Return to Basics
Reference Manual

Gordon Henderson
projects@drogon.net

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Preface

Return to Basics (RTB) is a project to re-create a modern interpretation of the BASIC interpreter and programming environment popular in the late 1970s through the 1980s on the popular 8-bit microprocessor systems such as the Apple // series, BBC Micro, Commodore PET, Tandy TRS-80, as well as the various Sinclair systems and a whole host of others too numerous to mention. The intention is to present an easy to use environment for young (and old) people to learn to write computer programs using an interactive system that's quick and easy to use.

BASIC (Beginners All-purpose Symbolic Instruction Code) first demonstrated 50 years ago[1], is regarded as somewhat old-fashioned in todays world but I believe it still has a place in the teaching and learning of computer programming. It arguably has many faults and has been criticised for encouraging bad programming practices[2], however RTB is a new implementation, capable of using modern structured programing techniques including named functions and procedures (which support local variables and recursion, if desired) and structured looping constructs, making line numbers and GOTO completely optional.

Today, BASIC is still used in commercial applications, but not in the traditional form – it exists in the form of Microsoft VB and VB.NET and many derivatives.

RTB is not intended to be used as a serious programming system – While it has the capabilities to write a large financial or scientific package in, I do not expect people to write the many, varied and large packages that were commonly written in BASIC in those early days, but rather to be used as a way to introduce programming in an easy to understand manner, then allow those who have the aptitude and skill to go on to learning other modern programming languages.

RTB features several graphical systems that were popular in those early microprocessor years – both a low and high resolution colour graphics system as well as "turtle" graphics with simplified colour and angle handling. Sprites and sounds are supported too and it is more than capable of being used to write games and animations in.

I would like to think that pre-teen children can be introduced to programming using RTB – the only prerequisite is a desire to learn and the ability to type some simple instructions into a computer. It doesn't even need a mouse! (Although you can enable mouse use in your own programs)

This book is intended to be used as a reference manual for RTB. It lists all the major programming constructs with a small number of examples.

Gordon Henderson, Last updated: June 2014

[1] 1st May, 1964, Dartmouth College, MA, USA

[2] BASIC doesn't teach bad programming, bad teachers do

Trademarks and Acknowledgements

- Raspberry Pi is a registered trademark of the Raspberry Pi Foundation.
- ”Minecraft” is a trademark of Notch Development AB.
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Chapter 1

Introduction

1.1 Audience

This book is aimed at people who may already have a familiarity with BASIC or other high-level languages. It's mainly a reference book for the language, but that are a few examples along the way to help emphasise some of the concepts and features being described.

It is assumes that you understand the basic principles of computing and know concepts like volatile and non-volatile storage and so on and how to type simple commands into your (Linux) computer.

The examples will make reference to RTB keywords, commands and functions that may not have been covered up to that point - use the rest of this book as a reference manual and consult the index - it's really not intended to be read from start to finish in that order.

1.2 Conventions used in this book

Keeping things simple is the aim here, so there are only really 3 things to look out for[1]. The first is that anything you may need to type into a computer running RTB, or anything it prints will be in this `typewriter` style font. The second is that anything of some importance, such as a name of an algorithm is emphasised *like this*.

The final thing to look out for is a warning, or just something that may be important

[1] OK, Possibly four as there may be the occasional footnote at the bottom of a page, so look out for them too.

to remember. It's represented by a warning exclamation point in a box to the side of the text. As demonstrated in this paragraph.

1.3 BASIC differences

If you know what you're doing, here are some brief differences between RTB and a "classic" BASIC:

- RTB does not allow multiple statements on one line; One statement per line only.
- Items to be printed using the PRINT command must be separated by a semicolon (;) and no additional spacing is added. See the `numformat` command for details on formatting numbers.
- Variable names can be of almost any length and upper/lower case is significant.
- `IF` statements must have `THEN` (So no `IF... num = 4`, or `IF... GOTO 10`, it must be the full `IF... THEN GOTO 10`, or `IF... THEN a = 7`, etc.)
- In `FOR` loops, there is no `NEXT` instruction – it's replaced by the `CYCLE...REPEAT` construct.
- Named procedures and functions. (Which can be called recursively)
- Local variables inside user-defined procedures and functions.
- A single looping construct (`CYCLE...REPEAT`) which can be modified with `FOR`, `WHILE` and `UNTIL` constructs.
- `BREAK` and `CONTINUE` as part of the looping construct.
- Arrays start at zero and go up to and include the number in the `DIM` statement. ie. the `DIM` statement specifies the size of the array plus one.

Additionally (where supported) the graphical systems may well be new or different to you. RTB incorporates simple block/line graphics as well as turtle graphics using a variety of angle modes (degrees, radians and clock).

Chapter 2

Starting RTB

RTB is primarily designed to run on computers running Linux. In the fullness of time, both MS windows and Apple Mac versions may be made available, but for now it's Linux only.

On the Raspberry Pi, there are some additional features to make use of the Pi's GPIO facility.

Starting RTB may vary from one Linux system another, however opening up a text (or command/shell) terminal and typing

```
rtb
```

at the prompt will usually get things going for you. You may have a desktop icon which you can click on too.

RTB runs equally well under X windows on directly on the console.

Whatever the system, once RTB has started it should look the same. There will be a keyboard to type commands into, this is connected to the main computer which should be connected to a screen or display of some sort. A Raspberry Pi may even be connected to your home TV set. The mouse is not normally needed, but may be used in the editor and by your own program.

2.1 Command line arguments

RTB can take additional arguments (parameters) on the command-line. The usage line is:

```
Usage: rtb [-s] [-f] [-d] [-H] [-m mode] [-x xSize] [-y ySize] [-z bpp]
```

```
[-l] [-D] <filename>
```

The arguments are:

`-s` Disables sound. You may occasionally need this to keep things quiet or as a workaround on some systems with no sound system installed.

`-f` Runs in full-screen mode. This would be the default when run directly on the console, but it can be used to force RTB to use the full screen when running under X Windows.

`-d` enabled double-buffering. This only works on some Linux system on some graphics cards. It's not recomended.

`-H` Use the hardware frame buffer directly. Not recomended.

`-m mode` Select the screen mode to use. This is a number, usually from 0 to about 9 and each will depend on the hardware capability of the graphics card and the monitor. Use this only with the `-f` flag.

`-D` Dump all avalable video modes. This is the mode number to use with the `-m` flag above. Use this with the `-f` flag.

`-x xSize` Force the X size of the window to be the size given. This is mostly usefull when running under X Windows to specify the window size.

`-y ySize` Force the Y size of the window to be the size given. This is mostly usefull when running under X Windows to specify the window size.

`-z bpp` Force the bits-per-pixel to the given value. Should be 8, 16, 24 or 32. It's generally not a good idea to use this - the system will pick the best possible value when it starts.

`-l` Start RTB with a double-sized font. This may be useful when running on very large displays.

`<filename>` Load the given filename into RTB and start executing it.

2.2 Autorun

When RTB starts, it looks for a file called `autorun.rtb`. Firstly in your current directory, then secondly in your home directory. This can be used to pre-set they function-keys and change the default colours in the editor.

This file is loaded and run before any filename given on the command-line is loaded and run.

2.3 Ready

When it's setup and ready, the screen should be clear apart from a logo, some introductory text and a prompt. It will probably look something like this:

```
Ready
>
```

The "$>$" symbol is the prompt. It's presence means that RTB is ready to accept commands and program lines typed into it.

Chapter 3

The command-line

The command line is the general term for typing commands and program lines into the system, however it has a few features to make your life easier.

Note that it is possible to develop and run RTB programs without ever using the command line! You can press `F2` as soon as the system has started to use the full-screen editor, then run your program from there. However, the commands you can enter in immediate mode may allow you to test parts of your program, examine the file-system and so on.

3.1 Editing

As you type characters into the system, you may make mistakes. To correct them you can use several different keys. The important one is probably the `Backspace` key. Usually a big key to the top-right of the main keyboard with an arrow pointing to the left. This will erase characters you've typed and move the cursor to the left, however there are more efficient ways to deal with the line you're typing noted below.

Some of the command characters listed below you access with the `Control` key. This is labelled as `Ctrl` on most keyboards and works like the `Shift` keys in that you push it, keep it pushed, then type another character before releasing them both.

`Ctrl-A`**,** `Ctrl-E`**:** Move the cursor to the start or the end of the line respectively. You can also use the `Home` and `End` keys if your keyboard has them.

← `(Left)` **and** → `(Right)`**:** arrow keys (not to be confused with the `Backspace` key) move the cursor one character to the left or right of the typed line.

`Ctrl-D`**:** Delete the character under the cursor. You can also use the `Del` or `Delete` key if your keyboard has one.

`Backspace`**:** Deletes the character to the Left of the cursor)

`Ctrl-S`**:** Swap the character under the cursor with the character immediately to the right. Handy for those who type the as teh like me. . .

`Ctrl-F`**:** Find the next occurrence of the next character typed. E.g. `Ctrl-F` followed by `G` will make the cursor jump to the next `G` in the line. `Ctrl-F` followed by another `Ctrl-F` will repeat the last find.

`Esc`**:** Abandon entering this entire line.

3.2 Command-line history

The RTB command line remembers the past 50 lines that you type in, and you can use the ↑ (`Up`) and ↓ (`Down`) arrow keys on your keyboard to scroll through past things you've typed in. This will enable you to quickly fix a mistake in a line already in the system, or a line you typed in which reported an error after you pressed the *Enter* key.

3.3 Editing program lines

If you spot a mistake in a program line and you can't find it in the history, then you can enter the `ED` command followed by the line number. E.g. `ED 10` will then present line 10 as if you had re-typed it, but not yet pressed *Enter* so you can change the line as required.

Chapter 4

Immediate mode commands

In immediate mode, as well as executing simple print instructions and other instructions you can use within a program, there are several commands which can only be executed in immediate mode.

Commands may be typed in in upper or lower case. Some commands are presented below in mixed case - this is just to make it easier to see what the command is.

`list [[first] last]`**:** This lists the program stored in memory to the screen. You can pause the listing with the space-bar and terminate it with the escape key. If `first` is given, then only that line will be listed. If both `first` and `last` are given, then lines in that range will be listed.

`save [filename]`**:** Saves your program to the local storage medium. `filename` is the name of the file you wish to save as. If you want to include spaces in the filename, then you need to enclose the name inside double-quotes. If you have already saved a file, then you can subsequently execute `SAVE` without the filename and it will overwrite the last file saved. (This is "safe" as it's reset when you load a new program or use the `NEW` command)

Note that the program is saved *without* line-numbers, even if you used line numbers to enter the program in interactive mode. If your program contains references to line numbers (e.g. `GOTO`, `GOSUB` or `RESTORE` commands) then you will be prompted to use the `saveN` command below.

`saveN [filename]`**:** Same as the normal `save` command, but saves with your line numbers included.

`load filename`**:** Loads in a program from the local storage. As with `save`, you need to use double-quotes if the filename contains spaces.

`ls [directory]`**:** Lists the RTB files and directories in your current working directory, or the given directory (as above, use double-quotes to select directories with spaces in them)

`dir [directory]`**:** An alias for `ls` above.

`cd [directory]`**:** Changes directory to the one given. If no directory is given, then it changes to your "home" directory.

`pwd`**:** Prints your current Working Directory.

`new`**:** Deletes the program in memory. There is no "Are you sure?" verification and once it's gone, it's gone. Remember to save first!

`run`**:** Runs the program in memory. You may give a line number and the program will start from that number rather than the first line in the program. Note that using `run` will clear all variables.

`cont`**:** Continues program execution after a `STOP` instruction. Variables are not cleared.

`resume`**:** An alias for the `cont` command.

`clear`**:** Clears all variables and deletes all arrays. It also removes any active sprites from the screen and stops all sounds playing. Stopped programs may not be continued after a `clear` command.

`tron`**:** Trace-On: Turns line-number tracing on. As each line is executed, it's number is printed to the text console that RTB was started from - you may need to run your program in a smaller window than full-screen to see the trace.

`troff`**:** Trace-Off: Turns line number tracing off.

`ed linenumber`**:** Edit the line given.

`edit`**:** Edits the current program in the full-screen editor.

`renumber [start [inc [first [last]]]]`**:** This renumbers your program - by default it will start at 100 and go in increments of 10, however you can change this as follows: The `start` and `inc` parameters specify the new starting line number and increment, the `first` and `last` parameters specify the first and last *exiting* line numbers to renumber. Using this latter way, you can move lines in the program, but beware of overlaps.

If an overlap does occur, then renumbering will stop at that point and you may find your program to be somewhat scrambled. . . Please make sure you save your program before renumbering!

`version`**:** Print the current version of RTB.

`scanKeys`: This prints out a table of all key names that can be used with the `scanKeyboard` function.

`showKeys`: This outputs a list of all the function-key definitions.

`showCols`: This prints out the current colours assigned to the syntax highlighting in the screen editor.

`mcBlocks`: This outputs a table containing the names of all Minecraft Block types. You can use the block types here rather than the internal Minecraft block number.

`exit`: Exit RTB and return to the environment you started RTB in.

4.1 File names

The system you run RTB on may have its own rules about what a filename can look like, and whether the name is case-sensitive. (ie. UPPER/lower case letters – are they considered the same, or different?) In the Linux environment then case *is* significant.

If you're not sure, just stick to simple names without spaces, and remember that if you do need or want to use spaces, then you need to enclose the filename inside "double-quotes".

If you are subsequently looking at the files outside the RTB environment note that the filenames will have the characters `.rtb` appended to it.

Chapter 5

The Screen Editor

To help you develop and edit programs, especially when you do not wish to use old style line numbers, RTB incorporates a simple full-screen editor with optional syntax highlighting.

To access the editor, just use the `EDIT` command, or press the `F3` key which defaults to `EDIT` unless you've re-defined it.

The editor will read in the last file you loaded or saved. If you have changed the current program in the interactive environment, then you will be asked to `SAVE` (or `NEW` before editing it. If you have not loaded or saved and programs so-far, it will start with an empty file and you'll be asked to save it before returning to the interpreter.

The screen editor shares some of the control-key commands as the line editor, but also introduces more of its own as well as a set of function keys.

There is no mode to the editor - anything you type is inserted into your program. To command the editor, you use control characters and the Function keys. If you are used to some Linux or MS editors, it is more like "nano", or "notepad" than "vim" in that respect.

Some of the command characters listed below you access with the `Control` key. This is labelled as `Ctrl` on most keyboards and works like the `Shift` keys in that you push it, keep it pushed, then type another character before releasing them both.

5.1 Function Keys

`ESC`**:** Abandon editing the entire file. (You are prompted if you have changed anything first)

`F1`**:** Pressing the `F1` key will bring up a quick-help page, should you forget some of the commands.

`F2`**:** This saves your file and loads it into the interpreter. If there are any load errors, you are promoted to return to the editor with the cursor positioned on the line in error.

`F3`**:** As above (`F2`) but also attempts to run the program. If there are any errors, you are prompted to return to the editor, or stay in the interactive environment (which may be handy for debugging, printing variables, and so on)

`F4`**:** Toggles syntax highlighting on or off.

`F5`**:** Saves your work. A save is performed automatically when you exit the editor, but this allows you to save at any time. (May be handy if you are expecting a power cut)

`F8`**:** Loads a new file into the editor. If you have changed the current file, you are prompted to save it first.

`F9`**:** Discards all edits and reverts to the last saved version of your file.

`F10`**:** Inserts a file at the current cursor location. This can allow you to build up libraries of procedures and functions.

`F12`**:** Erase the current file. This deletes the file from memory and resets the filename - it doesn't change any file on disk unless you subsequently save with the same filename.

5.2 Control Keys

`Ctrl-O`**:** This will open a new line for text entry *over* the current line. Handy if you're on the top line and want to add text above it.

`Ctrl-M`**:** This will open a new line for text entry *under* the current line. Normally to enter a new line, you would move to the end of the line then press enter. This is just a short cut.

`Ctrl-A`**,** `Ctrl-E`**:** Move the cursor to the start or the end of the line respectively. You can also use the `Home` and `End` keys if your keyboard has them.

$\leftarrow$ `(Left)` **and** $\rightarrow$ `(Right)`**:** arrow keys (not to be confused with the `Backspace` key) move the cursor one character to the left or right of the typed line.

↑ (Up) **and** ↓ (Down)**:** arrow keys move the cursor one character up or down from the current line.

Page Up**,** Page Down**:** Move the cursor one page up or down.

Ctrl-Z**:** Centres the cursor on the page. This will move the screen up or down to make the line the cursor is currently on in the middle of the screen.

Ctrl-D**:** Delete the character under the cursor. You can also use the Del or Delete key if your keyboard has one.

Backspace**:** Deletes the character to the Left of the cursor. (This is the key that's normally above the Enter key.

Ctrl-S**:** Swap the character under the cursor with the character immediately to the right. Handy for those who type the as teh like me...

Ctrl-F**:** Find the next occurrence of the next character typed on the current line. E.g. Ctrl-F followed by G will make the cursor jump to the next G in the line. Ctrl-F followed by another Ctrl-F will repeat the last find. The search is case-insensitive.

Ctrl-K **or** Ctrl-X**:** Kill the current line - this deletes the from the screen and copies it into the paste buffer. You can use Ctrl-K several times to delete multiple lines and move them to the paste buffer, however if you move the cursor, then kill more lines, the first batch of lines will be lost!

Ctrl-U**:** Un-kill Under: This copies all lines in the paste buffer *under* the current line.

Ctrl-V**:** Un-kill oVer: This copies all lines in the paste buffer *oVer* the current line.

Ctrl-W**:** Where Is: This is the word search facility. You are prompted for some text to search for and the editor will search through to try to find it. The search is case-insensitive.

Ctrl-J**:** Jump to a line number. You are prompted for the line number to jump to.

Ctrl-G**:** Prints the current line number. Note that this is the line number inside the file, and is not the same as the line numbers which may be used to enter programs in interactive mode.

5.3 A guide on usage

In-general the cursor can be moved by the arrow keys and the Page Up/Down keys. You can also use the mouse scroll wheel to move up and down, or click the mouse on any character to move the cursor directly there. Ctrl-Z will move the current line to the

middle of the screen which might make it easier to see more lines above or below the one you're working on.

You should be able to do all editing without using the mouse at all - it's far more efficient to keep your hands on the keyboard than to constantly move one over to the mouse and back again.

Copy and paste is accomplished using the `Ctrl-K` (to Kill lines) and `Ctrl-U` - to Un-Kill lines. To move a block of text, you would position the cursor on the first line in the block, then press `Ctrl-K` as many times as needed – noting that this will delete the lines. If you're copying the block, then you can immediately press Ctrl-U - which pastes the deleted lines back where they were, then move the cursor and press `Ctrl-U` again. You can paste as many times as you need to to repeat the lines, if required.

5.4 Syntax highlighting

Syntax highlighting is enabled by default. If you want to change the colours then you need to update some system variables. These are:

`editColNum` This holds the colour number for representing numbers.

`editColStr` Strings (enclosed inside double-quote characters)

`editColKeyw` Keywords - e.g. `PRINT`, `FOR`, etc.

`editColVar` Variables.

`editColRem` Remarks. Either `REM` or `//` style comments.

`editColArith` Arithmetic characters e.g. `+`, `*`, etc.

`editColRel` Relational operators - e.g. `<=`, `=`, etc.

`editColPV` Pseudo Variables - built-in variables e.g. `COLOUR`, `editColPV`, etc.

You can set these in a separate program. E.g.

```
// Set Editor Syntax colours
editColNum   = Pink
editColStr   = Olive
editColKeyw  = Aqua
editColVar   = Grey
editColRem   = Yellow
```

```
editColArith = Silver
editColRel   = Red
editColSysV  = Green
end
```

You may wish to investigate the `autorun.rtb` program too. This is a program that's automatically loaded and run each time you start RTB.

Chapter 6

Introduction to RTB programming

RTB programs are essentially a list of instructions for the computer to follow, one instruction per line.

The syntax follows an easy to read system, designed to make it easy to both enter a new program and understand an existing one.

The structure of your program, indentation, upper/lower case, etc. is entirely up to you. Nothing is enforced by the system, although if you use the `LIST` command, then you will get an idea of what the program looks like to the computer as it will interpret your program in the way it executes it.

Using the `LIST` command is handy from time to time too, as it will highlight potential places where you may have forgotten to use an `ENDIF`, or missing `REPEAT` from a `CYCLE` instruction.

Here is a quick guide to entering and running a program.

Start RTB. At the > prompt, press `F2` to enter the editor, and type the following into the editor:

```
print "Hello world"
end
```

Pressing `F3` will save then run your program. Enter a filename - e.g. `test` (no need to add `.rtb` to it) then your program will be saved and run.

You can then return to the editor, or press `ESC` to return to immediate mode where you can use the `RUN` command to re-run your program.

6.1 What an RTB program looks like

The example above is the simplest RTB program. Programs can be entered in upper or lower case, although if you `LIST` the program you'll note that some keywords have been changed, as well as the program spacing. This is how RTB sees the program internally - as long as you use the screen editor, you can maintain your program format, style, etc. as you wish. There is no need to use spacing or indentation although it can help make your programs more readable (and I strongly recommend you do space your programs out and indent sections inside loops, etc.) You can use upper case or lower case as you desire. My own preference is to use a form of "Camel Caps" but start with a lower-case letter. e.g. `numberOfCows`

Programs don't need to start with anything special - jump right in, but a few comment-lines are handy. Programs should also end with the `END` statement - this can be anywhere. It performs a graceful exit to the program. You can also use the `STOP` keyword too - then it will print a message and stop running. At this point, you can examine variables, etc. then, if-required use the `CONT` command to contine program execution. `STOP` and `CONT` are really intended as program debugging aids.

A sample program to give you more idea:

```
// Many Hello Worlds

cls
for lines = 1 to 10 cycle
  proc indent (lines)
  print "Hello, world"
repeat
end

// proc indent:
//  Output some dots (see also the space$() function)

def proc indent (distance)
  local count
  for count = 1 to distance cycle
    print ".";
  repeat
endproc
```

Chapter 7

Comments

It's always a good idea to include comments in your programs, and RTB provides 2 methods to help you do this.

Firstly, there is the traditional BASIC `REM` statement. Short for "Remark". Secondly there is the `//` statement which is common in many other programming languages.

`REM` must appear at the start of a program line, but `//` may appear anywhere in a line - and anything after the `//` is ignored.

Examples:

```
REM This is a demonstration of comments
//
REM // on its own can be used to separate program sections.
//

// But blank lines are also allowed when you use the screen editor
//    but appear as empty // lines in the LIST output.

// The line below is allowed:
LET test = 42 // Set test to 42

// But the line below this is not allowed:
LET test = 42 REM Set test to 42
```

Chapter 8

Variables

A variable is an area of computer memory that we can use to store data in. It has a name associated with it as well as the memory locations needed to store the data.

8.1 Names

Variable names must start with a letter but may otherwise contain any number of letters and digits and underscores. An example of a variable name might be: `counter`, or `height` or `numberOfCows` and so on.

8.2 Types

RTB Supports two types of variables; Numbers and Strings. These can be scalars (just a single number of string) or arrays (lots of numbers of strings with a common name).

String variables are differentiated from numeric variables by having the dollar character appended to them. E.g. `firstName$` or `homeTown$` and so on.

A number is any decimal value like `1`, `3.14`, `-5`, and so on. Numbers may also be expressed in scientific notation. and we use the letter "e" to represent the power of 10 so `1.234e7` is 1.234×10^7, or `12340000`. The number range is approximately $\pm 10^{308}$.

A string is a sequence of characters, e.g. `"Hello"`, `"Gordon"` and so on. Strings are always enclosed in double-quotes. The maximum length of a string is limited by available memory.

8.3 Assignment

We assign values to variables using the `LET` instruction. e.g.

```
LET numberOfCows = 0
```

and we can modify them as follows:

```
LET numberOfCows = cowsInField + cowsInBarn
```

! The `LET` statement is optional and rarely used.

8.4 Numeric operators and Precedence

There are various arithmetic and logical operators that can be used with numbers.

In order of precedence, they are:

Precedence	Operator	Description
Highest	^	Exponent, or “raise to the power of”
	-	Unary minus
	NOT	Logical NOT
	* / MOD DIV	Multiply, Divide, Modulo, Integer Division
	+ -	Addition, Subtraction
	| & XOR	Logical OR, AND and XOR
	< <= > >=	Conditional tests
	= <>	Conditional Equals and Not Equals
Lowest	AND OR	Conditional AND and OR

You can always use ()’s to alter the evaluation order, if required, and in some cases they may help to make the code more readable and obvious.

8.5 String Operators

There is only one string operator - the plus operator which we can use to concatenate strings.

```
firstName$ = "Gordon"
lastName$ = "Henderson"
fullName$ = firstName$ + " " + $lastName$
PRINT fullName$
```

8.6 Arrays

Arrays must be declared before they are first used and we must know the size of it before-hand. We declare them with the `DIM`[1] statement.

Arrays can be either numeric or string. They can not hold mixed values.

Arrays can have more than one dimension - the limit to the number of dimensions and overall size is program memory.

Arrays are used as follows:

```
DIM list (4)
list(0) = 1
list(2) = 4
PRINT list(2) + list(0)
END
```

8.7 Associative Arrays

Associative arrays (sometimes called a *map*) is another way to refer to the individual elements of an array. In the examples above we used a number, however RTB also accepts a string.

```
DIM record$ (10)
record$ ("firstName") = "Gordon"
record$ ("lastName") = "Henderson"
record$ ("county") = "Devon"
PRINT "First name is "; record$ ("firstName")
```

Associative arrays can be multi-dimensional and you can freely mix numbers and strings for the array indices.

[1] Short for Dimension.

Chapter 9

Flow Control

Programs are normally executed in line-number order, one after the other. There are many ways in which we can alter the flow of our programs, but the traditional BASIC ones are the GOTO and GOSUB instructions.

GOTO as its name implys causes program execution to go to the line number listed after the GOTO instruction.

```
120 GOTO 315
```

GOSUB[1] allows a program to temporarily jump to a new point and then, upon execution of the RETURN statement, flow resumes at the statement after the GOSUB instruction.

GOSUB is designed to be used to allow a piece of code to be executed over again from different parts of the main program.

Subroutines can call other subroutines and the number of subroutines that can be called is limited only by the memory capacity of the computer - some of which is required to keep track of where to return to.

Here is an example – It's code to print my name:

```
500 REM Simple subroutine to print my name
510 PRINT "Gordon Henderson"
580 RETURN
```

Then, anywhere we need to print my name:

```
100 PRINT "Hello ";
```

[1] Go to Subroutine

```
110 GOSUB 500
120 PRINT "Good to meet you ";
130 GOSUB 500
140 GOTO 100
```

Subroutines are a good way of saving and re-using code however there are more modern ways of doing this that removes the need to keep track of line-numbers.

9.1 GOTO and GOSUB – The great controversy

The use of `GOTO` and `GOSUB` is highly debated and both `GOTO` and `GOSUB` should be considered deprecated in their use. It is possible to write fully functional RTB programs without using either these instructions.

The original version of BASIC did not provide any more means to control the flow of your code, however newer programming languages have evolved which do help here, and in some areas the use of the `GOTO` instruction has been eliminated entirely!

However don't fix the idea in your head that all GOTOs are bad, we need to balance things up and note that not everyone thinks that GOTOs are bad – myself included. Very occasionally, a GOTO can get you out of a situation in a more elegant manner than some of the constructs you'll read about next, so don't be afraid of the GOTO, but instead respect it, try not to use it, but if you have to use it, then use it well!

9.2 Line numbers or No line numbers?

The controversy continues - to use line number means you code can potentially end up like a pile of spaghetti, but how to not use line numbers? The following example shows how:

Line Numbers	No Line Numbers

10 REM FLIP A COIN
20 c = RND (2)
30 IF c = 0 THEN GOTO 100
40 PRINT "Tails"
50 PRINT "Try again ";
60 INPUT t$
70 IF t$ = "y" THEN GOTO 20
80 END
100 PRINT "Heads"
110 GOTO 50
	// Flip a coin
	
	cycle
	  coin = rnd (2)
	
	  if coin = 0 then
	  print "Heads"
	  else
	  print "Tails"
	  endif
	
	  print "Try again ";
	  input try$
	repeat until try$ <> "y"
	end

Both programs accomplish the same thing, but the program on the right is coded without the use of line numbers or `GOTO` statements. It's a little longer, but is well spaced out and easier to read.

Chapter 10

Text and Number Input

There are several ways to get text and numbers into into your running program. Either a whole line of text or a number, or a single character at a time.

`input` The `input` statement will cause your program to pause, a question mark will be printed and it will wait for you to type a line of text, or a number. The type of data will depend on the variable that you put after the `input` statement.

e.g.

```
// Read in a name
print "What is your name"
input name$
print "Hello, "; name$

// Read in a number
print "How old are you"
input age
print age; " years old. A good vintage."
end
```

Normally, a single question mark is printed when the `input` statement is executed, but you can make it print any prompt by including it on the `input` command as follows:

```
// Read in a name
input "What is your name ? ", name$
print "Hello, "; name$

// Read in a number
```

```
input "How old are you ? ", age
print age; " years old. A good vintage."
end
```

If you type in a string when it was expecting a number, then it will assign zero to the number. If you type in a number when it is expecting a string, then it will assign the number as a string – the same sequence of characters that you typed.

`get$` The `get$` instruction pauses your program and reads a single character in from the keyboard and assigns it to the string variable. E.g.

```
print "Press the space-bar to continue ";
cycle
  key$ = get$
repeat until key$ = " "
end
```

`get` The `get` instruction pauses your program and reads a single character in from the keyboard and assigns that characters ASCII value to the numeric variable given. E.g.

```
print "Press any key to continue ";
key = get
print "The ASCII value of the key you pressed is: "; key
end
```

`inkey` The `inkey` instruction allows you to see if any keys have been pressed without stopping your program. This can be used in moving games where waiting for a keypress would not be acceptable. If no key has been pressed, then the return value is `-1` otherwise it returns the ASCII value the same as `get` above. E.g.

```
// Simple reaction timer
wait (2) // 2 seconds
start = time
print "Go!"
while inkey = -1 cycle
   // Do nothing
repeat
etime = time
print "Your reaction time is ";  etime - start;  " milliseconds"
end
```

When reading the keyboard using `get` or `inkey`, there are a number of pre-defined key values you can use. These represent the special keys on the keyboard and are as follows:

keyUp	keyDown	keyLeft	keyRight
sKeyUp	sKeyDown	sKeyLeft	sKeyRight
keyIns	keyDel	keyHome	keyEnd
keyPgUp	keyPgDn		
keyF1	keyF2	keyF3	keyF4
keyF5	keyF6	keyF7	keyF8
keyF9	keyF10	keyF11	keyF12

Hopefully their meaning is obvious, but the "s" keys above represent the shifted values. You can use them as follows:

```
key = inkey
switch (key)
  case keyUp
    proc moveUp
  endcase

  case keyeDown
    proc moveDown
  endcase

// and so on...
```

There is one other way to read the keyboard - you can read the scan code generated by the keyboard when a key is pressed. This method allows you to read keys that wouldn't normally return a value - such as the left and right shift keys and so on. The command to read the keyboard this way is the `scanKeyboard` function. You pass the scan code into `scanKeyboard` and it returns `TRUE` or `FALSE`.

This example demonstrates:

```
// scanKeyboard test

cycle
  if scanKeyboard (scanLShift) then print "Left-Shift"
  if scanKeyboard (scanRShift) then print "Right-Shift"
repeat
end
```

The constants `scanLShift`, `scanLShift`, etc. maybe be displayed on the screen using the `scanKeys` command in immediate mode. (You may need a long screen as there are currently 233 scan codes).

Note that using `scanKeyboard` in your program and pushing printable keys will leave those keys in the system input buffer ready for the next time your program performs a keyboard read using `input`, `get`, `get$` or when the program exits and returns to immediate mode. To throw away all these characters, you can use the `clearKeyboard` instruction.

Chapter 11

Text and Number Output

RTB has a flexible output system that allows you to change the colour of the foreground and background, change the font size, (simple scaling of height or width) and change the screen location for the next character to be printed. You can also define your own font characters if required, and read existing font definitions.

The important thing to remember is that the text (and graphics) may not always appear immediately on the screen. This is because all text and graphics output is written to a "shadow" display screen and this "shadow" screen is only sent to the actual display screen under certain conditions:

- Using the `cls`, `gr`, or `hgr` instruction will clear and update the screen immediately.
- If your program stops for input using `input`, `get` or `get$` instructions then the screen will be updated.
- You `print` something and the `updateMode` system variable is set to 1 or 2.

11.1 updateMode

The `updateMode` system variable controls how and when the screen is updated when you use a `print` instruction. You can change `updateMode` at any time during program execution. The default value is `1` and this is set every time a program is run.

- `updateMode = 0`: The screen is never explicitly updated. This is the fastest way to output lots of text to the screen. It's also the quickest way to frustration, however updates will happen when your program stops for input, or you explicitly use the `update` instruction.

- `updateMode = 1`: The screen is updated whenever your program prints something that causes a new-line to be output. ie. a `print` instruction without a trailing semicolon. Updates also happen when the program stops for input, as usual. This is the default mode.
- `updateMode = 2`: The screen is updated whenever your program prints anything. This is the slowest output mode, but can be useful in some circumstances.

For most text-based programs, having `updateMode` set to its default value of `1` is sufficient and you should not have to do anything. The time you may need to manually force an update would be when drawing graphics and you don't want to stop your program to read input (e.g. is using `inkey` or `scanKeyboard`).

`print` The `print` instruction is the command to print numbers and strings to the screen. It accepts any mix of numbers and strings, separated by the semicolon character. Normally a new-line is taken at the end, but if you add a trailing semicolon, then the newline is suppressed. This lets you use multiple `print` instructions to build up a line.

`numFormat (total, decimals)` This affects all future number printing via the `print` statement. The numbers will be printed right-justified in a total fields width of `total` with `decimals` digits after the decimal point. Setting the parameters both to zero restores the default format which is designed to be general purpose.

`cls` The screen is cleared.

`cls2` The screen is cleared, but not updated. See above for more details.

`hvTab (x, y)` The cursor is moved to the supplied column `x` and line `y`. Note that (0,0) is top-left of the text screen. See also the `hTab` and `vTab` system variables.

`fontScale (x, y)` This allows you to set the scaling factor for all subsequent text printing. If RTB was started with the `-l` flag, then a `fontScale` of `(2,2)` is assumed. When you execute this command, the cursor position (hvTab) is reset to (0,0), the top-left corner. You must then move the cursor using the `hvTab` or `hTab=` and `vTab=` instructions. The screen width and height will change to reflect the new font size.

`defChar (c, x0,x1,x2,x3,x4,x5,x6,x7,x8,x9)` This lets you define (or re-define) characters in the internal font. Characters are 8 pixels wide by 10 pixels deep. `c` is the character to re-define (0-255) and x0 through x9 are the 10 rows of 8 bits each. `x0` is the top row and the most significant bit is the leftmost pixel. E.g.

```
defChar (129, 0x80, 0x40, 0x20, 0x10, 0x08, 0x04, 0x02, 0x01, 0xFF, 0xFF)
print chr$ (129)
end
```

Note that you can't redefine characters number 8, 10 or 13 as these correspond to backspace line-feed and carriage return.

11.2 Variables affecting output

In addition to `updateMode` above, the following apply to text output:

`hTab` Set or read the horizontal screen position. The left-most column is position zero.

`vTab` Set or read the vertical screen position. The top-line is line zero.

`ink` Set or read the foreground colour of the output text. See the colours section and the `colours.rtb` demo program for more details.

`paper` Set or read the background colour of the output text. See the colours section and the `colours.rtb` demo program for more details.

`tWidth` This is the number of characters the current screen is wide. This changes if you use the `fontScale` instruction.

`tHeight` This is the number of characters the current screen is tall. This changes if you use the `fontScale` instruction.

Chapter 12

Conditionals: IF ... THEN ...

RTB has a comprehensive `IF` statement, but unlike traditional BASICs, you must use the corresponding `THEN` statement with it.

```
// IF Statement example
INPUT "dummy value: ", dummy
IF dummy < 100 THEN PRINT "it's < 100"

IF dummy = 42 THEN dummy = dummy + 1
PRINT "Dummy is "; dummy
END
```

The expression inside the `IF ... THEN` statement is evaluated as if it's an assignment expression. If the result if 0, then its treated as FALSE, anything else is treated as TRUE. See the section on operator precedence in the variables chapter for more details.

12.1 Multiple lines

We can extend the `IF` statement over multiple lines, if required. The way you do this is by making sure there is nothing after the `THEN` statement and ending it all with the `ENDIF` statement as this short example demonstrates:

```
// Program fragment to demonstrate multi-line IF
test = 42
IF test <> 15 THEN
  PRINT "Test was not 15"
```

```
    PRINT "We will end now"
    END
  ENDIF
  PRINT "Test was 15"
  PRINT "We can go home now"
  END
```

12.2 IF . . . THEN . . . ELSE . . . ENDIF

We can modify the IF. . .THEN construct with one more keyword; ELSE This can provide an alternative set of instructions to follow without using a GOTO instruction and can help to make your programs more readable.

The following example demonstrates:

```
REM Guess
secret = 42
CYCLE
  INPUT "Guess the number? ", guess
  IF guess = secret THEN
    PRINT "You Guessed it!"
    END
  ENDIF

  IF guess < secret THEN
    PRINT "Too low"
  ELSE
    PRINT "Too high"
  ENDIF
REPEAT
```

There are a few simple rules to observe when using multi-line IF. . .THEN. . .ELSE statements.

- IF, THEN and ELSE must be on separate lines, with nothing after the THEN statement (Some programming languages allow you to put them on the same lines, RTB doesn't)
- The IF, ELSE and ENDIF statements must be at the start of a line. ie. you can not have them after a THEN statement.

- If you are executing a `GOTO` instruction after a `THEN` instruction then you need to use both `THEN` and `GOTO`. Some variants of BASIC allow just one or the other, but not RTB. These *do not work* in RTB:

```
100 IF a = 5 THEN 120
120 IF b = 7 GOTO 155
```

Chapter 13

Conditionals: SWITCH and CASE...

There is another form of conditionals commonly known as the *switch statement* although it's actual representation varys from one programming language to another.

Essentially, the SWITCH instruction allows you to test a value against many different values, and execute different code depending on which one matches. It can often simplify the writing of multiple IF...THEN...ELSE statements.

It's probably easier to explain by example:

```
INPUT a
SWITCH (a)

  CASE 1, 2
    PRINT "You entered 1 or 2"
  ENDCASE

  CASE 7
    PRINT "You entered 7"
  ENDCASE

  DEFAULT
    PRINT "You entered something else"
  ENDCASE
ENDSWITCH
END
```

In this simple test, we input a number, then test it against a set of values. You can put any expression or variable inside the brackets on the SWITCH statement. What follows is lines of CASE statements and each CASE has one or more constant numbers after it. These numbers are matched against the value of the SWITCH instruction and if there is a

match then the code after the CASE is executed up to the ENDCASE instruction and at that point, control is transferred to the statement *after* the matching ENDSWITCH statement. Optionally you can use the instruction DEFAULT and this section will be executed if there are no other matches.

Like IF...THEN...ELSE, SWITCH has a few simple rules:

- Every SWITCH must have a matching ENDSWITCH statement.
- Every CASE or DEFAULT statement must have a matching ENDCASE statement.
- Statements after a CASE statement must not run-into another CASE statement. (Some programming languages do allow this, but not RTB)
- The constants after the CASE statement (and the expression in the SWITCH statement) can be either numbers or strings, but you can't mix both.

Finally, if you are reading some older BASIC programs, you may see a construct like ON...GOTO... Our SWITCH statement is the modern way to handle code like this and if you are converting older programs it should be relatively simple to use the newer SWITCH instructions to help eliminate the issues keeping track of line numbers. An example:

Old Way:

```
100 ON a GOTO 200,300,400
120 PRINT "a was NOT 1, 2 or 3"
130 STOP
200 PRINT "a was 1"
210 GOTO 500
300 PRINT "a was 2"
310 GOTO 500
400 PRINT "a was 3"
410 GOTO 500
500 PRINT "Do something else now"
```

New way:

```
SWITCH (a)
  CASE 1
    PRINT "a was 1"
  ENDCASE

  CASE 2
    PRINT "a was 2"
  ENDCASE

  CASE 3
    PRINT "a was 3"
  ENDCASE

  DEFAULT
    PRINT "a was NOT 1, 2 or 3"
    STOP
  ENDCASE
ENDSWITCH
PRINT "Do something else now"
```

So the new way is a bit longer and more to type, but it has the advantage of not relying on line numbers and if we use the indentation as a guide, we can quickly scan down to find the matching `ENDSWITCH` statement.

Chapter 14

Looping the Loop

This chapter explains the RTB instructions for handling loops. Using these instructions, you can almost always eliminate the use of the GOTO instruction, and hopefully make your program easier to read.

There are two new commands which RTB has to define a block of code which will be repeated. These are: CYCLE which defines the start of the block and REPEAT which defines the end.

14.1 CYCLE . . . REPEAT

On their own, these would cause a program to loop between them forever, however RTB provides 3 means to control these loops. Lets start with an example.

```
// Demonstration of CYCLE...REPEAT
count = 1
CYCLE
  PRINT "5 * "; count; " = "; 5 * count
  count = count + 1
REPEAT
END
```

If you enter and RUN this program, it will run forever until you hit the ESC key, so it's not that useful for anything other than to demonstrate CYCLE and REPEAT.

You can use an IF ... THEN GOTO sequence to jump out of the loop, but that's not very elegant and we're trying to not use GOTO anyway. Fortunately there are several modifiers.

14.1.1 UNTIL

Changing it to:

```
// Demonstration of CYCLE...REPEAT
count = 1
CYCLE
  PRINT "5 * "; count; " = "; 5 * count
  count = count + 1
REPEAT UNTIL count > 10
END
```

and run the program again. We get our 5 times table, as before, but not a GOTO in sight. We can see clearly the lines of code executed inside the loop and if we read the program it possibly makes more sense. We also don't need to keep track of any line numbers either.

14.1.2 WHILE

If we test the condition at the end of the loop (using UNTIL) then the loop will be executed at least once. There may be some situations where we don't want the loop executed at all, so to accomplish this we can move the test to the start of the loop, before the CYCLE instruction, but rather than use the UNTIL instruction we now use WHILE.

Note that you can use WHILE or UNTIL interchangeably. So you can re-write the above as:

```
// Demonstration of CYCLE...REPEAT
count = 1
WHILE COUNT <= 10 CYCLE
  PRINT "5 * "; count; " = "; 5 * count
  count = count + 1
REPEAT
END
```

or

```
// Demonstration of CYCLE, REPEAT...WHILE/UNTIL
count = 1
UNTIL COUNT > 10 CYCLE
```

```
    PRINT "5 * "; count; " = "; 5 * count
    count = count + 1
  REPEAT
  END
```

! Finally (in this section!) note that not all programing languages are as flexible as this – some only allow WHILE at the top of a loop and UNTIL (or their equivalents) at the bottom.

14.2 For Loops

There is another form of loop which combines a counter and a test in one instruction. This is a standard part of most programming languages in one form or another and is often called a “for loop”.

Here is our five times table program written with a for loop:

```
// Demonstration of FOR loop
FOR count = 1 TO 10 CYCLE
  PRINT "5 * "; count; " = "; 5 * count
REPEAT
END
```

The FOR loop works as follows: It initialises the variable (count in this instance) to the value given; 1, then executes the CYCLE...REPEAT loop, adding one to the value of the variable until the variable is greater than the end value 10.

There is an optional modification to the FOR loop in that allows you to specify how much the loop variable is incremented (or decremented!) by at each iteration by using the STEP instruction.

```
// Demonstration of FOR loop with STEP
FOR count = 1 TO 10 STEP 0.5 CYCLE
  PRINT "5 * "; count; " = "; 5 * count
REPEAT
END
```

This will print our 5 times table in steps of 0.5.

Note that that the end number (10 in this case) isn’t tested for exactly. The test is actually $>=$ So if you were incrementing by 4 (for example), count would start at 1,

then become 5, then 9, then 13 – at which point flow control would jump to the line after the REPEAT.

Another way to visualise the FOR loop is like this:

```
// Demonstration of how a FOR loop works
// ... FOR count = 1 to 10 STEP 0.5 CYCLE ...
count = 1
WHILE count <= 10 CYCLE
  PRINT "5 * "; count; " = "; 5 * count
  count = count + 0.5
REPEAT
END
```

the FOR loop is simply a convenient way to incorporate the three lines controlling count into one line.

14.3 Breaking and continuing the loop

There are two other instructions you can use with CYCLE...REPEAT loops – BREAK which will cause program execution to continue on the line *after* the REPEAT instruction, ie. You break out of the loop, and CONTINUE which will cause the loop to re-start at the line *containing* the CYCLE instruction, continuing a FOR instruction and re-evaluating and any WHILE or UNTIL instructions.

Chapter 15

Data, Read and Restore

Sometimes you need to initialise variables with a predetermined set of data – numbers or strings. BASIC and RTB has a relatively easy, if somewhat old-fashioned[1] way to do this.

There are three keywords to control this. This first is the `DATA` instruction. This doesn't do anything in its own right, but serves as a marker or placeholder for the data. After the `DATA` instruction, you list data values, numbers or strings separated by commas, as this example demonstrates:

```
DATA 1, 2, 17.4
DATA "Monday", "Tuesday", "Wednesday, "Thursday"
DATA "Friday,", "Saturday", "Sunday", 7
```

Note that you can mix numbers and strings on the same line.

To get data into your program variables, we use the `READ` instruction. We can read one, or many items of data at a time.

```
READ start, end, number
READ day1$, day2$
```

and so on.

RTB remembers the location of the last item of data read, so that the next read continues from where it left off. If you try to read more data than there is defined then you'll get an error message and the program will stop running.

[1] Old-fashioned in that hardly any other modern languages use this method, but it's still useful in this environment

You can reset RTBs data pointer with the `RESTORE` command. On its own, it will reset it to the very first `DATA` statement, but you can give it a line number to set the data pointer to the first data item on that line.

```
 100 RESTORE 1000
 110 READ day$
 120 PRINT day$
 130 RESTORE 1000
 140 READ day$
 150 PRINT day$
 160 END
1000 DATA "Monday", "Tuesday", "Wednesday, "Thursday"
1010 DATA "Friday,", "Saturday", "Sunday", 7
```

With the above set of data statements, this will print `Monday` twice.

You need to use line-numbers to use `RESTORE` with a line number! This should not be needed for most uses though.

! Data statements can be anywhere in your program – they are ignored by the interpreter and only used for `READ` instructions, however this does mean that we need to track line numbers to remember where our data is if using the `RESTORE` instruction... I recommend that you place your data at the very end of your program with high line numbers (or no line numbers at all!) to make it easier to work out where the data is and to keep track of it.

Here is an example which calculates the average of a set of numbers:

```
// Calculate the average of a set of numbers and print
// out numbers below, equal to or above average

READ numNumbers
DIM table (numNumbers)
FOR i = 0 to numNumbers - 1 CYCLE
  READ table (i)
REPEAT

// Average

total = 0
FOR i = 0 to numNumbers - 1 CYCLE
  total = total + table (i)
REPEAT
average = total / numNumbers
```

```
PRINT "The average is "; average

// Print all numbers

FOR i = 0 to numNumbers - 1 CYCLE
  PRINT "Number "; i + 1; " = "; table (i); " ";
  IF table (i) < average THEN PRINT "below"
  IF table (i) > average THEN PRINT "above"
  IF table (i) = average THEN PRINT "average"
REPEAT
END

DATA 10
DATA 1,2,3,4,5,6,7,8,9,0
```

Chapter 16

Miscellaneous Program instructions

Procedures listed here are not part of any one subsystem, (e.g. graphics) so are listed here for convenience.

`wait (time)` This waits for `time` seconds. This may be a fractional number, but the accuracy will depend on the computer you are running it on, however delays down to $\frac{1}{100}$th of a second or better should be achievable.

`STOP` Program execution is stopped with an message indicating the current line number. You may use the `CONT` command to continue your program at the line after the `STOP` instruction.

`END` Program execution is ended normally.

`SWAP (v1, v2)` This swaps the value of the 2 variables round. Both arguments must be the same type - ie. both numeric or both string, and both must be scalar (ie. ordinary variables, not array elements)

Chapter 17

Numerical Functions and data

Functions and system variables, etc. that return and deal with numbers.

17.1 System variables and constants

`PI`, `PI2` System constants that return the approximate value of π and $\frac{\pi}{2}$ respectively. E.g.

```
area = PI * radius * radius
```

`SEED` This can be assigned to to initialise the random number generator, or you can read it to find the current seed.

`TIME` This returns a number which represents the time that your program has been running in milliseconds. It is initialised to zero when your program starts. E.g.

```
print "Wait for it..."
wait (2)
print "Press the spacebar... "
start = TIME
cycle
  // Do nothing
repeat until get$ = " "
now = TIME
print "You took: "; (now - start) / 1000; " seconds."
end
```

`DEG` Switches the internal angle system to degrees. There are 360 degrees in a full circle. This is the default mode when a program starts.

`RAD` Switches the internal angle system to radians. There are 2π radians in a full circle.

`CLOCK` Switches the internal angle system to clock mode. There are 60 minutes in a full circle.

17.2 Functions

`RND (range)` This function returns a random number based on the value of `range`. If `range` is zero, then the last random number generated is returned, if `range` is 1, then a random number from 0 to 1 is returned, otherwise a random number from 0 up to, but not including `range` is returned.

`SIN (angle)` Returns the sine of the given `angle`.

`ASIN (x)` Returns the arc sine of the supplied argument `x`

`COS (angle)` Returns the cosine of the given `angle`.

`ACOS (x)` Returns the arc cosine of the supplied argument `x`

`TAN (angle)` Returns the tangent of the given `angle`.

`ATAN (x)` Returns the arc tangent of the supplied argument `x`

`ABS (x)` Returns the absolute value of the supplied argument `x` ie. if the argument is negative, make it positive.

`EXP (x)` Returns the value of e^x

`LOG (x)` Returns the natural logarithm of `x`

`SQRT (x)` Returns the square root of `x`

`SGN (x)` Returns -1 if the number is negative, 1 otherwise. (Zero is considered positive)

`INT (x)` Returns the integer part of `x`

`HASH (string, modulo)` Returns a hash value based on the `string` and `modulo`. The value returned is between 0 and `modulo`. This function is used internally in RTB for the associative array indexing. The hash function is based on the function in *The Practice of Programming (HASH TABLES, pg. 57)*

`MAX (x, y)` Returns the larger of `x` or `y`

`MIN (x, y)` Returns the smaller of `x` or `y`

`VAL (string$)` Returns the number represented by `string$`. e.g. ”1234” would return the number 1234. This is the opposite of the `STR` function.

`ASC (string$)` Returns the ASCII value represented by the first character of `string$`. e.g. ”A” would return 65. It is the opposite of the `CHR$` function.

`LEN (string$)` Returns the number of characters in `string$`.

Chapter 18

String Functions and data

Functions and system variables, etc. that return and deal with strings.

18.1 System variables

`DATE$` This returns a string with the current date in ISO 8601 format: `YYYY-MM-DD`.

`TIME$` This returns a string with the current time of day in ISO 8601 format: `HH:MM:SS`.

Date and Time example program:

```
now$   = TIME$
today$ = DATE$
print "full date & time: "; today$; " "; now$
end
```

18.2 Functions

`CHR$ (num)` This function returns a string from the ASCII value of `num` It is the opposite of the `ASC` function. e.g. CHR$ (65) returns ”A”.

`LEFT$ (string$, len)` Returns the leftmost `len` characters of `string$`.

E.g. `LEFT$ ("Hello", 2)` would return `"He"`.

`RIGHT$ (string$, len)` Returns the rightmost `len` characters of `string$`.

E.g. `RIGHT$ ("Hello", 2)` would return `"lo"`.

`MID$ (string$, start, len)` Returns the middle `len` characters of `string$` starting from position `start`. the first character of the string is at index position zero.

e.g. `MID$ ("Hello", 1,2)` would return `"el"`.

`SPACE$ (len)` Returns a string of length `len` comprising of spaces.

`STR$ (num)` Returns a string version of the supplied number `num`. e.g. `STR$ (42.42)` would return `"42.24"`. This is the opposite of the `VAL` function.

Chapter 19

Graphics

RTB supports two types of graphics; traditional 2-D Cartesian (x, y) type graphics with functions to plot points, lines, etc. and turtle graphics which can sometimes be easier to teach/demonstrate to younger people.

RTB normally works in the highest graphical resolution available to it, but it also supports two effective resolutions - the high resolution is the native resolution of the display you are using - e.g. on a PC monitor this may be up to 1280x1024, or 1920x1080 on an HD monitor. It also supports a lower resolution where each low resolution pixel is really 8x8 high resolution pixels.

Your programs should use the `gWidth` and `gHeight` system variables to scale their output to the current display size. Assuming a fixed resolution may not be advisable for programs designed to run on systems other than your own.

Note: In all the graphical instructions that take an `x, y` coordinate, this refers to the bottom left hand point if it's a rectangle. Similarly where you see `w, h` this refers to a width and height, extending to the right and above the corresponding `x, y` coordinate.

19.1 System Variables

`colour` This can be assigned to, or read from, and represents the current plotting colour. E.g.

```
colour = Yellow
```

`gWidth` This can be read to find current width of the display in either high resolution or low resolution pixels.

`gHeight` This can be read to find the current height of the display in either high resolution or low resolution pixels.

`tAngle` This can be read or assigned to and represents the current angle of the turtle when using turtle graphics mode. The angle returned will be expressed in the angular units used when the *last* `left()` or `right()` instruction was executed.

See also the colour names and note the current angle modes (degrees, radians or clock) when using turtle graphics or any trig. functions to plot graphics.

19.2 General Graphics

`hgr` This clears the screen and initialises high-resolution graphics mode. This is the default at startup time.

`gr` This clears the screen and initialises low-resolution graphics mode.

`saveScreen (filename$)` This takes a snapshot of the current screen and saves it to the filename given.

`saveRegion (filename$, x, y, w, h)` This takes a snapshot of the region identified by `x, y` (bottom left corner) and the width and height identified by `w, h`

`loadImage (filename$)` This loads the given image into memory and returns an identifier to the image which can be used in subsequent `plotImage` commands. Most image formats are accepted - JPG, PNG, BMP, GIF, TIFF, etc.

`plotImage (id, x, y)` This plot the image identified by `id` from a previous `loadImage` command at the given `x,y` location (bottom left). You can plot the same image many times at any location on the screen. The image is clipped is all or part of it would be off-screen.

`getImageW (id)`, `getImageH (id)` These functions return the width and height respectively of a loaded image.

Example:

```
// Tile an image
id = loadImage ("selfie.jpg")
w = getImageW (id)
h = getImageH (id)
for x = 0 to gWidth step w cycle
  for y = 0 to gHeight step h cycle
    plotImage (id, x, y)
```

```
  repeat
repeat
end
```

`copyRegion (x1, y1, w, h, x2, y2)` This copies an area of the screen from one place to another. The starting region is identified by the `x1, y1` location (bottom left), and width and height identified by `w, h`. This is copied to the new location identified by `x2, y2`

`scrollUp (x, y, w, h, lines)` This scrolls the region identified by `x, y, w, h` up or down by `lines` lines.

`scrollDown (x, y, w, h, lines)`

`scrollLeft (x, y, w, h, lines)`

`scrollRight (x, y, w, h, lines)` As above, but scrolls the region down, left or right.

`rgbColour (r, g, b)` This sets the current graphical plot colour to an RGB (Red, Green, Blue) value. The values should be from 0 to 255.

`update` When plotting graphics, (and text) they are actually plotted to a separate off-screen working area, so if you write a program that does lots and lots of graphical actions, then you may not see the display being updated. The `update` procedure forces the working area to be copied to the display. An update is also performed automatically if your program stops for input. (`input, get, get$`), and also at output (via the `print` instruction) depending on the setting of `updateMode`.

`getPixel (x, y)` This returns the standard colour of the pixel at the supplied `x,y` location on the screen. If the colour of the pixel is not one of the 16 standard colours, then -1 is returned.

`getPixelRBG (x, y)` This returns the 24-bit value of the pixel at the supplied `x,y` location on the screen. See the following example program for its use:

```
rgbColour (1,2,3)
plot (0,0)
pixel = getPixelRGB (0,0)
print "Pixel is: "; pixel
r = (pixel >> 16) & 0xFF
g = (pixel >>  8) & 0xFF
b = (pixel >>  0) & 0xFF
print "r: "; r; ", g: "; g ; ", b: "; b
end
```

19.3 Cartesian Graphics

The graphical origin at (0,0) is at the bottom-left of the display. Coordinates may be negative and may also be off-screen when lines are clipped to the edge of the display. The `ORIGIN` command may be used to change the graphical origin.

`plot (x, y)` This plots a single pixel in the selected graphics mode in the selected colour. Note that (0,0) is normally bottom left.

`hLine (x1, x2, y)` Draws a horizontal line on row `y`, from column `x1` to column `x2`.

`vLine (y1, y2, x)` Draws a vertical line on column `x`, from row `y1` to row `y2`.

`line (x1, y1, x2, y2)` Draws a line from point `x1, y1` to `x2, y2`.

`lineTo (x1, y1)` Draws a line from the last point plotted (by the `plot` or `line` procedures to point `x1, y1`.

`circle (cx, cy, r, f)` Draws a circle at (`cx,cy`) with radius `r`. The final parameter, `f` is either `TRUE` or `FALSE`, and specifies filled (TRUE) or outline (FALSE).

`ellipse (cx, cy, xr, yr, r, f)` Draws an ellipse at (`cx,cy`) with x radius `xr` and y radius `yr`. The final parameter, `f` is either `TRUE` or `FALSE`, and specifies filled (TRUE) or outline (FALSE).

`triangle (x1, y1, x2, y2, x3, y3, f)` Draws a triangle with its corners at the three given points. The final parameter, `f` is either `TRUE` or `FALSE`, and specifies filled (TRUE) or outline (FALSE).

`polyStart` This marks the start of drawing a filled polygon.

`polyPlot (x, y)` This remembers the given X,Y coordinates as part of a filled polygon. Nothing is actually drawn on the screen until the `polyEnd` instruction is executed. Polygons can have a maximum of 64 points.

`polyEnd` This marks the end of drawing a polygon. When this is called, the stored points will be plotted on the screen and the polygon will be filled.

`rect (x, y, w, h, f)` Draws a rectangle at (`x,y`) with width `w` and height `h`. The final parameter, `f` is either `TRUE` or `FALSE`, and specifies filled (TRUE) or outline (FALSE).

`origin (x, y)` This changes the graphics origin for the Cartesian plotting procedures. The `x, y` coordinates are always absolute coordinates with (0,0) being bottom left.

19.4 Turtle Graphics

When the graphics are initialised with either `GR` or `HGR`, the turtle position is set to the middle of the screen, pointing at an angle of 0 degrees (up) with the pen lifted. However note that the turtles position is affected by the `origin` command above, so you may have to take this into consideration if using `origin`.

With the noted effects of the `origin` procedure, you may mix turtle and Cartesian graphics without any issues.

`penDown` This lowers the "pen" that the turtle is using to draw with. Nothing will be drawn until you execute this procedure.

`penUp` This lifts the "pen" that the turtle uses to draw. You can move the turtle without drawing while the pan is up.

`move (distance)` This causes the turtle to move forwards `distance` screen pixels.

`moveTo (x, y)` This moves the turtle to the absolute location (`x, y`). A line will be drawn if the pen is down.

`left (angle)` Turns the turtle to the left (counter clockwise) by the given angle.

`right (angle)` Turns the turtle to the right (clockwise) by the given angle.

19.5 Sprites

Sprites are (usually) small bitmap images which you can plot to the screen under program control. You can create them using one of the many graphical image creation packages available. RTB accepts many different file formats for sprites but you are strongly recommended to use a "non-lossy" format such as BMP, GIF, PNG, etc. to avoid any block/aliasing effects in e.g. JPG.

RTB can handle up to 1024 sprites and each sprite can have up to 64 sub-sprites. (If you're used to programming in Scratch, think of the sub-sprites as "costumes") All sub-sprites in one sprite should have the same dimension.

Sprites "float" above the background image, and above each other. The first sprite plotted to the screen is above the background image, then 2nd sprite plotted is above that and so on. The sub-sprites can be used to perform simple animations - e.g. a space invader might have 2 sub-sprites in each sprite to give the illusion of its legs moving as it moved over the screen. A "pacman" sprite could have 3 or 4 sub-sprites to represent the various stages of the "mouth" moving from open to closed.

The position of a sprite on the screen is affected by three parameters. The first is the supplied `x, y` coordinates and this is adjusted by the sprites own origin position (see `setSpriteOrigin` below), and finally by the global graphics `origin` setting.

To move a sprite over the screen, all you need to do is update its position with the `plotSprite` instruction. The system takes care of un-plotting it and plotting it in the new position.

Typically you would draw the background, then:

```
cycle
  // plot the sprites
  update
repeat
```

`newSprite (subSprites)` This initialises some storage and structures to take a new sprite and a stack of "sub sprites". Once you have created the sprite in this way you need to load the individual image(s) into it. The return value is a handle that you must use when referencing this sprite in future operations. E.g.

```
// create a new sprite with space for just one sub-sprite
spr1 = newSprite (1)
```

`loadSprite (filename$, sprite, subSprite)` This loads a sprite from the supplied file into memory. `sprite` is the handle returned by the `newSprite` instruction and `subSprite` is the sub-sprite index. E.g.

```
loadSprite ("test.png", spr1, 0) // subSprite starts at zero
```

`setSpriteTrans (sprite, r, g, b)` This sets the transparency mask on the given sprite. It is applies to all sprites in the stack, so they should all use the same colour to represent the transparent colour.

! Note: On the Raspberry Pi, the graphics are 16 bits per pixel, so the actual RGB values may be different to what you're expecting. A typical value might be red: 247, green: 251, blue: 247.

`plotSprite (sprite, x, y)` This plots the given sprite `sprite` at the suppled `x, y` coordinates. The coordinates normally specify the bottom-left corner of the bounding rectangle of the sprite but may be moved with the `setSpriteOrigin` instruction.

`setSpriteOrigin (sprite, x, y)` This sets the origin point inside a sprite (and all sub sprites). Note that if you want to set the origin to the exact middle of the sprite then the sprite has to be an odd number of pixels wide and high.

`hideSprite` This removes a sprite from the screen on the next update.

`getSpriteW (sprite)` This returns the width of the sprite indicated by `sprite`.

`getSpriteH (sprite)` This returns the height of the sprite indicated by `sprite`.

`spriteCollide (sprite)` This is a fast "bounding box" sprite collision test. It takes the sprite identified by `sprite` and searches the other sprites to see if it has collided. It returns the sprite identifier of the first sprite it has collided with, or `-1` if it's not in collision.

`spriteCollidePP (sprite, accuracy)` This is a slow "perfect pixel" sprite collision test. It takes the sprite identified by `sprite` and searches the other sprites to see if it has collided within the accuracy specified. It returns the sprite identifier of the first sprite it has collided with, or `-1` if it's not in collision.

The accuracy is expressed in pixels and should be from 1 (best) to 16 (poor, but still usable). It all depends on the amount of overlap your application can tolerate.

You do not have to erase a sprite from the screen when you move it, just call `plotSprite` with the new coordinates.

Chapter 20

Mouse Input

RTB can use the mouse connected to your system. You can enable or disable it, read its position and button states. You can even move it to a new location on the screen.

Moving the scroll wheel on the mouse has the same effect as pushing the up and down arrow keys on the keyboard.

`mouseOn` This turns on the visible mouse cursor on the screen. It's probably a good thing to call this before reading its position.

`mouseOff` This removed the mouse cursor from the screen.

`getMouse (x, y, z)` This returns the `x, y` location of the mouse as well as a variable `z` this represents the buttons on the mouse. Bits 0, 1 and 2 of `z` represent the Left, right and middle mouse button respectively. Any origin set with the `origin` instruction is taken into account, so if you set `origin (gWidth / 2, gHeight / 2)` then with the mouse in the middle of the screen, the returned coordinate will be `0,0`.

`setMouse (x, y)` This sets the mouse position to the supplied `x,y` coordinate. The current origin is taken into account as with `getMouse` above.

Chapter 21

Sound

RTB has several different ways to make sound. You can play background music, sound samples, simple tones and synthesised sounds based on the old BBC Micro SOUND and ENVELOPE commands.

Internally, all sound samples, music, etc. is held as 8-bit, mono at 11025 samples per second. This is more for efficiency on the Raspberry Pi than anything else.

21.1 Music

Music is intended to be used as a background to your program. Most file formats are recognised. E.g. WAV, MP3, etc. RTB can load as many different music files as it has memory for and you can start/stop, pause and resume the music track.

`loadMusic (filename$)` This loads a music file into memory for later playing and returns an identifier than can be used in subsequent calls to `playMusic`, etc.

`playMusic (id, repetitions$)` This starts playing the previously loaded music identified by `id` for `repetitions` times. If any music is currently playing, it is stopped and the new music is started.

`stopMusic` Stops any music that may be playing.

`pauseMusic` Temporarily stops any music that may be playing.

`resumeMusic` Resumes playing any previously paused music.

`setMusicVol (volume)` Sets the volume of the music channel to `volume`. The volume is expressed as a percentage; 0 to 100.

21.2 Sound Samples

As with music, sound samples can be in several different formats. WAV, MP3, and others are supported. RTB can load as many samples as it has memory for but can only play 4 at once.

`loadSample (filename$)` This loads a sample file into memory for later playing and returns an identifier than can be used in subsequent calls to `playSample`, etc.

`playSample (handle, channel, loops)` This plays the previously loaded sample identified by `handle` on the supplied channel for the given number of loops. Slightly different from `playMusic` above in that this is the number of loops and not the number of repetitions, so it needs to be `1` to play once.

There are 4 channels available, numbered 0 through 3.

`stopChan (channel)` Stops the sound sample playing on the given channel.

`pauseChan (channel)` Pauses the sound sample playing on the given channel.

`resumeChan (channel)` Resumes the sound playing on a previously paused sound channel.

`setChanVol (channel, volume)` Sets the channel volume on the given channel. The volume is expressed as a percentage; 0 to 100.

21.3 Tones and Sounds

There are four channels for tone/sound playing; 0, 1, 2 and 3. Channel 0 always generates white noise. The sound system will queue one sound per channel (ie. it will return immediately the sound starts playing) so its possible to execute three `tone` instructions one after the other on different channels to play a simple chord, or you use the `sound` instruction to do this automatically.

`tone (channel, volume, frequency, duration)` This plays a simple tone on the given channel of the given frequency. The volume is expressed as a percentage; 0 to 100. The duration is in seconds and may be fractional. The longest tone you can play is 20 seconds in duration. E.g. Play concert A (440Hz) for 1 second:

```
tone (1, 30, 440, 1)
```

Playing a C major chord:

```
tone (1,30, 261, 1)
tone (2,30, 330, 1)
tone (3,30, 392, 1)
```

`sound (channel, volume, pitch, duration)` The `sound` instruction seems similar to the `tone` instruction, but its much more complex and can be used in conjunction with the `envelope` instruction to generate comple sounds and tones.

- `channel`: 0, 1, 2 or 3. Channel 0 generates white noise.
- `volume`: 0 to -15 to select one of 16 volume levels (0 is silent, -15 is full volume), or a positive number to identify the `envelope` to use.
- `pitch`: The pitch value - this is not the same as the frequency in the tone command. See the table at the end for a list of pitch vs. piano note values.
- `duration`: This is the duration of the note in 20ths of a second intervals.

`envelope (...)` the `envelope` instruction is somewhat complex and takes 14 parameters. they are:

- `id`: This is the identifier for this envelope. You can create up to 8 envelopes numbered 1 through 8.
- `stepLen`: This is the number of 100ths of a second that each pitch or amplitude step takes.
- `dP1, dP2, dP3`: These represent the change (delta) in pitch for each of the three corresponding step times (`pStepsX`), in intervals of `stepLen` 100th of a second.
- `pSteps1, pSteps2, pSteps3`: These represent the number of steps of `stepLen` 100ths of a second for pitch (`dPX`) change.
- `aRate, dRate, sRate, rRate`: The rate of change of the volume during the attac, decay, sustain and release phase of the note. The release phase is not implemented here - the note ends at the end of the sustain phase.
- `targetAttack, targetDecay`: This is the target volume level (0-127) of the note at the end of the attack or decay phase.

! Note:More to come, but read any document on the BBC Micro sound and envelope command for more details.

Chapter 22

File and System program handling

22.1 File handling

RTB supports reading and writing of ordinary text files. There are two main methods of file accessing; sequential and random-access. When you open a file, it is assigned a numerical *"handle"* and you need to use this handle when performing other operations on the file. RTB allows you to open multiple files at the same time, up to a limit set by the implementation. (64 by default). Each open file will have a unique handle, which you must keep track of when manipulating files.

All data written to, or read from a file is textual in nature. You can not write binary data in RTB. Numbers are stored as literal strings as if they ha: been printed on the screen. (And in particular, the format set by the `numFormat` instruction is used when printing numbers into files).

22.2 Sequential access

Sequential file access is straightforward. You open a file, then read from it, or write to it. You can reset the file pointer to the start of the file using the `rewind` instruction, so you can write data to a file, then `rewind`, then read the data back again. There is no structure to the file other than what you write into it yourself. ie. if you want to read the 15th line in a file, then you need to read the preceding 14 lines unless you know the exact line length of each line, then you can use the `seek` instruction to jump to that line, but if the lines are all different length, then you need to read the while file from start to end.

22.3 Random access

Random file access is similar to sequential, however it additionally allows you to split your file into fixed-size records, then you can `seek` to any of these records at random.

There are no special instructions that make a file any different when in sequential mode to random mode other than those you code yourself. You must plan the record size (in bytes or characters) beforehand and you must always seek to the correct record in your file before reading or writing. Each record is then treated like a small sequential file and you can read and write into it - however you must make sure that you don't write more data into the record than you have planned for, otherwise that data will overflow into the next record with unpredictable results.

Random access files can be wasteful of disk space, but they can also be a fast an versatile method of storing and retrieving data. Most modern databases use this technique to store data for fast retrieval.

The functions here only return a simple error code - usually `-1` in cases of file not found, or insufficient access rights to open the file.

22.4 File handling instructions

`openIn (filename$)` This function opens a file and makes it available for input only. A numeric handle associated with the file is returned, or `-1` is returned on any file error (e.g. file not found)

`openOut (filename$)` This function opens a file and makes it available for output only. A numeric handle associated with the file is returned or `-1` if there was an error when trying to open/create the file. The file is created if it doesn't exist, or truncated to zero length if it does exist.

`openUp (filename$)` This function opens a file and makes it available for reading or writing (ie. updating) A numeric handle associated with the file is returned or `-1` if there was an error when trying to open the file. The file is created if it doesn't exist.

`close (handle)` The file identified by the supplied `handle` is closed and all data is written to disk. Subsequent read or writes to the file will return an error.

`eof (handle)` This function returns a `TRUE` or `FALSE` indication of the state of the file pointer when reading the file. It is an error to try to read past the end of the file, so if you are reading a file with unknown data in it, then you must check at well defined intervals (e.g. before each `input#`.

`rewind (handle), ffwd (handle)` These instructions move the file pointer back to the start of the file or to the end of the file respectively. If you want to append data to the end of an existing file, then you need to use `openUp` followed by `ffwd` before writing the data.

`seek (handle, offset)` This instruction moves the file pointer to any place in the file. It can even move the file pointer beyond the end of the file in which case the file is extended. The argument suppled to `seek` is an absolute number of bytes from the start of the file. If you are using random access files and want to access the 7th record in the file, then you need to multiple your record size by 7 to work out the location to seek to.

`print# handle, ...` This instruction acts just like the regular `print` instruction except that it sends data to the file identified by the supplied file-handle rather than to the screen. Numbers are formatted according to the settings of `numFormat`. It is strongly recommended to only print one item per line if you are going to read those items back into an RTB program again.

```
// Append data to the end of a file
myFile = openUp ("testfile.txt")
ffwd (myFile)
print# myFile, "Appended line"
close (myFile)
```

`input# handle, variable` This works similarly to the regular `input` instruction, but reads from the file identified by the supplied file-handle rather than from the keyboard.

```
// Copy file to screen
myFile = openIn ("testfile.txt")
while not eof (myFile)
  input# myFile, line$
  print line$
close (myFile)
```

The `popenOut`, and `pOpenIn` functions use the existing `print#` and `input#` instructions. See the file handling section for more details on these.

22.5 Calling system programs

RTB programs can call existing system programs via three different ways. These instructions are mentioned in this chapter as they share some of the above file handling instructions.

`system (filename$)` This function calls a system program. RTB program execution is suspended while the program is running. Input to the program and output from the program is not avalable, and there is no notification of error from the program.

`pOpenIn (filename$)` This function opens a program and makes it available for input only. A numeric handle associated with the file is returned, or `-1` is returned on any file error (e.g. file not found)

Use `input#` to read data from the program.

```
//  Test the pOpenIn function

  x = pOpenIn ("/bin/ls -l /var")  // Open the ls program for input

  while  not eof (x) cycle
    input# x, a$
    print a$
  repeat
  pClose (x)
  END
```

`popenOut (filename$)` This function opens a program and makes it available for output only. (ie. data from your RTB program output and fed into the system program) A numeric handle associated with the file is returned or `-1` if there was an error when trying to open/create the file. The file is created if it doesn't exist, or truncated to zero length if it does exist.

Use `print#` to send data to the program.

Chapter 23

Serial Port Programming

RTB supports a few instructions to allow you to send and receive data over serial ports. These go by various names, a common one being RS232.

Moderns PCs often lack a directly connected serial port, so you may have to use a USB connected device. Using them is the same whether directly connected or via USB. The important thing to know is the name of the serial device. For directly connected devices, this might be something like ”/dev/ttyS1”, or for USB devices it might be something like `/dev/ttyUSB0`. Occasionally you have find a `/dev/ttyACM0` for some older USB devices. The Raspberry Pi’s on-board serial port is called `/dev/ttyAMA0`.

`sOpen (filename$, baud)` This opens a serial device and makes it available for our use. It takes the name of the serial port and the speed as an argument and returns a number (the *handle*) of the device. We can use this handle to reference the device and allow us to open several devices at once. Example:

```
arduino = sOpen ("/dev/ttyUSB0", 115200)
```

Most standard baud rates are recognised. The device is always opened with the data format set to 8 data bits, 1 stop bit and no parity. All handshaking is turned off.

`sClose (handle)` This closes a serial port and frees up and resources used by it. It’s not strictly necessary to do this when you end your program, but it is considered good practice.

`sGet (handle), sGet$ (handle)` Fetch a single byte of data from an open serial port and return the data as a number or a single character string. This function will pause program execution for up to 10 seconds if no data is available. If there is still not data after 10 seconds, the function will return -1 or an empty string.

`sPut (handle. data), sPut$ (handle, data)` Send a single byte of data, or a string of characters to an open serial port. Example:

```
SPUT (arduino, 64)
SPUT$ (arduino, "Hello")
```

`sReady (handle)` Returns the number of characters available to be read from an open serial port. This can be used to poll the device to avoid stalling your program when there is no data available to be read.

Chapter 24

Minecraft

RTB can interface to the popular Minecraft server running on a Raspberry Pi (or any other Raspberry Pi via LAN/Internet)

Using the Minecraft interface, your programs can post messages to the screen, read the players location, set the players location (ie. teleport), place blocks anywhere and more.

The Minecraft world on the Pi appears as a box that measures 256 blocks on each of its three sides, however the end points may not always be -127 through +127. Occasionally they appear to be offset by some amount, so be aware of this.

Minecraft coordinates follow fairly standard 3D coordinates. If standing in the middle of the "world" facing north, then up and down is the Y axis, left and right is the X axis and forward and back is the Z axis.

`mcConnect (hostname$)` This is the first instruction you need to execute to connect to your running Minecraft server. the `hostname$` parameter is the name of the server you want to connect to. `"localhost"` is probably the most useful as that's the Pi you're running everything on, but you can use any IP address here (either numeric form, IPv4, IPv6 or a domain name), to connect to any other Pi running Minecraft.

`mcConnect` returns a handle which you need to use in all subsequent Minecraft instructions.

`mcChat (handle, message$)` This sends the message to the Minecraft server. Example:

```
handle = mcConnect ("localhost")
mcChat (handle, "Welcome to Minecraft)
```

`mcSetBlock (handle, x, y, z, type)` This sets a block of type `type` at the given `x, y, z` location. You can use a number for the type if you know, them or use one of the built-in constants to describe a block. Use the `mcBlocks` command in immediate mode to give a complete list of the block types supported.

`mcSetBlocks (handle, x1,y1,z1, x2,y2,z2, type)` This fills an area bounded by the two sets of coordinates with the given block type As with `mcSetBlock` above, you can use a number for the type if you know, them or use one of the built-in constants to describe a block. Use the `mcBlocks` command in immediate mode to give a complete list of the block types supported.

`mcGetBlock (handle, x, y, z)` *(RTB v2.22+)* This returns the block type `type` at the given `x, y, z` location.

`mcLine (handle, x1,y1,z1, x2,y2,z2, type)` This draws a line from the first to the 2nd set of 3D coordinates with the given block type.

`mcCircleZ (handle, x1,y1,z1, radius, fill, type)` This draws a 2D circle in the Z-plan centered on the coordinates given with the block type set to `type`. If `fill` is `TRUE` then the circle is drawn filled, else it's just the outline.

`mcSetTile (handle, x, y, z)` This sets the players position - ie. can be used to "teleport" the player. The corodinates specify the location of the block the player is standing on.

`mcGetTile (handle, x, y, z)` This returns the type of block at the supplied `x,y,z` coordinates.

`mcGetPos (handle, x, y, z)` This sets the supplied `x,y,z` coordinates to the current coordinate that the player is located at. This is a floating point number as it's possible to move within a block location. You could "glide" a player from one corner of a block to another using this instruction.

Chapter 25

Raspberry Pi - GPIO Programming

RTB supports the on-board GPIO hardware in the Raspberry Pi computer, as well as external devices using the wiringPi extensions.

! Note:The on-board GPIO pins on the Raspberry Pi can be addressed in three different ways: wiringPi pin numbers, BCM_GPIO pin numbers and the physical P1 (and P5) pin numbers. RTB uses the wiringPi pin numbers by default but if you start RTB with the `-g` flag then it will use the BCM_GPIO numbers, or start it with the `-1` flag, then it will use the hardware P1 pin numbers. See `http://wiringpi.com/pins/` for details.

Also note that the Raspberry Pi doesn't have analog hardware by default, so the analog functions below will only work when you use the `wPiExtension` instruction to add an external analog input or output device to the Pi.

25.1 Constants

The following constants are defined to help you use the GPIO more effectively:

`pinInput` Returns the value use to set a GPIO pin to input mode when used in the `pinMode` instruction.

`pinOutput` Returns the value use to set a GPIO pin to output mode when used in the `pinMode` instruction.

`pinPWM` Returns the value use to set a GPIO pin to PWM mode when used in the `pinMode` instruction.

`pinSoftPWM` Returns the value use to set a GPIO pin to software PWM mode when used in the `pinMode` instruction.

`pudUp` Returns the value use when enabling the internal pull-up resistor on a GPIO pin using the `pullUpDn` instruction.

`pudDown` Returns the value use when enabling the internal pull-down resistor on a GPIO pin using the `pullUpDn` instruction.

`pudOff` Returns the value use when disabling the internal pull-up and pull-down resistors on a GPIO pin using the `pullUpDn` instruction.

25.2 GPIO Instructions

`pinMode (pin, mode)` Sets the mode of a pin. Use the `pin?` constants above for input, output, etc. modes.

`digitalRead (pin)` Reads the value from the pin number supplied. The return value will be 1 or 0 (`TRUE`, or `FALSE`)

`digitalWrite (pin, value)` Writes the value sets a digital pin to the pin. Use 0 (or `FALSE` for off or `1` or `TRUE` for on. E.g.

```
// Blink program
pinMode (0, pinOutput)
cycle
  digitalWrite (0, 1) // Pin 0 On
  wait (0.5)
  digitalWrite (0, 0) // Pin 0 Off
  wait (0.5)
repeat
end
```

`analogRead (pin)` *(RTB v2.22+)* Reads the analog value from the pin number supplied. The return value will be from 0 to whatever maximum the analog to digital converter supplies.

`analogWrite (pin, value)` *(RTB 2.22+)* Writes the value given to the analog output pin. The range will be dependant on the output device.

`pwmWrite (pin, value)` This instruction writes the value to the pin configured as hardware PWM on the Raspberry Pi. The default range for the value is 0 through 1024 inclusive.

`softPwmWrite (pin, value)` This instruction writes the value to the pin configured as software PWM on the Raspberry Pi. The default range for the value is 0 through 100 inclusive.

`pullUpDn (pin, mode)` This instruction sets the internal pull-up or pull-down resistors on the supplied pin to the mode given. Use the `pud?` constants above for the modes.

`wpiExtension (extensionData$)` This instruction loads a new extension module into the wiringPi library used by RTB. The `extensionData$` string will be specific to each module loaded. E.g. to load the combined ADC and DAC driver for the pcf8591 chip, then:

```
wpiExtension ("pcf8591:100:0x48")
```

That loads the driver which uses I2C address 0x48 and assigns it a new pin base of 100. You can then use the `analogRead` and `analogWrite` instructions on pins 100 through 103. (It's a 3-channel device). E.g. if channel 0 had an LM35 temperature sensor on it, then:

```
wpiExtension ("pcf8591:100:0x48")
value = analogRead (100)
temp = value / 255 * 330
numformat (4,1)
print "The temperature is "; temp; " celsius"
end
```

Chapter 26

Maplin Robot Arm

RTB can talk to the Maplin robot arm[1] to make it move. Unfortunately, due to the simple design of the arm, there is no feedback from the arm, so at best all you can do is write simple "joystick" type applications to control the arm.

`armReset` You should call this instruction at the start of your program before you do any other arm movements. It makes sure that RTB can communicate with the arm and stops all movement. (You can call it at any other time too as an "emergency stop" function too)

The other robot arm commands are all similar in that they take one parameter which represents the direction or stop. `-1` to start turn one way, `0` to stop, and `1` to start turning the opposite way. Once you give a command to start the arm moving, it will keep moving, so be prepared to give the command to stop the arm moving otherwise it will go to the end-stop and start to make loud clicking noises...

The commands are:

- `armBody`
- `armShoulder`
- `armElbow`
- `armWrist`
- `armGripper`
- `armLight`

[1] Maplin order code A37JN

Example:

```
// Maplin robot arm test
armReset
armBody (1) // Move one way for one second
wait (1)
armBody (-1) // Move the other way for one second
wait (1)
armBody (0) // Stop
end
```

Chapter 27

Writing your own Procedures and Functions

This chapter will show you how you can eliminate the `GOSUB` instruction once and for all and not be reliant on line numbers for your programs.

27.1 User defined Procedures

Procedures (and functions) have a name, so just like variable names, make them something that's easy to understand. We'll start by example and write a procedure to print out a multiplication table:

```
// Procedure to print a multiplication table
def proc multiplication
for num = 1 to 10 cycle
  print num; " * "; table; " = "; num * table
repeat
endproc
```

You should put this near the end of your program - it's currently an error if the interpreter encounters the `def proc` instruction in normal execution.

Understanding the above: `def proc` tells the system to define a new procedure and call it `multiplication`. The procedure uses a global variable called `table` to represent the table to be printed.

Demonstration of the above procedure, used to print the 2,4,6 and 8 times tables:

```
// Print some tables
```

```
for table = 2 TO 8 step 2 cycle
  proc multiplication
repeat
end
```

`proc` without the `def` calls the procedure.

Like built-in procedures and functions, we can give our procedures arguments. They can also have variables local to themselves.

Re-writing with an argument and local variable:

```
// Procedure to print a multiplication table
def proc multiplication (table)
local num
for num = 1 to 10 cycle
  print num; " * "; table; " = "; num * table
repeat
endproc
```

and our calling program is now:

```
// Print some tables
for table = 2 TO 8 step 2 cycle
  proc multiplication (table)
repeat
end
```

27.2 User defined Functions

Functions work in almost exactly the same was as procedures. We can give them parameters and declare `local` variables, however the one difference is that a function can return a result, and you do this by ending the function with the value to return after an equals symbol = as this simple example demonstrates:

```
// Function test - print squares
for i = 1 to 10 cycle
  x = fn square (i)
  print i; " squared is"; x
repeat
end
```

```
// Function to return the square of a number
def fn square (num)
local result
result = num * num
= result
```

You can use user-defined functions anywhere you might use a built-in function, and you can define functions that return strings too – just make sure its name ends with a dollar sign.

This example reverses a string:

```
// Function to reverse a string
def fn reverse$ (s$)
local i
local new$
new$ = "" // Start with nothing
for i = 1 to len (s$) cycle
  new$ = new$ + mid$ (s$, len (s$) - i, 1)
repeat
= new$
```

27.3 Recursion

Recursion is when a procedure or function calls itself.

Here is an example – The factorial function is defined as the number multiplied by one less than itself multiplied by one less than that and so on until you reach one.

e.g. 5 factorial is 5 * 4 * 3 * 2 * 1 (or 120)

A way of representing this is to say that 5 factorial is 5 times 4 factorial.

We know that 4 factorial is 4 times 3 factorial, . . .

We also know that 1 factorial is 1 (and that we normally use the exclamation mark to represent the factorial function)

So in general terms as can say that $N! = N * (N - 1)!$

If you're having problems thinking that one through, think of Russian matryoshka dolls – A matryoshka doll is a matryoshka doll with another matryoshka doll inside. . .

Have a look at this test program:

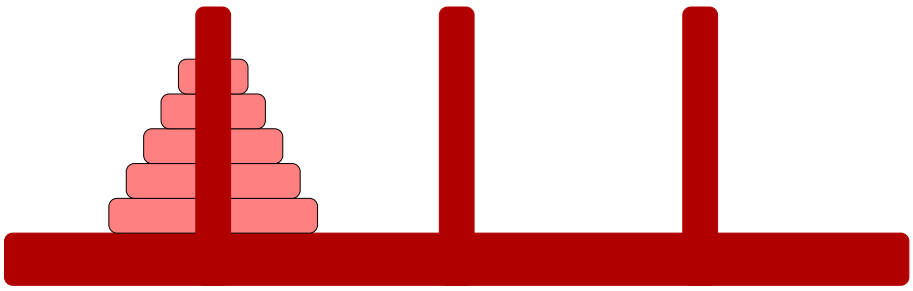
```
numformat (6,0)
for n = 1 to 10 cycle
  print n; "! is "; fn factorial (n)
repeat
end

def fn factorial (n)
if n = 1 then
  = n
else
  = n * fn factorial (n - 1)
endif
```

27.3.1 Recursion challenges

- Write the string reversal function using recursion. Think of this: A reversed string is last character of the string followed by the rest of the string, reversed.
- The Towers of Hanoi. You have a board with three short wooden rods. On one rod is 5 different sized disks with a hole in the middle to slide down the rod. Each disk is a different size and the largest is at the bottom and the smallest at the top. See the picture below.

  Your task is to move them from one pole to another, but you must never place a larger disk on top of a smaller one and you can only move one disk at a time. This puzzle is called the *Towers of Hanoi* and is one of the old "classic" problems where a recursive solution works well.



The Towers of Hanoi

27.4 Variable Scope

We talk about the "scope" of a variable to mean what parts of your program can see a variable (and change it!) We've seen that subroutines can see (and change!) all

variables we use in the main program, but what about user defined procedures and functions?

The rules in RTB are somewhat simple, and whilst not identical, are similar enough to most other programing languages to give you a good insight.

When a procedure or function is called, the arguments and `local` variables store a copy of any variables with the same name, making them available for use inside that procedure or function. When the procedure ends, then the stored values are copied back into the original variables.

So what happens if a procedure calls another procedure which doesn't have local variables? Well, the values it sees are those of the last procedure and not those in the main program. Essentially, RTB propagates local variables into each new procedure. The easiest way to demonstrate is by example:

```
// Variable Scope Test
v1 = 123
v2 = 456
print "start: v1 is: "; v1; " v2 is "; v2
proc test1 (v1)
print "end    v1 is: "; v1; " v2 is "; v2
end

// proc test1:
//   Declare a local v1
def proc test1 (num1)
local v1
v1 = 888
print "test1: v1 is: "; v1; " v2 is "; v2; " num1 is: "; num1
proc test2
endproc

// proc test2:
//    try changing v1 and v2
def proc test2
v1 = 1
v2 = 2
print "test2: v1 is: "; v1; " v2 is "; v2; " num1 is: "; num1
endproc
```

Chapter 28

Colours

To keep thing simple, RTB has 16 colours pre-defined for your use. You can use numbers to represent them, or use the built-in names. The colours are:

0 Black	1 Navy	2 Green	3 Teal	4 Maroon	5 Purple	6 Olive	7 Silver
8 Grey	9 Blue	10 Lime	11 Aqua	12 Red	13 Pink	14 Yellow	15 White

Note that the colours here are just representative and might not be what you see on the video screen you are using to run RTB on.

These colours are available in both text and graphics modes.

If these 16 colours are not sufficient, then it's possible to use the full colour pallet of the computer system you are using - this is usually a 24-bit system with 8 bits for each of Red, Green and Blue, giving a maximum of 16777216 different colours available. *Note that the Raspberry Pi only has a 16-bit colour pallet and the closest true RGB colour will be picked*

To use the full-colour mode, you need to use the built-in procedure

- `rgbColour (red, green blue)`

where the values of `red, green` and `blue` are numbers from 0 to 255 inclusive.

The extended RGB colours are available in graphics modes only. Text is limited to the standard 16 colours.

28.1 A Text Colour Demo

There should be a program supplied with your RTB installation called ”colours” which will demo the basic colours in text mode. `LOAD colours` should obtain it for you, but if it’s not available then:

```
// Colour test program

updateMode = 0
DIM c$(15)
FOR i = 0 TO 15 CYCLE
  READ c$(i)
REPEAT

CLS
VTAB = 4
PRINT "Colour test program"
PRINT "=================="
VTAB = 8
FOR bg = 0 TO 15 CYCLE
  FOR i = 0 TO 1 CYCLE
    BCOLOUR = 0
    TCOLOUR = bg
    PRINT c$(bg);
    FOR fg = 0 TO 7 CYCLE
      PROC testcolour(fg + i * 8, bg)
    REPEAT
    HTAB = 0
    VTAB = VTAB + 1
  REPEAT
REPEAT
TCOLOUR = 15
BCOLOUR = 0
HVTAB (0, THEIGHT - 1)
END

// Procedure to print some text in the colours supplied

DEF PROC testcolour(f, b)
TCOLOUR = f
BCOLOUR = b
PRINT c$(f);
ENDPROC

DATA " Black  ", " Navy   ", " Green  ", " Teal   "
DATA " Maroon ", " Purple ", " Olive  ", " Silver "
DATA " Grey   ", " Blue   ", " Lime   ", " Aqua   "
DATA " Red    ", " Pink   ", " Yellow ", " White  "
```

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