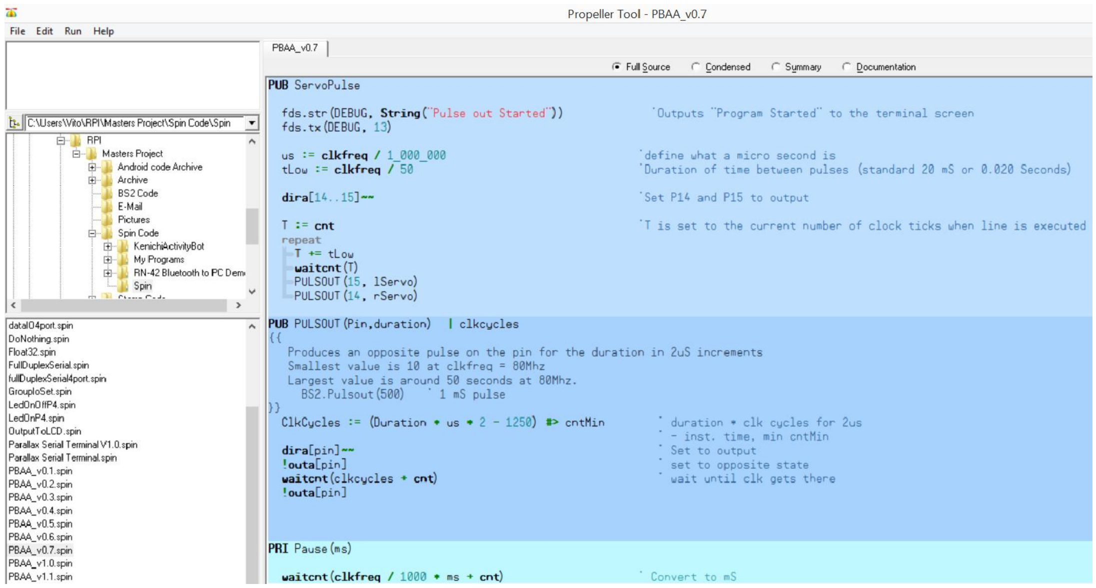


Figure 13 - Spin IDE with Code Snippet from the PBAA_v0.7.spin Program

2.2 Communication Protocol and Control Logic Design

In the next section I will elaborate on the communication protocol designed and created for implementation between the mobile operating system and the robotic platform. Additionally I will describe at a high level, the control logic implemented on both the Android device and the Propeller controlled robotic platform.

2.2.1 Development of a Communication Protocol

In its most basic form the communication protocols purpose is to serve as a common language that can be interpreted by any device design to accept the language and rules of the communication protocol. A device receiving a message per the communication protocol would not care how the message was generated or by what type of device the message was generated from. Additionally, the device generating the message would not care what type of device the message is going to. This is because compatibility between the two devices is guaranteed based on following the rules of the protocol.

To suit the needs of this project while remaining general enough that its implementation could be widely accepted I set out to create as basic a communication protocol as possible. This was in an attempt to make the requirements imposed on devices as basic as possible in order to capture as many devices as possible. The rules of the protocol are as follows:

1. The device should parse all messages and transmit them a single byte of data at a time.
2. The data must be transmitted as 8-bit ASCII (American Standard Code for Information Interchange) characters.
3. The first character must be an Alpha and is the Index that represents the parameter the following data will be relative to.
4. The characters following the index, i.e. the second and so forth bytes must be numeric as the expectation is they will be converted to and stored as a single number. This number can contain up to 10 characters and its numeric value must not exceed 2,147,483,647. This value may be positive or negative.
5. The last character of the message must be an "!" (Exclamation Point). This acts as a stop byte and lets the program know that the message is complete.

An example of a message written to the rules of the communication can be seen in Figure 14. Note that the example message shown "X123!" is displayed in its symbol format per the ASCII code. A conversion chart between the Symbol, Decimal, and Binary formats for the first 128 ASCII characters is included in Appendix 6.1.

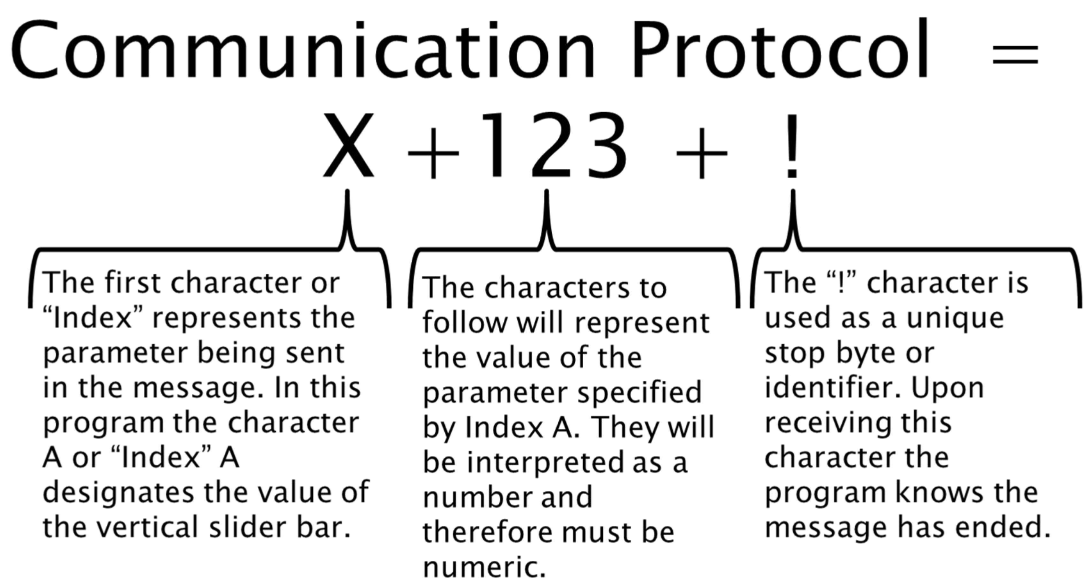


Figure 14 - Example Message per the Communication Protocol

As an example "X123!" broken down and converted to binary format would be displayed as "10110001100011100001100111000 01". This communication protocol establishes the ability to send up to 52 unique parameters (includes upper and lower case alphas) with assigned values up to 10 characters long. The reason for the 10 character 2,147,483,647 numeric value limitation is due to the 32 bit architecture of the Propeller microcontroller. The value 2,147,483,647 which can be represented in binary as "1111111111111111111111111111111" is the largest value that can be stored in a single variable or register of a 32 bit microcontroller.

2.2.2 Implementing and Demonstrating the Communication Protocol

To demonstrate the applicability of the protocol designed, I implemented its use on the communication between a mobile operating system, Android, and a robotic platform, the Parallax ActivityBot over Bluetooth. In the actual implementation of the communication protocol an additional level of detail is required. As noted earlier the first character transmitted in the message represents the Index or parameter of the data being transferred. In practical terms it is a label for the data so that when the data is received the receiving device knows how to handle it. To properly use the index I must establish the index values required and assign them their respective functions. Due to the simple nature of the robotic platform selected all that is needed to control its movement is a value to control its speed and a value for its direction. This will also be true for almost all wheeled robotic platforms. Indexes and their corresponding incarnations on the Android device and ActivityBot are listed in Table 2.

Table 2 - Correlation between Index, its Meaning on the Android Device and the Robot

Index	Android Correlation	Robotic Platform Correlation
A	Vertical Slider Position	Speed
B	Horizontal Slider Position	Direction

Furthermore, to properly implement the communication protocol, limits and boundaries of the parameters being transmitted must be defined and correlated in terms of numeric value, their physical appearance on the user interface and their expected effect on the robotic platform. Table 3 contains the numeric value boundaries and their correlation to the Android application and the Robotic platform. Note that the values are to a degree arbitrary, as the important item is consistency in their meaning between the Android application and the robot. The values selected and their correlations were chosen based in that they appeared convenient and logical. As shown below in Table 3 the numeric value 100 represent full speed forward on the robotic platform and on the android application it represents the vertical slider in its topmost position. The parameters are arbitrary in the sense that the numeric value 150 representing full speed forward could be implemented with little to no effect on the results.

Table 3 - Correlation between Numerical Value, its Physical Implementation on the Android Application and the Robotic Platform for Parameters A & B

Numeric Value	Parameter A		Parameter B	
	Android Correlation	Robotic Platform Correlation	Android Correlation	Robotic Platform Correlation
100	Slider in topmost position	Full speed forward	Slider in rightmost position	Full turn right
50	Slider in central position	Neutral	Slider in center position	Neutral
0	Slider in bottommost position	Full speed reverse	Slider in leftmost position	Full turn left

Additionally, before we can dive into the implementation of the protocol on the Android and robotic platforms, it is important to create a roadmap or high level system block diagram describing the flow of input form the user to the eventual signals that will be sent to the motors on the robotic platform. The block diagram governing the entire system can be seen in Figure 15. This diagram shows which tasks will be the responsibility of the Android device and which operations the robotic platform will be responsible for. Additional block diagrams showing in greater detail the operations on the individual devices as well as their interaction are included in later sections of this report.

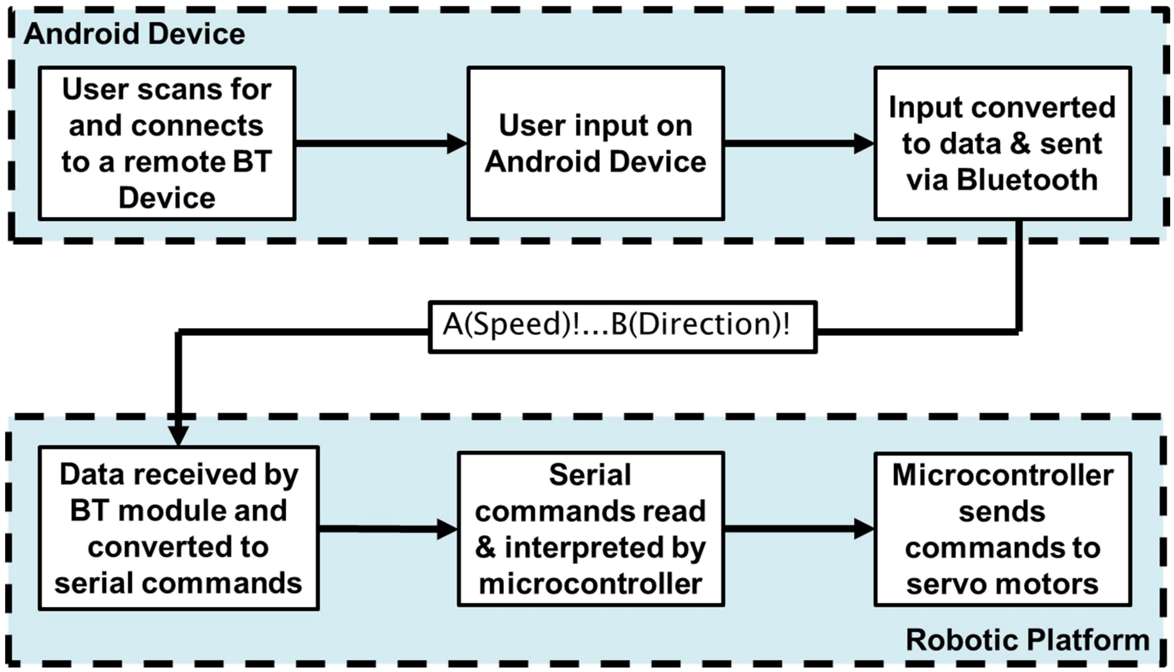


Figure 15 - Level 0 System Block Diagram

2.2.2.1 Implementation of the Communication Protocol on the Android Device

To implement the communication protocol on the Android powered mobile device one must first create an Android application. In addition to the behind the scenes code that runs the Android application, which is responsible for taking the users input and converting it into what will eventually become messages sent via the communication protocol, a large part of the Android application development is the user interface. To create the user interface for controlling a wheeled robotic platform I decided to mimic as closely as possible a standard remote that would be used to control a RC car Figure 16. A vertical scrolling bar will be used to control the speed of the robot, while a similar horizontal scrolling bar will be used to control the direction of the robot.

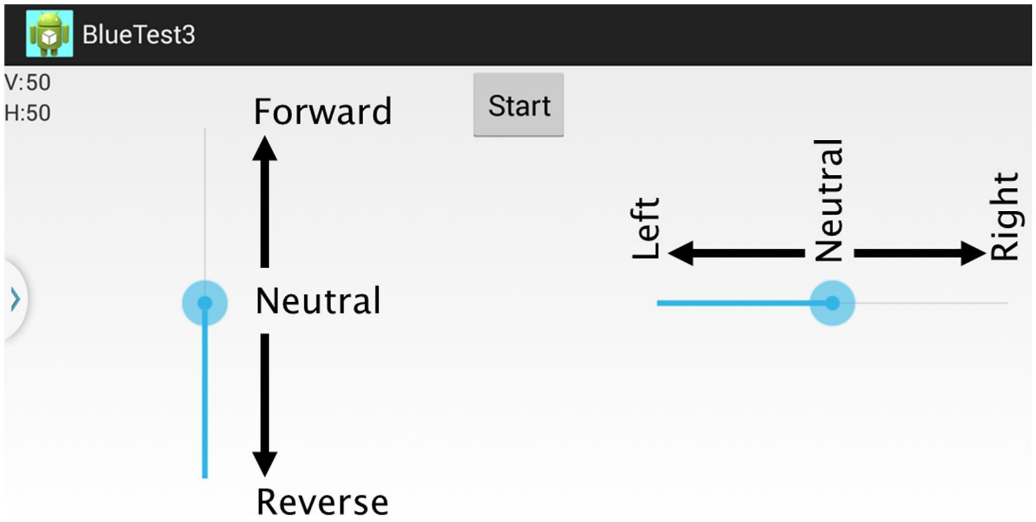


Figure 16 - Android User Interface for Controlling the Robotic Platform

In addition to the controls of the robotic platform the GUI (Graphical User Interface) needs to provide the user with a method to search for and connect to other discoverable Bluetooth enabled devices. This was implemented utilizing the menu button (one of the three standard buttons on all android devices), upon selecting the menu button the user is presented with the option to search for and connect to remote Bluetooth devices. After which the user is presented with the Names and MAC Addresses of devices found. See Appendix 6.2 for screen captures of the various screens a user sees when interacting with the android application. In addition to the movement of the sliding bars, the values of the sliders are displayed in the top left corner of the application, this was done to provide the user with additional visual feedback and helps to verify that the user input is being understood by the Android application, this was also very helpful in the development and debugging of the application. This feature could be removed in a final production version of the application and is not critical to the functionality of the application. Finally, the user interface and its various sub menus and screens is written in the XML language / format. Figure 17 is a Code Snippet of the XML code written to display two text views and a button on the user interface. The XML code used to generate the Android User interface can be found in Appendix 6.3 XML Code for Android User Interface and Context Menus.

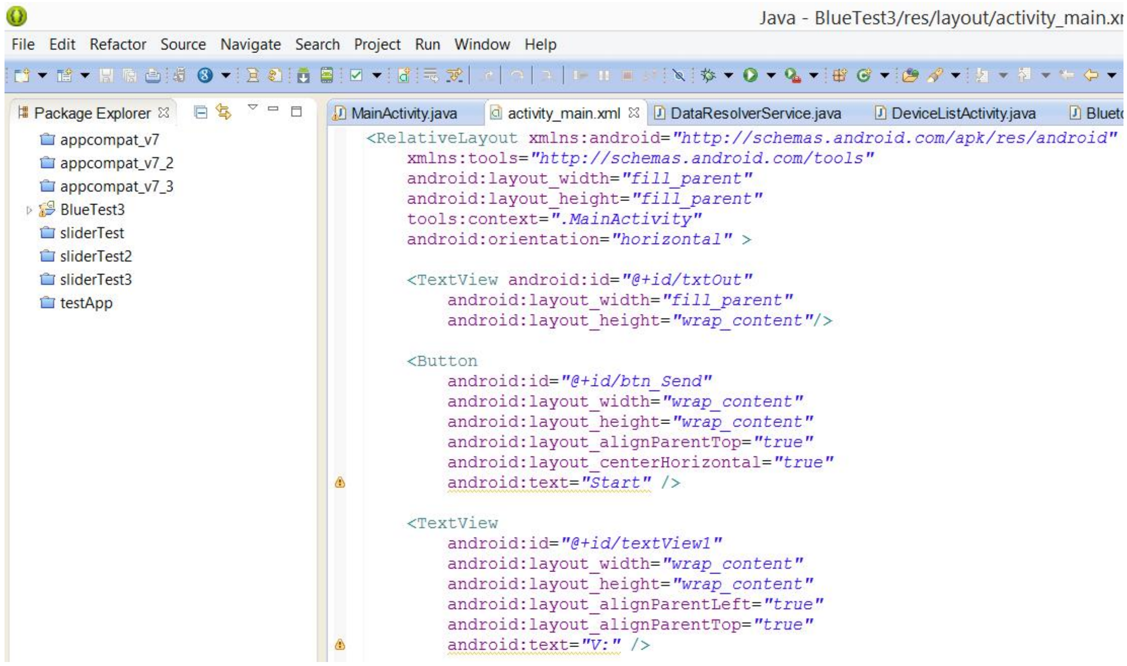


Figure 17 - Android User Interface Code Snippet

In addition to the user Interface the behind the scenes control logic written in Java for the Android application has an even larger role to play. This is where all of the activity takes place to support the user interface, interpret user input, manage the Bluetooth connection / data transmissions, and last but certainly not least to implement mistake proofing features like ensuring the Bluetooth device is enabled before starting the application. Figure 18 is a block diagram that represents the process for connecting to a remote discoverable Bluetooth enabled device from the Android device. Note that the application ensures that Bluetooth is enabled on the mobile device, requesting user input when required or else the application is terminated. Note also that it is possible to write an application that will on its own enable Bluetooth communication without notifying or requesting permission from the user. However this is generally frowned upon by the Android development community as well as most application users as there is an implicit trust among users that one would not have written an application that may harm their device or act in any malicious manner. When applications start to modify the state of the device without first requesting permission that trust can be lost very quickly and is not likely to be regained. Java source code supporting the Android application can be found in Appendix 6.4. Additionally, screen captures of the user interface showing the automated prompts as well as the other screens the user will see during the Bluetooth connection process can be seen in Appendix 6.2 Android Device User Interface Screen Captures.

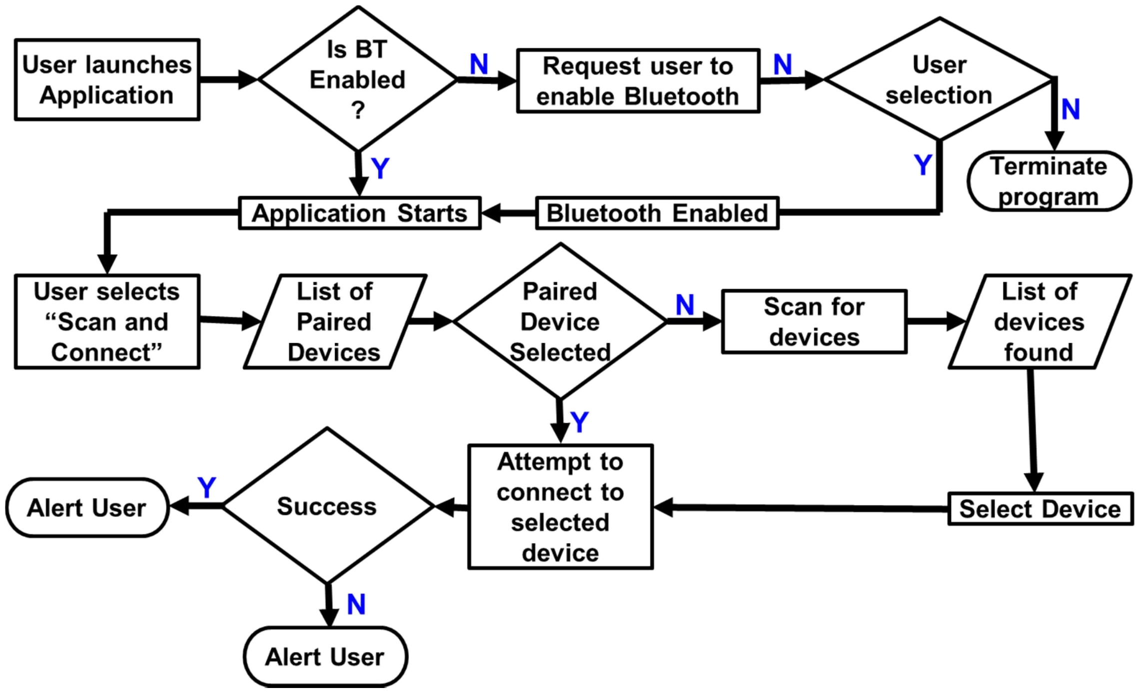


Figure 18 - Level 1 Block Diagram Android Process for Connecting to a Remote Bluetooth Device

In addition to detecting and connecting to a remote Bluetooth device the Android application is also responsible for obtaining the user’s input through the user interface and converting the gestures and motions of the user’s hand on the touch screen into input for controlling the robotic platform. Ultimately, the application takes the user’s input, constructs messages that fit the established communication protocol and then transmits them over the Bluetooth connection. A block diagram of the process implemented can be seen in Figure 19. Note that at this point a successful connection with a remote device has already been established. Also note that this process is repeated as to continuously monitor user input and transfer data to the remote device. It is also worth noting that data transmission is triggered by user input, if user input is not received or remains unchanged over a period of time, data is not transmitted. Keep in mind that this is just one method for implementing the communication protocol, another approach could have been to transmit updated values of the sliders at a fixed time interval independent of whether the input had changed. The Java source code associated with the block diagram from Figure 19 can be found in Appendix 6.3.6. Likewise relevant screen captures of the user interface can be found in Appendix 6.2.

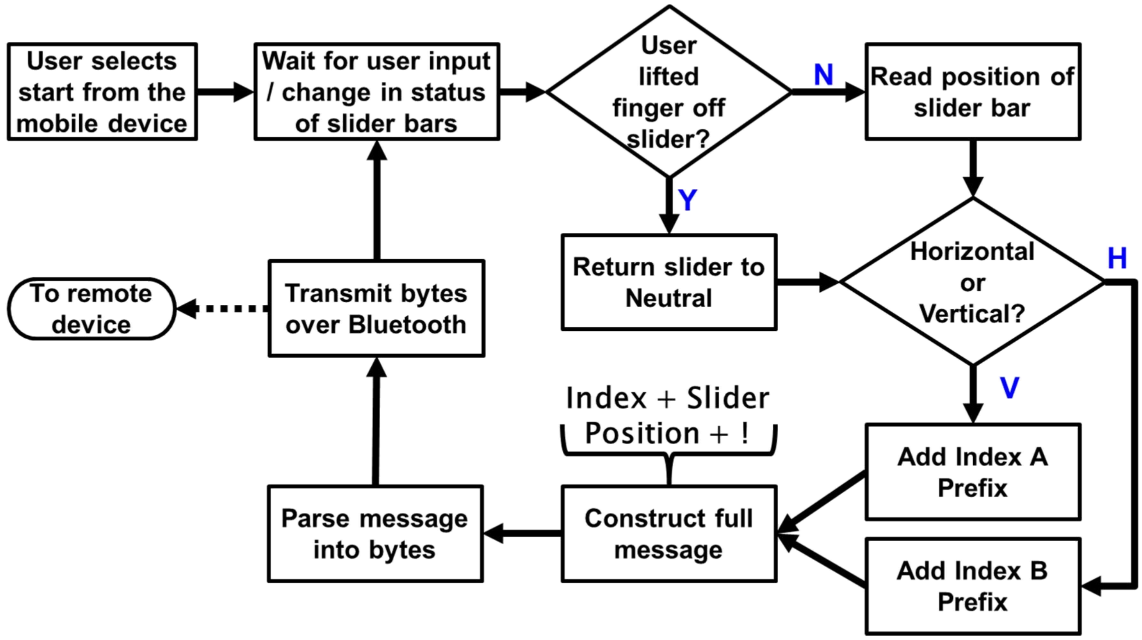


Figure 19 - Level 1 Block Diagram for Reading User Input and Transmitting to a Remote Device

2.2.2.2 Implementation of the Communication Protocol on the Robotic Platform

The task of implementing the communication protocol on the robotic platform and Propeller microcontroller is similar to that of its implementation on the Android device. However, there is one key difference that simplifies to some degree the task on the robotic platform, no user interface is required. While instead of interfacing with a user and obtaining input, the Propeller microcontroller is tasked with reading input per the communication protocol and outputting signals to drive the platforms motors.

To establish communication between the Bluetooth module and the Propeller microcontroller as well as setting the module in the correct mode for accepting connection attempts, the module must first be configured. This is done via the asynchronous serial interface with RTS/CTS flow control which can be established between the Propeller and the Bluetooth module. Supporting documentation and the products user manual go into sufficient detail on how to set up and configure the Bluetooth module based on the desired application, both are available on the product's webpage [11]. Additionally the Propeller .Spin code used to configure and then verify the state of the Bluetooth adapter can be found in Appendix sections 6.5.1 and 6.5.2.

The task of implementing the communication protocol on the ActivityBot robotic platform utilizes the multiple cores of the Propeller microcontroller. Since the communication protocol does not specify when or how frequent data will be transmitted and received, the robotic platform must be ready and capable of receiving a message at any time. For example on a single processor microcontroller, if a message was received while the microcontroller was processing a piece of data that was received earlier or outputting a pulse command to one of the servo motors the incoming message could be missed. However, since the Propeller microcontroller is capable of preforming multiple tasks simultaneously by utilizing its 8 processors or cogs, it can have one processor that is solely devoted to listening for incoming data, helping to ensure a message is not missed. This can be done while other cogs work to interpret the data received and generate the pulse commands require to run the platforms motors.

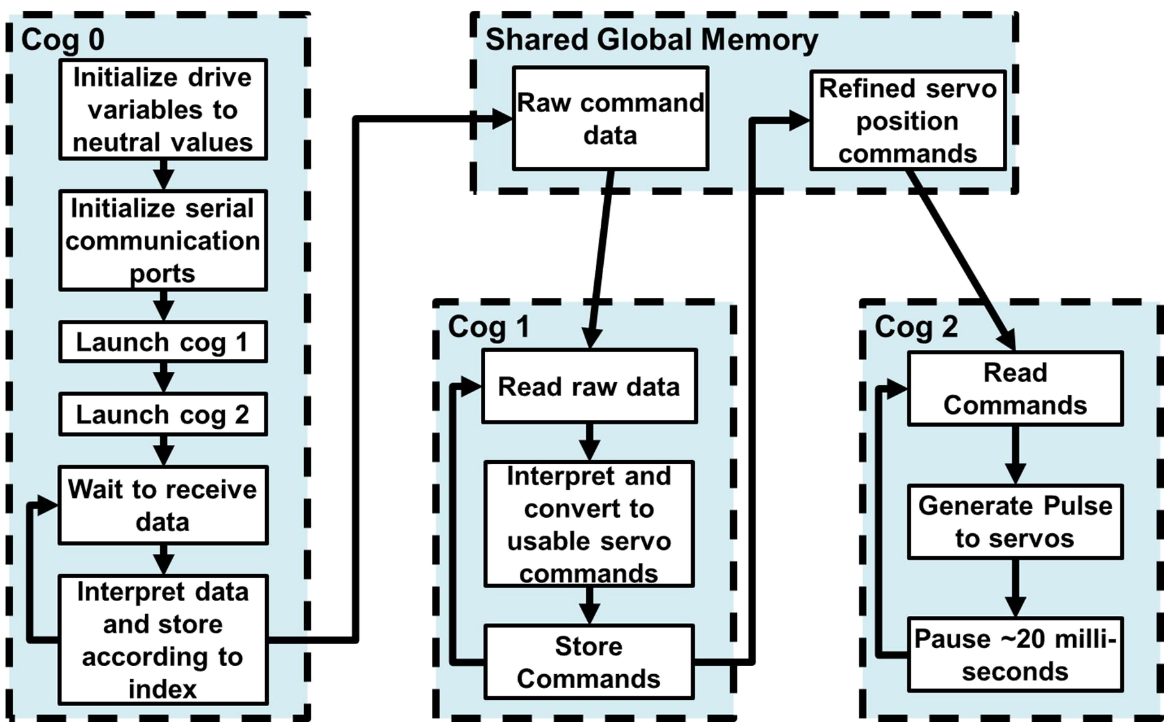


Figure 20 - Level 1 Block Diagram of the Propeller Microcontroller and the Interaction between Cogs

A block diagram of the processes executed on each cog as well as the interaction between cogs and the shared global memory can be seen in Figure 20. Additionally the

.Spin source code implemented on the Propeller microcontroller can be found in Appendix 6.5.3 with supporting libraries in appendix sections 6.5.4 and 6.5.5.

3. RESULTS AND DISCUSSION

To determine if the attempt to create and implement a communication protocol between a mobile device and a robotic platform was successful I determined it was best to implement the device on physical hardware. This would provide means of comparison between existing radio controlled robotic platforms, even something as simple as an RC car would serve as an acceptable analog for comparison.

Along the way I uncovered several unforeseen challenges that did create good learning opportunities, some directly relevant to my work and others not as much. One such example was the use of the Easy Bluetooth Module which was offered by Parallax for some period of time. The most notable difference between the Easy Bluetooth Module and the RN-42 Bluetooth Adapter was the lack of RTS/CTS flow control for the asynchronous serial interface between the Bluetooth module and the microcontroller. While initially I did not believe this would be an issue, I was unable to write an application that was able to maintain a good connection. The adapter and the Propeller were constantly getting out of sync causing slow transfer rates and data loss. This issue was especially challenging to debug as it was difficult to determine if the issue was with the data being transmitted over Bluetooth or if it was the sync between the module and the Propeller. However, I am now confident that the lack of flow control was the source of the problem as all sync issues were resolved with the implementation of the RN-42 module with no major changes to the structure of the Propeller code. It is also worth noting that the Easy Bluetooth module is now discontinued, however Parallax does still offer support for the product on their web page.

As an additional means for measuring success I set a bench mark for the minimum number of data transfers or parameter updates that needed to be able to occur per second. This was in an attempt to quantify the responsiveness of the platform and the implementation of the communication protocol. Additionally, it would help flush out if the protocol had any inherent attributes that were not conducive to rapid data transfer. I initially had set out to show that the given parameters could be updated 4 times per second, this should ensure that the robotic platform would be responsive and react to user input without a significant visual delay. With some simple testing I observed that the configuration was capable of preforming over 20 updates per second. The capability for this high refresh rate meant that the robotic platform would be able to react to the users input with virtually no visual delay, on par with existing R/C solutions and products currently on the market.

A video of the application and robotic platform in action has been uploaded to You Tube [16].

4. CONCLUSIONS

The intent of this project was to demonstrate the possibility to create a communication protocol that could be implemented over Bluetooth between a mobile device and a robotic platform. The intent being that if the robotic platform was designed to receive messages per the protocol, it could be implemented without creating a unique application on the mobile device for each robotic platform.

I have shown in my creation of an Android application that outputs messages per the communication protocol and development of a robotic platform that accepts messages per the communication protocol and response with the appropriate actions that it is possible to implement such a communication protocol. However, there is still further work to be done, as I have thus far only defined two parameters in the communication protocol, speed and direction or A and B. While these two parameters are sufficient for a simple two wheeled robot they would not be sufficient for control of say a helicopter which would require at least 4 parameters for control over roll, pitch, yaw, and elevation. I can envision a protocol that takes advantage of the full 52 upper and lower case characters for all sorts of different parameters and for all sorts of different robotic platforms. Additionally, the protocol can also be utilized to transmit data from the robotic platform back to the Android application possible using upper versus lower case letters to distinguish the difference of in the direction of flow of the data.

5. REFERENCES

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[3] Parallax RN-42 Bluetooth to PC demo

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[4] MicroTronics Technologies Mobile Controlled Robot

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[6] Android platform names, API levels, and Code names

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http://developer.android.com/reference/android/bluetooth/BluetoothAdapter.html

[8] Relative number of devices running a given Android version or API level

http://developer.android.com/about/dashboards/index.html

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[10] Propeller Activity Board Manufactured by Parallax

http://www.parallax.com/product/32910

[11] RN-42 Bluetooth Adapter manufactured by parallax

http://www.parallax.com/product/30086

[12] Android Developers Website

http://developer.android.com/index.html

[13] Android SDK download link

http://developer.android.com/sdk/index.html

[14] Parallax Main Webpage

http://www.parallax.com/

[15] Propeller software and driver download

http://www.parallax.com/downloads/propeller-tool-software

[16] You Tube video of application and robotic platform in action

http://youtu.be/ytDogEmw2ZQ

6. APPENDICES

6.1 Table of the first 128 Characters of the ASCII Code

Table 4 - First 128 Characters of the ASCII code

Decimal	BIN	Symbol	Description	Decimal	BIN	Symbol	Description
0	0	NUL	Null char	64	1000000	@	At symbol
1	1	SOH	Start of Heading	65	1000001	A	Uppercase A
2	10	STX	Start of Text	66	1000010	B	Uppercase B
3	11	ETX	End of Text	67	1000011	C	Uppercase C
4	100	EOT	End of Transmission	68	1000100	D	Uppercase D
5	101	ENQ	Enquiry	69	1000101	E	Uppercase E
6	110	ACK	Acknowledgment	70	1000110	F	Uppercase F
7	111	BEL	Bell	71	1000111	G	Uppercase G
8	1000	BS	Back Space	72	1001000	H	Uppercase H
9	1001	HT	Horizontal Tab	73	1001001	I	Uppercase I
10	1010	LF	Line Feed	74	1001010	J	Uppercase J
11	1011	VT	Vertical Tab	75	1001011	K	Uppercase K
12	1100	FF	Form Feed	76	1001100	L	Uppercase L
13	1101	CR	Carriage Return	77	1001101	M	Uppercase M
14	1110	SO	Shift Out / X-On	78	1001110	N	Uppercase N
15	1111	SI	Shift In / X-Off	79	1001111	O	Uppercase O
16	10000	DLE	Data Line Escape	80	1010000	P	Uppercase P
17	10001	DC1	Device Control 1 (oft. XON)	81	1010001	Q	Uppercase Q
18	10010	DC2	Device Control 2	82	1010010	R	Uppercase R
19	10011	DC3	Device Control 3 (oft. XOFF)	83	1010011	S	Uppercase S
20	10100	DC4	Device Control 4	84	1010100	T	Uppercase T
21	10101	NAK	Negative Acknowledgement	85	1010101	U	Uppercase U
22	10110	SYN	Synchronous Idle	86	1010110	V	Uppercase V
23	10111	ETB	End of Transmit Block	87	1010111	W	Uppercase W
24	11000	CAN	Cancel	88	1011000	X	Uppercase X
25	11001	EM	End of Medium	89	1011001	Y	Uppercase Y
26	11010	SUB	Substitute	90	1011010	Z	Uppercase Z
27	11011	ESC	Escape	91	1011011	[	Opening bracket
28	11100	FS	File Separator	92	1011100	\	Backslash
29	11101	GS	Group Separator	93	1011101	]	Closing bracket
30	11110	RS	Record Separator	94	1011110	^	Caret - circumflex
31	11111	US	Unit Separator	95	1011111	_	Underscore
32	100000		Space	96	1100000	`	Grave accent
33	100001	!	Exclamation mark	97	1100001	a	Lowercase a
34	100010	"	Double quotes (or speech marks)	98	1100010	b	Lowercase b
35	100011	#	Number	99	1100011	c	Lowercase c

36	100100	$	Dollar	100	1100100	d	Lowercase d
37	100101	%	Percent	101	1100101	e	Lowercase e
38	100110	&	Ampersand	102	1100110	f	Lowercase f
39	100111	'	Single quote	103	1100111	g	Lowercase g
40	101000	(	Open parenthesis (or open bracket)	104	1101000	h	Lowercase h
41	101001	)	Close parenthesis (or close bracket)	105	1101001	i	Lowercase i
42	101010	*	Asterisk	106	1101010	j	Lowercase j
43	101011	+	Plus	107	1101011	k	Lowercase k
44	101100	,	Comma	108	1101100	l	Lowercase l
45	101101	-	Hyphen	109	1101101	m	Lowercase m
46	101110	.	Period, dot or full stop	110	1101110	n	Lowercase n
47	101111	/	Slash or divide	111	1101111	o	Lowercase o
48	110000	0	Zero	112	1110000	p	Lowercase p
49	110001	1	One	113	1110001	q	Lowercase q
50	110010	2	Two	114	1110010	r	Lowercase r
51	110011	3	Three	115	1110011	s	Lowercase s
52	110100	4	Four	116	1110100	t	Lowercase t
53	110101	5	Five	117	1110101	u	Lowercase u
54	110110	6	Six	118	1110110	v	Lowercase v
55	110111	7	Seven	119	1110111	w	Lowercase w
56	111000	8	Eight	120	1111000	x	Lowercase x
57	111001	9	Nine	121	1111001	y	Lowercase y
58	111010	:	Colon	122	1111010	z	Lowercase z
59	111011	;	Semicolon	123	1111011	{	Opening brace
60	111100	<	Less than (or open angled bracket)	124	1111100	|	Vertical bar
61	111101	=	Equals	125	1111101	}	Closing brace
62	111110	>	Greater than (or close angled bracket)	126	1111110	~	Equivalency sign - tilde
63	111111	?	Question mark	127	1111111		Delete

6.2 Android Device User Interface Screen Captures

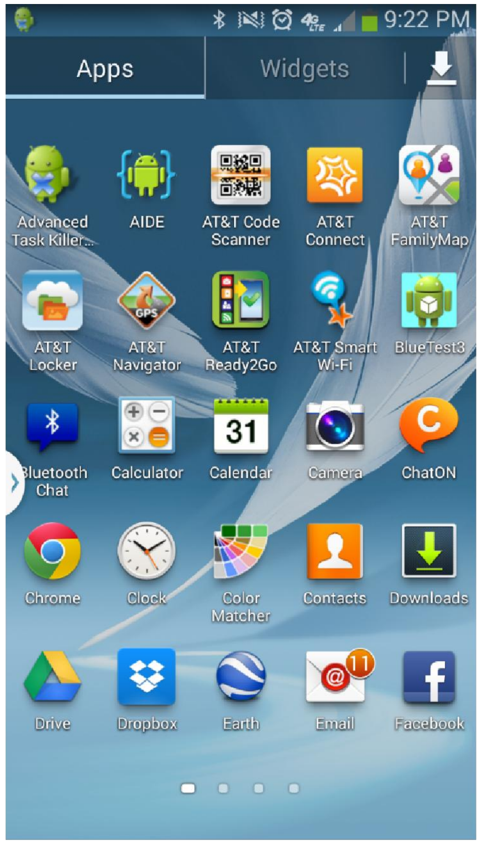

Figure 21 - BlueTest 3 Application Launched from the Application Menu

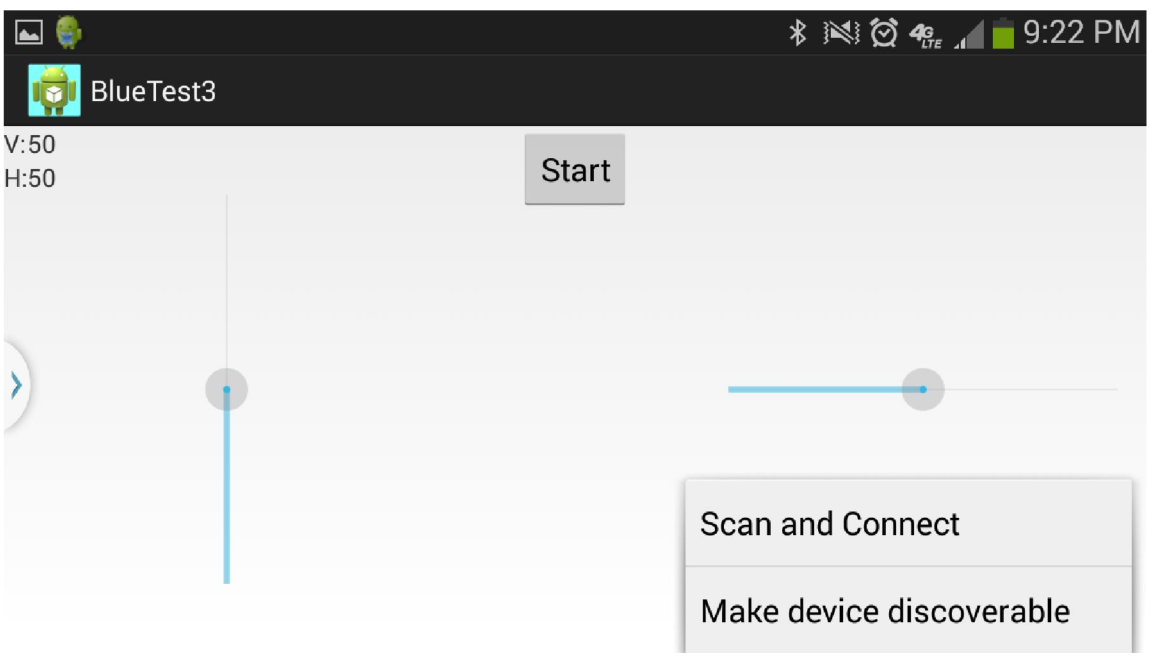

Figure 22 - User Menu within the Application

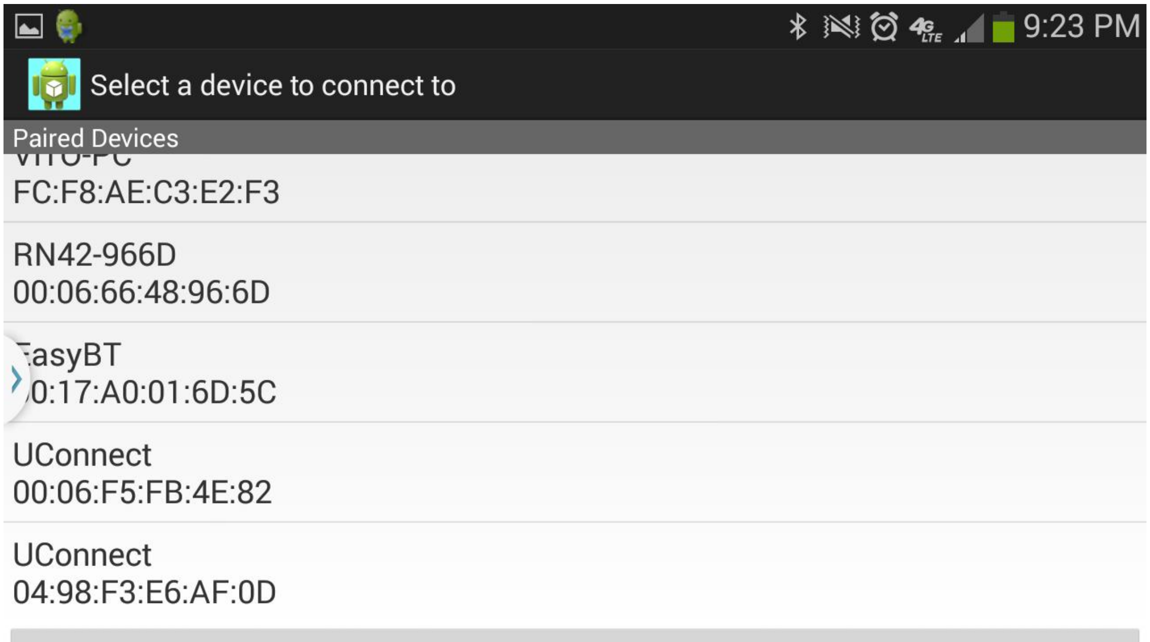

Figure 23 - List of Bluetooth Devices Found for Pairing

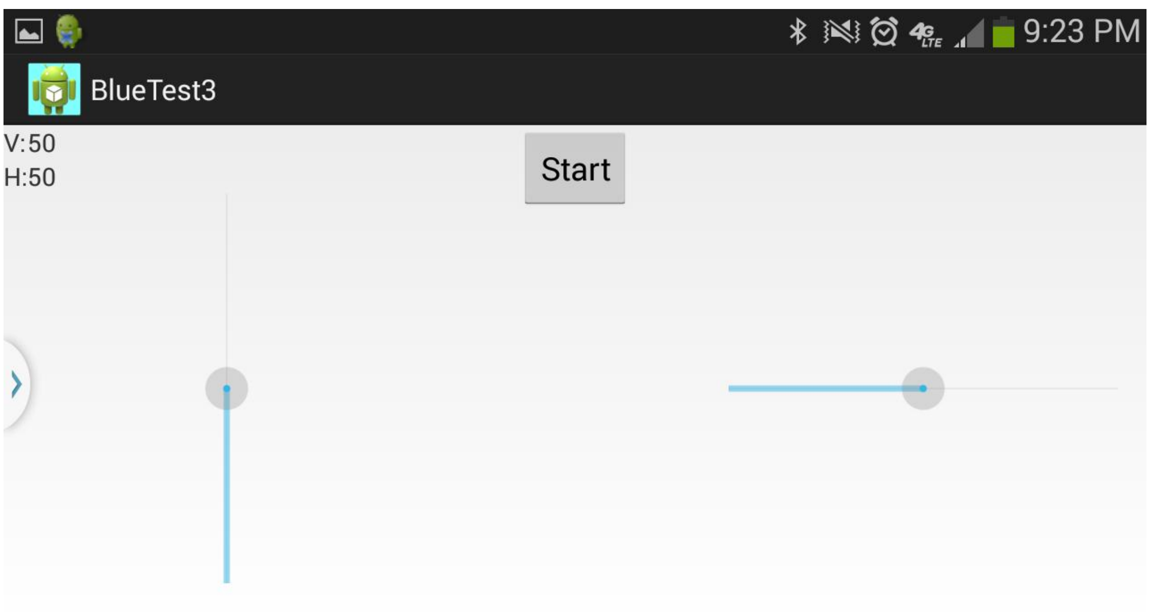

Figure 24 - Screen Prior to Selecting Start, Slider Bars Disabled

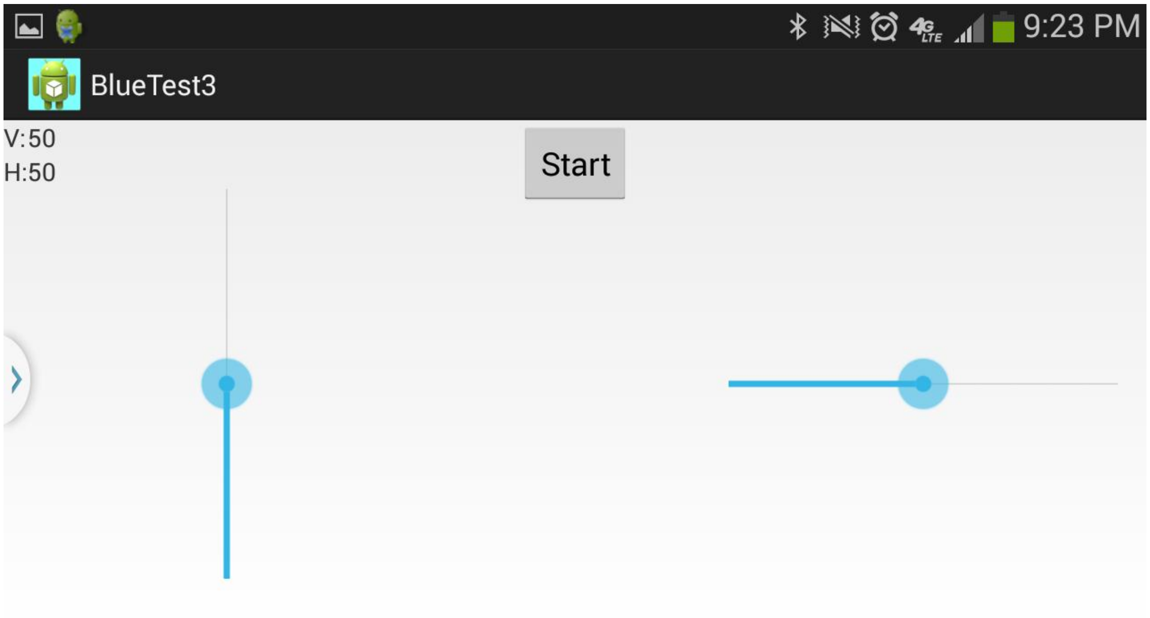

Figure 25 - Screen after Selecting Start, Slider Bars Enabled

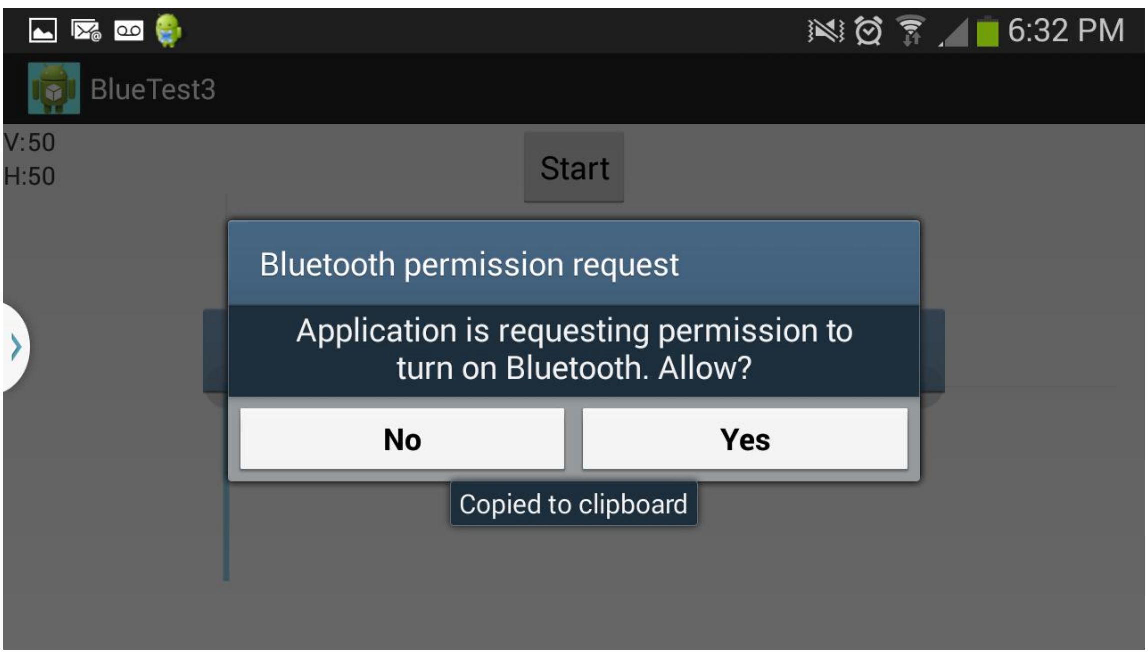

Figure 26 - Screen Requesting the User to Enable Bluetooth on the Device

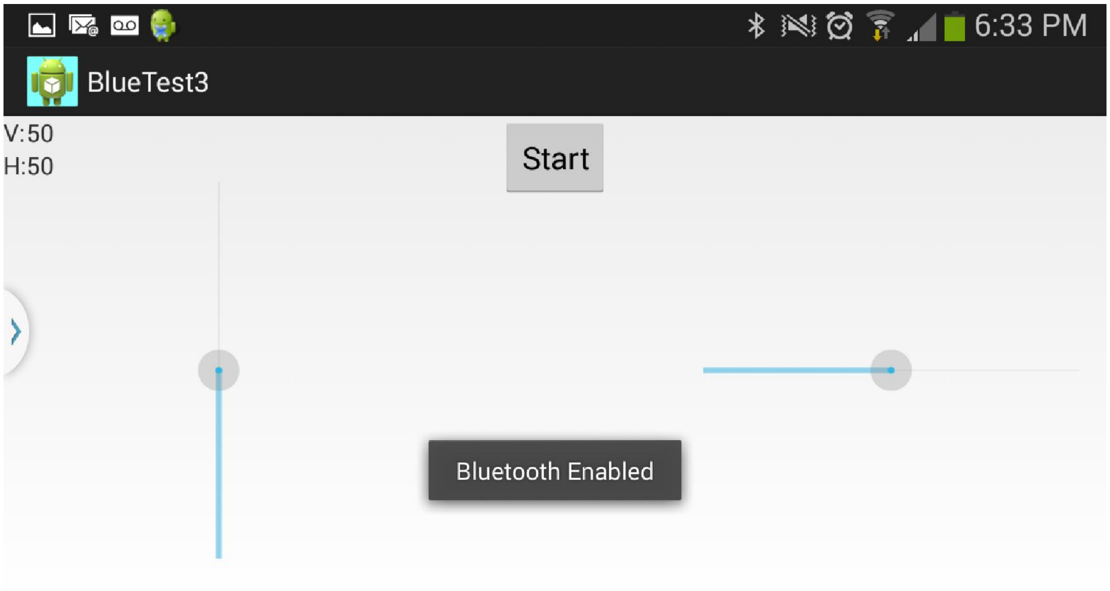

Figure 27 - Alerting the User of Successfully Enabling Bluetooth

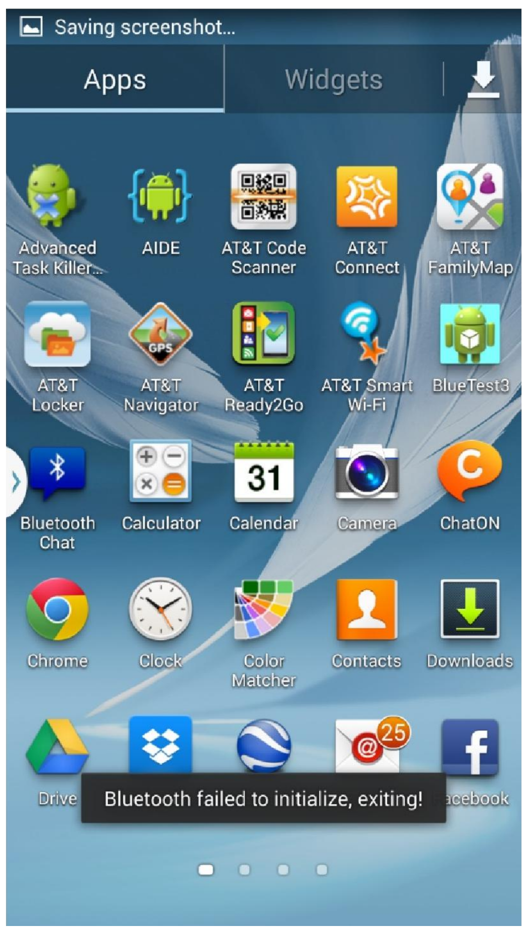

Figure 28 - Alerting the User, Bluetooth Failed to Initialize

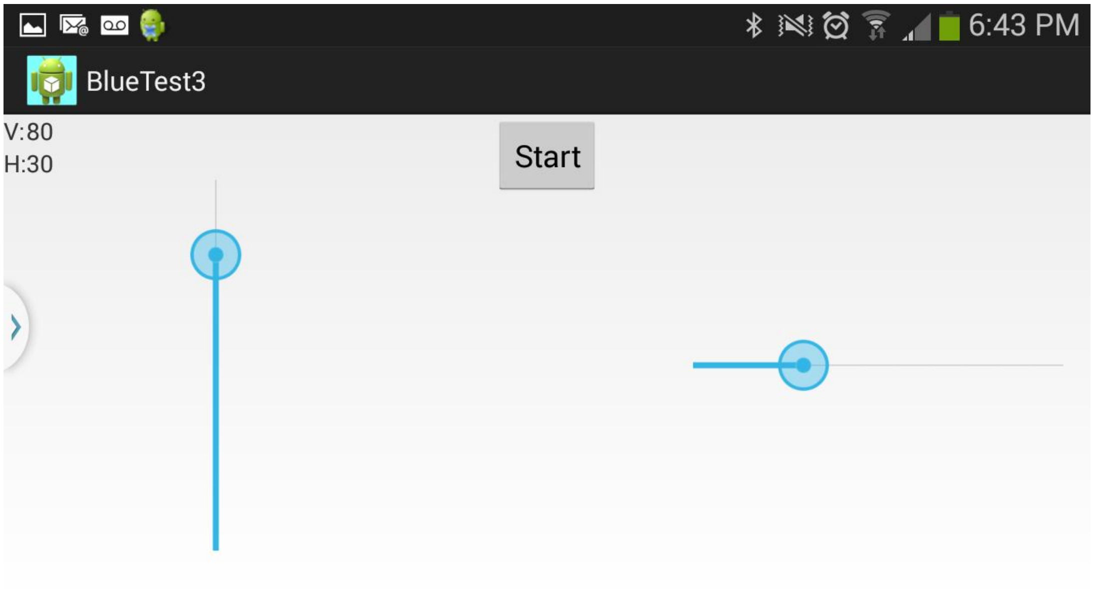

Figure 29 - Example of User Input

6.3 XML Code for Android User Interface and Context Menus

6.3.1 Main User Interface XML Code

```
<RelativeLayout
xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    tools:context=".MainActivity"
    android:orientation="horizontal" >

      <TextView android:id="@+id/txtOut"
      android:layout_width="fill_parent"
      android:layout_height="wrap_content"/>

      <Button
          android:id="@+id/btn_Send"
          android:layout_width="wrap_content"
          android:layout_height="wrap_content"
          android:layout_alignParentTop="true"
          android:layout_centerHorizontal="true"
          android:text="Start" />

    <TextView
        android:id="@+id/textView1"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="true"
        android:layout_alignParentTop="true"
        android:text="V:" />
```

```
    <TextView
        android:id="@+id/textView2"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="true"
        android:layout_below="@+id/txtOut"
        android:text="H:" />

    <TextView
        android:id="@+id/vTextView"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_above="@+id/hTextView"
        android:layout_toRightOf="@+id/textView2"
        android:text="50" />

    <TextView
        android:id="@+id/hTextView"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_alignBaseline="@+id/textView2"
        android:layout_alignBottom="@+id/textView2"
        android:layout_alignLeft="@+id/vTextView"
        android:text="50" />

    <SeekBar
        android:id="@+id/vSeekBar1"
        android:layout_width="250dip"
        android:layout_height="wrap_content"
        android:layout_alignParentLeft="true"
        android:layout_centerVertical="true"
        android:rotation="270" />

    <SeekBar
        android:id="@+id/hSeekBar1"
        android:layout_width="250dip"
        android:layout_height="wrap_content"
        android:layout_alignParentRight="true"
        android:layout_alignTop="@+id/vSeekBar1" />
```

6.3.2 Discovered and Connected Bluetooth Device List

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    android:orientation="vertical" >

    <TextView android:id="@+id/title_paired_devices"
        android:layout_width="match_parent"
        android:layout_height="wrap_content"
        android:text="@string/title_paired_devices"
        android:visibility="gone"
        android:background="#666"
        android:textColor="#fff"
```

```
        android:paddingLeft="5dip" />

    <ListView android:id="@+id/paired_devices_list"
         android:layout_width="match_parent"
         android:layout_height="wrap_content"
         android:stackFromBottom="true"
         android:layout_weight="1"/>

    <TextView android:id="@+id/title_new_devices"
        android:layout_width="match_parent"
        android:layout_height="wrap_content"
        android:text="@string/title_new_devices"
        android:visibility="gone"
        android:background="#666"
        android:textColor="#fff"
        android:paddingLeft="5dip" />

    <ListView android:id="@+id/new_device_list"
        android:layout_width="match_parent"
        android:layout_height="wrap_content"
        android:stackFromBottom="true"
        android:layout_weight="1" />

    <Button android:id="@+id/btn_scan"
        android:layout_width="match_parent"
        android:layout_height="wrap_content"
        android:text="@string/btn_scan" />


</LinearLayout>
```

6.3.3 Display Format of Device Names

```
<?xml version="1.0" encoding="utf-8"?>
<TextView xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="match_parent"
    android:layout_height="wrap_content"
    android:textSize="18sp"
    android:padding="5dip" />
```

6.3.4 XML Code for Options Menu

```
<?xml version="1.0" encoding="utf-8"?>
<menu xmlns:android="http://schemas.android.com/apk/res/android" >
    <item android:id="@+id/scan_and_connect"
          android:icon="@android:drawable/ic_menu_search"
          android:title="@string/scan_and_connect" />
    <item android:id="@+id/discoverable"
          android:icon="@android:drawable/ic_menu_mylocation"
          android:title="@string/discoverable"/>
</menu> <?xml version="1.0" encoding="utf-8"?>
<menu xmlns:android="http://schemas.android.com/apk/res/android" >
    <item android:id="@+id/scan_and_connect"
          android:icon="@android:drawable/ic_menu_search"
          android:title="@string/scan_and_connect" />
```

```
    <item android:id="@+id/discoverable"
          android:icon="@android:drawable/ic_menu_mylocation"
          android:title="@string/discoverable"/>
</menu>
```

6.3.5 String Constants Referenced in the User Interface

```
<?xml version="1.0" encoding="utf-8"?>
<resources>

    <string name="app_name">BlueTest3</string>
      <string name="scan_and_connect">Scan and Connect</string>
      <string name="discoverable">Make device discoverable</string>
      <string name="title_paired_devices">Paired Devices</string>
      <string name="title_new_devices">New Devices</string>
      <string name="btn_scan">Scan for Devices</string>
      <string name="scanning">Scanning for devices</string>
      <string name="none_paired">No devices have been paired</string>
      <string name="select_device">Select a device to connect
to</string>
      <string name="none_found">No devices found</string>

</resources>
```

6.3.6 Android Manifest File

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.dynamicsolutions.bluetest3"
    android:versionCode="1"
    android:versionName="1.0" >

    <uses-sdk
        android:minSdkVersion="9"
        android:targetSdkVersion="17" />
    <uses-permission android:name="android.permission.BLUETOOTH"/>
    <uses-permission
android:name="android.permission.BLUETOOTH_ADMIN"/>

    <application
        android:allowBackup="true"
        android:icon="@drawable/ic_launcher"
        android:label="@string/app_name"
        android:theme="@style/AppTheme" >
        <activity
            android:name="com.dynamicsolutions.bluetest3.MainActivity"
            android:label="@string/app_name" >
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />

                <category
android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
        <activity android:name=".DeviceListActivity"
```

```
                    android:label="@string/select_device"/>
    </application>

</manifest>
```

6.4 Java Source Code for Android Device

6.4.1 Main Activity Java Code

```java
package com.dynamicsolutions.bluetest3;

import android.os.Bundle;
import android.os.Handler;
import android.os.Message;
import android.util.Log;
import android.view.Menu;
import android.view.MenuInflater;
import android.view.MenuItem;
import android.view.View;
import android.view.View.OnClickListener;
import android.widget.Button;
import android.widget.SeekBar;
import android.widget.TextView;
import android.widget.Toast;
import android.widget.SeekBar.OnSeekBarChangeListener;
import android.app.Activity;
import android.bluetooth.BluetoothAdapter;
import android.bluetooth.BluetoothDevice;
import android.content.Intent;
import java.util.Timer;
import java.util.TimerTask;



public class MainActivity extends Activity {

      //Declare variables and constants

      //Declare buttons
      Button btnSend;

      // Declare Seek Bars
      SeekBar hSeek;
      SeekBar vSeek;
      TextView hText;
      TextView vText;

      //Timer declarations
      static final int UPDATE_INTERVAL = 250;
      private Timer timer = new Timer();
      int i;

      // The local Bluetooth Adapter
      private BluetoothAdapter mBluetoothAdapter = null;
```

```
	// Intent request codes
	private static final int REQUEST_ENABLE_BT = 1;
	private static final int REQUEST_CONNECT_DEVICE = 2;

	// Message types sent form the BluetoothDataTransferService
handler
	public static final int MESSAGE_READ = 2;
	public static final int MESSAGE_TOAST = 5;

	// Key names received from the BluetoothDataTransferService
handler
	public static final String TOAST = "toast";

	//public static String EXTRA_DEVICE_ADDRESS = "device_address";

	// Member of object for the data transfer service
	private BluetoothDataTransferService mDataService = null;

	//Member of object for the data resolver service
	private DataResolverService mResolverService = null;

	@Override
	public void onCreate(Bundle savedInstanceState) {
		super.onCreate(savedInstanceState);
		setContentView(R.layout.activity_main);


		// Get the default bluetooth adapter
		mBluetoothAdapter = BluetoothAdapter.getDefaultAdapter();

		// Check to see if bluetooth is supported and if not alert
the user
		if (mBluetoothAdapter == null)
		{
			Toast.makeText(this, "Bluetooth is not supported on
this device", Toast.LENGTH_LONG).show();
			finish();
			return;
		}

		mResolverService = new DataResolverService(this, mHandler);

		//---Send Button

		btnSend = (Button) findViewById(R.id.btn_Send);
		hText = (TextView) findViewById(R.id.hTextView);
		hSeek = (SeekBar) findViewById(R.id.hSeekBar1);
		vText = (TextView) findViewById(R.id.vTextView);
		vSeek = (SeekBar) findViewById(R.id.vSeekBar1);

		hSeek.setProgress(50);
		hSeek.setEnabled(false);
		vSeek.setProgress(50);
		vSeek.setEnabled(false);
```

```
		hSeek.setOnSeekBarChangeListener( new 
OnSeekBarChangeListener() {
			
			@Override
			public void onStopTrackingTouch(SeekBar seekBar) {
				
				hSeek.setProgress(50);
				
			}
			
			@Override
			public void onStartTrackingTouch(SeekBar seekBar) {
				// TODO Auto-generated method stub
				
			}
			
			@Override
			public void onProgressChanged(SeekBar seekBar, int 
progress,
					boolean fromUser) {
				
				String stringH = Integer.toString(progress);
				hText.setText(stringH);
				String messageB = "B";
				String messageF = "!";
				byte[] sendB = messageB.getBytes();
				mDataService.write(sendB);
				try {
					Thread.sleep(1);
				} catch (InterruptedException e) {
					// TODO Auto-generated catch block
					e.printStackTrace();
				}
				Log.d("OutputService", "Output B Complete");
				byte[] sendH = stringH.getBytes();
				mDataService.write(sendH);
				try {
					Thread.sleep(1);
				} catch (InterruptedException e) {
					// TODO Auto-generated catch block
					e.printStackTrace();
				}
				Log.d("OutputService", "Output H Complete");
				byte[] sendF = messageF.getBytes();
				mDataService.write(sendF);
				try {
					Thread.sleep(1);
				} catch (InterruptedException e) {
					// TODO Auto-generated catch block
					e.printStackTrace();
				}
				Log.d("OutputService", "Output F Complete");
				
			}
		});
```

```
		vSeek.setOnSeekBarChangeListener( new
OnSeekBarChangeListener() {

			@Override
			public void onStopTrackingTouch(SeekBar seekBar) {
				vSeek.setProgress(50);

			}

			@Override
			public void onStartTrackingTouch(SeekBar seekBar) {
				// TODO Auto-generated method stub

			}

			@Override
			public void onProgressChanged(SeekBar seekBar, int
progress,
					boolean fromUser) {
				String stringV = Integer.toString(progress);
				vText.setText(stringV);
				String messageA = "A";
				String messageF = "!";
				byte[] sendA = messageA.getBytes();
				mDataService.write(sendA);
				try {
					Thread.sleep(1);
				} catch (InterruptedException e) {
					// TODO Auto-generated catch block
					e.printStackTrace();
				}
				Log.d("OutputService", "Output A Complete");
				byte[] sendV = stringV.getBytes();
				mDataService.write(sendV);
				try {
					Thread.sleep(1);
				} catch (InterruptedException e) {
					// TODO Auto-generated catch block
					e.printStackTrace();
				}
				Log.d("OutputService", "Output V Complete");
				byte[] sendF = messageF.getBytes();
				mDataService.write(sendF);
				try {
					Thread.sleep(1);
				} catch (InterruptedException e) {
					// TODO Auto-generated catch block
					e.printStackTrace();
				}
				Log.d("OutputService", "Output F Complete");

			}
		});


		btnSend.setOnClickListener(new OnClickListener()
		{
```

```
                        public void onClick(View arg0) {
                              vSeek.setEnabled(true);
                              hSeek.setEnabled(true);


                        }
                  } );

            } // End of onCreate


            @Override
            public void onStart() {
                  super.onStart();

                  // If bluetooth is not enabled request that it is enabled
                  if( !mBluetoothAdapter.isEnabled() ){
                        Intent enableBTIntent = new
      Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
                        startActivityForResult(enableBTIntent,
      REQUEST_ENABLE_BT);
                  }

            } // End of onStart

            @Override
            public synchronized void onResume() {
                  super.onResume();


            } // End of on resume


            @Override
            public void onDestroy() {
                  super.onDestroy();
                  if (timer != null){
                        timer.cancel();
                  }// End of if
            }// End of on destroy



            @Override
            public void onActivityResult(int requestCode, int resultCode,
      Intent data) {
                  switch (requestCode){
                  case REQUEST_CONNECT_DEVICE:
                        //When DeviceListActivity returns with a device to
      connect to if results ok, then launch connectDevice
                        if(resultCode == Activity.RESULT_OK) {
                              connectDevice(data);
                        }
                        break;
                  case REQUEST_ENABLE_BT:
                        if(resultCode == Activity.RESULT_OK){
                              // Bluetooth is now enabled, notify the user
```

```
                        Toast.makeText(this, "Bluetooth Enabled",
Toast.LENGTH_SHORT).show();
                  }
                  else
                  {
                        //The user chose not to enable bluetooth or
there was an error
                        Toast.makeText(this, "Bluetooth failed to
initialize, exiting!", Toast.LENGTH_SHORT).show();
                        finish();
                  }
            } // end request code switch
      }// end on activity result



      // Creates an option menu for when the user presses the menu key
      @Override
      public boolean onCreateOptionsMenu(Menu menu){
            MenuInflater inflater = getMenuInflater();
            inflater.inflate(R.menu.option_menu, menu);
            return true;
      } // End of onCreateOptionsMenu


      @Override
      public boolean onOptionsItemSelected(MenuItem item){
            Intent serverIntent = null;
            switch (item.getItemId()) {
            case R.id.scan_and_connect:
                  //Launch the device list activity to see existing,
find new, and select a device to connect to
                  serverIntent = new Intent(this,
DeviceListActivity.class);
                  startActivityForResult(serverIntent,
REQUEST_CONNECT_DEVICE);
                  return true;
            case R.id.discoverable:
                  //Enable bluetooth device discovery
                  Toast.makeText(getBaseContext(), "Discover",
Toast.LENGTH_SHORT).show();
                  return true;
            } // end switch
            return false;
      }// end of onOptionsItemSelected

      private void connectDevice(Intent data) {
            //Initialize the BluetoothDataTransferService to perform
bluetooth connections
            mDataService = new BluetoothDataTransferService(this,
mHandler);
            //Get the MAC Address
            String address =
data.getExtras().getString(DeviceListActivity.EXTRA_DEVICE_ADDRESS);
            //Get the bluetooth Device object
            BluetoothDevice device =
mBluetoothAdapter.getRemoteDevice(address);
```

```
            // Attempt to connect to the device
            Toast.makeText(getBaseContext(), "Attempting to connect to
" + address, Toast.LENGTH_SHORT).show();
            mDataService.connect(device);
      }

      //The Handler that gets information back from the
BluetoothDataTransferService
      private final Handler mHandler = new Handler(){
            @Override
            public void handleMessage(Message msg) {
                  switch (msg.what) {
                  case MESSAGE_TOAST:
                        Toast.makeText(getBaseContext(),
msg.getData().getString(TOAST), Toast.LENGTH_SHORT).show();
                        break;
                  case MESSAGE_READ:


                        resolveData(msgFull);


                        break;
                  }// End of switch
            }// End of handleMessage
      };//End of mHandler

      private void resolveData( String inputString ){
            String message = "ABCDE!";

            String test = mResolverService.SortInputData(inputString);

            Toast.makeText(getBaseContext(), test,
Toast.LENGTH_SHORT).show();

            TextView txtOut = (TextView) findViewById(R.id.txtOut);
            txtOut.setText(test);


            byte[] send = message.getBytes();
                  mDataService.write(send);

            //}//End if
      }


}// end main
```

6.4.2 Bluetooth Data Transfer Service

```
package com.dynamicsolutions.bluetest3;



import java.io.IOException;
import java.io.InputStream;
```

```java
import java.io.OutputStream;
import java.nio.charset.Charset;
import java.util.UUID;

import android.bluetooth.BluetoothAdapter;
import android.bluetooth.BluetoothDevice;
import android.bluetooth.BluetoothSocket;
import android.content.Context;
import android.os.Build;
import android.os.Handler;
import android.util.Log;
import android.widget.Toast;




public class BluetoothDataTransferService {

	// Member Fields
	private ConnectThread mConnectThread;
	private final BluetoothAdapter mAdapter;
	private final Handler mHandler;
	private ConnectedThread mConnectedThread;

	// UUID for this application - MY_UUID is the secure UUID from
the google bluetooth chat example
	private static final UUID MY_UUID =
			UUID.fromString("00001101-0000-1000-8000-
00805f9b34fb");
			//UUID.fromString("fa87c0d0-afac-11de-8a39-
0800200c9a66");


	public BluetoothDataTransferService(Context context,Handler
handler) {
		mAdapter = BluetoothAdapter.getDefaultAdapter();
		mHandler = handler;
	}


	public synchronized void connect(BluetoothDevice device){
		// Start the tread to connect with the given device
		mConnectThread = new ConnectThread(device);
		mConnectThread.start();

	}


	private class ConnectThread extends Thread {
		private final BluetoothSocket mmSocket;
		private final BluetoothDevice mmDevice;
		private String mSocketType = "Secure";

		public ConnectThread(BluetoothDevice device) {
			mmDevice = device;
			BluetoothSocket tmp = null;
```

```
                  // Get a bluetoothSocket for a connection with the
given BluetoothDevice
                  try {
                        tmp =
device.createRfcommSocketToServiceRecord(MY_UUID);
                  }//End try
                  catch (IOException e) {

                  }//End Catch
                  mmSocket = tmp;
            }//End of ConnectThread - public method

            public void run() {
                  setName("ConnectThread" + mSocketType);

                  //Always cancel discovery because it will slow down
the connection
                  mAdapter.cancelDiscovery();

                  //Make a connection to the bluetooth socket
                  try{
                        //This is a blocking call and will only return
on a successful connection or an exception
                        mmSocket.connect();
                  }//End try
                  catch (IOException e){
                        //Close the socket
                        try{
                              mmSocket.close();
                        }//End try
                        catch (IOException E2){

                        }//End catch
                        connectionFailed();
                        return;
                  }//End catch

            // Reset the ConnectThread because we're done
            synchronized (BluetoothDataTransferService.this) {
                mConnectThread = null;
            }

            // Start the connected thread
            connected(mmSocket, mmDevice, mSocketType);

            }//End run

            public void cancel() {
            try {
                mmSocket.close();
            } catch (IOException e) {

            }
        }//End of cancel

      }//End of ConnectThread - private class
```

```
	public void write(byte[] out) {
		// Create temporary object
		ConnectedThread r;
		//Synchronize a copy of the connected thread
		synchronized (this) {
			// should check for a connected thread here first
			// need to add code....
			r = mConnectedThread;
		}// End of synchronized
		//Perform the write unsynchronized
		r.write(out);
		Log.d("Data Transfer", "Sent");

	}// End of write

	private void connectionFailed(){


	}//End of connection failed


	public synchronized void connected(BluetoothSocket socket,
BluetoothDevice device, final String socketType) {
		//Start the thread to manage the connection and perfor
transmission
		mConnectedThread = new ConnectedThread(socket, socketType);
		mConnectedThread.start();


	}//End of connected

	private class ConnectedThread extends Thread {
		private final BluetoothSocket mmSocket;
		private final InputStream mmInStream;
		private final OutputStream mmOutStream;

		public ConnectedThread(BluetoothSocket socket, String
socketType) {
			mmSocket = socket;
			InputStream tmpIn = null;
			OutputStream tmpOut = null;

			// Get the bluetooth socket input and output streams
			try {
				tmpIn = socket.getInputStream();
				tmpOut = socket.getOutputStream();
			}// End of try
			catch (IOException e) {
				//Log.e(TAG,"temp sockets not created", e);
			}// End of Catch

			mmInStream = tmpIn;
			mmOutStream = tmpOut;
		}

		public void run() {
			byte[] buffer = new byte[1024];
```

```
                        int bytes;
                        String end = "!";
                        StringBuilder curMsg = new StringBuilder();

                        //Keep listening to the input stream while connected
                        while(true) {
                              try{

                                    while (-1 != (bytes =
mmInStream.read(buffer))) {
                                          curMsg.append(new String(buffer, 0,
bytes, Charset.forName("UTF-8")));
                                          String fullMessage =
curMsg.toString();

      mHandler.obtainMessage(MainActivity.MESSAGE_READ,
fullMessage).sendToTarget();
                                          curMsg.delete(0, bytes);
                                    }

                              }//End of try
                              catch (IOException e) {
                                    //connectionLost();
                                    break;
                              }//End of Catch
                        }// End of while
                  }//End of run

                  public void cancel() {
                        try {
                              mmSocket.close();
                        }//end of try
                        catch (IOException e) {
                              // TODO: handle exception
                        }//End of cancel
                  }//End of cancel

                  /**
                   * Write to the connected OutStream.
                   * @param buffer The bytes to write
                   */
                  public void write(byte[] buffer) {
                        String good = new String(buffer,
Charset.forName("ISO-8859-1") );
                        buffer = good.getBytes(Charset.forName(("ISO-8859-
1")));
                        try {
                              mmOutStream.write(buffer);

                        }// end of try
                        catch (IOException e){

                        }// end of catch
```

```
            }// End of write
      }//End of ConnectedThread


}// End of BluetoothData
```

6.4.3 Device List Activity

```
package com.dynamicsolutions.bluetest3;

import java.util.Set;

import android.app.Activity;
import android.bluetooth.BluetoothAdapter;
import android.bluetooth.BluetoothDevice;
import android.content.BroadcastReceiver;
import android.content.Context;
import android.content.Intent;
import android.content.IntentFilter;
import android.os.Bundle;
import android.view.View;
import android.view.View.OnClickListener;
import android.view.Window;
import android.widget.AdapterView;
import android.widget.AdapterView.OnItemClickListener;
import android.widget.ArrayAdapter;
import android.widget.Button;
import android.widget.ListView;
import android.widget.TextView;
import android.widget.Toast;

public class DeviceListActivity extends Activity {

      private BluetoothAdapter mBtAdapter;
      private ArrayAdapter<String> mPairedDevicesArrayAdapter;
      private ArrayAdapter<String> mNewDevicesArrayAdapter;

      //Return Intent extras
      public static String EXTRA_DEVICE_ADDRESS = "device_address";

      @Override
      protected void onCreate(Bundle savedInstanceState) {
            super.onCreate(savedInstanceState);

            //Set up the display window

      requestWindowFeature(Window.FEATURE_INDETERMINATE_PROGRESS);
            setContentView(R.layout.device_list);

            //Set results as canceled in case the user backs out
            setResult(Activity.RESULT_CANCELED);

            // Initialize the button to perform device discovery
            Button btnScan = (Button) findViewById(R.id.btn_scan);
            btnScan.setOnClickListener(new OnClickListener() {
                  public void onClick(View v) {
```

```
                        discoverDevices();
                        v.setVisibility(View.GONE);
                  }

            }); // End of setOnClickListener

            //Initialize the array adapters. One for the paired devices
and one for the newly discovered devices
            mPairedDevicesArrayAdapter = new ArrayAdapter<String>(this,
R.layout.device_name);
            mNewDevicesArrayAdapter = new ArrayAdapter<String>(this,
R.layout.device_name);

            // Find and set up the list view for paired devices
            ListView lstPairedDevices = (ListView)
findViewById(R.id.paired_devices_list);
            lstPairedDevices.setAdapter(mPairedDevicesArrayAdapter);

      lstPairedDevices.setOnItemClickListener(mDeviceSelectedListener);

            // Find and set up list view for new devices
            ListView lstNewDevices = (ListView)
findViewById(R.id.new_device_list);
            lstNewDevices.setAdapter(mNewDevicesArrayAdapter);

      lstNewDevices.setOnItemClickListener(mDeviceSelectedListener);

            // Register for broadcasts when a device is found
            IntentFilter filter = new
IntentFilter(BluetoothDevice.ACTION_FOUND);
            this.registerReceiver(mReceiver, filter);

            //Register for broadcasts when discovery has finished
            filter = new
IntentFilter(BluetoothAdapter.ACTION_DISCOVERY_FINISHED);
            this.registerReceiver(mReceiver, filter);

            // Get the local bluetooth adapter
            mBtAdapter = BluetoothAdapter.getDefaultAdapter();

            // Get a set of currently paired devices
            Set<BluetoothDevice> pairedDevices =
mBtAdapter.getBondedDevices();

            // If there are paired devices add them to the Array
Adapter
            if (pairedDevices.size() >0) {

      findViewById(R.id.title_paired_devices).setVisibility(View.VISIBL
E);
                  for (BluetoothDevice device : pairedDevices){
                        mPairedDevicesArrayAdapter.add(device.getName()
+ "\n" + device.getAddress());
                  } //End for
            } //End of if
            else {
```

```
                  String noDevices =
getResources().getText(R.string.none_paired).toString();
                  mPairedDevicesArrayAdapter.add(noDevices);
            } // End else

      } // End of OnCreate


      protected void onDestroy() {
            super.onDestroy();

            //Make sure we are not still discovering devices
            mBtAdapter.cancelDiscovery();

            //Unregister broadcast listeners
            this.unregisterReceiver(mReceiver);

      }//End of on destroy

      // Starts device discovery with the  bluetooth adapter
      private void discoverDevices() {
            // indicate scanning in the title
            setProgressBarIndeterminateVisibility(true);
            setTitle(R.string.scanning);

            // Turn on the subtitle for new devices

      findViewById(R.id.title_new_devices).setVisibility(View.VISIBLE);

            //If we are already discovering stop it
            if (mBtAdapter.isDiscovering()) {
                  mBtAdapter.cancelDiscovery();
            } // end if

            // Request discovery from Bluetooth Adapter
            mBtAdapter.startDiscovery();

      }// end of discoverDevices


      // The on click listener for all of the devices in the ListViews
      private OnItemClickListener mDeviceSelectedListener = new
OnItemClickListener(){
            public void onItemClick(AdapterView<?> av, View v, int
arg2, long arg3) {
                  // Cancel discovery if it is still active
                  mBtAdapter.cancelDiscovery();

                  //Get the MAC address, which is the last 17
characters in the View
                  String info = ((TextView) v).getText().toString();
                  String address = info.substring(info.length() - 17);

                  //create the result Intent and include the MAC
address
                  Intent intent = new Intent();
                  intent.putExtra(EXTRA_DEVICE_ADDRESS, address);
```

```
                  Toast.makeText(getBaseContext(), address.toString(), 
Toast.LENGTH_SHORT).show();

                  //Set the results and finish the activity
                  setResult(Activity.RESULT_OK, intent);
                  finish();

            }// End of on item click
      };// End mDeviceSelectedListener


      //The Broadcast Receiver for when devices are found and discovery 
is finished
      private final BroadcastReceiver mReceiver = new 
BroadcastReceiver() {
            @Override
            public void onReceive(Context context, Intent intent) {
                  String action = intent.getAction();

                  //When discovery finds a device
                  if (BluetoothDevice.ACTION_FOUND.equals(action)) {
                        // Get the Bluetooth Device from the Intent
                        BluetoothDevice device = 
intent.getParcelableExtra(BluetoothDevice.EXTRA_DEVICE);
                        //If its already paired skip is since its 
already been listed
                        if (device.getBondState() != 
BluetoothDevice.BOND_BONDED) {

      mNewDevicesArrayAdapter.add(device.getName() + "\n" + 
device.getAddress());
                        }//End if
                  }// End if
                  else if 
(BluetoothAdapter.ACTION_DISCOVERY_FINISHED.equals(action)) {
                        setProgressBarIndeterminateVisibility(false);
                        setTitle(R.string.select_device);
                        if (mNewDevicesArrayAdapter.getCount() == 0) {
                              String noDevices = 
getResources().getText(R.string.none_found).toString();
                              mNewDevicesArrayAdapter.add(noDevices);
                        }//End if
                  }// End else if



            }// End onRecieve
      };//End Broadcast Receiver



} // End of DeviceListActivity Class
```

6.4.4 Data Resolver Service

```
package com.dynamicsolutions.bluetest3;

import android.content.Context;
import android.os.Handler;

public class DataResolverService {

	//Member Fields
	private final Handler mHandler;
	private StringBuilder masterString = new StringBuilder();
	private String end = "!";


	public DataResolverService(Context context, Handler handler) {
		mHandler = handler;


	}


	public String SortInputData(String inputString) {
		String completeSegment;
		masterString.append(inputString);

		String temp = masterString.toString();

		int endIdX = masterString.indexOf(end);

		if (-1 != endIdX) {
			completeSegment = masterString.substring(0, endIdX);
			masterString.delete(0, endIdX+1);

			return completeSegment;

		}
		else
		{
		return "Working";
		}

	}

} //End of DataResolver
```

6.5 ActivityBot Propeller .Spin Source Code

6.5.1 RN-42 Bluetooth Module Configuration .Spin Source Code

" File: PBAA_v0.2.spin

" PBAA = Propeller Bluetooth and Android

" v0.2 = This application programs the RN-42 to communicate with a 9600 Baud rate

```
"       It also demonstrates how to enter command mode and also how to exit it.
"        The program also demonstrates how to record the responses received after issuing
commands.
" New to Version 0.2


CON

  _xinfreq = 5_000_000
  _clkmode = xtal1 + pll16x

  'Bluetooth Constants

  DEBUG      = 0                              ' Debug port sends results to Parallax Serial
Terminal
  A_PORT     = 1                              ' Bluetooth Module

  A_RESET    = 0                              ' To RST pin on RN-42 Bluetooth Module
  A_TX       = 1                              ' To RX pin on RN-42 Bluetooth Module
  A_RX       = 2                              ' To TX pin on RN-42 Bluetooth Module
  A_CTS      = 3                              ' To RTS pin on RN-42 Bluetooth Module
  A_RTS      = 4                              ' To CTS pin on RN-42 Bluetooth Module

  BAUD       = 9600                           ' Baud Rate 9600 bps


VAR

  long tLow, tHigh, T, dt, stack[700], cntr, inByte, inString, ctr, testStr[15], milis, char
  word cntMin
  byte i, inByteArr[25], bufferSize
```

```
OBJ
  fds   : "FullDuplexSerial4port"
  dio   : "dataIO4port"

  {
    pst: "Parallax Serial Terminal V1.0"                    'Create the Parallax Serial Terminal
Object for the LCD Screen & Bluetooth module
    'Need to use pst file in this folder as it has been modified to use Pin 1 & 12 for serial
comm
    }

PUB Main

  milis := clkfreq / 1_000

  dira[26..27] := %11                           'Set Pin 26 & 27 to output
  outa[26..27] := %00                           'Set pin 26 & 27 to low
  dira[A_TX] := 1
  outa[A_TX] := 1

  Pause(100)

  outa[A_TX] := 0

  fds.Init
  fds.AddPort(A_PORT, A_RX, A_TX, A_CTS, A_RTS, 0, %000000, BAUD)
  fds.AddPort(DEBUG, 31, 30, -1, -1, 0, %000000, BAUD)   ' Debug to the terminal
screen
  fds.Start
```

```
  fds.str(DEBUG, String("Program Started"))             'Outputs "Program Started" to the
terminal screen

  Pause(2000)                                    'UART startup delay



  fds.str(A_PORT, String("$$$"))                        'Sends "$$$" to the RN-42 to enter
command mode

  ctr := 0                                'This block of code reads in characters until "13" is
found
  inByteArr[ctr] := fds.rx(A_PORT)                      '"13" represents the Carraige Return
which is sent at the end of
  fds.tx(DEBUG, inByteArr[ctr])                  'every message from the RN-42 Unit
  repeat until inByteArr[ctr] == 13               'If successfull "CMD" is returned
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
    fds.tx(DEBUG, inByteArr[ctr])



  Pause(1200)                                'Pause for 1.2 seconds, the "$$$" message will
be ignored if
                                           'additional messages are sent within 1 second of the
"$$$"

  fds.str(A_PORT, String("SU,96"))                          'Set up message that sets the
programmed serial baud rate to 9600
  fds.tx(A_PORT, 13)                              'If successfull "AOK" is returned
  fds.tx(A_PORT, 10)

  ctr := 0
```

```
  inByteArr[ctr] := fds.rx(A_PORT)
  fds.tx(DEBUG, inByteArr[ctr])
  repeat until inByteArr[ctr] == 13
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
    fds.tx(DEBUG, inByteArr[ctr])



  fds.str(A_PORT, String("---"))                    'Message sent "---" that tells the RN-42 to
Exit command mode
  fds.tx(A_PORT, 13)                               'If successfull "END" is returned
  fds.tx(A_PORT, 10)

  ctr := 0
  inByteArr[ctr] := fds.rx(A_PORT)
  fds.tx(DEBUG, inByteArr[ctr])
  repeat until inByteArr[ctr] == 13
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
    fds.tx(DEBUG, inByteArr[ctr])
```

6.5.2 RN-42 Bluetooth Module Verification .Spin Source Code

```
'' File: PBAA_v0.3.spin
'' PBAA = Propeller Bluetooth and Android
'' v0.3 = Test the use of get commands on the RN-42 Bluetooth Module
''       Assumption is that the module is set to 9600 Baud rate

CON

  _xinfreq = 5_000_000
  _clkmode = xtal1 + pll16x
```

```
 'Bluetooth Constants

 DEBUG      = 0                                    ' Debug port sends results to Parallax Serial
Terminal
 A_PORT     = 1                               ' Bluetooth Module

 A_RESET    = 0                               ' To RST pin on RN-42 Bluetooth Module
 A_TX       = 1                               ' To RX pin on RN-42 Bluetooth Module
 A_RX       = 2                               ' To TX pin on RN-42 Bluetooth Module
 A_CTS      = 3                               ' To RTS pin on RN-42 Bluetooth Module
 A_RTS      = 4                               ' To CTS pin on RN-42 Bluetooth Module

 BAUD       = 9600                            ' Baud Rate 9600 bps


VAR

 long tLow, tHigh, T, dt, stack[700], cntr, inByte, inString, ctr, testStr[15], milis, char
 word cntMin
 byte i, inByteArr[300], bufferSize

OBJ
 fds   : "FullDuplexSerial4port"
 dio   : "dataIO4port"

 {
  pst: "Parallax Serial Terminal V1.0"                 'Create the Parallax Serial Terminal
Object for the LCD Screen & Bluetooth module
  'Need to use pst file in this folder as it has been modified to use Pin 1 & 12 for serial
comm
```

```
    }

PUB Main

  milis := clkfreq / 1_000

  dira[26..27] := %11                                'Set Pin 26 & 27 to output
  outa[26..27] := %00                                'Set pin 26 & 27 to low
  dira[A_TX] := 1
  outa[A_TX] := 1

  Pause(100)

  outa[A_TX] := 0

  fds.Init
  fds.AddPort(A_PORT, A_RX, A_TX, A_CTS, A_RTS, 0, %000000, BAUD)
  fds.AddPort(DEBUG, 31, 30, -1, -1, 0, %000000, BAUD)  ' Debug to the terminal
screen
  fds.Start

  fds.str(DEBUG, String("Program Started"))             'Outputs "Program Started" to the
terminal screen
  fds.tx(DEBUG, 13)

  Pause(2000)                                  'UART startup delay

fds.str(A_PORT, String("$$$"))                          'Sends "$$$" to the RN-42 to enter
command mode
```

```
  ctr := 0                                   'This block of code reads in characters until "13" is
found
  inByteArr[ctr] := fds.rx(A_PORT)                     '"13" represents the Carraige Return
which is sent at the end of
  fds.tx(DEBUG, inByteArr[ctr])                    'every message from the RN-42 Unit
  repeat until inByteArr[ctr] == 13                'If successfull "CMD" is returned
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
    fds.tx(DEBUG, inByteArr[ctr])


  Pause(1200)                                  'Pause for 1.2 seconds, the "$$$" message will
be ignored if
                                              'additional messages are sent within 1 second of the
"$$$"

  fds.str(A_PORT, String("D"))
  fds.tx(A_PORT, 13)
  fds.tx(A_PORT, 10)

  repeat 11
    ctr := 0
    inByteArr[ctr] := fds.rx(A_PORT)
    fds.tx(DEBUG, inByteArr[ctr])
    repeat until inByteArr[ctr] == 13
      ctr++
      inByteArr[ctr] := fds.rx(A_PORT)
      fds.tx(DEBUG, inByteArr[ctr])
```

```
  fds.str(A_PORT, String("---"))                    'Message sent "---" that tells the RN-42 to
Exit command mode
  fds.tx(A_PORT, 13)                              'If successfull "END" is returned
  fds.tx(A_PORT, 10)

  ctr := 0
  inByteArr[ctr] := fds.rx(A_PORT)
  fds.tx(DEBUG, inByteArr[ctr])
  repeat until inByteArr[ctr] == 13
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
    fds.tx(DEBUG, inByteArr[ctr])
```

6.5.3 ActivityBot .Spin Source Code Implemented on the Propeller Microcontroller

```
'' File: PBAA_v0.7.spin
'' PBAA = Propellar Bluetooth and Android
'' v0.7 = Working control of platfrom and successfull bluetooth comm

CON

  _xinfreq = 5_000_000
  _clkmode = xtal1 + pll16x

  'Bluetooth Constants

  DEBUG      = 0                                  ' Debug port sends results to Parallax Serial
Terminal
  A_PORT     = 1                              ' Bluetooth Module

  A_RESET    = 0                               ' To RST pin on RN-42 Bluetooth Module
  A_TX       = 1                              ' To RX pin on RN-42 Bluetooth Module
```

```
  A_RX       = 2                              ' To TX pin on RN-42 Bluetooth Module
  A_CTS      = 3                              ' To RTS pin on RN-42 Bluetooth Module
  A_RTS      = 4                              ' To CTS pin on RN-42 Bluetooth Module

  BAUD       = 9600                           ' Baud Rate 9600 bps


VAR

  long tLow, tHigh, T, dt, stack[700], cntr, inByte, inString, ctr, testStr[15], milis,
char,us, dataV, dataH, scale, rawSpeed, rawDirection, speed, lServo, rServo, direction,
range
  word cntMin
  byte i, inByteArr[300], bufferSize, cntB, temp, Index

OBJ
  fds   : "FullDuplexSerial4port"
  dio   : "dataIO4port"



PUB Main

  milis := clkfreq / 1_000

  dira[26..27] := %11                         'Set Pin 26 & 27 to output
  outa[26..27] := %00                         'Set pin 26 & 27 to low
  dira[A_TX] := 1
  outa[A_TX] := 1
  rawSpeed := 50
  rawDirection := 50
```

```
  lServo := 750
  rServo := 750

  Pause(100)

  outa[A_TX] := 0

  fds.Init
  fds.AddPort(A_PORT, A_RX, A_TX, A_CTS, A_RTS, 0, %000000, BAUD)
  fds.AddPort(DEBUG, 31, 30, -1, -1, 0, %000000, BAUD)   ' Debug to the terminal
screen
  fds.Start

  fds.str(DEBUG, String("Program Started"))              'Outputs "Program Started" to the
terminal screen
  fds.tx(DEBUG, 13)

  Pause(2000)                                    'UART startup delay

  cognew(Values, @stack[0])                     'Start a new cog to manage the servo pulses

  Pause(250)

  cognew(ServoPulse, @stack[300])

repeat
  repeat
    ctr := 0
    inByteArr[ctr] := fds.rx(A_PORT)
  until inByteArr[ctr] == "A" or inByteArr[ctr] == "B"
  if inByteArr[ctr] == "A"
```

```
  repeat
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
  until inByteArr[ctr] == "!"
  dataV := 0
  scale := 0
  repeat Index from 1 to (ctr - 1)
    scale := ctr - 1 - Index
    if scale == 2
      dataV := dataV + (inByteArr[Index] - 48) * 100
    elseif scale == 1
      dataV := dataV + (inByteArr[Index] - 48) * 10
    else
      dataV := dataV + (inByteArr[Index] - 48)
  rawSpeed := dataV
  'dio.dec(DEBUG, dataV)
  'fds.tx(DEBUG, 13)
if inByteArr[ctr] == "B"
  repeat
    ctr++
    inByteArr[ctr] := fds.rx(A_PORT)
  until inByteArr[ctr] == "!"
  dataH := 0
  scale := 0
  repeat Index from 1 to (ctr - 1)
    scale := ctr - 1 - Index
    if scale == 2
      dataH := dataH + (inByteArr[Index] - 48) * 100
    elseif scale == 1
      dataH := dataH + (inByteArr[Index] - 48) * 10
    else
```

```
      dataH := dataH + (inByteArr[Index] - 48)
    rawDirection := dataH
    'dio.dec(DEBUG, dataH)
    'fds.tx(DEBUG, 13)


PUB Values
fds.str(DEBUG, String("Values Started"))             'Outputs "Program Started" to the
terminal screen
fds.tx(DEBUG, 13)
repeat
  waitcnt(clkfreq/20 + cnt)
  if rawSpeed > 50 and rawDirection < 50            'Forward and Left
    range := 100
    speed := (range * (((rawSpeed - 50) * 100) / 50)) / 100
    direction:= (speed * (100 - (((50 - rawDirection) * 100) / 50))) / 100
    lServo := 750 + direction
    rServo := 750 - speed
  elseif rawSpeed > 50 and rawDirection > 50        'Forward and Right
    range := 100
    speed := (range * (((rawSpeed - 50) * 100) / 50)) / 100
    direction:= (speed * (100 - (((rawDirection - 50) * 100) / 50))) / 100
    lServo := 750 + speed
    rServo := 750 - direction
  elseif rawSpeed < 50 and rawDirection < 50        'Reverse and Right
    range := 100
    speed := (range * (((50 - rawSpeed) * 100) / 50)) / 100
    direction:= (speed * (100 - (((50 - rawDirection) * 100) / 50))) / 100
    lServo := 750 - direction
    rServo := 750 + speed
  elseif rawSpeed < 50 and rawDirection > 50        'Reverse and Left
```

```
    range := 100
    speed := (range * (((50 - rawSpeed) * 100) / 50)) / 100
    direction:= (speed * (100 - (((rawDirection - 50) * 100) / 50))) / 100
    lServo := 750 - speed
    rServo := 750 + direction
  elseif rawDirection == 50 and rawSpeed > 50
    speed := ((rawSpeed - 50) * 2)
    lServo := 750 + speed
    rServo := 750 - speed
  elseif rawDirection == 50 and rawSpeed < 50
    speed := ((50 - rawSpeed) * 2)
    lServo := 750 - speed
    rServo := 750 + speed
  elseif rawSpeed == 50 and rawDirection > 50
    speed := ((rawDirection - 50) *2)
    lServo := 750 + speed
    rServo := 750 + speed
  elseif rawSpeed == 50 and rawDirection < 50
    speed := ((50 - rawDirection) *2)
    lServo := 750 - speed
    rServo := 750 - speed
  else
    lServo := 750
    rServo := 750


PUB ServoPulse

  fds.str(DEBUG, String("Pulse out Started"))          'Outputs "Program Started" to the
terminal screen
```

```
  fds.tx(DEBUG, 13)

  us := clkfreq / 1_000_000                        'define what a micro second is
  tLow := clkfreq / 50                             'Duration of time between pulses (standard 20
mS or 0.020 Seconds)

  dira[14..15]~~                                   'Set P14 and P15 to output

  T := cnt                                         'T is set to the current number of clock ticks when
line is executed
  repeat
    T += tLow
    waitcnt(T)
    PULSOUT(15, lServo)
    PULSOUT(14, rServo)

PUB PULSOUT(Pin,duration)  | clkcycles
{{
   Produces an opposite pulse on the pin for the duration in 2uS increments
   Smallest value is 10 at clkfreq = 80Mhz
   Largest value is around 50 seconds at 80Mhz.
     BS2.Pulsout(500)   ' 1 mS pulse
}}
  ClkCycles := (Duration * us * 2 - 1250) #> cntMin       ' duration * clk cycles for 2us
                                                          ' - inst. time, min cntMin
  dira[pin]~~                                      ' Set to output
  !outa[pin]                                       ' set to opposite state
  waitcnt(clkcycles + cnt)                         ' wait until clk gets there
  !outa[pin]
```

PRI Pause(ms)

```
  waitcnt(clkfreq / 1000 * ms + cnt)                    ' Convert to mS
```

6.5.4 FullDuplexSerial4port.Spin Library

{{ FullDuplexSerial4portPlus version 1.01

- Tracy Allen (TTA) (c)22-Jan-2011 MIT license, see end of file for terms of use. Extends existing terms of use.
- Can open up to 4 independent serial ports, using only one pasm cog for all 4.
- Supports flow control and open and inverted baud modes
- Individually configurable tx and rx buffers for all 4 ports, any size, set in CONstants section at compile time
- Part of the buffer fits within the object's hub footprint, but even so the object is restartable
- Buffers are DAT type variables, therefore a single instance of the object can be accessed throughout a complex project.

- Modified from Tim Moore's pcFullDuplexSerial4fc, with further motivation and ideas from Duane Degn's pcFullDuplexSerial4fc128
- Changes and bug fixes include:
  - Flow control is now operational when called for, with correct polarity (bug correction)
  - Jitter is reduced, unused ports are properly skipped over (bug correction), operation speed is increased.
  - Stop bit on reception is now checked, and if there is a framing error, the byte is not put in the buffer.
  - Buffer sizes are arbitrary, each port separate rx & tx up to available memory

    Changes in pasm and in Spin methods to accomodate larger buffers, major reorganization of DAT section.
  - Added strn method for counted string, and rxHowFull method for buffer size.

- Cut out most of the format methods such as DEC and HEX, expecting those to be their own object calling rx, tx, str and strn methods.

See companion object DataIO4port.spin in order to maintain compatibility with methods in the original pcFullDuplexSerial4fc.

- 1v01
  - init method returns pointer @rxsize, for data buffers and data structure.
- 1v00
  - documentation
- 0v91
  - restored DEFAULTTHRESHOLD constant
  - made default buffer sizes in the DAT section rather than init
  - removed the numeric methods to their own companion object, dataIO4port.
- 0v3
  - first public release with the jitter and flow control issues fixed, and large buffers.

Links:

Development of this version:

--- http://forums.parallax.com/showthread.php?137349-yet-another-variant-fullDuplexSerial4portplus

Tim Moore's original pcFullDuplexSerial4fc and updates to allow flow control:

--- http://forums.parallaxinc.com/forums/default.aspx?f=25&p=1&m=273291#m276667

--- http://obex.parallax.com/objects/340/ 7/24/08 version

--- http://forums.parallaxinc.com/forums/default.aspx?f=25&p=1&m=349173 8/14/08 update, flow polarity correction, not in obex

Duane Degn's thread, larger 128 or 512 byte buffers and reusing buffer space, discussion of issues

--- http://forums.parallax.com/showthread.php?129714-Tim-Moore-s-pcFullDuplexSerial4FC-with-larger-%28512-byte%29-rx-buffer

Juergen Buchmueller, 2 port trimmed down version

--- http://forums.parallax.com/showthread.php?128184-Serial-Objects-for-SPIN-Programming&p=967075&viewfull=1#post967075

Serial Mirror, single port but same idea regarding buffers in the DATa space

--- http://forums.parallax.com/showthread.php?94311-SerialMirror-A-FullDuplexSerial-enhancement

--- http://obex.parallax.com/objects/189/

Re baud rates attainable, hiccups:

--- http://forums.parallaxinc.com/forums/default.aspx?f=25&p=1&m=282923#m282978

--- http://forums.parallaxinc.com/forums/default.aspx?f=25&p=1&m=334784

--- http://forums.parallax.com/showthread.php?120868-FullDuplexSerial-hiccups

Jitter, discussions of jitter in different Prop serial programs, PhiPi's development of PBnJ full duplex:

--- http://forums.parallax.com/showthread.php?129776-Anybody-aware-of-high-accuracy-(0.7-or-less)-serial-full-duplex-driver

--- http://forums.parallax.com/showthread.php?136431-Serial-objects-question

Humanoido's catalog of serial port objects

--- http://forums.parallax.com/showthread.php?128184-Serial-Objects-for-SPIN-Programming

Tim Moore's release notes follow... Also note by Duane Degn.

Not all these comments apply to FullDuplexSerial4port.

```
}}
'****************************************************************
'*  Based on                                   *
'*  Full-Duplex Serial Driver v1.1             *
'*  Author: Chip Gracey                        *
'*  Copyright (c) 2006 Parallax, Inc.          *
'*  See end of file for terms of use.          *
'*                                             *
'*  Tim Moore 2008                             *
```

```
"*   Modified to support 4 serial ports                     *
"*   It should run 1 port faster than FullDuplexSerial or run     *
"*   up to 4 ports                                   *
"*   Merged 64 byte rx buffer change                       *
"*   Merged Debug_PC (Jon Williams)                           *
"*   (TTA) cut the numeric methods, see dataIO4port.spin         *
"*   to maintain compatibility with pcFullDuplexSerial4fc        *
"*   or use other numeric methods such as "simpleNumbers"        *
"*   Uses DAT rather than VAR so can be used in multiple objects  *
"*   If you want multiple objects using this driver, you must     *
"*   copy the driver to a new file and make sure version long is  *
"*   unique in each version
"*   Added txflush                                    *
"*   Optimization perf                                 *
"*    1 port up to 750kbps                             *
"*    2 port up to 230kbps                             *
"*    3 port up to 140kbps                             *
"*    4 port up to 100kbps                             *
"*   Tested 4 ports to 115Kbps with 6MHz crystal                *
"*   These are approx theoretical worse case you may get faster   *
"*   if port is active but idle                        *
"*   Added RTS/CTS flow control                            *
"*                                          *
"*   There is no perf penalty supporting 4 serial ports when they *
"*   are not enabled                                 *
"*   There is no perf penalty supporting CTS and RTS             *
"*   Enabling CTS on any port costs 4 clocks per port           *
"*   Enabling RTS on any port costs 32 clocks per port          *
"*   Main Rx+Tx loop is ~256 clocks per port (without CTS/RTS)    *
"*   compared with FullDuplexSerial at ~356 clocks              *
"*                                          *
```

```
"*   There is a cost to read/write a byte in the transmit/        *
"*   receive routines. The transmit cost is greater than the      *
"*   receive cost so between propellors you can run at max baud   *
"*   rate. If receiving from another device, the sending device   *
"*   needs a delay between each byte once you are above ~470kbps  *
"*   with 1 port enabled                                          *
"*                                                                *
"*   (TTA) I have not updated the following comments.             *
"*   Size:                                                        *
"*     Cog Initialzation code 1 x 8 + 4 x 25                      *
"*     Cog Receive code 4 x 30 words                              *
"*     Cog Transmit code 4 x 26 words                             *
"*     Spin/Cog circular buffer indexes 4 x 4 words               *
"*       Used in both spin and Cog and read/written in both       *
"*       directions                                               *
"*     Spin/Cog per port info 4 x 8 words                         *
"*       Passed from Spin to Cog on cog initialization            *
"*     Spin per port info 4 x 1 byte                              *
"*       Used by Spin                                             *
"*     Spin/Cog rx/tx buffer hub address 4 x 4 words              *
"*       Passed from Spin to Cog on cog initialization            *
"*     Spin/Cog rx/tx index hub address 4 x 4 words               *
"*       Passed from Spin to Cog on cog initialization            *
"*     Spin per port rx buffer 4 x 64 byte                        *
"*                                                                *
"*     DWD Changed to 4 x 128 bytes                               *
"*       Read by Spin, written by cog                             *
"*                                                                *
"*     Cog per port rx state 4 x 4 words (overlayed on rx buffer) *
"*       Used by Cog                                              *
"*     Spin per port tx buffer 4 x 16 byte                        *
```

```
"*      Written by Spin, read by Cog                          *
"*    Cog per port tx state 4 x 4 words (overlayed on tx buffer) *
"*      Used by Cog                                    *
"*    Cog constants 4 words                               *
"*   A significant amount of space (4 x 16 words) is used for     *
"*   pre-calculated information: hub addresses, per port          *
"*   configuration. This speeds up the tx/rx routines at the cost *
"*   of this space.                                  *
"*                                              *
"*   Note: There are 8 longs remaining in the cog's memory,       *
"*   expect to do some work to add features :).                 *
"*                                              *
"*   DWD Note from Duane: Many of the longs in the cog image      *
"*   are only used in hub RAM.  There is still lots of room       *
"*   in cog RAM. (TTA) agreed, thanks DWD!                      *
"*                                              *
"*   7/1/08: Fixed bug of not receiving with only 1 port enabled  *
"*          Fixed bug of rts not working on ports 0, 2 and 3     *
"*  7/22/08: Missed a jmpret call in port 1 and 3 tx             *
"*          Fixed a bug in port 3 tx not increasing tx ptr       *
"*  7/24/08: Added version variable to change if need multiple    *
"*          copies of the driver                          *
"*                                              *
"*****************************************************************

CON

  NOMODE                  = %000000
  INVERTRX                = %000001
  INVERTTX                = %000010
  OCTX                  = %000100
```

```
  NOECHO                  = %001000
  INVERTCTS               = %010000
  INVERTRTS               = %100000

  PINNOTUSED              = -1              'tx/tx/cts/rts pin is not used
  DEFAULTTHRESHOLD              = 0                 ' zero defaults to 3/4 of buffer
length

  BAUD1200                = 1200
  BAUD2400                = 2400
  BAUD4800                = 4800
  BAUD9600                = 9600
  BAUD19200               = 19200
  BAUD38400               = 38400
  BAUD57600               = 57600
  BAUD115200              = 115200

' The following constants declare the sizes of the rx and tx buffers.
' Enter in the needed size in bytes for each rx and tx buffer
' These values can be any size within available memory. They do not have to be a power
of two.
' Unused buffers can be reduced to 1 byte.
  RX_SIZE0                = 200  ' receive buffer allocations
  RX_SIZE1                = 200
  RX_SIZE2                = 80
  RX_SIZE3                = 80

  TX_SIZE0                = 20  ' transmit buffer allocations
  TX_SIZE1                = 20
  TX_SIZE2                = 20
  TX_SIZE3                = 20   '
```

RXTX_BUFSIZE = (TX_SIZE0 + TX_SIZE1 + TX_SIZE2 + TX_SIZE3 + RX_SIZE0 + RX_SIZE1 + RX_SIZE2 + RX_SIZE3)

' total buffer footprint in bytes

' 77 longs, 308 bytes are available for buffers within the hub footprint of the object

' the final instruction in this program allocates additional buffer space beyond that if necessary

' to accomodate all of the buffers.

' if the sum totals to 308, then the buffers exactly fit within the object footprint.

PUB Init

''Always call init before adding ports

Stop

bytefill(@startfill, 0, (@endfill-@startfill)) ' initialize head/tails,port info and hub buffer pointers

return @rxsize ' TTA returns pointer to data structure, buffer sizes.

PUB AddPort(port,rxpin,txpin,ctspin,rtspin,rtsthreshold,mode,baudrate)

'' Call AddPort to define each port

'' port 0-3 port index of which serial port

'' rx/tx/cts/rtspin pin number XXX#PINNOTUSED if not used

'' rtsthreshold - buffer threshold before rts is used XXX#DEFAULTTHRSHOLD means use default

'' mode bit 0 = invert rx XXX#INVERTRX

'' mode bit 1 = invert tx XXX#INVERTTX

'' mode bit 2 = open-drain/source tx XXX#OCTX

```
'' mode bit 3 = ignore tx echo on rx                    XXX#NOECHO
'' mode bit 4 = invert cts                              XXX#INVERTCTS
'' mode bit 5 = invert rts                              XXX#INVERTRTS
'' baudrate
  if cog OR (port > 3)
    abort
  if rxpin <> -1
    long[@rxmask][port] := |< rxpin
  if txpin <> -1
    long[@txmask][port] := |< txpin
  if ctspin <> -1
    long[@ctsmask][port] := |< ctspin
  if rtspin <> -1
    long[@rtsmask][port] := |< rtspin
    if (rtsthreshold > 0) AND (rtsthreshold < rxsize[port])             ' (TTA) modified for
variable buffer size
      long[@rtssize][port] := rtsthreshold
    else
      long[@rtssize][port] := rxsize[port]*3/4                          'default rts threshold 3/4 of
buffer  TTS ref RX_BUFSIZE
  long[@rxtx_mode][port] := mode
  if mode & INVERTRX
    byte[@rxchar][port] := $ff
  long[@bit_ticks][port] := (clkfreq / baudrate)
  long[@bit4_ticks][port] := long[@bit_ticks][port] >> 2

PUB Start : okay
'' Call start to start cog
'' Start serial driver - starts a cog
'' returns false if no cog available
''
```

'' tx buffers will start within the object footprint, overlaying certain locations that were initialized in spin

'' for use within the cog but are not needed by spin thereafter and are not needed for object restart.

txbuff_tail_ptr := txbuff_ptr := @buffers ' (TTA) all buffers are calculated as offsets from this address.

txbuff_tail_ptr1 := txbuff_ptr1 := txbuff_ptr + txsize 'base addresses of the corresponding port buffer.

txbuff_tail_ptr2 := txbuff_ptr2 := txbuff_ptr1 + txsize1

txbuff_tail_ptr3 := txbuff_ptr3 := txbuff_ptr2 + txsize2

rxbuff_head_ptr := rxbuff_ptr := txbuff_ptr3 + txsize3 ' rx buffers follow immediately after the tx buffers, by size

rxbuff_head_ptr1 := rxbuff_ptr1 := rxbuff_ptr + rxsize

rxbuff_head_ptr2 := rxbuff_ptr2 := rxbuff_ptr1 + rxsize1

rxbuff_head_ptr3 := rxbuff_ptr3 := rxbuff_ptr2 + rxsize2

' note that txbuff_ptr ... rxbuff_ptr3 are the base addresses fixed

' in memory for use by both spin and pasm

' while txbuff_tail_ptr ... rxbuff_head_ptr3 are dynamic addresses used only by pasm

' and here initialized to point to the start of the buffers.

' the rx buffer #3 comes last, up through address @endfill

rx_head_ptr := @rx_head ' (TTA) note: addresses of the head and tail counts are passed to the cog

rx_head_ptr1 := @rx_head1 ' if that is confusing, take heart. These are pointers to pointers to pointers

rx_head_ptr2 := @rx_head2

rx_head_ptr3 := @rx_head3

```
  rx_tail_ptr  := @rx_tail
  rx_tail_ptr1 := @rx_tail1
  rx_tail_ptr2 := @rx_tail2
  rx_tail_ptr3 := @rx_tail3
  tx_head_ptr  := @tx_head
  tx_head_ptr1 := @tx_head1
  tx_head_ptr2 := @tx_head2
  tx_head_ptr3 := @tx_head3
  tx_tail_ptr  := @tx_tail
  tx_tail_ptr1 := @tx_tail1
  tx_tail_ptr2 := @tx_tail2
  tx_tail_ptr3 := @tx_tail3
  okay := cog := cognew(@entry, @rx_head) + 1

PUB Stop
'' Stop serial driver - frees a cog
  if cog
    cogstop(cog~ - 1)



PUB getCogID : result
  return cog -1

PUB rxflush(port)
'' Flush receive buffer, here until empty.
  repeat while rxcheck(port) => 0

PUB rxHowFull(port)    ' (TTA) added method
'' returns number of chars in rx buffer
  return ((rx_head[port] - rx_tail[port]) + rxsize[port]) // rxsize[port]
'   rx_head and rx_tail are values in the range 0=< ... < RX_BUFSIZE
```

```
PUB rxcheck(port) : rxbyte
" Check if byte received (never waits)
" returns -1 if no byte received, $00..$FF if byte
" (TTA) simplified references
  if port > 3
    abort
  rxbyte--
  if rx_tail[port] <> rx_head[port]
    rxbyte := rxchar[port] ^ byte[rxbuff_ptr[port]+rx_tail[port]]
    rx_tail[port] := (rx_tail[port] + 1) // rxsize[port]

PUB rxtime(port,ms) : rxbyte | t
" Wait ms milliseconds for a byte to be received
" returns -1 if no byte received, $00..$FF if byte
  t := cnt
  repeat until (rxbyte := rxcheck(port)) => 0 or (cnt - t) / (clkfreq / 1000) > ms

PUB rx(port) : rxbyte
" Receive byte (may wait for byte)
" returns $00..$FF
  repeat while (rxbyte := rxcheck(port)) < 0

PUB tx(port,txbyte)
" Send byte (may wait for room in buffer)
  if port > 3
    abort
  repeat until (tx_tail[port] <> (tx_head[port] + 1) // txsize[port])
  byte[txbuff_ptr[port]+tx_head[port]] := txbyte
  tx_head[port] := (tx_head[port] + 1) // txsize[port]
```

```
  if rxtx_mode[port] & NOECHO
    rx(port)

PUB txflush(port)
  repeat until (long[@tx_tail][port] == long[@tx_head][port])

PUB str(port,stringptr)
'' Send zstring
  strn(port,stringptr,strsize(stringptr))

PUB strn(port,stringptr,nchar)
'' Send counted string
  repeat nchar
    tx(port,byte[stringptr++])

DAT
'***********************************
'* Assembly language serial driver *
'***********************************
'
                        org 0
'
' Entry
'
'To maximize the speed of rx and tx processing, all the mode checks are no longer inline
'The initialization code checks the modes and modifies the rx/tx code for that mode
'e.g. the if condition for rx checking for a start bit will be inverted if mode INVERTRX
'is it, similar for other mode flags
'The code is also patched depending on whether a cts or rts pin are supplied. The normal
' routines support cts/rts processing. If the cts/rts mask is 0, then the code is patched
```

'to remove the addtional code. This means I/O modes and CTS/RTS handling adds no extra code
'in the rx/tx routines which not required.
'Similar with the co-routine variables. If a rx or tx pin is not configured the co-routine
'variable for the routine that handles that pin is modified so the routine is never called
'We start with port 3 and work down to ports because we will be updating the co-routine pointers
'and the order matters. e.g. we can update txcode3 and then update rxcode3 based on txcode3.
'(TTA): coroutine patch was not working in the way originally described. (TTA) patched
'unused coroutines jmprets become simple jmps.
' Tim's comments about the order from 3 to 0 no longer apply.

```
' The following 8 locations are skipped at entry due to if_never.
' The mov instruction and the destination address are here only for syntax.
' the important thing are the source field
' primed to contain the start address of each port routine.
' When jmpret instructions are executed, the source adresses here are used for jumps
' And new source addresses will be written in the process.
entry
rxcode  if_never       mov     rxcode,#receive       ' set source fields to initial entry points
txcode  if_never       mov     txcode,#transmit
rxcode1 if_never       mov     rxcode1,#receive1
txcode1 if_never       mov     txcode1,#transmit1
rxcode2 if_never       mov     rxcode2,#receive2
txcode2 if_never       mov     txcode2,#transmit2
rxcode3 if_never       mov     rxcode3,#receive3
txcode3 if_never       mov     txcode3,#transmit3
```

```
'                                                    INITIALIZATIONS
===========================================================================
===============
' port 3 initialization ------------------------------------------------------------
              test    rxtx_mode3,#OCTX wz   'init tx pin according to mode
              test    rxtx_mode3,#INVERTTX wc
    if_z_ne_c or          outa,txmask3
    if_z          or      dira,txmask3
                                        'patch tx routine depending on invert and oc
                                        'if invert change muxc to muxnc
                                        'if oc change outa to dira
    if_z_eq_c or          txout3,domuxnc        'patch muxc to muxnc
    if_nz         movd    txout3,#dira          'change destination from outa to dira
                                        'patch rx wait for start bit depending on invert
              test    rxtx_mode3,#INVERTRX wz 'wait for start bit on rx pin
    if_nz         xor     start3,doifc2ifnc     'if_c jmp to if_nc
                                        'patch tx routine depending on whether cts is used
                                        'and if it is inverted
              or      ctsmask3,#0     wz    'cts pin? z not set if in use
    if_nz         test    rxtx_mode3,#INVERTCTS wc 'c set if inverted
    if_nz_and_c       or        ctsi3,doif_z_or_nc      'if_nc jmp    (TTA) reversed order to
correctly invert CTS
    if_nz_and_nc    or      ctsi3,doif_z_or_c     'if_c jmp
                                        'if not cts remove the test by moving
                                        'the transmit entry point down 1 instruction
                                        'and moving the jmpret over the cts test
                                        'and changing co-routine entry point
    if_z          mov     txcts3,transmit3      'copy the jmpret over the cts test
    if_z          movs    ctsi3,#txcts3         'patch the jmps to transmit to txcts0
    if_z          add     txcode3,#1            'change co-routine entry to skip first jmpret
                                        'patch rx routine depending on whether rts is used
```

```
                                        'and if it is inverted
              or      rtsmask3,#0     wz
    if_nz          or      dira,rtsmask3         ' (TTA) rts needs to be an output
    if_nz          test    rxtx_mode3,#INVERTRTS wc
    if_nz_and_nc   or      rts3,domuxnc          'patch muxc to muxnc
    if_z           mov     norts3,rec3i          'patch rts code to a jmp #receive3
    if_z           movs    start3,#receive3      'skip all rts processing

              or      txmask3,#0      wz       'if tx pin not used
    if_z           movi    transmit3, #%010111_000  ' patch it out entirely by making the
jmpret into a jmp (TTA)
              or      rxmask3,#0      wz       'ditto for rx routine
    if_z           movi    receive3, #%010111_000   ' (TTA)
                                        ' in pcFullDuplexSerial4fc, the bypass was ostensibly
done
                                        ' by patching the co-routine variables,
                                        ' but it was commented out, and didn't work when
restored
                                        ' so I did it by changing the affected jmpret to jmp.
                                        ' Now the jitter is MUCH reduced.
' port 2 initialization -------------------------------------------------------------
              test    rxtx_mode2,#OCTX wz   'init tx pin according to mode
              test    rxtx_mode2,#INVERTTX wc
    if_z_ne_c      or      outa,txmask2
    if_z           or      dira,txmask2
    if_z_eq_c      or      txout2,domuxnc       'patch muxc to muxnc
    if_nz          movd    txout2,#dira         'change destination from outa to dira
              test    rxtx_mode2,#INVERTRX wz 'wait for start bit on rx pin
    if_nz          xor     start2,doifc2ifnc     'if_c jmp to if_nc
              or      ctsmask2,#0     wz
    if_nz          test    rxtx_mode2,#INVERTCTS wc
```

```
        if_nz_and_c      or        ctsi2,doif_z_or_nc     'if_nc jmp    (TTA) reversed order to
correctly invert CTS
        if_nz_and_nc    or      ctsi2,doif_z_or_c     'if_c jmp
       if_z            mov     txcts2,transmit2      'copy the jmpret over the cts test
        if_z            movs    ctsi2,#txcts2         'patch the jmps to transmit to txcts0
        if_z            add     txcode2,#1            'change co-routine entry to skip first jmpret
                        or      rtsmask2,#0     wz
        if_nz           or      dira,rtsmask2         ' (TTA) rts needs to be an output
        if_nz           test    rxtx_mode2,#INVERTRTS wc
        if_nz_and_nc    or      rts2,domuxnc          'patch muxc to muxnc
        if_z            mov     norts2,rec2i          'patch to a jmp #receive2
        if_z            movs    start2,#receive2      'skip all rts processing

                                or txmask2,#0    wz       'if tx pin not used
        if_z            movi    transmit2, #%010111_000   ' patch it out entirely by making the
jmpret into a jmp (TTA)
                        or      rxmask2,#0      wz        'ditto for rx routine
        if_z            movi    receive2, #%010111_000    ' (TTA)

' port 1 initialization -------------------------------------------------------------
                        test    rxtx_mode1,#OCTX wz   'init tx pin according to mode
                        test    rxtx_mode1,#INVERTTX wc
        if_z_ne_c       or      outa,txmask1
        if_z            or      dira,txmask1
        if_z_eq_c       or      txout1,domuxnc        'patch muxc to muxnc
        if_nz           movd    txout1,#dira          'change destination from outa to dira
                        test    rxtx_mode1,#INVERTRX wz 'wait for start bit on rx pin
        if_nz           xor     start1,doifc2ifnc     'if_c jmp to if_nc
                        or      ctsmask1,#0     wz
        if_nz           test    rxtx_mode1,#INVERTCTS wc
```

```
        if_nz_and_c     or      ctsi1,doif_z_or_nc    'if_nc jmp   (TTA) reversed order to
correctly invert CTS
        if_nz_and_nc    or      ctsi1,doif_z_or_c     'if_c jmp
        if_z            mov     txcts1,transmit1      'copy the jmpret over the cts test
        if_z            movs    ctsi1,#txcts1         'patch the jmps to transmit to txcts0
        if_z            add     txcode1,#1            'change co-routine entry to skip first jmpret
                                                      'patch rx routine depending on whether rts is used
                                                      'and if it is inverted
                        or      rtsmask1,#0     wz
        if_nz           or      dira,rtsmask1         ' (TTA) rts needs to be an output
        if_nz           test    rxtx_mode1,#INVERTRTS wc
        if_nz_and_nc    or      rts1,domuxnc          'patch muxc to muxnc
        if_z            mov     norts1,rec1i          'patch to a jmp #receive1
        if_z            movs    start1,#receive1      'skip all rts processing

                        or      txmask1,#0      wz    'if tx pin not used
        if_z            movi    transmit1, #%010111_000  ' patch it out entirely by making the
jmpret into a jmp (TTA)
                        or      rxmask1,#0      wz    'ditto for rx routine
        if_z            movi    receive1, #%010111_000   ' (TTA)

' port 0 initialization ----------------------------------------------------------
                        test    rxtx_mode,#OCTX wz    'init tx pin according to mode
                        test    rxtx_mode,#INVERTTX wc
        if_z_ne_c       or      outa,txmask
        if_z            or      dira,txmask
                                                      'patch tx routine depending on invert and oc
                                                      'if invert change muxc to muxnc
                                                      'if oc change out1 to dira
        if_z_eq_c       or      txout0,domuxnc        'patch muxc to muxnc
        if_nz           movd    txout0,#dira          'change destination from outa to dira
```

```
                                'patch rx wait for start bit depending on invert
              test    rxtx_mode,#INVERTRX wz  'wait for start bit on rx pin
    if_nz         xor     start0,doifc2ifnc     'if_c jmp to if_nc
                                'patch tx routine depending on whether cts is used
                                'and if it is inverted
              or      ctsmask,#0     wz     'cts pin? z not set if in use
    if_nz         or      dira,rtsmask          ' (TTA) rts needs to be an output
    if_nz         test    rxtx_mode,#INVERTCTS wc 'c set if inverted
    if_nz_and_c       or        ctsi0,doif_z_or_nc      'if_nc jmp    (TTA) reversed order to
correctly invert CTS
    if_nz_and_nc    or      ctsi0,doif_z_or_c     'if_c jmp
    if_z          mov     txcts0,transmit       'copy the jmpret over the cts test
    if_z          movs    ctsi0,#txcts0         'patch the jmps to transmit to txcts0
    if_z          add     txcode,#1             'change co-routine entry to skip first jmpret
                                'patch rx routine depending on whether rts is used
                                'and if it is inverted
              or      rtsmask,#0     wz     'rts pin, z not set if in use
    if_nz         test    rxtx_mode,#INVERTRTS wc
    if_nz_and_nc    or      rts0,domuxnc          'patch muxc to muxnc
    if_z          mov     norts0,rec0i          'patch to a jmp #receive
    if_z          movs    start0,#receive       'skip all rts processing if not used

              or      txmask,#0      wz       'if tx pin not used
    if_z            movi    transmit, #%010111_000  ' patch it out entirely by making the
jmpret into a jmp (TTA)
              or      rxmask,#0      wz       'ditto for rx routine
    if_z          movi    receive, #%010111_000   ' (TTA)
'
'                                   MAIN                                        LOOP
==================================================================================
========================
```

```
' Receive0 ------------------------------------------------------------------------------------
receive          jmpret  rxcode,txcode        'run a chunk of transmit code, then return
                                      'patched to a jmp if pin not used
                 test    rxmask,ina      wc
start0  if_c     jmp     #norts0           'go check rts if no start bit
                                      ' have to check rts because other process may remove
chars
                                      'will be patched to jmp #receive if no rts

                 mov     rxbits,#9          'ready to receive byte
                 mov     rxcnt,bit4_ticks      '1/4 bits
                 add     rxcnt,cnt

:bit             add     rxcnt,bit_ticks       '1 bit period

:wait            jmpret  rxcode,txcode        'run a chuck of transmit code, then return

                 mov     t1,rxcnt            'check if bit receive period done
                 sub     t1,cnt
                 cmps    t1,#0          wc
      if_nc      jmp     #:wait

                 test    rxmask,ina      wc    'receive bit on rx pin
                 rcr     rxdata,#1
                 djnz    rxbits,#:bit         'get remaining bits
                 test    rxtx_mode,#INVERTRX  wz      'find out if rx is inverted
      if_z_ne_c       jmp       #receive                 'abort if no stop bit    (TTA) (from
serialMirror)
                 jmpret  rxcode,txcode        'run a chunk of transmit code, then return

                 shr     rxdata,#32-9         'justify and trim received byte
```

```
                wrbyte  rxdata,rxbuff_head_ptr'{7-22} '1wr
                add     rx_head,#1
                cmpsub  rx_head,rxsize   ' (TTA) allows non-binary buffer size
                wrlong  rx_head,rx_head_ptr   '{8}     '2wr
                mov     rxbuff_head_ptr,rxbuff_ptr 'calculate next byte head_ptr
                add     rxbuff_head_ptr,rx_head
norts0          rdlong  rx_tail,rx_tail_ptr   '{7-22 or 8} will be patched to jmp #r3 if no
rts
                                          '1rd
                mov     t1,rx_head
                sub     t1,rx_tail  wc        'calculate number bytes in buffer, (TTA) add
wc
'               and     t1,#$7F              'fix wrap
      if_c      add     t1,rxsize           ' fix wrap, (TTA) change
                cmps    t1,rtssize     wc    'is it more than the threshold
rts0            muxc    outa,rtsmask         'set rts correctly

rec0i           jmp     #receive            'byte done, receive next byte
'
' Receive1 -------------------------------------------------------------------------------------
'
receive1        jmpret  rxcode1,txcode1      'run a chunk of transmit code, then return

                test    rxmask1,ina     wc
start1  if_c    jmp     #norts1             'go check rts if no start bit

                mov     rxbits1,#9          'ready to receive byte
                mov     rxcnt1,bit4_ticks1    '1/4 bits
                add     rxcnt1,cnt
```

```
:bit1                add     rxcnt1,bit_ticks1     '1 bit period

:wait1               jmpret  rxcode1,txcode1       'run a chuck of transmit code, then return

                     mov     t1,rxcnt1             'check if bit receive period done
                     sub     t1,cnt
                     cmps    t1,#0           wc
        if_nc        jmp     #:wait1

                     test    rxmask1,ina     wc    'receive bit on rx pin
                     rcr     rxdata1,#1
                     djnz    rxbits1,#:bit1

                     test    rxtx_mode1,#INVERTRX  wz      'find out if rx is inverted
        if_z_ne_c    jmp     #receive1             'abort if no stop bit    (TTA) (from
serialMirror)

                     jmpret  rxcode1,txcode1       'run a chunk of transmit code, then return
                     shr     rxdata1,#32-9         'justify and trim received byte

                     wrbyte  rxdata1,rxbuff_head_ptr1 '7-22
                     add     rx_head1,#1
                     cmpsub  rx_head1,rxsize1      ' (TTA) allows non-binary buffer size
                     wrlong  rx_head1,rx_head_ptr1
                     mov     rxbuff_head_ptr1,rxbuff_ptr1 'calculate next byte head_ptr
                     add     rxbuff_head_ptr1,rx_head1
norts1               rdlong  rx_tail1,rx_tail_ptr1     '7-22 or 8 will be patched to jmp #r3 if
no rts
                     mov     t1,rx_head1
                     sub     t1,rx_tail1     wc
        if_c         add     t1,rxsize1            ' fix wrap, (TTA) change
```

```
                cmps    t1,rtssize1     wc
rts1            muxc    outa,rtsmask1

rec1i           jmp     #receive1          'byte done, receive next byte
'
' Receive2 ---------------------------------------------------------------------------------
'
receive2        jmpret  rxcode2,txcode2      'run a chunk of transmit code, then return

                test    rxmask2,ina     wc
start2 if_c     jmp     #norts2            'go check rts if no start bit

                mov     rxbits2,#9         'ready to receive byte
                mov     rxcnt2,bit4_ticks2    '1/4 bits
                add     rxcnt2,cnt

:bit2           add     rxcnt2,bit_ticks2     '1 bit period

:wait2          jmpret  rxcode2,txcode2      'run a chuck of transmit code, then return

                mov     t1,rxcnt2          'check if bit receive period done
                sub     t1,cnt
                cmps    t1,#0         wc
        if_nc   jmp     #:wait2

                test    rxmask2,ina     wc    'receive bit on rx pin
                rcr     rxdata2,#1
                djnz    rxbits2,#:bit2
                test    rxtx_mode2,#INVERTRX  wz      'find out if rx is inverted
        if_z_ne_c       jmp     #receive2            'abort if no stop bit    (TTA) (from
serialMirror)
```

```
                jmpret  rxcode2,txcode2       'run a chunk of transmit code, then return
                shr     rxdata2,#32-9         'justify and trim received byte

                wrbyte  rxdata2,rxbuff_head_ptr2 '7-22
                add     rx_head2,#1
                cmpsub  rx_head2,rxsize2        ' ' (TTA) allows non-binary buffer size
                wrlong  rx_head2,rx_head_ptr2
                mov     rxbuff_head_ptr2,rxbuff_ptr2 'calculate next byte head_ptr
                add     rxbuff_head_ptr2,rx_head2
norts2          rdlong  rx_tail2,rx_tail_ptr2    '7-22 or 8 will be patched to jmp #r3 if
no rts
                mov     t1,rx_head2
                sub     t1,rx_tail2    wc
      if_c      add     t1,rxsize2           ' fix wrap, (TTA) change
                cmps    t1,rtssize2     wc
rts2            muxc    outa,rtsmask2

rec2i           jmp     #receive2            'byte done, receive next byte
'
' Receive3 -----------------------------------------------------------------------------------
'
receive3        jmpret  rxcode3,txcode3       'run a chunk of transmit code, then return

                test    rxmask3,ina     wc
start3 if_c     jmp     #norts3              'go check rts if no start bit

                mov     rxbits3,#9           'ready to receive byte
                mov     rxcnt3,bit4_ticks3    '1/4 bits
                add     rxcnt3,cnt
```

```
:bit3           add     rxcnt3,bit_ticks3     '1 bit period

:wait3          jmpret  rxcode3,txcode3       'run a chuck of transmit code, then return

                mov     t1,rxcnt3             'check if bit receive period done
                sub     t1,cnt
                cmps    t1,#0           wc
        if_nc   jmp     #:wait3

                test    rxmask3,ina     wc    'receive bit on rx pin
                rcr     rxdata3,#1
                djnz    rxbits3,#:bit3
                test    rxtx_mode3,#INVERTRX  wz      'find out if rx is inverted
        if_z_ne_c       jmp     #receive3             'abort if no stop bit    (TTA) (from
serialMirror)

                jmpret  rxcode3,txcode3       'run a chunk of transmit code, then return
                shr     rxdata3,#32-9         'justify and trim received byte

                wrbyte  rxdata3,rxbuff_head_ptr3 '7-22
                add     rx_head3,#1
                cmpsub  rx_head3,rxsize3      ' (TTA) allows non-binary buffer size
                wrlong  rx_head3,rx_head_ptr3    '8
                mov     rxbuff_head_ptr3,rxbuff_ptr3 'calculate next byte head_ptr
                add     rxbuff_head_ptr3,rx_head3
norts3          rdlong  rx_tail3,rx_tail_ptr3    '7-22 or 8, may be patched to jmp #r3 if
no rts
                mov     t1,rx_head3
                sub     t1,rx_tail3     wc
        if_c    add     t1,rxsize3            ' fix wrap, (TTA) change
                cmps    t1,rtssize3     wc    'is buffer more that 3/4 full?
```

```
rts3                    muxc    outa,rtsmask3

rec3i                   jmp     #receive3           'byte done, receive next byte
'
'                                                                          TRANSMIT
===========================================================================
========================
'
transmit                jmpret  txcode,rxcode1        'run a chunk of receive code, then return
                                                'patched to a jmp if pin not used

txcts0                  test    ctsmask,ina     wc    'if flow-controlled dont send
                        rdlong  t1,tx_head_ptr        '{7-22} - head[0]
                        cmp     t1,tx_tail      wz    'tail[0]
ctsi0   if_z            jmp     #transmit             'may be patched to if_z_or_c or if_z_or_nc

                        rdbyte  txdata,txbuff_tail_ptr '{8}
                        add     tx_tail,#1
                        cmpsub  tx_tail,txsize    wz   ' (TTA) for individually sized buffers, will
zero at rollover
                        wrlong  tx_tail,tx_tail_ptr    '{8}
        if_z            mov     txbuff_tail_ptr,txbuff_ptr 'reset tail_ptr if we wrapped
        if_nz           add     txbuff_tail_ptr,#1     'otherwise add 1

                        jmpret  txcode,rxcode1

                        shl     txdata,#2
                        or      txdata,txbitor        'ready byte to transmit
                        mov     txbits,#11
                        mov     txcnt,cnt
```

```
txbit          shr    txdata,#1     wc
txout0         muxc   outa,txmask        'maybe patched to muxnc dira,txmask
               add    txcnt,bit_ticks    'ready next cnt

:wait          jmpret txcode,rxcode1     'run a chunk of receive code, then return

               mov    t1,txcnt           'check if bit transmit period done
               sub    t1,cnt
               cmps   t1,#0         wc
     if_nc     jmp    #:wait

               djnz   txbits,#txbit      'another bit to transmit?
txjmp0         jmp    ctsi0              'byte done, transmit next byte
'
' Transmit1 ---------------------------------------------------------------------------------
'
transmit1      jmpret txcode1,rxcode2    'run a chunk of receive code, then return

txcts1         test   ctsmask1,ina  wc   'if flow-controlled dont send
               rdlong t1,tx_head_ptr1
               cmp    t1,tx_tail1   wz
ctsi1 if_z     jmp    #transmit1         'may be patched to if_z_or_c or if_z_or_nc

               rdbyte txdata1,txbuff_tail_ptr1
               add    tx_tail1,#1
               cmpsub    tx_tail1,txsize1   wz   ' (TTA) for individually sized buffers,
will zero at rollover
               wrlong tx_tail1,tx_tail_ptr1
     if_z      mov    txbuff_tail_ptr1,txbuff_ptr1 'reset tail_ptr if we wrapped
     if_nz     add    txbuff_tail_ptr1,#1   'otherwise add 1
```

```
                jmpret  txcode1,rxcode2       'run a chunk of receive code, then return

                shl     txdata1,#2
                or      txdata1,txbitor       'ready byte to transmit
                mov     txbits1,#11
                mov     txcnt1,cnt

txbit1          shr     txdata1,#1      wc
txout1          muxc    outa,txmask1          'maybe patched to muxnc dira,txmask
                add     txcnt1,bit_ticks1     'ready next cnt

:wait1          jmpret  txcode1,rxcode2       'run a chunk of receive code, then return

                mov     t1,txcnt1             'check if bit transmit period done
                sub     t1,cnt
                cmps    t1,#0           wc
        if_nc   jmp     #:wait1

                djnz    txbits1,#txbit1       'another bit to transmit?
txjmp1          jmp     ctsi1                 'byte done, transmit next byte
'
' Transmit2 -------------------------------------------------------------------------------------
'
transmit2       jmpret  txcode2,rxcode3       'run a chunk of receive code, then return

txcts2          test    ctsmask2,ina    wc    'if flow-controlled dont send
                rdlong  t1,tx_head_ptr2
                cmp     t1,tx_tail2     wz
ctsi2   if_z    jmp     #transmit2            'may be patched to if_z_or_c or if_z_or_nc

                rdbyte  txdata2,txbuff_tail_ptr2
```

```
                add     tx_tail2,#1
                cmpsub      tx_tail2,txsize2    wz    ' (TTA) for individually sized buffers,
will zero at rollover
                wrlong  tx_tail2,tx_tail_ptr2
        if_z        mov     txbuff_tail_ptr2,txbuff_ptr2 'reset tail_ptr if we wrapped
        if_nz       add     txbuff_tail_ptr2,#1   'otherwise add 1

                jmpret  txcode2,rxcode3

                shl     txdata2,#2
                or      txdata2,txbitor       'ready byte to transmit
                mov     txbits2,#11
                mov     txcnt2,cnt

txbit2              shr     txdata2,#1      wc
txout2              muxc    outa,txmask2          'maybe patched to muxnc dira,txmask
                add     txcnt2,bit_ticks2     'ready next cnt

:wait2              jmpret  txcode2,rxcode3       'run a chunk of receive code, then return

                mov     t1,txcnt2             'check if bit transmit period done
                sub     t1,cnt
                cmps    t1,#0           wc
        if_nc       jmp     #:wait2

                djnz    txbits2,#txbit2       'another bit to transmit?
txjmp2              jmp     ctsi2                 'byte done, transmit next byte
'
' Transmit3 -------------------------------------------------------------------------------------
'
transmit3           jmpret  txcode3,rxcode        'run a chunk of receive code, then return
```

```
txcts3          test    ctsmask3,ina    wc    'if flow-controlled dont send
                rdlong  t1,tx_head_ptr3
                cmp     t1,tx_tail3     wz
ctsi3   if_z    jmp     #transmit3          'may be patched to if_z_or_c or if_z_or_nc

                rdbyte  txdata3,txbuff_tail_ptr3
                add     tx_tail3,#1
                cmpsub      tx_tail3,txsize3    wz    ' (TTA) for individually sized buffers,
will zero at rollover
                wrlong  tx_tail3,tx_tail_ptr3
        if_z    mov     txbuff_tail_ptr3,txbuff_ptr3 'reset tail_ptr if we wrapped
        if_nz   add     txbuff_tail_ptr3,#1   'otherwise add 1

                jmpret  txcode3,rxcode

                shl     txdata3,#2
                or      txdata3,txbitor       'ready byte to transmit
                mov     txbits3,#11
                mov     txcnt3,cnt

txbit3          shr     txdata3,#1      wc
txout3          muxc    outa,txmask3          'maybe patched to muxnc dira,txmask
                add     txcnt3,bit_ticks3     'ready next cnt

:wait3          jmpret  txcode3,rxcode        'run a chunk of receive code, then return

                mov     t1,txcnt3             'check if bit transmit period done
                sub     t1,cnt
                cmps    t1,#0           wc
        if_nc   jmp     #:wait3
```

```
                djnz    txbits3,#txbit3      'another bit to transmit?
txjmp3          jmp     ctsi3                'byte done, transmit next byte
'
'The following are constants used by pasm for patching the code, depending on options required
doifc2ifnc      long    $003c0000       'patch condition if_c to if_nc using xor
doif_z_or_c     long    $00380000       'patch condition if_z to if_z_or_c using or
doif_z_or_nc    long    $002c0000       'patch condition if_z to if_z_or_nc using or
domuxnc         long    $04000000       'patch muxc to muxnc using or
txbitor         long    $0401           'bits to or for transmitting, adding start and stop bits

' Buffer sizes initialized from CONstants and used by both spin and pasm

rxsize          long    RX_SIZE0        ' (TTA) size of the rx and tx buffers is available to pasm and spin
rxsize1         long    RX_SIZE1        ' these values are transfered from the declared CONstants
rxsize2         long    RX_SIZE2        ' at startup, individually configurable
rxsize3         long    RX_SIZE3
txsize          long    TX_SIZE0
txsize1         long    TX_SIZE1
txsize2         long    TX_SIZE2
txsize3         long    TX_SIZE3


' Object memory from here to the end is zeroed in the init/stop method ---------------'
' Some locations within the next set of values, after being initialized to zero, are then filled with alternative options
```

' That are accessed from both spin and pasm

' Dont Change the order of these initialized variables within port groups of 4 without modifying

' the code to match - both spin and assembler

startfill

rxchar byte 0 ' used by spin rxcheck, for inversion of received data

rxchar1 byte 0

rxchar2 byte 0

rxchar3 byte 0

cog long 0 'cog flag/id

rxtx_mode long 0 ' mode setting from values passed in by addport

rxtx_mode1 long 0 '

rxtx_mode2 long 0

rxtx_mode3 long 0

rx_head long 0 ' rx head pointer, from 0 to size of rx buffer, used in spin and pasm

rx_head1 long 0 ' data is enqueued to this offset above base, rxbuff_ptr

rx_head2 long 0

rx_head3 long 0

rx_tail long 0 ' rx tail pointer, ditto, zero to size of rx buffer

rx_tail1 long 0 ' data is dequeued from this offset above base, rxbuff_ptr

rx_tail2 long 0

rx_tail3 long 0

tx_head long 0 ' tx head pointer, , from 0 to size of tx buffer, used in spin and pasm

tx_head1 long 0 ' data is enqueued to this offset above base, txbuff_ptr

tx_head2 long 0

```
tx_head3        long    0
tx_tail         long    0       ' tx tail pointer, ditto, zero to size of rx buffer
tx_tail1        long    0       ' data is transmitted from this offset above base,
txbuff_ptr
tx_tail2        long    0
tx_tail3        long    0
rxbuff_ptr      long    0       ' These are the base hub addresses of the receive
buffers
rxbuff_ptr1     long    0       ' initialized in spin, referenced in pasm and spin
rxbuff_ptr2     long    0       ' these buffers and sizes are individually configurable
rxbuff_ptr3     long    0
txbuff_ptr      long    0       ' These are the base hub addresses of the transmit
buffers
txbuff_ptr1     long    0
txbuff_ptr2     long    0
txbuff_ptr3     long    0

'  Start of HUB overlay -----------------------------------------------------------------------
' Some locations within the next set of values, after being init'd to zero, are then filled
from spin with options
' That are transferred to and accessed by the pasm cog once started, but no longer needed
in spin.
' Therefore, tx and rx buffers start here and overlays the hub footprint of these variables.
' tx_buffers come first, 0,1,2,3, then rx buffers 0,1,2,3 by offset from "buffers"
overlay
buffers
txdata          long    0
txbits          long    0
txcnt           long    0
txdata1         long    0
txbits1         long    0
```

```
txcnt1          long    0
txdata2         long    0
txbits2         long    0
txcnt2          long    0
txdata3         long    0
txbits3         long    0
txcnt3          long    0
rxdata          long    0
rxbits          long    0
rxcnt           long    0
rxdata1         long    0
rxbits1         long    0
rxcnt1          long    0
rxdata2         long    0
rxbits2         long    0
rxcnt2          long    0
rxdata3         long    0
rxbits3         long    0
rxcnt3          long    0
t1              long    0           ' this is a temporary variable used by pasm
rxmask          long    0           ' a single bit set, a mask for the pin used for receive,
zero if port not used for receive
rxmask1         long    0
rxmask2         long    0
rxmask3         long    0
txmask          long    0           ' a single bit set, a mask for the pin used for transmit,
zero if port not used for transmit
txmask1         long    0
txmask2         long    0
txmask3         long    0
```

ctsmask long 0 ' a single bit set, a mask for the pin used for cts input, zero if port not using cts

ctsmask1 long 0

ctsmask2 long 0

ctsmask3 long 0

rtsmask long 0 ' a single bit set, a mask for the pin used for rts output, zero if port not using rts

rtsmask1 long 0

rtsmask2 long 0

rtsmask3 long 0

bit4_ticks long 0 ' bit ticks for start bit, 1/4 of standard bit

bit4_ticks1 long 0

bit4_ticks2 long 0

bit4_ticks3 long 0

bit_ticks long 0 ' clock ticks per bit

bit_ticks1 long 0

bit_ticks2 long 0

bit_ticks3 long 0

rtssize long 0 ' threshold in count of bytes above which will assert rts to stop flow

rtssize1 long 0

rtssize2 long 0

rtssize3 long 0

rxbuff_head_ptr long 0 ' Hub address of data received, base plus offset

rxbuff_head_ptr1 long 0 ' pasm writes WRBYTE to hub at this address, initialized in spin to base address

rxbuff_head_ptr2 long 0

rxbuff_head_ptr3 long 0

txbuff_tail_ptr long 0 ' Hub address of data tranmitted, base plus offset

txbuff_tail_ptr1 long 0 ' pasm reads RDBYTE from hub at this address, initialized in spin to base address

```
txbuff_tail_ptr2       long     0
txbuff_tail_ptr3       long     0
rx_head_ptr            long     0           ' pointer to the hub address of where the head and
tail offset pointers are stored
rx_head_ptr1           long     0          ' these pointers are initialized in spin but then used
only by pasm
rx_head_ptr2           long     0           ' the pasm cog has to know where in the hub to
find those offsets.
rx_head_ptr3           long     0
rx_tail_ptr            long     0
rx_tail_ptr1           long     0
rx_tail_ptr2           long     0
rx_tail_ptr3           long     0
tx_head_ptr            long     0
tx_head_ptr1           long     0
tx_head_ptr2           long     0
tx_head_ptr3           long     0
tx_tail_ptr            long     0
tx_tail_ptr1           long     0
tx_tail_ptr2           long     0
tx_tail_ptr3           long     0
    '' ----------- End of the  object memory zeroed from startfill to endfill in the init/stop
method ------
endfill
    FIT
'' The above is all of the necessary code that must fit in the cog
'' The following are extra bytes if necessary to provide the required rx and tx buffers.
'' the number required is computed from the aggregate buffer size declared, minus the
above initialized but recycled variables.
```

```
extra                    byte    0 [RXTX_BUFSIZE - (RXTX_BUFSIZE <# (@extra - @overlay))]

{{
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6.5.5 DataIO4port.Spin Library

```
''****************************************************************
''*  DataIO4port   version 1.0       1/22/2012                  *
''*  Author: Tracy Allen                                         *
''*  Copyright (c), EME Systems and others under MIT licence     *
''*  See end of file for terms of use.                           *
''*  adapted from pcFullDuplexSerial4fc by Tim Moore 2008        *
''*  Merged Debug_PC (Jon Williams)                              *
''*  Merged Parallax Serial Terminal numeric input  (Jeff Martin, *
''*  Andy Lindsay, Chip Gracey)                                  *
''*                                                              *
''*  Release Notes:                                              *
''*  These are methods for string and numeric output and input   *
''*  using fullDuplexSerial4port, my adaptation of Tim Moore's   *
''*  pcFullDuplexSerial4fc.   In the original these were included *
''*  in the main program, but here I have broken them off as pass- *
''*  through routines, and added string and numeric input methods. *
''*  These methods are called with reference to a port as defined *
''*  when FullDuplexSerial4port is initialized.                  *
''*                                                              *
''*  If you do want to merge these methods back into the main    *
''*  object, simply remove all the "uarts." object references    *
```

```
"*                                                  *
"*  I made these separate, because for my own work I often use a  *
"*  completely different set of string & numeric i/o methods.     *
"*                                                  *
"*************************************************************


CON
  FF                    = 12              ' form feed
  CR                     = 13              ' carriage return
  NL                     = 13



  MAXSTR_LENGTH             = 32                  ' this limits the size of a binary string
that can be entered


VAR
   byte   str_buffer[MAXSTR_LENGTH+1]                     'String buffer for numerical
string input only
                                         ' This is in VAR space.  If multiple cogs will be
_inputing_ numerical data
                                         ' simultaneously, it is necessary to delare another
instance so that
                                         ' the buffers do not clash!  That applies to numerical
parsing only.



OBJ
  uarts :  "FullDuplexSerial4port"



PUB str(port,stringptr)
```

```
'' Send string
  repeat strsize(stringptr)
    uarts.tx(port,byte[stringptr++])

PUB strln(port,strAddr)
'' Print a zero-terminated string
  str(port,strAddr)
  uarts.tx(port,CR)

PUB dec(port,value) | i
'' Print a decimal number
  decl(port,value,10,0)

PUB decf(port,value, width) | i
'' Prints signed decimal value in space-padded, fixed-width field
  decl(port,value,width,1)

PUB decx(port,value, digits) | i
'' Prints zero-padded, signed-decimal string
'' -- if value is negative, field width is digits+1
  decl(port,value,digits,2)

PUB decl(port,value,digits,flag) | i, x
  digits := 1 #> digits <# 10
  x := value == NEGX                                  'Check for max negative
  if value < 0
    value := ||(value+x)                              'If negative, make positive;
adjust for max negative
    uarts.tx(port,"-")

  i := 1_000_000_000
```

```
  if flag & 3
    if digits < 10                              ' less than 10 digits?
      repeat (10 - digits)                        '   yes, adjust divisor
        i /= 10
  repeat digits
    if value => i
      uarts.tx(port,value / i + "0")
      value //= i
      result~~
    elseif (i == 1) OR result OR (flag & 2)
      uarts.tx(port,"0")
    elseif flag & 1
      uarts.tx(port," ")
    i /= 10

PUB decDp(port,value,places) | divisor  ' prints out a fixed point number with a decimal
point, places
  divisor := 1
  repeat places
    divisor := divisor * 10
  dec(port,value/divisor)
  uarts.tx(port,".")
  decx(port,||value//divisor,places)


PUB hex(port,value, digits)
'' Print a hexadecimal number
  value <<= (8 - digits) << 2
  repeat digits
    uarts.tx(port,lookupz((value <-= 4) & $F : "0".."9", "A".."F"))
```

```
PUB ihex(port,value, digits)
'' Print an indicated hexadecimal number
  uarts.tx(port,"$")
  hex(port,value,digits)

PUB bin(port,value, digits)
'' Print a binary number
  value <<= 32 - digits
  repeat digits
    uarts.tx(port,(value <-= 1) & 1 + "0")

PUB padchar(port,count, txbyte)
  repeat count
     uarts.tx(port,txbyte)

PUB ibin(port,value, digits)
'' Print an indicated binary number
  uarts.tx(port,"%")
  bin(port,value,digits)

PUB putc(port,txbyte)
'' Send a byte to the terminal
  uarts.tx(port,txbyte)

PUB newline(port)
  putc(port,CR)

PUB cls(port)
  putc(port,FF)

PUB getc(port)
```

```
'' Get a character
'' -- will not block if nothing in uart buffer
   return uarts.rxcheck(port)
'  return rx

con
{the following added from PST primarily for data input}
PUB StrIn(port,stringptr)
{{TTA from PST.
Receive a string (carriage return terminated) and stores it (zero terminated) starting at
stringptr.
Waits until full string received.
  Parameter:
    stringptr - pointer to memory in which to store received string characters.
                Memory reserved must be large enough for all string characters plus a zero
terminator.}}

  StrInMax(port, stringptr, -1)

PUB StrInMax(port, stringptr, maxcount) | char, ticks
{{from PST, modified
Receive a string of characters (either carriage return terminated or maxcount in length)
and stores it (zero terminated)
starting at stringptr.  Waits until either full string received or maxcount characters
received.
  Parameters:
    stringptr - pointer to memory in which to store received string characters.
                Memory reserved must be large enough for all string characters plus a zero
terminator (maxcount + 1).
    maxcount  - maximum length of string to receive, or -1 for unlimited.}}
```

```
  maxcount <#= MAXSTR_LENGTH
  repeat maxcount                                 'While maxcount not reached
    if (byte[stringptr++] := uarts.rx(0)) == NL             'Get chars until NL
      quit
  byte[stringptr+(byte[stringptr-1] == NL)]~                'Zero terminate string;
overwrite NL or append 0 char


PUB StrInB(port, stringptr, seconds) | char, ticks
  ticks := clkfreq*seconds+cnt
  repeat MAXSTR_LENGTH
    repeat
      char := uarts.rxcheck(port)
    until char > -1
    case char
      32..126 : byte[stringptr++] := char   ' encompasses all numeric chars in dec and hex
      8, 127 :stringptr--
      13 : quit
    if ticks -= cnt < 0
      quit
  byte[stringptr]~

PUB DecIn(port) : value
{{PST.
Receive carriage return terminated string of characters representing a decimal value.
  Returns: the corresponding decimal value.}}

  StrInMax(port, @str_buffer, MAXSTR_LENGTH)
  value := StrToBase(@str_buffer, 10)
```

```
PUB HexIn(port) : value
{{from PST.
Receive carriage return terminated string of characters representing a hexadecimal value.
  Returns: the corresponding hexadecimal value.}}

  StrInMax(port, @str_buffer, MAXSTR_LENGTH)
  value := StrToBase(@str_buffer, 16)

PUB BinIn(port) : value
{{from PST.
Receive carriage return terminated string of characters representing a binary value.
 Returns: the corresponding binary value.   Note that the constant MAXSTR_LENGTH
limits the # of digits}}

  StrInMax(port, @str_buffer, MAXSTR_LENGTH)
  value := StrToBase(@str_buffer, 2)



PRI StrToBase(stringptr, base) : value | chr, index
{from PST.
Converts a zero terminated string representation of a number to a value in the designated
base.
Ignores all non-digit characters (except negative (-) when base is decimal (10)).}

  value := index := 0
  repeat until ((chr := byte[stringptr][index++]) == 0)
    chr := -15 + --chr & %11011111 + 39*(chr > 56)                              'Make "0"-
"9","A"-"F","a"-"f" be 0 - 15, others out of range
    if (chr > -1) and (chr < base)                                    'Accumulate valid values
into result; ignore others
      value := value * base + chr
```

```
  if (base == 10) and (byte[stringptr] == "-")                        'If decimal, address
negative sign; ignore otherwise
    value := - value


DAT
'***********************************
'* Assembly language serial driver *
'***********************************
{{
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